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Case Article

Desalination: Case study of Lakshdweep Islands and Gran Canaria Islands

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Abstract

This paper aims to know about the desalination process and classification of thermal desalination process. how the environment impact on desalination process. Desalination can be a good alternative to obtain fresh water from seawater or brackish water, which can be utilized for drinking, domestic, industrial and agricultural applications. Reverse Osmosis and Multi Stage Flash Desalination technologies are the most widely used in various countries of the world. These desalination plants are located near the coastal areas away from tourist development and populations. The pipes, for seawater and brine, lay over the aquifer. If the pipe leaks anywhere, the salt water may penetrate into the aquifer causing pollution.

Keywords: *Bhabha Atomic Research Centre (BARC), Confederation of Indian Industry (CII), public private partnership (PPP), Israel Desalination Enterprises Technologies (IDE), multistage flash (MSF), multiple-effect distillation (MED), vapour compression (VC)*

1. Introduction

Desalination refers to any of several processes that remove excess salt and other minerals from water. More generally, desalination may also refer to the removal of salts and minerals. Water is desalinated in order to convert salt water to fresh water so it is suitable for human consumption or irrigation. Sometimes the process produces table salt as a byproduct. Most of the modern interest in desalination is focused on developing cost effective ways of providing fresh water for human use in regions where the availability of fresh water is, or is becoming, limited.

The world's water consumption rate is doubling every 20 years, outpacing by two times the rate of population growth. The availability of good quality water is on the decline and water demand is on the rise. Worldwide availability of fresh water for industrial needs and human consumption is limited. Various industrial and developmental activities in recent times have resulted in increasing the pollution level and deteriorating the water quality. Water shortages and unreliable water quality are considered major obstacles to achieve sustainable development and improvement in the quality of life. The water demand in the country is increasing fast due to progressive increase in the demand of water for irrigation, rapid industrialization, population growth and improving life standards. The existing water resources are diminishing (i) due to unequal distribution of rain water and occasional drought, (ii) excessive exploitation of ground water sources and its insufficient recharge, (iii) deterioration of water quality due to the discharge of domestic and industrial effluents without adequate treatment. This is resulting into water stress/ scarcity. Country is currently passing through social and economic transition. The proportion of the population which is urban has doubled over the last thirty years. Setting up desalination plants will also prove less time consuming than any irrigation or drinking water projects involving rivers, which have to bear huge opportunity costs of displacing population from one place to another. Desalination plants at three or four places can be interconnected in a state like Tamil Nadu to form a water grid, which should be connected to the existing municipal water supply network, which can end the dependence on the rivers like Cauvery or Rewati. Bhabha Atomic Research Centre (BARC) set up a 1.8 million-liters-a-day capacity desalination plant at Kalpakkam in Tamil Nadu in 2008 and is set to commission a MSF-based plant there itself. BARC has set up several desalination plants in rural Rajasthan, Andhra Pradesh and Gujarat, producing 30,000 L per day. It has licensed its technology to as many as seven industries. IVRCL, IL&FS, Mahindra and Reliance are other companies that have set up desalination plants. Foreign players like Israel Desalination Enterprises Technologies (IDE) and GE are also setting up such plants in India.

Calculations reveal that on an average the production cost from brackish water plants come to Rs 10 to15 for every cubic meter, and from seawater comes to Rs 40 to 50 per cubic meter. The production cost of desalted water from effluents comes to Rs 15 to 50 per cubic meter depending upon the TDS load. This translates to a household expenditure of Rs 300 to 400 per month on drinking water, which a family is anyway bearing in cities like Chennai, Bangalore, Hyderabad, and Mumbai.

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Water and desalination: Key figures for India	
Demand for fresh water in India (annual)	900 billion cu m
Fresh water available in India (annual)	500-600 billion cu m
Population with no access to safe drinking water in India	22.5 crore
Number of plants installed in India so far	175
Global desalination market by 2015	US$ 95 billion
Annual desalination market in Middle East	US$ 8 billion
Current global water treatment market	US$ 400 billion
Current size of Indian water market	US$ 1 billion
Current share of desalination in water market	0.10%
Share of RO in desalination technologies	59%

During the 'Gujarat Water Summit-2011' that was organised by industrial body Confederation of Indian Industry (CII) on July 16, 2011, a state government official said the proposed desalination plants would come up on a public private partnership (PPP) basis. Narmada Water Resources, Water Supply and Kalpasar Department Principal Secretary H K Dash said that Jamnagar (100 MLD), Pipavav (100 MLD), Dahej and Kutch sites are identified for setting up desalination plants having nearly 300 MLD installed capacity over the next five years. The government has already given approval to a project to be executed by Welspun and Adani group in Kutch. In the first phase it would be a 50 MLD water project, and thereafter it could be expanded to 150 MLD per day. Once the project is through, sweet water shall be evacuated by Gujarat Water Infrastructure Limited and it shall be distributed to industry, mostly situated in Kutch district.

Classification of Desalination Technologies

Desalination refers to the process by which pure water is recovered from saline water using different forms of energy. Saline water is classified as either brackish water or seawater depending on the salinity and water source. Desalination produces two streams - freshwater and a more concentrated stream (brine). The two main commercial desalination technologies are those based on thermal and membrane processes.

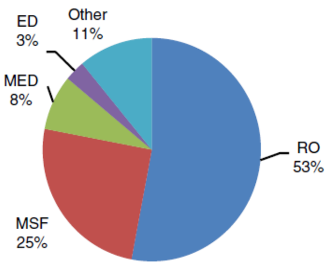

Fig.1 Global desalination capacity by process

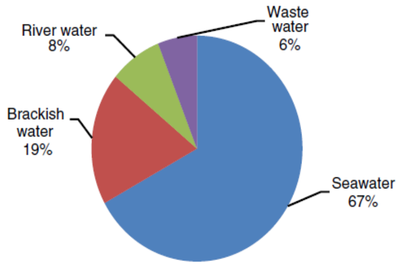

Fig.2 Worldwide raw water quantity used in desalination

Thermal Desalination

Thermal processes, except freezing, mimic the natural process of producing rain. Saline water is heated, producing water vapour that in turn condenses to form distilled water. These processes include multistage flash (MSF), multiple-effect distillation (MED), vapour compression (VC) and low temperature evaporation (LTE). In all these processes, condensing steam is used to supply the latent heat needed to vapourize the water. Owing to their high-energy requirements, thermal processes are normally used for seawater desalination. Thermal processes are capable of producing high purity water and suited for industrial process applications. Thermal processes account for 55% of the total production and their unit capacities are higher compared to membrane processes.

Multi Stage Flash (MSF) Process

The basic principle involved in the MSF process is to heat the sea water to about 90– 120°C using the heat of condensation of the vapour produced and supplementing with external steam. The heated sea water is subsequently flashed in successive stages maintained at decreasing levels of pressure. The vapor produced is condensed and recovered as pure water. MSF can accept higher contaminant loading (suspended solids, heavy metals, oil, grease, COD, BOD etc.) in feed sea water. It is capable of producing distilled quality product water good for power plants, process industries and several other high purity applications.

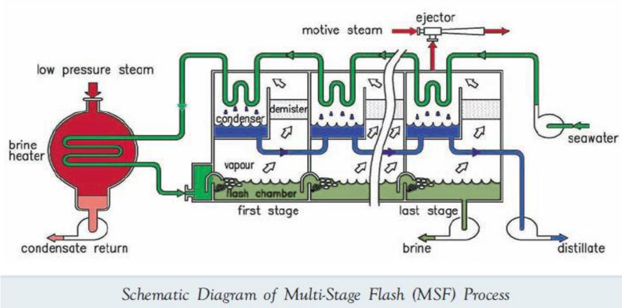

Fig.3 Multistage flash process

Multi Effect Distillation (MED)

MED plant has two or more effects. Each effect operates at a successively lower temperature and pressure. The first effect is heated by low pressure steam (about 0.3 bar). Vapours are generated from the feed sea water in the first effect and directed to the second effect. Thus vapours from the previous effect serve as the heat source to the succeeding effect for evaporating the brine. Vapour from the last effect is condensed in the final condenser where sea water is used as the coolant. The vapour produced in each effect is passed through the demisters to next effect. It is condensed inside the tubes transferring the latent heat to the brine falling outside the tube enabling a portion of the brine to evaporate. Low temperature MED unit operates at about 65°C and therefore allows the use of cheaper materials of construction due to less scaling and corrosion problems. MED is capable of producing pure distilled water similar to MSF. The possibility of low temperature operation, low grade heat and waste heat utilization, low cooling water requirement and low energy consumption have made MED an attractive alternative in recent years for sea water desalination.

Efficiency of MED plant can be improved by adding a vapour compressor. Mechanical Vapour Compressor (MVC) or Thermal Vapour Compressor (TVC) is used for this purpose depending on site specific conditions.

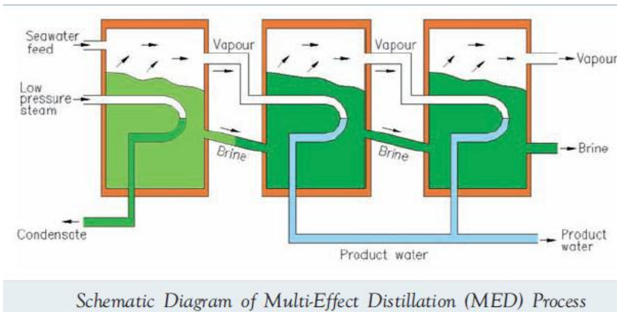

Fig.4 MultiEffect distillation process

Low Temperature Thermal Desalination

As the energy cost component is a major fraction of the desalinated water cost, utilization of waste heat as energy input for seawater desalination is an attractive option. It is one of the eco-friendly ways to produce desalinated water as it does not require chemical pretreatment of feed seawater. Ocean thermal energy can also be utilized for sea water desalination.

The surface sea water at about 28°C – 30°C is pumped into flash chamber which is maintained under low pressure of about 25 mbar absolute (below the saturated vapour pressure of water). The warm sea water in the flash chamber evaporates due to low pressure being maintained, taking latent heat of evaporation from the warm water stream itself. The evaporated water vapours move towards the shell & tube condenser and the return water, loosing temp by about 7°C is returned back to the sea. The main condenser has a circulation of cold sea water at a temp of 12°-13°C, pumped from the lower layers of sea & is used for the condensation of the evaporated water vapour. The condensate thus produced is fresh drinking water fit for human consumption. The cold water pumped used in the condenser can subsequently be used for air conditioning as the return temperature of this water is around 17°-18°C. This water being pumped from the lower levels of the sea is rich in minerals & plankton and when discharged on sea surface becomes a potential breeding area for fish and other marine life.

LTTD method of producing fresh water from sea water consists of flash evaporator, main condenser, fresh water & warm water pump and a vacuum pumping system. Since the major equipment is static the entire project requires low maintenance, having long operational life (Refer schematic diagram). The surface sea water is pumped into the flash chamber where low pressure is maintained. Almost 1% of water is evaporated in the flash chamber and the rest of the water freely flows back into the sea as the flash chamber is maintained at a barometric height. The vapours evaporated in the flash chamber are driven over the main shell & tube condenser and almost all of them are condensed. The cold source of water pumped from lower layers of the sea takes away the condenser heat. The discharge water of the condenser, available at about 17°-18°C, can be used for other cooling applications such as air conditioning etc before discharging back into the sea.

During the process of evaporation non condensable gases released from the sea water & the plant leakage load are constantly pumped by a vacuum system to ensure that absolute pressure in the range of 25 mbar is maintained in the vessel. The estimated consumption of energy per KL on a medium size plant is estimated around 8 units/Kl of fresh water generated. As per the current rate of energy, the estimated cost of generation is about 3 paise/lt which is very economical as compared to other conventional methods presently in use. To improve, additional technique of de-aeration of sea water prior to its admittance in the flash chamber was planned which resulted in higher efficiency, yield and low power consumption.

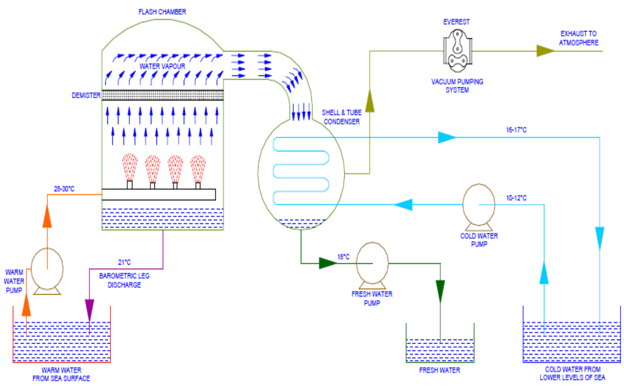

Fig. 5 Flow Diagram for Low Temperature Thermal Desalination Process

Membrane based desalination processes

Reverse Osmosis (RO)

RO is used for both brackish water and seawater desalination as well as for waste water treatment and water recovery/reuse. A typical RO desalting plant consists of three sections, namely pretreatment section, membrane section and post treatment section. Conventional pretreatment section typically consists of particulate filtration, micron filtration and chemicals additions. Membrane section consists of membrane elements housed in pressure vessels through which pretreated saline water is passed under pressure in excess of its osmotic pressure with the help of a high pressure pump coupled with energy recovery device. The post treatment section consists of lime treatment for pH correction and chlorination for disinfection as required to meet public health standards and to make the water noncorrosive to the water distribution systems. Energy consumption depends on the salt content of the feed water. Development of RO membranes of very high rejection, while maintaining high permeability, has potential to reduce the energy consumption. Development of better energy recovery devices can further reduce the energy consumption. As the success of RO desalination hinges on the proper pre-treatment of the feed water, various membranes could precede RO in order to selectively remove suspended solids (microfiltration), colloids/turbidity & organics (ultrafiltration) and hardness and sulphates (nanofiltration). The following figure explains the basic principle of Reverse Osmosis Process.

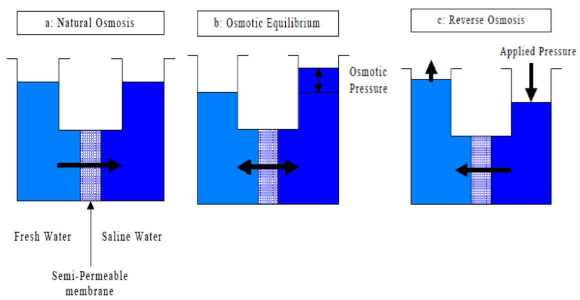

Fig.6 Reverse osmosis

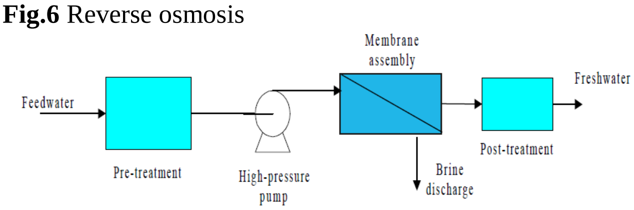

Fig.7 Flow diagram for RO system

Electrodialysis

The following figure illustrates an electrodialysis process. In electrodialysis (ED), two types of membranes are used. The cation membrane allows only cations (positive ions) to permeate, and the anion membrane allows only anions (negative ions) to permeate. These exchange membranes are alternately immersed in salty water in parallel, and an electric current is passed through the liquid. The cations will migrate to the cathode, and the anions will migrate to the anode. Therefore, water passing between membranes is split into two streams. One is pure water, and the other is concentrated brine. Because ED uses energy at a rate directly proportional to the quantity of salts to be removed, this process is more useful in desalting brackish water.

Reverse osmosis and electrodialysis are the two most important membrane processes. To affect salt separation, RO uses hydraulic pressure, whereas ED uses electric current.

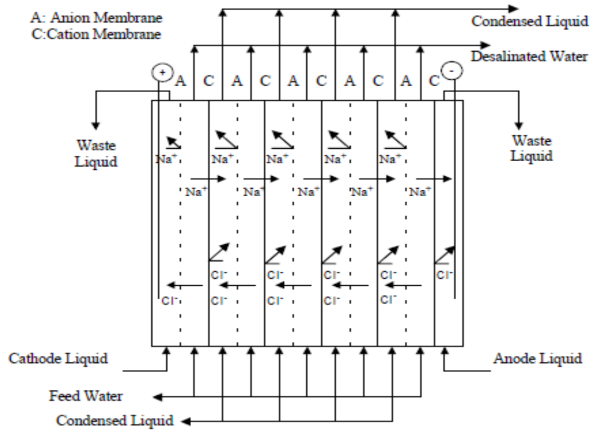

Fig.8 electro dialysis process

Environmental Impacts of desalination

There are five aspects to the impact of desalination plants on the environment:

1. **Adverse effect on land use**. As factories are located near the shoreline, seashores serve as the sites for industrial plants and for pumping stations rather than for recreation and tourism.
2. **Impact on the aquifer**. If a desalination plant is constructed inland in order to minimize the impact on the beach, there is a need for pipes to transport the seawater and brine. Leakage from the pipes may result in penetration of salt water and therefore presents a danger to the aquifer. The aquifer is further endangered if drilling is initiated in order to draw brackish feed water.
3. **Impact on the marine environment** as a result of returning the concentrated brine to the sea. Although the brine contains materials, which originated in the sea, its high specific weight and the potential presence of additional chemicals introduced in the pretreatment stage may harm the marine population in the area of the discharge of the brine. The installation of the feed and discharge pipes may itself be harmful. Layers of sand and clay may suffer re-suspension during the laying of the pipes and rocky areas and reefs may suffer mechanical blows.
4. **Impact of noise.** Seawater desalination plants require the use of high-pressure pumps and turbines for recovering energy, which produces noise. They should therefore be located far away from populated areas or equipped with the appropriate technologies for lowering noise intensities.
5. **Intensive use of energy**. This has an indirect impact on the environment due to the need to increase production of electricity with the well known related environmental consequences.

Case study

Environmental impacts of some desalination plants are reviewed, providing brief descriptions of the Impact.

1. Low Temperature Thermal Desalination (LTTD) Plant on the Lakshdweep Islands.

National Institute of Ocean Technology (NIOT), (Ministry of Earth Sciences) has setup a land based demonstration plant in Kavaratti with a capacity of producing 1 lakh litre per day of freshwater in May 2005. The sea bed bathymetry near the island was such that 350m water depth was available at about 600m from the shore. Temperature gradient of 15^{o}C was utilized (Temperature at surface water at 28^{o}C , water at 350 m depth at 12^{o}C). High Density Polyethylene (HDPE) pipes of 630mm diameter and 600m long were deployed to draw cold water from a depth of about 350m. The sea water pumps inside the partitioned sump supply warm and cold water to the plant on the land. The plant has been running continuously ever since, fulfilling the needs of the 10000 strong local community for over four years. The salinity of the freshwater produced was reduced from 35000 ppm of the seawater to 280 ppm whereas the permissible limit for drinking water is 2000 ppm.

Table: 1 Characteristics of desalinated water

parameter	**Desirable limit for drinking water**	**Permissible limit for drinking water**	**Desalinated Water at Kavaratti**
Color	5 Hazen	25 Hazen	OK
Odour	Unobjectionable	Unobjectionable	OK
Taste	Unobjectionable	Unobjectionable	OK
pH	6.5	8.5	7-8
TDS (ppm)	500	2000	280
Chloride (ppm)	250	1000	90
Total Hardness (PPM)	300	600	100
Total Coli form (MPN)	-	10	Not Detected

Table: 2 Water borne disease

Name of Disease	Viral Hepatitis	Diarrhea with vomiting under 5 year	Diarrhea with vomiting above 5 year	Dysentery
Before Installation	455	812	439	198
After Installation	342	701	347	10

Fig. 9 LTTD Plant in Kavaratti on the Lakshdweep Islands

Subsequent to the commencement of the plant water supply for drinking water needs, there have been significant drop in the incidence of water borne diseases among the consumers as may be seen from Table. NIOT is currently in the process of establishing similar plants in three more islands of the region.

2. Bocabarranco desalination plant

This installation is located in the northwest (NW) of the island of Gran Canaria, at Bocabarranco beach, in Galdar. Technical specifications are:

Technical specification in Bocabarranco SWRO desalination plant

Capacity of production	7,000 m^3/day
Recovery	45%
TDS water product	400 ppm
Application	Domestic consumption

The plant installation is integrated into a larger desalination system on a 10,000 m^2 plot, and all the infrastructure services are also use by the unit. There is also another seawater reverse osmosis desalination plant for agriculture purposes in a different building, and a waste water treatment plant nearby.

Brine discharge is realized though two pipelines to the coastline, first one is double for the brine reject of potable water plant with 300 mm diameter and the second one is 400 mm diameter for agriculture use. Both pipelines discharge close to the beach. The solution taken consists of joining all discharges, even waste water, by a long outfall discharging into the sea. Seawater and brine reject are:

Table:3 Chemical composition of seawater and brine reject in Bocabarranco Plant

mg/l	Sea water	Brine
Calcium	450	814
Magnesium	1,520	2,751
Sodium	11,415	20,657
Potassium	450	814
Bicarbonate	250	452
Chloride	20,800	37,639
Sulphate	3,110	5,628
Silicon	5	9
TDS	38000	68764

Table: 4 Chemical Doses used in Bocabarranco Plant

Chemical doses	kg/m^3	ppm
NaOCL	0.053	3.0
H_2SO_4	0.068	16.4
$NaHSO_3$	0.027	2.0
Antiscalant	0.009	4.1
$FeCl_3$	0.055	1.7
Calcium hypochloride	0.005	2.8

Conclusion

Desalination can be a good alternative to obtain fresh water from seawater or brackish water, which can be utilized for drinking, domestic, industrial and agricultural applications. Reverse Osmosis and Multi Stage Flash Desalination technologies are the most widely used in various countries of the world. But it affects the environment in various ways. Any process requires energy, which is supplied using electricity. And the electricity is produced in the power plants by burning fuels. So it is an indirectly causes air pollution. The concentrated brine reject, containing chemicals used for cleaning of membranes, is discharged into the ocean, which can affect the marine environment. These desalination plants are located near the coastal areas away from tourist development and populations. The pipes, for seawater and brine, lay over the aquifer. If the pipe leaks anywhere, the salt water may penetrate into the aquifer causing pollution.

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