# OVERVIEW OF DESALINATION IN THE PACIFIC REGION

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**ABSTRACT**
The authors classify the countries of the region into three categories. They are: (1) Japan and Korea where their desalination technology is developed enough to compete in the world market (2) Australia and China where they have their own technology, but domestic and overseas plants are mingled and (3) the rest of the countries where all the desalination plants come from overseas. The paper will review the first and second categories.
Australia has the highest natural water availability per capita (because of its vast size and low population) followed by Japan, China and Korea in that order. Resources, however, are uneven in both time and space. Fresh water consumption reflects land use and industrialization. Agriculture consumes more than 80% of the total consumption of fresh water in Australia and China compared to around 65% in Japan and Korea. Japan consumes 16% of its total in industry compared to 7.5% for Australia and 11% in China and Korea. Water for living purpose is highest in Korea (26%) followed by Japan in 19%, Australia in 10% and China in 2%.
In Australia, the potential use of desalination is for industry and small remote communities, particularly for tourism. The total capacity is about 84,000 $m^3$/day with 45% RO, 18% VC and 12% MSF plus ME. Micro-filtration membrane and equipment are manufactured in Australia. This system is becoming used widely as an RO pretreatment in industry using secondary treated wastewater as the feed supply. In China, the market of desalination is growing, but will not become very large. The main demand for desalination is still pure and ultra-pure water production in power plants and factories. The total capacity excluding ultra-pure water is about 180,000 $m^3$/day with 85% RO, 15% MSF and some ED. There are some public and private organizations engaged in desalination R & D.
As of March 1998, the desalination capacity in Japan was 69,000 $m^3$/day for industry and 61,000 $m^3$/day for water supply. The RO process is preferred, but the MSF, ME and ED processes have some shares depending on local conditions. There are two R&D trends in RO process development. One is pretreatment with membranes, and the other is high recovery SWRO. In Korea, the government initiated serious examination of desalination potential in 1996. Already desalination plants for industry and for remote islands have been installed. The total capacity is about 180,000 $m^3$/day mostly for factories and power stations. Korea Atomic Energy Research Institute (KAERI) is developing desalination as part of its nuclear power generation program.

## 1 INTRODUCTION

The Pacific Region has diversity in term of desalination. The present authors classify the countries of the region into three categories, namely (1) Japan and Korea where their desalination technology is developed enough to compete in the world market (2) Australia and China where they have their own technology, but domestic and overseas plants are mingled and (3) the rest of the countries where all the desalination plants come from overseas. The paper will review the first and second categories.

## 2 AVAILABLE NATURAL WATER RESOURCES

Table 1 shows some data on natural water resources of Australia, China, Japan and Korea in the alphabetical order.

Table 1. Natural Water resources in the Pacific Region

| Country | Annual Precipitation in mm | Available Water in billion $m^3$/year | Population In million | Water per Capita in $m^3$/year |
|---|---|---|---|---|
| Australia | 465 | 100 | 18.1 | 5,520 |
| China | 648 | 2,813 | 1,224 | 2,340 |
| Japan | 1,714 | 422 | 125.6 | 3,360 |
| Korea | 1,274 | 69.7 | 46.4 | 1,500 |

According to the table, Australia and Japan have rather high values of water per capita, which is followed by China and Korea. On the other hand, Australia and China have vast territory with a variety of climates and of water distribution, while Japan and Korea are reverse. On the whole, Australia seems most abundant in water resource because of small population with rather little precipitation. Japan is the second with much population and the largest precipitation. In China, the characteristics of water resource are uneven in both time and space with too much in spring and summer and with too much in southern part of the country. Korea has the second largest precipitation but the least water per capita.

Water resource per capita is one of the fundamental indexes indicating of water abundance. However, the values express only a part of potential water availability. One can not use fresh water unless it exists in forms of rivers, lakes or underground water. In addition to those, the geographical distance between water supply and its demand must be close enough economically, because water transportation is rather expensive. Australia, for example, suffers from extremely irregular precipitation and high evaporation. Two thirds of the country is arid and flat, and incorporates no topographical features suitable for major water storage. Of historical interest is a proposal in the 1950s to use atomic energy to create giant underground water storage caverns to overcome the problems of flat terrain, high evaporation and irregular rainfall.

## 3 TREND OF FRESH WATER CONSUMPTION

Consumption is grouped into agriculture (including livestock), living and industry (including power generation). The agricultural use occupies the largest portion through the region, and the consumption for living is dependent on standard of living, life-style and climate. Industrial water consumption is increased by industrial development, but can be depressed by efforts of rational use such as recycling.

### 3.1 Australia

Table 2 shows fresh water consumption pattern in Australia. As shown in the table, consumption has been increasing in all the fields. The increase is about twice the population growth for the last 10 years.

Table 2. Trend in Fresh Water Consumption
Unit: billion $m^3$/year

| Year | Agriculture & Stock Feed | Living | Industry & Commercial | Total |
|---|---|---|---|---|
| 1987 | 11.54 | 1.79 | 1.27 | 14.60 |
| 1995 | 14.84 | 1.87 | 1.35 | 18.06 |

Australia is not short of surface water around the coastal fringe where 80% of the population live. One exception is Perth in West Australia. The city is largely supplied by groundwater close to maximum abstraction rates. Additional surface water is available some distance away but at cost less than desalination. One option is to replace industrial use with treated wastewater.

Various large industrial water users, such as power station, are examining the use of treated wastewater in lieu of town water as price for the latter continues to rise. Once the town wastewater price approaches \$A 1/$m^3$ (US\$ 1 = \$A 1.65 in 1998), it becomes feasible to use treated wastewater where the industry is close to a source of secondary treated wastewater.

### 3.2 China

Agriculture and industry consume 87% and 11% of the total demand, respectively. The consumption for living occupies only 2%. The recent trend is that the agricultural demand is flattening while consumption is increasing steadily in industry and living, especially at newly developing cities of medium size.

With development of industry and agriculture, the increase in total population and the resulting deterioration of water quality, the water supply is not enough for real requirement. Consequently, the annual shortage of 30 billion cubic meters for irrigation is estimated in the early period of the $21^{st}$ century, and another 30 billion cubic meters shortage is expected in urban areas.

To cope with the situation, the followings can be considered:

(1) Water conservation is the first and main approach.

(2) Diversions of river are the other way in some areas where constructing canals is possible.

### 3.3 Japan

The total fresh water consumption was 90.7 billion cubic meters in 1995. The consumption trend is shown in Table 3. As shown in the table, the total increased by about 4% in the two decades.

The agricultural use grew in the past, but recently the increase is flattening. On the contrary, the industrial water is flattening or decreasing because of recycling and rational use. The consumption of potable water including commercial activities (both are provided by the same water supply systems) is showing steady increase with an average consumption of 338 liter/day per capita in 1995.

Table 3. Annual Fresh Water Consumption

Unit: billion cubic meters

| Use | 1975 | 1980 | 1985 | 1990 | 1995 |
|---|---|---|---|---|---|
| Agriculture | 57.0 | 58.0 | 58.5 | 58.6 | 58.7 |
| Living | 12.4 | 13.7 | 15.1 | 16.6 | 17.2 |
| Industry | 18.1 | 16.6 | 15.6 | 15.6 | 14.8 |
| Total | 87.4 | 88.3 | 89.2 | 90.9 | 90.7 |

### 3.4 Korea

The annual demand of 14,877 million cubic meters for agriculture was the largest, and those for living and industries were 6,209 and 2,582 million cubic meters, respectively in 1996. In addition, the basic flow demand in rivers needed 6,476 million cubic meters, totaling 30,144 million cubic meters.

Fresh water for agriculture and living can be supplied by natural water as a whole at present. However, according to Kim and Chang [1] the rapid industrialization, increase in population and its urbanization are considered to be the key factors causing the fresh water shortage in future. At present, these problems are limited to certain regions, but it is expected that they will expand to the national scale and become much more severe in the near future unless some countermeasures are taken.

The increase in water of living surpasses conservation of industrial water, which brings gradual increases in total consumption of city water. Table 4 shows the water supply data in the past, mainly in the 1980s.

Table 4. Water Supply

| Year | Population in thousand | | | Supply Capacity in 1,000 $m^3$/day | Amount Supplied in 1,000 $m^3$/day | Amount per Capita/day in liter |
|---|---|---|---|---|---|---|
| | Total | Waterworks Supplied | Supplied Ratio (%) | | | |
| 1983 | 39,723 | 23,437 | 59.0 | 8,386 | 6,735 | 287 |
| 1984 | 40,106 | 24,866 | 62.0 | 9,498 | 7,339 | 295 |
| 1985 | 40,655 | 26,426 | 65.0 | 10,214 | 7,662 | 290 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1986 | 41,184 | 28,289 | 68.7 | 11,505 | 8,345 | 295 |
| 1987 | 41,575 | 29,556 | 71.1 | 12,613 | 9,192 | 311 |
| 1988 | 41,975 | 31,161 | 74.2 | 14,442 | 10,127 | 325 |
| 1989 | 42,380 | 32,968 | 77.8 | 15,752 | 11,176 | 339 |
| 1990 | 42,869 | 33,630 | 78.4 | 16,273 | 12,409 | 369 |

## 4 POTENTIAL NEED FOR DESALINATION AND ITS PRACTICE

### 4.1 Australia

The potential use of desalination is for industry and small remote communities for tourism, for example, barriers reef islands. Most will treat brackish rather than seawater. There are existing and planned mining and processing projects in the North West of Australia, such as the BHP iron ore briquette facility, where desalination in preference to surface water is a possibility.

There is a large industrial expansion planned for Kwinana 15 km south of Perth that will require an additional water supply, possibly 30,000 $m^3$/day. One option that looks economically attractive is to treat wastewater using the RO process and appropriate pretreatment (probably micro-filtration). A 100,000 $m^3$/day wastewater treatment plant is situated 5 kilometers north of Kwinana.

Existing Plants: [2]

(1) Capacity: 84,000 $m^3$/day in total, with the largest 29,300 $m^3$/day for a power station, NSW Bayswater. The average capacity is about 2,550 $m^3$/day. Most plants started to operate in 1980s and 1990s.
(2) Use: 45% for industry, 33% for power generation and 15% for municipal.
(3) Feed: 70% brackish, 18% wastewater and 10% seawater.
(4) Process: 64% RO, 18% VC and 12% MSF plus ME.
(5) Supplier: Both domestic and foreign.

### 4.2 China

The market of seawater desalination is now growing, but it can not become a very large one. The main demand of desalination has been still in pure and ultra-pure water production in power plants, electronics, pharmaceutical, chemical, car, food, beverage, etc. Much attention will be paid to brackish water desalination and wastewater treatments.

Desalination activity was started in 1970s. In those days, many ED plants were built in coal mines and at islands for brackish water desalination. The largest ED plant with capacity of 6,000 $m^3$ /day, was operated in Jinshan Chemical Factory, Shanghai. In 1980, a 200 $m^3$ /day seawater desalination plant by ED process was operated at Xisha Island. The energy consumption is about 20 kWh/$m^3$.

In 1980s, dozens of mobile ED and RO plants have been operated in oil fields of Xinjiang Province for drinking water production from brackish water. In 1997, a 500 $m^3$ /day SWRO desalination plant was built at Chengshan Island, Zhejiang Province. It spends 6 kWh/$m^3$ for drinking water production. A desalination plant with a capacity of 1,000 $m^3$/day at Dachangshan Island, Dalian has been put into operation with power consumption of 5.7 kWh/$m^3$ for the whole system. Another brackish water desalination plant with a capacity of 18,000 $m^3$/day will be operated at the end of 1999 for Cangzhou Chemical Industry Corporation. An MSF plant of 10,000 $m^3$/day in Dalian Oil Refinery is under feasibility study. In addition, a feasibility study on a seawater desalination plant of 4,000$m^3$/day capacity is being prepared for Zhejiang Province.

As for the cost of desalination, the operation cost in Dalian for seawater will be 6 RMB/$m^3$ (US$ 1 = RMB 8.28 in 1998) and that in Cangzhou for brackish water of 12,400 ppm TDS will be 3 RMB/$m^3$. It is also said that the operation cost of the above-mentioned 500 $m^3$/day SWRO at Chengshan Island is nearly 7 RMB/$m^3$. Those for brackish water is dependent on salinity of the feed, ranging from 1 RMB/$m^3$ for less than 1,000 mg/L to 3 to 4 RMB/$m^3$ for 5,000 to 10,000 mg/L.

Existing Plants: [2]

(1) Capacity: About 182,000 $m^3$/d in total with RO of 15,000 $m^3$/d at Shanghai, MSF of 10,000

$m^3$/d at Dalian Oil Refinery and RO of 11,520 $m^3$/d at Daging Oil Refinery. Rapid increase in 1990's.

(2) Use: More than 50% for factories, 40% for power plant with some exception for living.
(3) Feed: More than 50% of brackish, 20% of pure water and some river, waste and seawater.
(4) Process: About 85% of RO, about 15% of MSF and ME with some exceptions of ED.
(5) Plant Supplier: Mostly foreign and affiliate, but the 10,000 $m^3$/d MSF plant supplied by domestic.

**4. 3 Japan**

The desalination plants in Japan can be classified into two categories; one is industrial use and the other is use of water supply systems. The total capacity of industrial use was 69,000 $m^3$/day with 26 locations of 48 units excluding pure water purpose, while that of water supply was 61,000 $m^3$/day with 38 locations of 48 units as of March 1998.

Most of desalted water in industries is used for boiler feed of thermal power stations with some exceptions. The desalination capacities range from 1,000 to 13,660 $m^3$/day with an average of 1,432 $m^3$/day. The desalination plants for water supply systems had been installed in remote islands or regions before 1996. The average capacity was 462 $m^3$/day, ranging from 10 to 3,000 $m^3$/day. However, a seawater reverse osmosis desalination plant of 40,000 $m^3$/day was built at Okinawa in 1997, and that of 50,000 $m^3$/day is planned at Fukuoka. No such large plants are expected in the near future.

More than half of feed water for desalination in industries is seawater because all the thermal power stations in Japan are located on seashore. The plants for water supply systems use generally seawater, but in some cases underground brackish water is fed to the plants in remote islands where it is available.

The RO process is preferred to the desalination plants in industries, but the MSF and ME processes have a share of 30% in the total capacity. The RO process is also preferred for the plants for water supply systems in most cases. The exceptions are one MSF and six ED installations among the 48 units.

Natural water resources will meet the demand of fresh water as a whole. However, limited regions such as remote islands, some local governments having a little water resources will need desalination plants. Electric power plants can not always rely on natural water resources, and require desalination plants of thousands cubic meter per day capacity. However, we can not expect a large but a small market in future.

Existing Plants: [3]

(1) Capacity: 68,766 $m^3$/day for industry and 61,119 $m^3$/day for living, totally 129,885 $m^3$/day with the largest RO 40,000 $m^3$/day plant of the Okinawa water supply system.
(2) Use: 53% for industry including power generation and 47% of water supply systems.
(3) Feed: For water supply systems, mostly seawater with some brackish where the ED process is applied. For industry, seawater, brackish and sometimes groundwater are used.
(4) Process: 88% of RO, 6.5% of ED for brackish, 3.5% of MSF and 1.8% of ME.
(5) Plant Supplier: Almost all are domestic with some exceptions of US suppliers in 1970s.

**4.4 Korea**

The Korean Government started to study seriously to introduce desalination plants from 1996. It will take some time to build desalination plants at full scale for living purpose. There already introduced some desalination plants from 1980s for industrial purpose and for remote islands. Most of them are RO plants.

It is not expected a large desalination market in Korea as a whole. Limited regions such as remote islands and some district with seasonal short of rainfall will require barge mounted desalination plants in the near future. The Korean Government has done feasibility study to install desalination plants to cope with steady supply of water.

Industry recognized necessity for desalination early on because many industrial complexes have to produce their own process water [1]. The RO technology is widely employed for the desalination process of those plants. They do not, however, desalinate seawater directly, but produce the required water quality from brackish or low quality groundwater. The capacity of most of those plants is around 4,800 $m^3$/day, but the total capacity reaches around 175, 000 $m^3$/day. The largest desalination plant with a capacity of about 70,000 $m^3$/day is located at the Daesan Chemical/Petrochemical complex, and takes brackish water from a lake and produces fresh water for industrial purpose using the RO process. As yet, no desalination plant that produces fresh water directly from seawater has been constructed or operated on large scale in Korea. There are a few seawater desalination plants with a small capacity to provide fresh water to localized regions such as remote islands. However, such cases are considered exceptional.

Existing Plants: [2]
(1) Capacity: About 180,000 $m^3$/d in total, with the largest 70,000 $m^3$/d plant of Daesan Chemical/Petrochemical Complex. Rapid increase in the 1990s.
(3) Use: Mostly for factories (large share of pure water) and one for power plant.
(4) Feed: Pure>brackish>waste water>river water in this order.
(5) Process: RO dominates with some ED exceptions.
(6) Plant Supplier: mostly foreign, but some domestic.

## 5 DESALINATION TECHNLOGY

### 5.1 Australia

Most suppliers of RO plant import the RO membranes and pressure housings. These are fitted to both small off-the-self units and larger tailor-designed plant. There is no RO membrane manufacture nor R&D of any consequence in Australia.
However, micro-filtration membrane and equipment are manufactured. This technology is becoming used widely as an RO pretreatment in industry using secondary treated wastewater as the feed supply. The Memcor Division of US Filter (previously Memtec Limited) has its global micro-filtration manufacturing and R&D facility at Windsor 50 km west of Sydney.
US Filter in Australia offers for bidding in Asian countries based on skid mounted equipment from USF Bekox in Spain.

### 5.2 China

MF and UF membranes have already been tested for pretreatment of SWRO plants. In addition, two devices of VP-ME with a capacity of 1 $m^3$/hr were also operated intermittently for oil field water supply and seawater desalination. Wastewater is considered feed water as well.
There are mainly four institutes for desalination and membrane research. They are:
(1) The Development Center of Water Treatment Technology, Hangzhou (M)
(2) Dalin Institute of Chemical Physics, Chinese Academy of Science (M)
(3) Institute of Sea Water Desalination and Multipurpose Utilization (D & M)
(4) Tianjin University (D)
* M: membrane, D: distillation

Concerning business activities, there are the following membrane and plant manufacturers:
(1) Membrane Manufactures
1) Liao Yuan Membrane and Separation Equipment Factory, Jilin Province
2) Liaoning 8271 Factory, Liaoning Provine
3) YCQ Company, Guanxi Province
4) Ocean Membrane Engineering Company, Jiangsu Province

(2) Plant Manufacturers
There are hundreds of plant manufacturers engaging in membrane and distillation business,

including foreigner's, joint ventures, state-runs and privates.

### 5.3 Japan

The R & D activities in desalination seem to be shifting from evaporation processes to membrane processes. Recently, there are two important trends in the RO process. One is pretreatment with MF or UF membranes, and the other is so-called "high recovery SWRO membranes" with which one can expect 60% recovery for seawater desalination.
Several types of MF and UF membranes have been tested for SWRO pretreatment in the past some years, and it was found that the pretreatment with membranes be promising. In this connection, a patent of NF and RO combination systems for higher recovery was filed.
Recently, some membrane manufacturers in Japan are insisting that they have developed high recovery SWRO membranes. It was proposed so-called "the optimum system of MF or UF, NF and the high recovery RO for desalination". One can anticipate desalination cost reduction by 25%, compared with the conventional sand filtration pretreatment and 40% recovery membranes, if everything is done as expected.
There are two types of business companies. One type is manufacturers of desalination membranes, and the other is plant manufacturers that are concerned with plant engineering of not only RO but evaporative processes. The representative companies are:

(1) Membrane Manufacturers

| | |
|---|---|
| Asahi Chemical Industry, Co., Ltd. | Asahi Class Co., Ltd. |
| Nitto Denko Corporation | Tokuyama Corporation |
| Toray Industries, Inc. | Toyobo Co., Ltd. |

(2) Plant Manufacturers

| | |
|---|---|
| Ace Water Treatment Co., Ltd. | Asahi Chemical Industry, Co., Ltd. |
| Asahi Glass Co., Ltd. | Babcok-Hitachi K. K. |
| Ebara Co., Ltd. | Hitachi Zosen Corporation |
| Kawasaki Heavy Industries, Ltd. | Kubota, Ltd. |
| Kurita Water Industries, Ltd. | Mitsubishi Heavy Industries, Ltd. |
| Mitusi Eng. & Shipbuilding Co., Ltd. | Japan Organo Co., Ltd. |
| Sakakura Engineering Co., Ltd. | Sumitomo Heavy Industries, Ltd. |
| Tokuyama Corporation | Toray Engineering Co., Ltd. |

### 5.4 Korea

Korea Atomic Energy Research Institute (KAERI) is under developing desalination plant by use of nuclear power and know-how holding turnkey contractors are developing their process contract by contract.
Sea Han Industries is a membrane manufacturer in Korea. The following are plant manufacturers.

1) Korea Heavy Industries and Construction Co., Ltd.(HANJUNG)
   Design & engineering, manufacturing, civil & erection, start-up & commissioning, etc. as a turnkey contractor for MSF/MED/RO desalination plants
2) Hyundai Heavy Industries Co.
   Manufacturing, civil & erection for MSF desalination plants
3) Daewoo Heavy Industries Co.
   Manufacturing for desalination equipment

## 6 CONCLUSION

In the present paper, the authors reviewed natural water availability, water consumption, potential need and practice of desalination, technology of desalination in the region. Their conclusions are:

(1) The demands for fresh water are met as a whole with some exceptions. However, water shortage is expected along with development of industry and improvement in standard of living in the next century.
(2) The countermeasures against water shortage are water conservation, rational use, wastewater reuse and desalination.
(3) Since desalination is supposed to be more expensive than other measures, it could be used when desalination is needed essentially. Essential needs for fresh water occur in factory production, power generation and household use in remote areas. Desalination in remote areas is confined to small scale.
(4) Concerning desalination practice, general interest focusing on the membrane processes especially the RO process. However the distillation processes still attract some attention, making the best use of their merits.
(5) Concerning desalination technology, Australia's MF membrane modules and Japan's SWRO membranes are giving some impact on advancement. China and Korea are making national effort to cope with the expected water shortage in future.

## 7 ACKNOWLEDGEMENTS

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