Seawater Desalination Facility on Okinawa

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1. Introduction

Okinawa Seawater Desalination Center was completed with full capacity in 1997. The facility was constructed to ease water shortage on Okinawa by converting surrounding clean seawater into drinking water. With ten years of operation, the facility has proved to be successfully functioning to meet demand for drinking water especially in drought situation.

This presentation covers an overview of Okinawa Seawater Desalination Center, issues including product water quality and facility maintenance, and finally, the facility's overall performance of the past ten years.

2. Overview

2.1 Need for desalination facility on Okinawa

Due to population growth and economic development, the average water consumption on Okinawa doubled from approximately 200,000 m^3/day in 1972 to 420,000 m^3/day in 2002. Water rationing occurred in 14 years out of 34 years since 1972. The longest water rationing continued for 326 days from 1981 to 1982. The most recent water rationing occurred in 1993.

Shortages were anticipated for water resources dependent on the development of dams and rivers. As a countermeasure, the Enterprise Bureau of Okinawa Prefecture decided to promote the desalination project. The first survey was conducted by the Japanese government in 1977, and construction began in 1993.

2.2 Reverse osmosis seawater desalination facility

The construction cost of Okinawa Seawater Desalination Center was 34.7 billion yen, 85% of which was subsidized by the national government.

The facility exploits reverse osmosis technology to desalt seawater. The production capacity is 40,000 m^3/day, which is nearly equal to 10% of the average water consumption on Okinawa. Fig.1 shows the process flow.

The facility needs approximately 9,000 kW of electricity for full operation.

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High pressure pumps, which are necessary to bring about reverse osmosis, consume most of the energy. Energy recovery turbines retrieve approximately 30% of the energy from the brine, which still has high pressure.

The desalted fresh water is sent to adjoining Chatan Water Purification Plant and mixed with potable water produced from inland water.

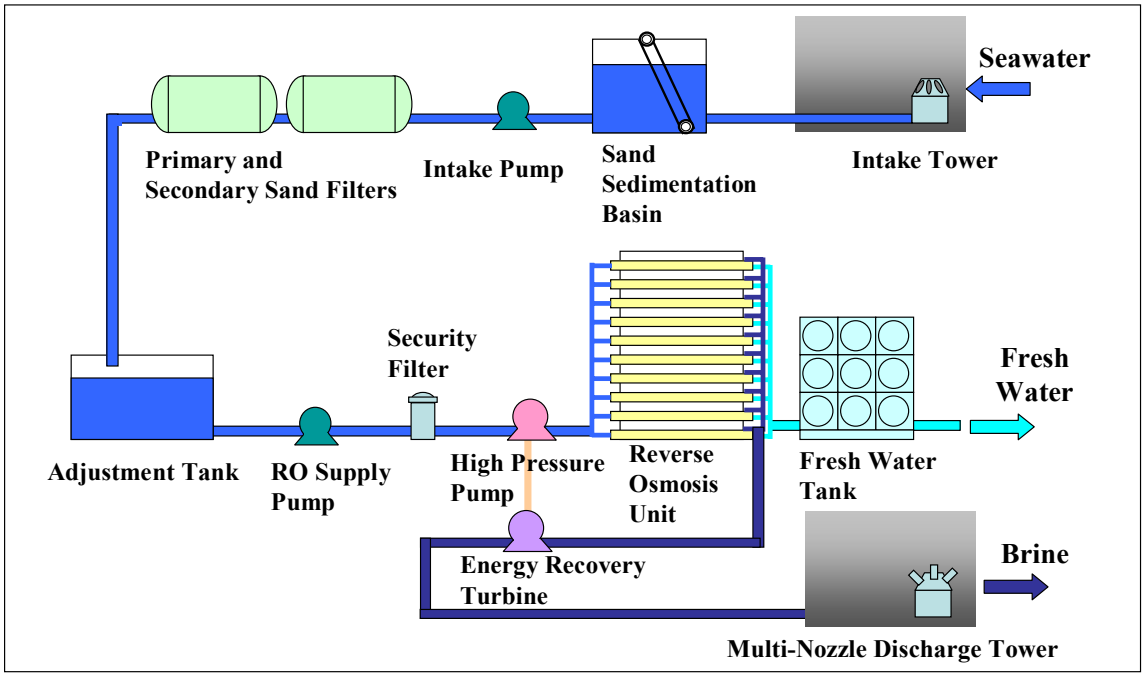

Fig.1 Process flow of Okinawa Seawater Desalination Center

3. Water quality

3.1 Effect of desalination

In the reverse osmosis (RO) process, most of the substances in seawater are removed. Table.1 compares quality of the RO feed seawater, the desalted product water, and the mixed potable water.

Table.1 Comparison of water quality

Item	RO feed water	Desalted water	Mixed water
Total Dissolved Solids	34,800	278	256
Chloride Ion	19,800	119	46.5
Sodium and its compounds	11,400	96.1	38.8
Sulfate Ion	2,490	5.9	36.8
Hardness	6,360	10	113
Electrical conductivity	50,800	456	436
Boron and its compounds	4.68	1.14	0.12

(Units: [μ S/cm] for electrical conductivity and [mg/l] for others)

The mixing strategy has several advantages, as explained in the following sections.

3.2 Hardness

Desalted fresh water has an extremely low hardness and is considered corrosive. Usually, a mineralizing process follows the RO process as a post-treatment in order to prevent corrosion. However, since the water produced in Chatan Water Purification Plant has relatively high hardness, the hardness of the mixed water becomes moderate. Therefore, the post-treatment is not needed.

3.3 Conductivity

Salt rejection rate is a great concern in the desalination facility. Electrical conductivity is a good scale of salinity and easy to monitor continuously. Okinawa Seawater Desalination Center has set 720 μS/cm as the maximum operational conductivity for the product water. This value corresponds to the allowable concentration of chloride ion according to water quality regulations.

3.4 Boron concentration

Boron is hard to remove in a single stage reverse osmosis process. Japanese water quality regulations demand boron concentration to be less than 1.0 mg/l. Table.1 shows that boron concentration was not sufficiently reduced by the desalination process alone but successfully suppressed by mixing.

4. Maintenance

4.1 Biofouling

The RO process utilizes polyamide membrane, which does not tolerate oxidizing agents. Since the feed water does not contain chlorine, biofilm tends to grow inside the seawater channel and obstruct the feed flow in the RO elements. This phenomenon, biofouling, may cause irreversible damage to the membrane elements. Okinawa Seawater Desalination Center conducts sulfuric acid shock treatment and membrane cleaning to control biofouling. An effective cleaning method has been established. However, the shock treatment still needs to be investigated to achieve reliable efficiency.

4.2 Element replacement

As the RO elements are used, the salt rejection rate declines, and average conductivity of the product water increases. The deteriorated elements must be replaced in order to maintain quality of the product water. The life span of an RO element depends on the operating conditions such as quality of pretreatment. Okinawa Seawater Desalination Center began element replacement in 2000 and had replaced about a half of the originally installed 3,024 elements by 2006.

5. Overall performance

5.1 Production

Ten years have passed since the facility started operating. For the first five years, Okinawa had enough rainfall, and full operation of the desalination facility was not necessary. Since 2001, there have been occasional drought, and Okinawa Seawater Desalination Center has performed long term full operations. Fig.2 shows the annual production and the operating rate of each year. The total production through 2005 had reached over 37 million cubic meters. Due to recent droughty climate, the operating rate reached 44.2%, the facility's highest record.

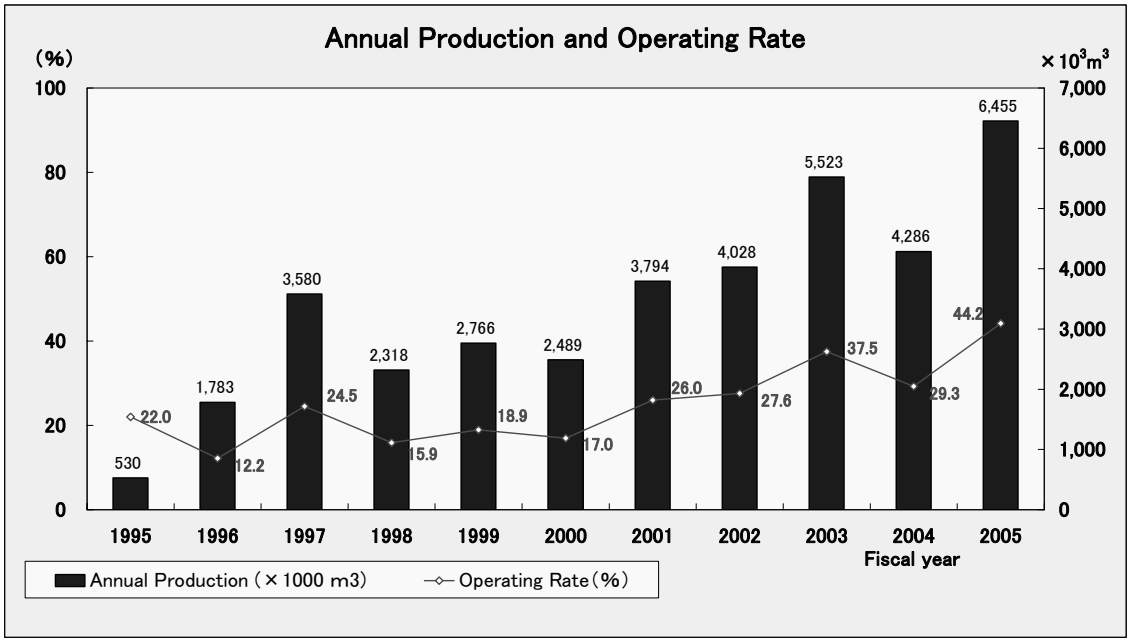

Fig.2 Annual production and operating rate

5.2 Cost

As of 2004, the production cost of the fresh water produced in Okinawa Seawater Desalination Center is approximately 132 yen/m^3. Fig.3 shows the components of the cost. As shown, electricity is the most dominant factor of the cost.

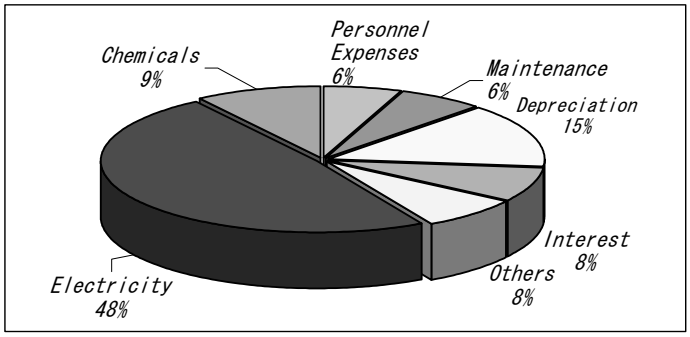

Fig.3 Components of the production cost

5.3 Water quality and element replacement

Table.2 lists some of the water quality items maintained in Okinawa Seawater Desalination Center. Fig.4 shows the ten year trends of the product water quality. The standards have been maintained for all the items except boron. Fig.4 also shows the numbers of replaced membrane elements within the same period. The figure clearly shows the effect of the membrane replacement on the product water quality.

Table.2 Water quality items

Standard	Item	Value
Max Operational Value	Conductivity	720 μs/cm
Water Quality Regulations	Total Dissolved Solids	500 mg/l
	Chloride Ion	200 mg/l
	Boron	1.0 mg/l

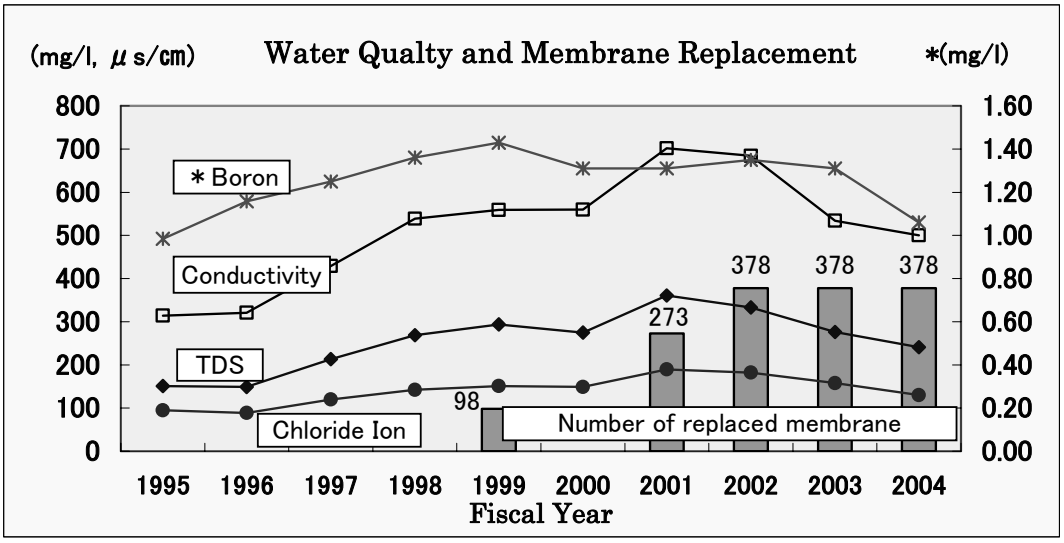

Fig.4 Water quality and membrane replacement

6. Conclusion

With ten years of operation, Okinawa Seawater Desalination Center has accumulated valuable technical experiences. The membrane cleaning and the element replacement have been successful in maintaining quantity and quality of the product water. Since biofouling is a drawback for long term full operation, an effective shock treatment method is sought. The operating rate of the facility has been increasing due to the droughty climate. Therefore, the facility has been functioning as a crucial water resource on main island of Okinawa.

Reference

Japan Water Works Association, Design Criteria for Waterworks Facilities (2000) 352

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Introduction

1. Overview
2. Water quality
3. Facility maintenance
4. Overall performance

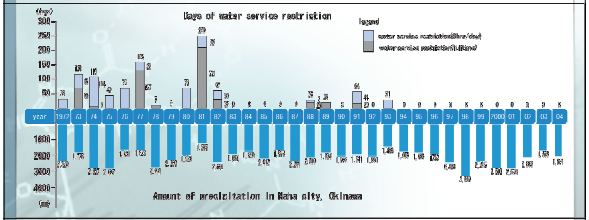
1. Overview

- Needs for desalination
- Reverse osmosis seawater desalination facility

Needs for desalination

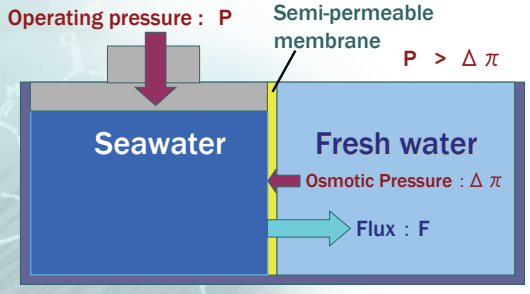
- Water demand doubled in 30 years
- Supply dependent on dams and rivers
- Merit of desalination
  - Abundant water from the sea
  - Short construction period
  - Location near consumers

Water rationing

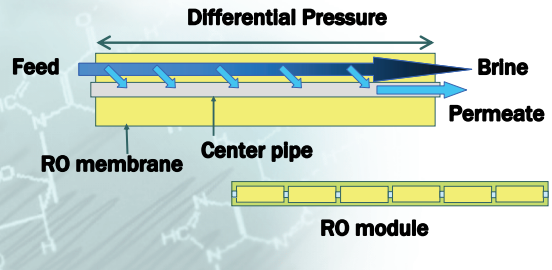


- Water rationing occurred in 14 years out of 34 years since 1972.
- The longest continued 326 days.
- No water service restriction occurred since 1993.

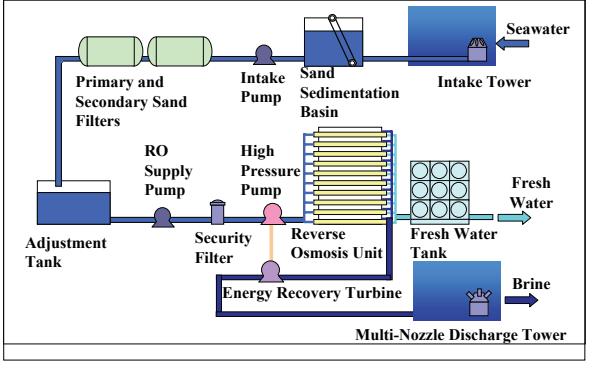
Reverse osmosis



Reverse osmosis (RO) membrane element



Okinawa Seawater Desalination Center



Okinawa Seawater Desalination Center

- Production capacity : 40,000m^3/day
- Recovery rate : 40%
- Maximum power consumption : 9,000 kW
- 378 elements / unit × 8 units = 3,024 elements
- Product water is sent to adjoining water purification plant to be mixed with water from inland.
- Construction cost : 34.7 billion yen
- 85% subsidized by the national government
- Partly operational in 1995
- Fully operational in 1997

2. Water quality

Item	RO feed water	Desalted water	Mixed water
Total Dissolved Solids	34,800	278	256
Chloride Ion	19,800	119	46.5
Sodium	11,400	96.1	38.8
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(Units: [μS/cm] for electrical conductivity and [mg/l] for others)

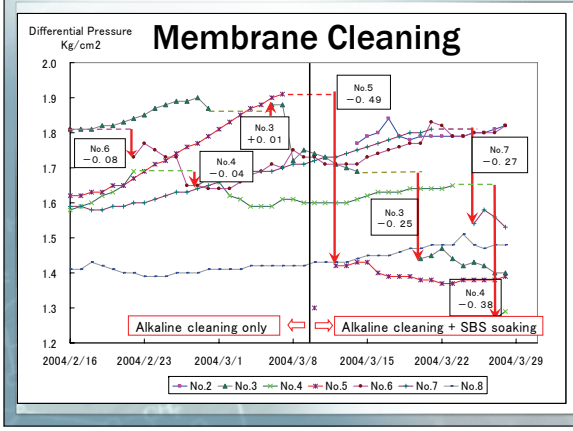
3. Maintenance

- **Biofouling**
  - Polyamide membrane and oxidizing agents
  - Biofilm in the feed channel
  - Damage to the membrane elements

Countermeasure for biofouling

- **Sulfuric acid shock treatment**
  - Acid injection to the feed
  - pH = 2.5 ～ 3.0 30 minutes
  - Advantage : Long running time of RO units
- **Membrane cleaning**
  - Off-line cleaning
  - pH = 10.5 3 days
  - Advantage : Fundamental and efficient

Membrane Cleaning



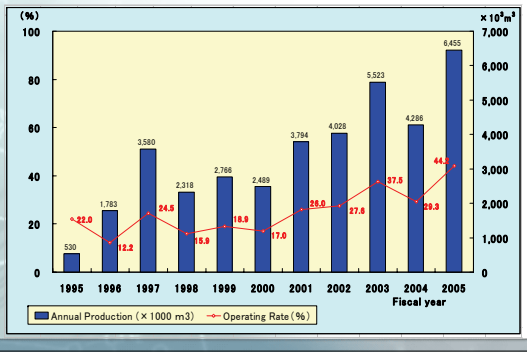
Element replacement

- **Salt rejection declines**
  - Conductivity of the product water increases.
  - Replacement started in 2000.
  - About a half of the elements were replaced by 2006.

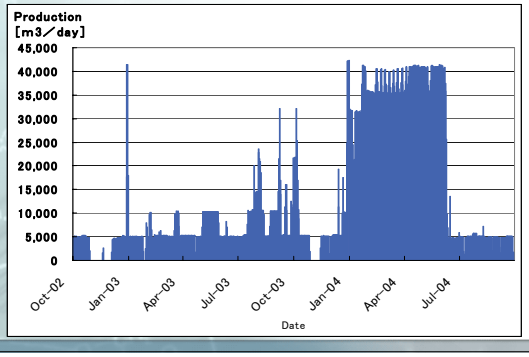
4. Overall performance

- **Production**
- **Cost**
- **Water quality and membrane elements**

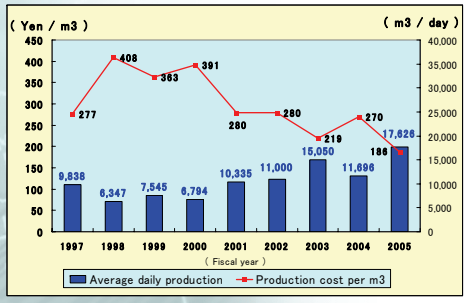
Production and Operating Rate



Long Term Full Operation

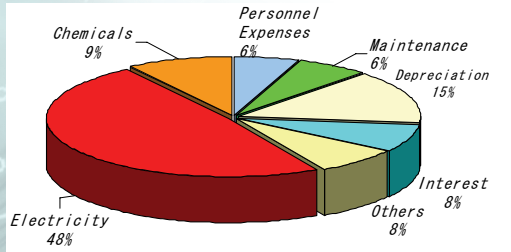


Production Cost



Components of Production Cost

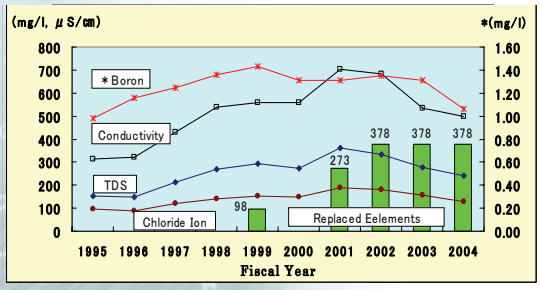
(132 yen / m³ , as of 2004 - 40,000m³/day operation is assumed)



Example of standards maintained

Standard	Item	Value
Max Operational Value	Conductivity	720 μS/cm
Water Quality Regulations	TDS	500 mg/l
	Chloride Ion	200 mg/l
	Boron	1.0 mg/l

Water Quality and Membrane Replacement



Conclusion

- Okinawa Seawater Desalination Center accumulated valuable technical experiences.
- Membrane cleaning and element replacement have been successful.
- An effective shock treatment method is needed.
- The operating rate has been increasing due to droughty climate.
- Therefore, the facility has been functioning as a crucial water resource on Okinawa.