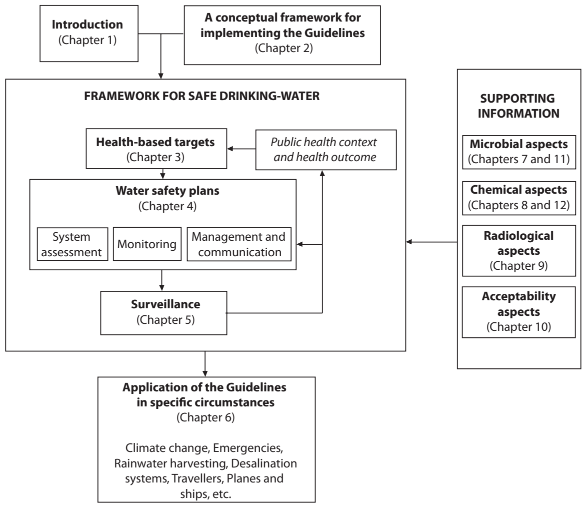
Water Supply System in Japan

Water & Waste Engineering 03
2023/4/28

名古屋大学減災連携研究センター
Disaster Mitigation Research Center, NAGOYA UNIVERSITY

Framework for safe drinking water



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Disability-Adjusted Life Year (DALY)

- ✓ Definition: One DALY can be the thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.
- ✓ DAYLs for disease or health condition are calculated as the sum of the Years of Life Lost (YLL) due to premature mortality in the population and the Years Lost due to Disability (YLD) for people living with the health condition or its consequences.

Calculation of DALYs

- ✓ **DALY = YLL + YLD**
- ✓ The YLL basically correspond to the number of deaths multiplied by the standard life expectancy at the age at which death occurs. The basic formula for YLL (without yet including other social preferences discussed below), is the following for a given cause, age and sex:
- ✓ **YLL = N x L**
- ✓ where:
  - N = number of deaths
  - L = standard life expectancy at age of death in years

Calculation of DALYs

- ✓ Because YLL measure the incident stream of lost years of life due to deaths, an incidence perspective has also been taken for the calculation of YLD in the original Global Burden of Disease Study for year 1990 and in subsequent WHO updates for years 2000 to 2004.

Calculation of DALYs

- To estimate YLD for a particular cause in a particular time period, the number of incident cases in that period is multiplied by the average duration of the disease and a weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (dead). The basic formula for YLD is the following (again, without applying social preferences):
- **YLD = I x DW x L**
- where:
  - ✓ I = number of incident cases
  - ✓ DW = disability weight
  - ✓ L = average duration of the case until remission or death

The various hazards that can be present in water can have very different health outcomes

- ✓ Some outcomes are **mild** (e.g. diarrhoea), wheres others can be **severe** (e.g. chlera, hemolytic uremic syndrome associated with Escherichia coli O157 or cancer).
- ✓ Some are **acute** (e.g. diarrhoea), whereas others are **delayed** (e.g. infectious hepatitis or cancer).
- ✓ Some especially relate to **certain age ranges and groups** (e.g. skeletal fluorosis in older adults often arises from long-term exposure to high levels of fluoride in childhood; infection with hepatitis E virus has a very high mortality rate among preg- nant women).
- ✓ In addition, any one hazard may cause **multiple effects** (e.g. gastroenteritis, Gullain- Barré syndrome, reactive arthritis and mortality associated with Campylobacter).

DALY provides the common metric

- ✓ In order to support public health priority setting, a **common metric** is required that can be applied to all types of hazard and takes into account different health outcomes, including probabilities, severities and duration of effects.
- ✓ The disability-adjusted life year (DALY) provides this metric.

Basic principle of the DALY

- ✓ The basic principle of the DALY is to weight each health impact in terms of severity within the range of **0 for good health to 1 for death**.
- ✓ The weighting is then multiplied by duration of the effect and the number of people affected.
- ✓ In the case of death, duration is regarded as the years lost in relation to normal life expectancy.
- ✓ Using this approach, a mild diarrhoea with a severity weighting of 0.1 and lasting for 7 days results in a DALY of 0.002, whereas death resulting in a loss of 30 years of life equates to a DALY of 30.

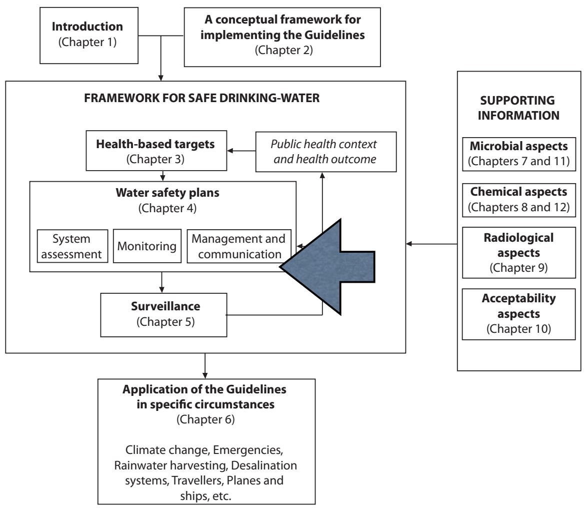
infection with rotavirus (in developed countries)

- ✓ mild diarrhoea (severity rating of 0.1) lasting 7 days in 97.5% of cases;
- ✓ severe diarrhoea (severity rating of 0.23) lasting 7 days in 2.5% of cases;
- ✓ rare deaths of very young children in 0.015% of cases.
- ✓ The DALY per case can be calculated as follows:
  - DALY = (0.1 x 7/365 x 0.975) + (0.23 x 7/365 x 0.025) + (1 x 70 x 0.00015) = 0.0019 + 0.0001 + 0.0105 = 0.0125

infection with Cryptosporidium

- ✓ Infection with Cryptosporidium can cause watery diarrhoea (severity weighting of 0.067) lasting for 7 days with extremely rare deaths in 0.0001% of cases.
- ✓ This equates to a DALY per case of 0.0015.

Framework for safe drinking water



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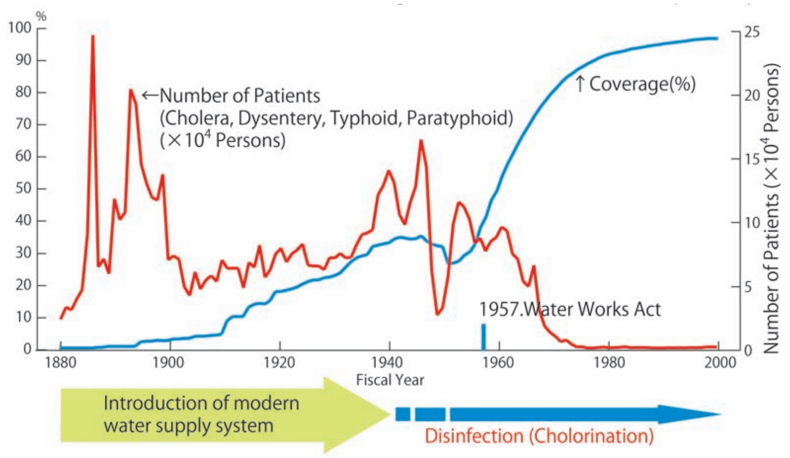
Water supply system in Japan

History of Japan Water Supply

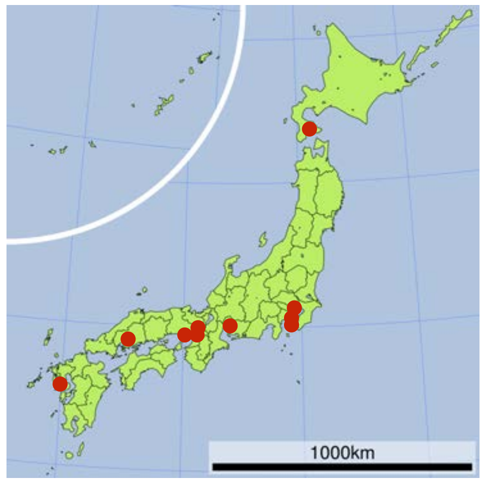
- Japan's first modern water supply system was introduced in Yokohama and began its operation in 1887.
- Following the operation in Yokohama, the water supply system spread in municipalities all over Japan.
- The waterworks act, in which the chlorination was imposed, was implemented in 1957.

Development modern waterworks in Japan



Spread in municipalities

1887 Yokohama
1889 Hakodate, Hokkaido
1891 Nagasaki
1895 Osaka
1898 Tokyo
1899 Hiroshima
1900 Kobe
1908 Yokosuka
1912 Kyoto
1914 Nagoya



Numbers of Waterworks in FY2014

- Large Public Water Supply: N. of customers > 5,001
- Small Public Water Supply: N. of customers > 101
- Private Water Supply: population exceeding 100

	Served Population	Number of Supplies	Population Served	Supplied Water Volume (100 million m³/year)	Daily Demand per Capita: Maximum(ℓ)	Daily Demand per Capita: Average(ℓ)	Daily Demand per Capita: Capacity of Facility(m³/day)
Public Water Supply	More than 1,000,000	14	39,050,000	45.6	353	320	545,000
	500,000 ~ 999,999	12	8,180,000	9.5	352	320	534,000
	250,000 ~ 499,999	56	19,330,000	23.0	361	325	532,000
	100,000 ~ 249,999	144	21,520,000	25.8	370	329	535,000
	50,000 ~ 99,999	206	14,340,000	18.0	397	344	589,000
	30,000 ~ 49,999	198	7,680,000	9.9	417	353	613,000
	20,000 ~ 29,999	144	3,590,000	4.7	437	359	651,000
	10,000 ~ 19,999	269	3,920,000	5.5	485	385	722,000
	5,000 ~ 9,999	243	1,740,000	2.5	517	394	800,000
	Less than 4,999	98	320,000	0.6	729	508	1,212,000
	Under Construction	4	—	—	—	—	—
	Total	1,388	119,670	145.1	377	332	565,000
Small Public Water Supply		5,890	4,200	6.1	553	397	—
Private Water Supply		8,186	400	0.3	—	—	—
Total		15,558	124,270	151.5	—	—	—

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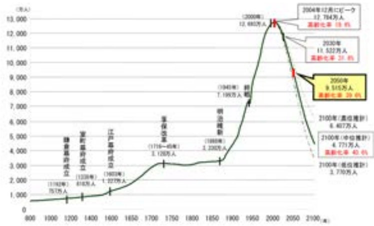
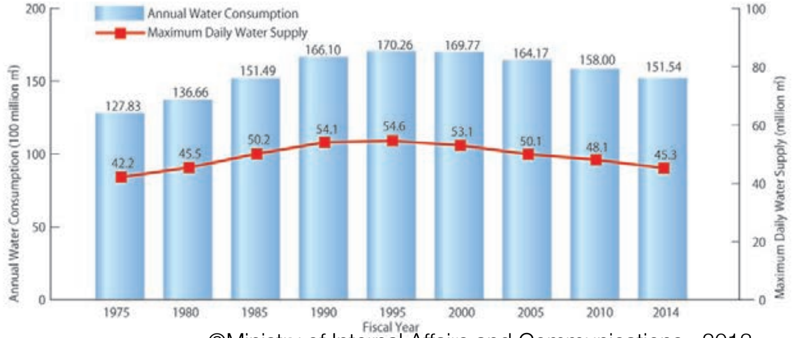
Water Consumption



Population of Japan

Trend of Annual Water Consumption and Maximum Daily Water Supply



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How much is daily average supply per capita?

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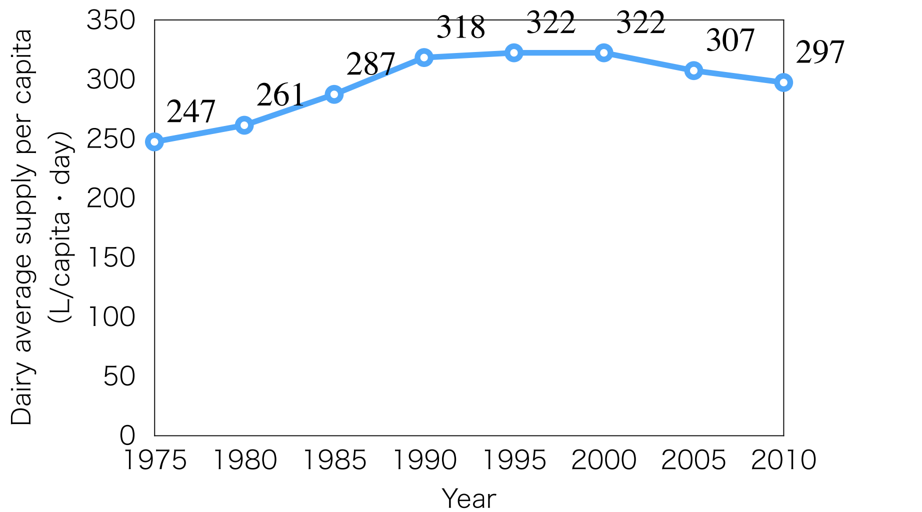
Daily average supply per capita in Japan



Ministry of Land, Infrastructure, Transport and Tourism, 2014

Average daily water use, a household

- Japan: 200-250 L/day/capita
- U.S: 80-100 gallons/day/capita 302-378 L/day/capita
- U.K: 149 L/day/capita
- Europe: 144 L/day/capita
- China: 178 L/day/capita
- India: 135 L/day/capita
- Asia: 95 L/day/capita
- Australia: 340 L/day/capita
- Africa: 47 L/day/capita

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How much is the volume of water of one flush toilet ?

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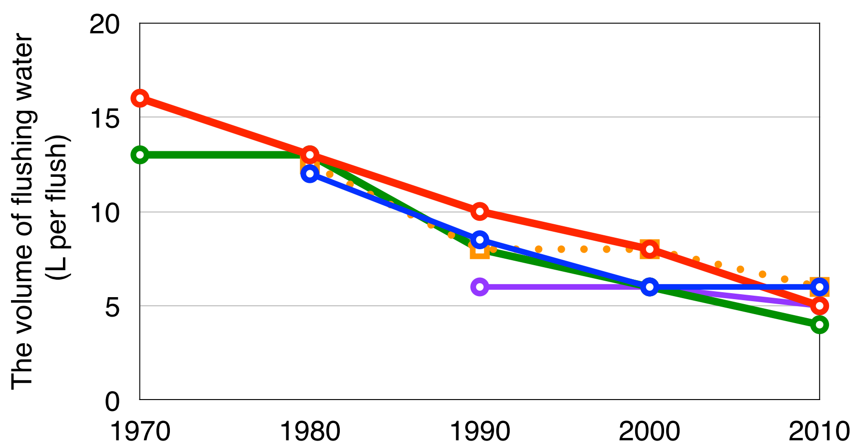
The Latest Toilet requires less than 6L



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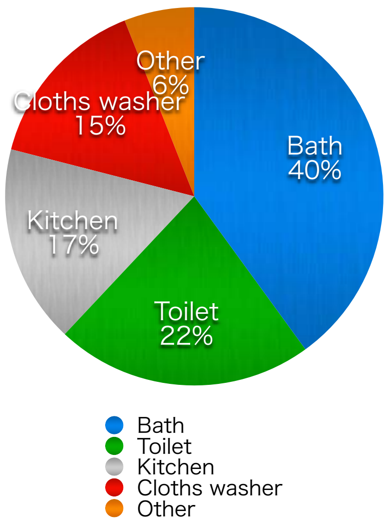
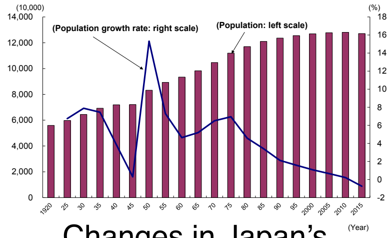
Water in Daily Life



Uses		使用量
Handwash	1 minute	12 L
teethbrushing	30 seconds	6 L
Dishwashing	5 minutes	60 L
Car washing	Keep flowing	90 L
Shower	3 minutes	36 L

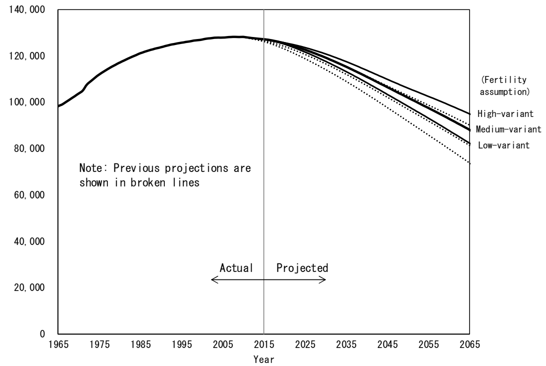
Tokyo Metropolitan Waterworks Bureau

Japan's Depopulating Society



Changes in Japan's population and population growth

Actual and projected population of Japan



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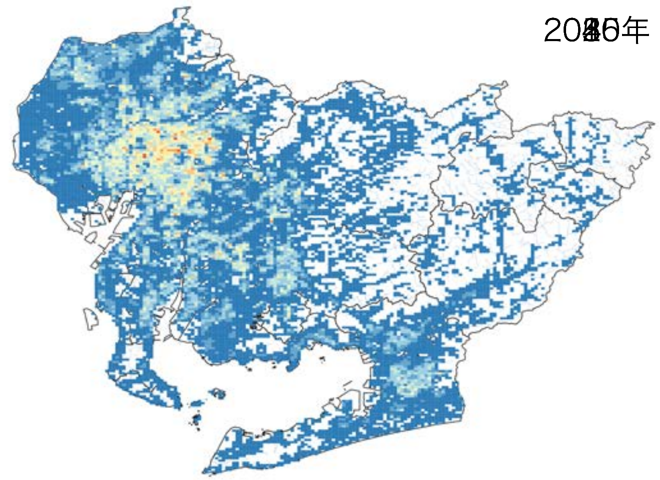
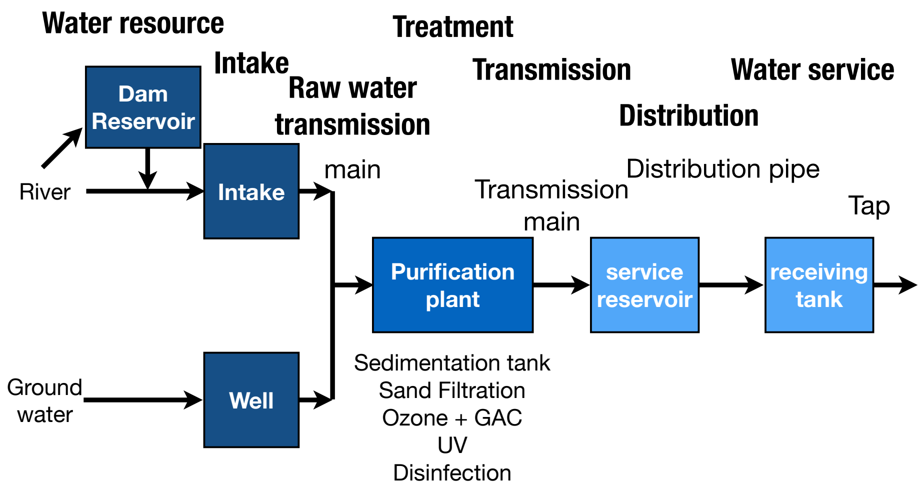
Projected Population of Aichi Prefecture



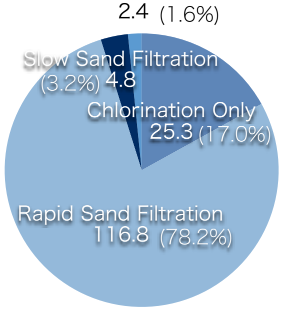
©National Land Numerical Information, 2018

Water supply system



Basic Water Purification Process

Annual fresh water Volume:
14.93 billion cubic meter

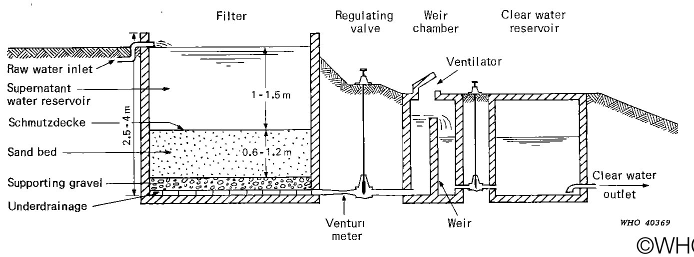


- **Removal of turbidity & disinfection**
- **Process**
  - ✓ Slow sand filtration
  - ✓ Rapid sand filtration
  - ✓ Membran filtration
  - ✓ Chlorination only
  - ✓ Advanced water treatment (ozone+GAC(Granular activated carbon))

Nabeya Ueno Water Purification Plant, Nagoya City

Slow Sand Filtration

- Slow sand filtration is an efficient method of removing particulate suspended matter and is therefore applicable to the treatment of groundwater containing solids in suspensions.
- Its principal use is in the removal of organic matter and pathogenic organisms.



©WHO, 2006

Advantages of slow sand filters - 1

- **Quality of treated water**
  - ✓ No other single process can effect such an improvement in the physical, chemical, and bacteriological quality of normal surface waters as that accomplished by biological filtration. No chemicals area added, thus obviating one cause of taste and odour problems.
- **Cost and ease of construction**
  - ✓ The simple design of slow sand filters makes it easy to use local materials and skills in their construction.

Advantages of slow sand filters - 2

- **Cost and ease of operation**
  - ✓ No imported chemicals or other materials are needed for the process, though in many cases chlorination is practiced as an additional safeguard.
- **Conservation of water**
  - ✓ Not requiring the regular flushing to waste of wash water
- **Disposal of sludge**
  - ✓ The waste material is usually accepted by farmers as a useful dressing for their land.

Limitations of slow sand filters - 1

- Where land is restricted or very expensive, the **much larger area** needed for biological filters. The areas required for treatment plants vary widely.
- In countries where construction methods are largely mechanized and where the importation of such materials as steel and cast-iron pipework presents no problems, the reinforced concrete construction and metal fittings of rapid filters may be cheaper to construct then the more extensive non-reinforced construction of slow filters.

Limitations of slow sand filters - 2

- Where unskilled labour for cleaning is in short supply it may be easier and cheaper to recruit **the skilled staff** required to operate and maintain rapid filters. However, the mechanical cleaning of slow sand filters has been developed.
- In climates where the winters are very cold it may be necessary to install expensive structural precautions against freezing.

Limitations of slow sand filters - 3

- Where the water to be treated is liable to severe and **sudden changes in quality** or where certain types of **toxic industrial wastes** or **heavy concentrations** of colloids may be present, the working of biological filters can be upset.
- Certain types of algae may interfere with the working of the filters, the usual result being premature choking, which calls for frequent cleaning. In such cases it may be necessary to cover the filter-beds to exclude light

Rapid Sand Filtration

- Rapid sand filters use relatively coarse sand and other granular media to remove particles and impurities that have been trapped in a floc through the use of flocculation chemicals—typically alum (aluminum sulfate $Al_2(SO_4)_3 18H_2O$, Polyaluminum chloride(PAC) ($(Al_2(OH)_nCl_{6-n})_m$).

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A Typical Rapid Sand Filter

Design and operation

- Mixing, flocculation and sedimentation processes are typical treatment stages that precede filtration.
- The two types of rapid sand filter are the gravity type and pressure type.
- A disinfection system (typically using chlorine or ozone) is commonly used following filtration.
- Rapid sand filters must be cleaned frequently, often several times a day, by backwashing, which involves reversing the direction of the water and adding compressed air.

Advantages of RSF

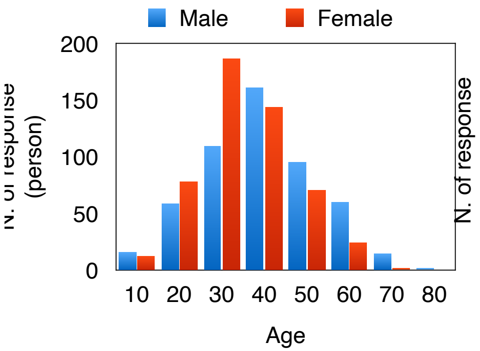
- **Much higher flow rate** than a slow sand filter
- Requires relatively **small** land area
- **Less sensitive to changes in raw water quality**, e.g. turbidity
- Requires less quantity of sand

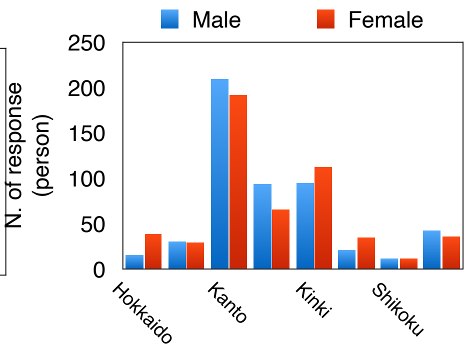
Disadvantages of RSF

- Large pore size will not, without coagulant or flocculent, remove pathogens smaller than 20 micro-meter like ***Cryptosporidium***.
- Requires greater **maintenance** than a slow sand filters.
- Generally ineffective against **taste and odor** problems.
- Produces **large volumes of sludge** for disposal.
- Requires ongoing investment in costly flocculation reagents.
- Treatment of raw water **with chemicals** is essential.
- Skilled supervision is essential.
- Cost of maintenance is higher.

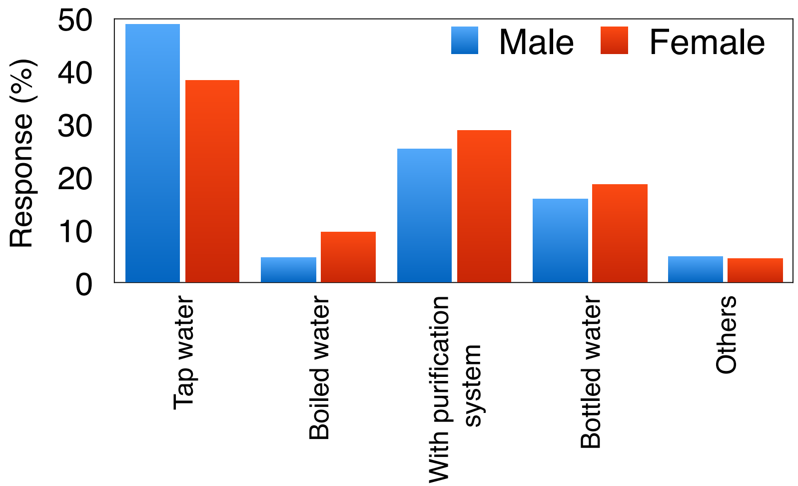
Questionnaire Survey

- Internet-based, residents in Japan
- Duration: 2 days (March 21 - 22, 2012)
- 1,000 responses (male: 50%, female: 50%)





Alternative Drinking Tap Water

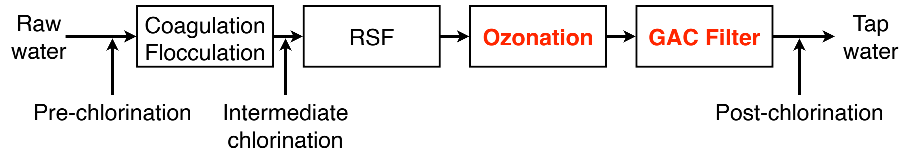


©N. Hirayama & S. Itoh, 2015

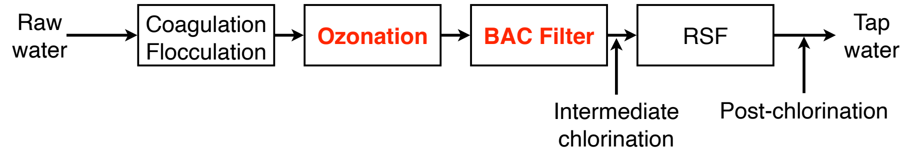
Advanced Treatment Process (Ozone+GAC/BAC)

- **Ozone**
  - ✓ Removal of offensive taste and odor
  - ✓ Reduction of THMs formation potential
- **Activated Carbon**
  - ✓ a form of carbon processed to have small, low-volume pores that increase the surface area available for adsorption or chemical reactions
  - ✓ Removal of offensive taste and odor, organic carbon matter, synthetic detergent, pesticide
  - ✓ **PAC (Powdered Activated Carbon)**
  - ✓ **GAC (Granular Activated Carbon)**
  - ✓ **BAC (Biological Activated Carbon)**

Advanced Treatment Process (Ozone+GAC/BAC)

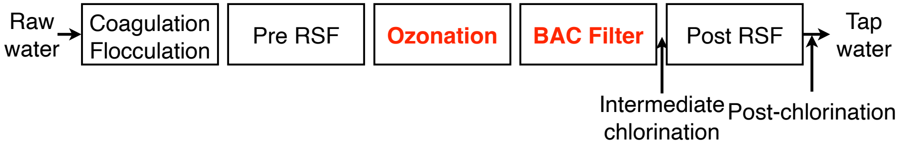


Treated water quality ◎ Cost of construction △ Cost of operation △

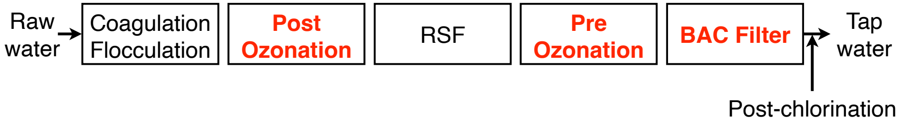


Treated water quality ◎ Cost of construction △ Cost of operation ○

Advanced Treatment Process (Ozone+GAC/BAC)



Treated water Quality ◎ Cost of construction △ Cost of operation ○



Treated water quality ◎ Cost of construction △ Cost of operation ○

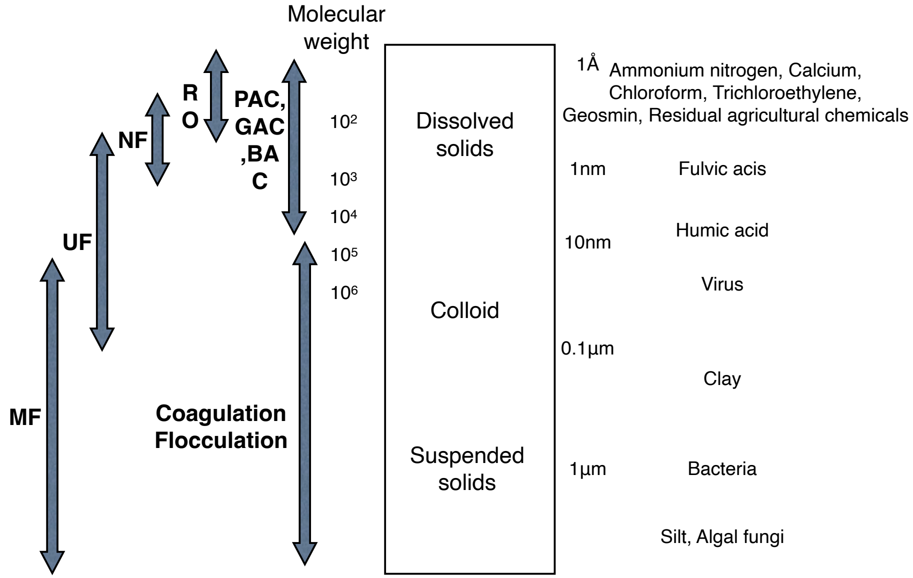
Membrane Process

- Membranes are commonly used at various stages in the water treatment process.
- In general, membrane processes offer the possibility of separating water from various types of solute and of separating solutes either on the basis of size or because some are ionized and others are not.
- In addition to these cases where a high degree of separation is achieved, there are many instances where the composition of the dissolved material is altered.

Membrane Filtration Process

- **MF: Micro-filtration**
  - ✓ 0.01 - 10 micrometer
- **UF: Ultra-filtration**
  - ✓ Molecular weight 1,000 - 3 million
- **NF: Nano-filtration**
  - ✓ Molecular weight 100 - 1,000
- **RO: Reverse Osmosis**
  - ✓ Molecular weight - 350

Separating Water from Various Types of Materials



Kawai Water Purification Plant (Yokohama City)

Capacity: 172,800 cubic meter per day

Gold Coast Desalination Plant, Queensland, Australia

Water Quality Standards of Drinking Water

No	Item	Standard Value
1	Common Bacteria	100 per 1 ml less or equal
2	E. coli	Not to be detected
3	Cadmium	0.003 mg/L less or equal
4	Mercury	0.0005 mg/L 〃
5	Selenium	0.01 mg/L 〃
6	Lead	0.01 mg/L 〃
7	Arsenic	0.01 mg/L 〃
8	Chromium (VI)	0.05 mg/L 〃
9	Nitrite Nitrogen	0.04 mg/L 〃
10	Cyanide ion and Cyanogens chloride	0.01mg/L as Cyanide 〃
11	Nitrate and Nitrite	10mg/L as Nitrogen 〃
12	Fluoide	0.8 mg/L 〃
13	Boron	1.0 mg/L 〃
14	Carbon Tetrachloride	0.002 mg/L 〃
15	1,4-dioxane	0.05 mg/L 〃
16	cis-1,2-Dichloroethylene & Trans-1,2-Dichloroethylene	0.04 mg/L 〃
17	Dichloromethane	0.02 mg/L 〃
18	Tetrachloroethylene	0.01 mg/L 〃
19	Trichloroethylene	0.01 mg/L 〃
20	Benzene	0.01 mg/L 〃
21	Chlorate	0.6mg/L 〃
22	Chloroacetic acid	0.02mg/L 〃
23	Chloroform	0.06mg/L 〃
24	Dichloroacetic acid	0.03mg/L 〃
25	Dibromochloromethane	0.1mg/L 〃
26	Bromate	0.01mg/L 〃

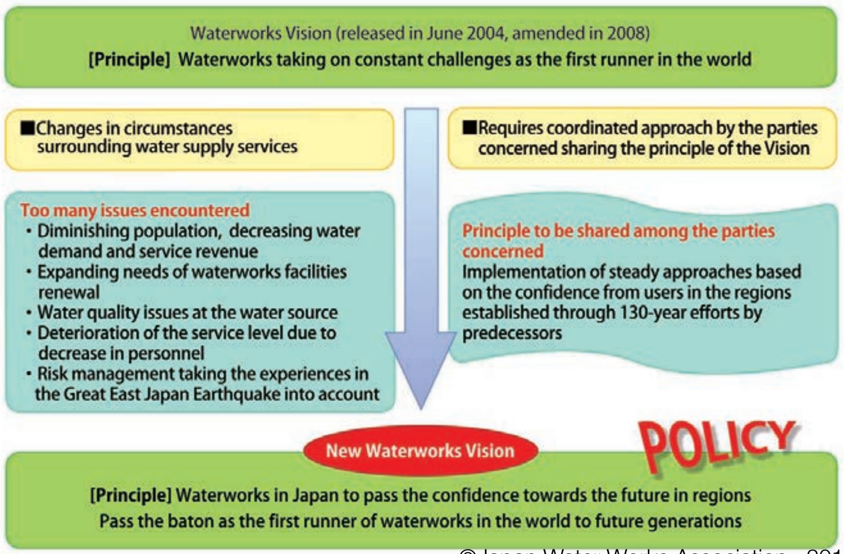
No	Item	Standard Value
27	Total Trihalomethanes (Total of Chloroform, Dibromochloromethane, Bromodichloromethane and Bromoform)	0.1 mg/L less or equal
28	Trichloroacetic acid	0.2 mg/L 〃
29	Bromodichloromethane	0.03 mg/L 〃
30	Bromoform	0.09 mg/L1 〃
31	Formaldehyde	0.08 mg/L 〃
32	Zinc	1.0 mg/L 〃
33	Aluminium	0.2 mg/L 〃
34	Iron	0.3 mg/L 〃
35	Copper	1.0 mg/L 〃
36	Sodium	200 mg/L 〃
37	Manganese	0.05 mg/L 〃
38	Chloride	200 mg/L 〃
39	Calcium, Magnesium (Hardness)	300 mg/L 〃
40	Total residue	500 mg/L 〃
41	Anionic surface active agent	0.2 mg/L 〃
42	(4S, 4aS, 8aR)-Octahydro-4,8a-Dimethylenaphtalene-4a(2H)-ol	0.00001 mg/L 〃
43	1,2,7,7 - Tetramethylbicyclo[2,2,1]Heptane-2-ol	0.00001 mg/L 〃
44	Nonionic surface active agent	0.02 mg/L 〃
45	Phenols	0.005mg/L in terms of Phenol 〃
46	Organic substances (Total Organic Carbon)	3 mg/L 〃
47	pH Value	5.8-8.6
48	Taste	Not abnormal
49	Odor	Not abnormal
50	Color	5 degree less or equal
51	Turbidity	2 degree 〃

©Japan Water Works Association, 2016

Future Water Supply Services in Japan - New Waterworks Vision

- ✓ In June 2004, the Ministry of Health, Labour and Welfare had issued the "Waterworks Vision" and indicated the desire state of waterworks in Japan in the future together with the policies and pathway towards realization of such a vision. More than eight years have passed since release of the Vision, and the circumstances surrounding waterworks in Japan have changed significantly.
- ✓ In response to such changes, the Ministry radically reviewed the Waterworks Vision and formulated and announced the New Vision for the next 50 years and a century ahead. From FY2013, all the parties concerned will advance various steps toward realization of the ideal waterworks by sharing the principles of the "**New Waterworks Vision**" based on the aspects of "**safety**", "**resilience**", and "**sustainability**".

Principles of New Waterworks Vision



Safety, Resilience, and Sustainability

- **Safety**
  - ✓ Waterworks providing tasty drinking water to all the people at any time and any place.
- **Resilience**
  - ✓ Waterworks minimizing suffering from natural disaster etc. and flexibly and quickly recoverable from the damage, when suffered.
- **Sustainability**
  - ✓ Waterworks ensuring a sound, stable water supply in spite of diminishing population to receive the supply of water and decreasing supply of water.

Partial Revision of the Waterworks Act, 2018

- The objectives of partial revision of the Waterworks Act are to **reinforce the waterworks management** bases, and to respond the subjects which waterworks in Japan are faced with, for example decreasing water demand due to depopulation, deterioration of water supply facilities, a critical shortage of human resources.

1. Clarification of the accountability of the person concerned
2. Promotion of the wide area cooperation
3. Promotion of appropriate asset management
4. **Promotion of the public-private partnership**
5. Improvement of system for designated water pipe plumber

Public-Private Partnership

- **Private Finance Initiative (PFI)**
- **Concession Agreement**
  - ✓ In the case of a public service concession, a private company enters into an agreement with the waterworks to have the exclusive right to operate, maintain and carry out investment in a public utility for a given number of years. Other forms of contracts between public and private entities, namely lease contract and management contract (in the water sector often called by the French term affermage), are closely related but differ from a concession in the rights of the operator and its remuneration. A lease gives a company the right to operate and maintain a public utility, but investment remains the responsibility of the public. Under a management contract the operator will collect the revenue only on behalf of the government and will in turn be paid an agreed fee.

One more thing…

Water Supply Cost and Water Charge in Japan

- **Water Supply Cost**
  - ✓ Domestic usage of 20 cubic meter/month: 3,254 JPY
- **Water Charge**
  - ✓ Domestic usage of 20 cubic meter/month: 3,226 JPY

Discussion

Imagine;

You are a resident of the A city.

The mayor of A city declare that a private enterprise will manage the water utility of the A city.

Do you agree?

A. YES

B. NO