Drinking water quality risk management

Water & Waste Engineering
2020/05/08

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

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Water & Waste Engineering

Keywords: water system, waste treatment system, water supply engineering, wastewater engineering, waste management engineering

Outline: We will give lectures on the water and wastewater system, waste management system, the management system and cutting-edge technologies for water, waste, and human health and the environment. In addition, we consider the water and waste system from the viewpoint of natural disaster, climate change, and depopulation society. And, we will discuss the emergency environmental management.

Objectives:

- To management system and technology for water and waste management system
- To discuss and explain on water, wastewater and waste management.
- To discuss the future water and waste system with the influence on natural disaster, climate change, and depopulation society.
- To understand emergency environmental management.

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6/12 Watershed water quality management & recovery of clean water
6/19 Solid waste management system in Japan
6/26 Solid waste management & recycling technology
7/3 Disaster debris management
7/10 Emergency environmental management
7/17 Presentation 1
7/31 Presentation 2
8/7 Report (no class)

Water & Waste Engineering

Credits: 2

Grading criteria:

Participation 45%
Presentation 25%
Report 30%

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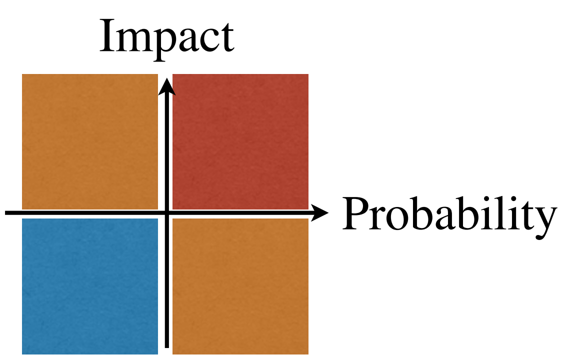
Concept of risk management

- **Risk = Impact × Probability**
  - **prioritization process**
  - **balancing resources**



risk management: method

- Method consist of the following elements, performed, more or less, in the following order.
  1. identify, characterize threats
  2. assess the vulnerability of critical assets to specific threats
  3. determine the risk
  4. identify ways to reduce those risks
  5. prioritize risk reduction measures based on a strategy

©ISO/Guide 73:2009 Risk management — Vocabulary

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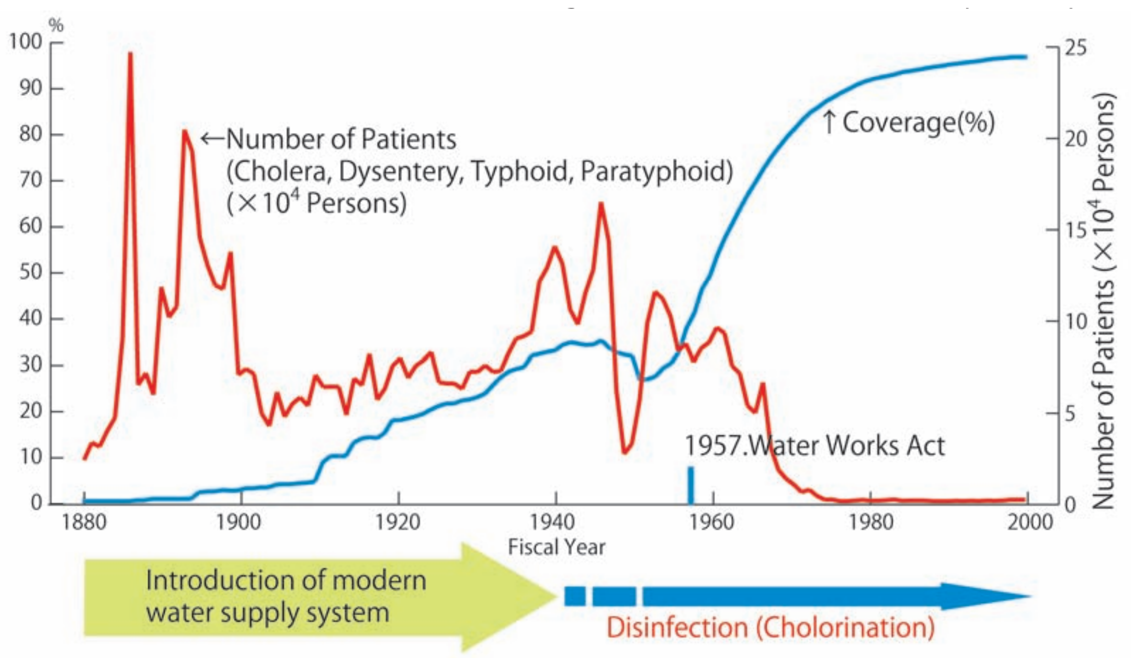
Water supply system in Japan

History of Japan Water Supply

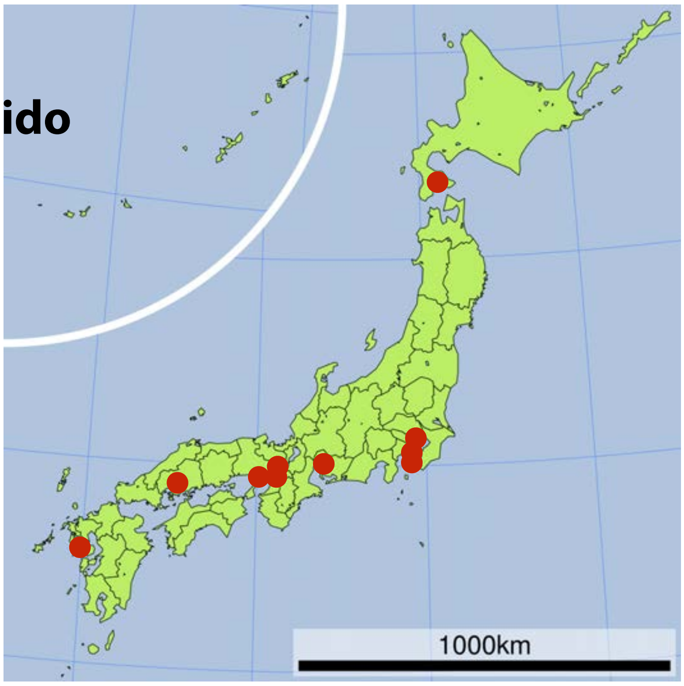
- Japan's first modern water supply system was introduced in Yokohama and began its operation in 1887.
- Following the operation in Yokohama, the water supply system spread in municipalities all over Japan.
- The waterworks act, in which the chlorination was imposed, was implemented in 1957.

Development modern waterworks in Japan

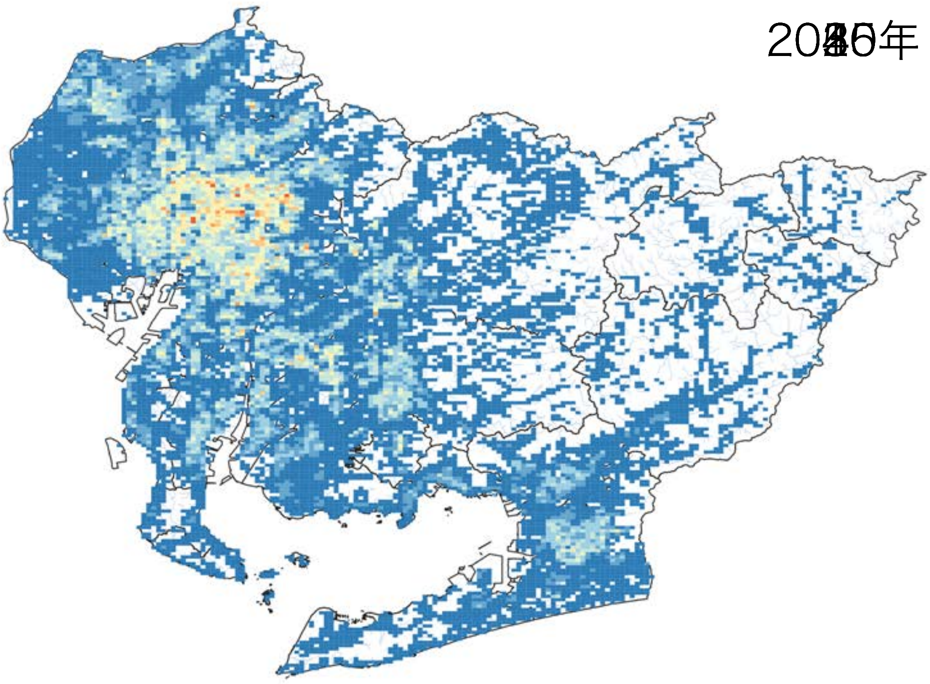


Spread in municipalities

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



Projected Population of Aichi Prefecture

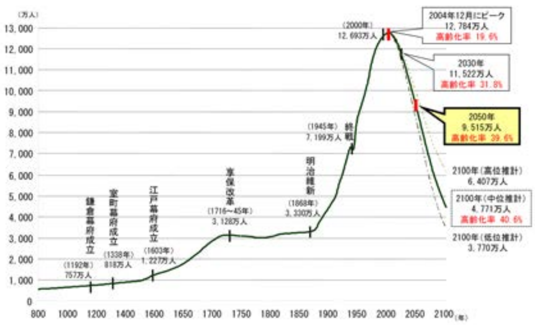


Numbers of Waterworks in FY2014

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

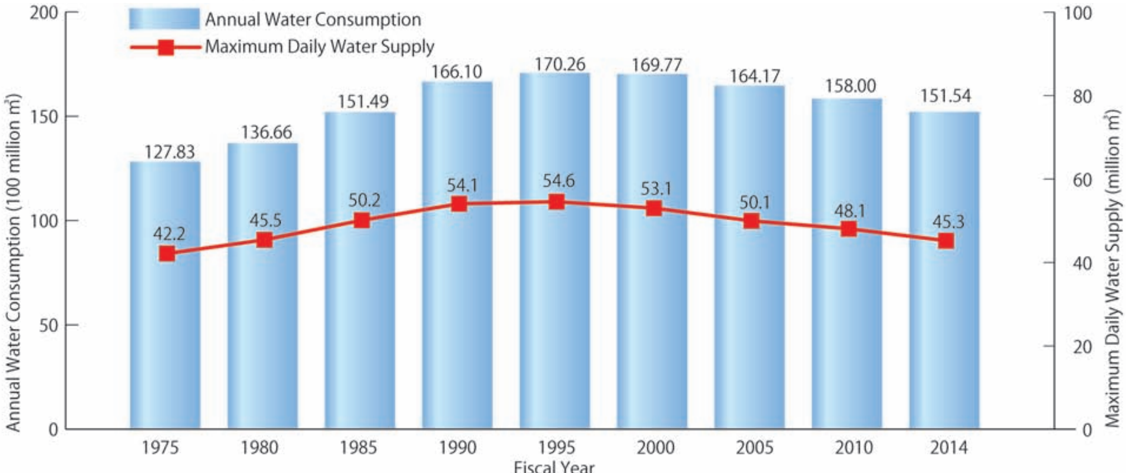
	Served Population	Number of Supplies	Population Served	Supplied Water Volume (100 million m³/year)	Daily Demand per Capita		
					Maximum(ℓ)	Average(ℓ)	Capacity of Facility(m³/day)
Public Water Supply	More than 1,000,000	14	39,050,000	45.6	353	320	545,000
	500,000 ～ 999,999	12	8,180,000	9.5	352	320	534,000
	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	—	—	—

Water Consumption



Population of Japan

Trend of Annual Water Consumption and Maximum Daily Water Supply



How much is daily average supply per capita?

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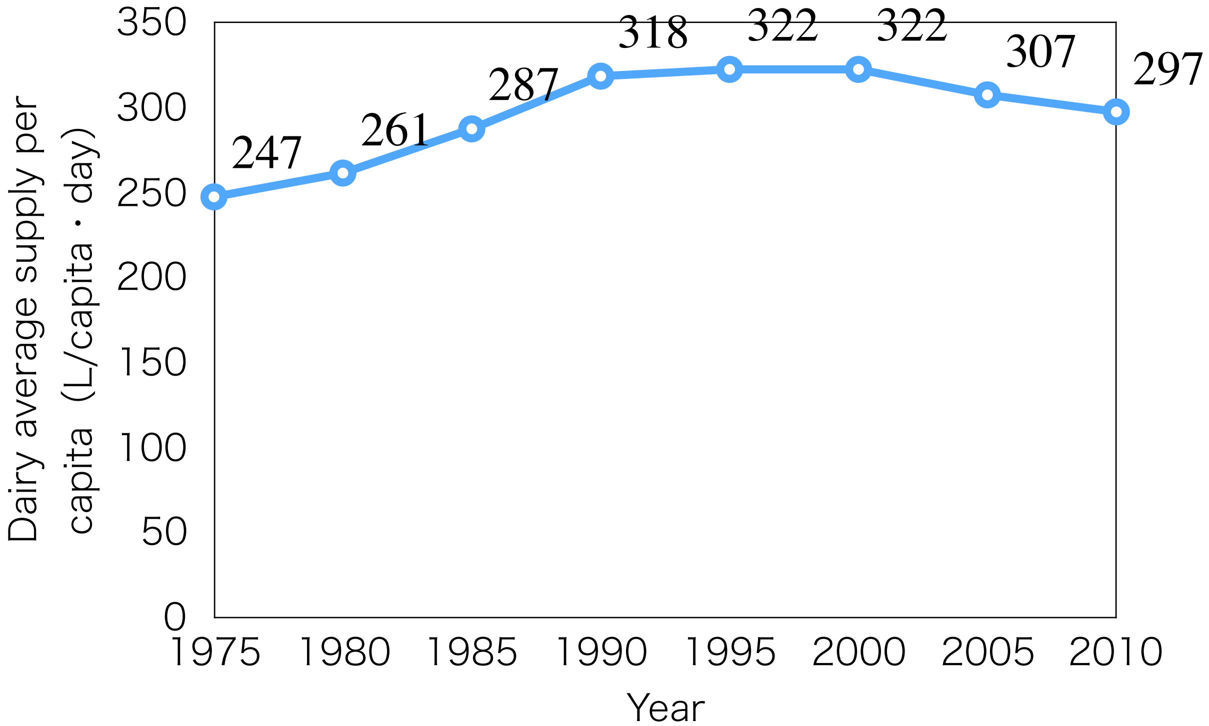
Daily average supply per capita in Japan



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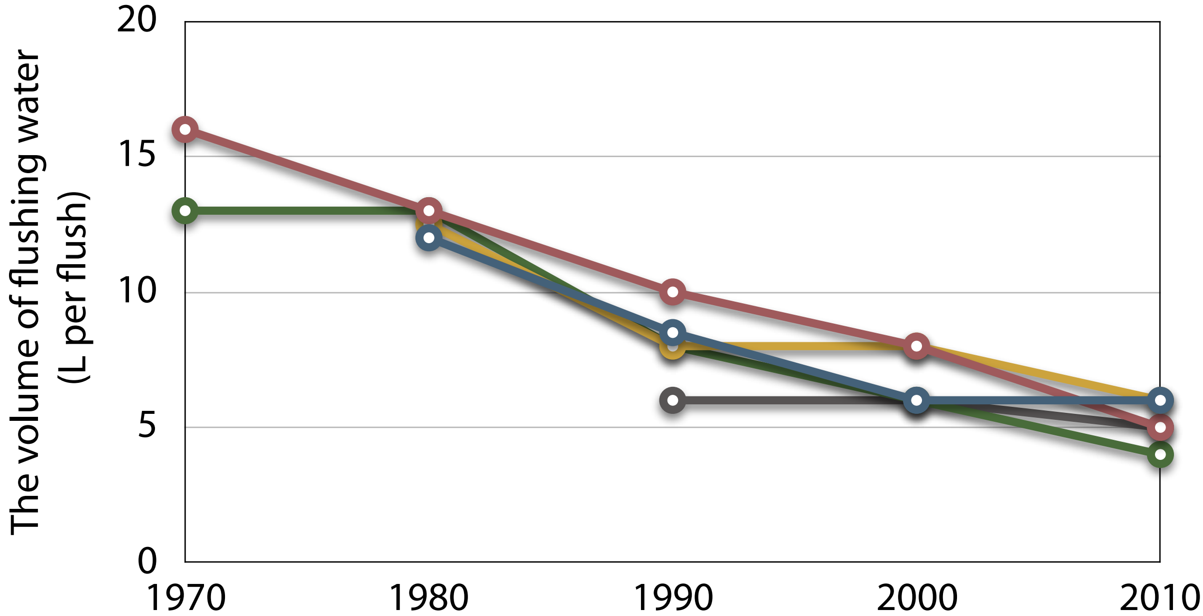
How much is the volume of water of one flush toilet ?

The Latest Toilet requires less than 6L



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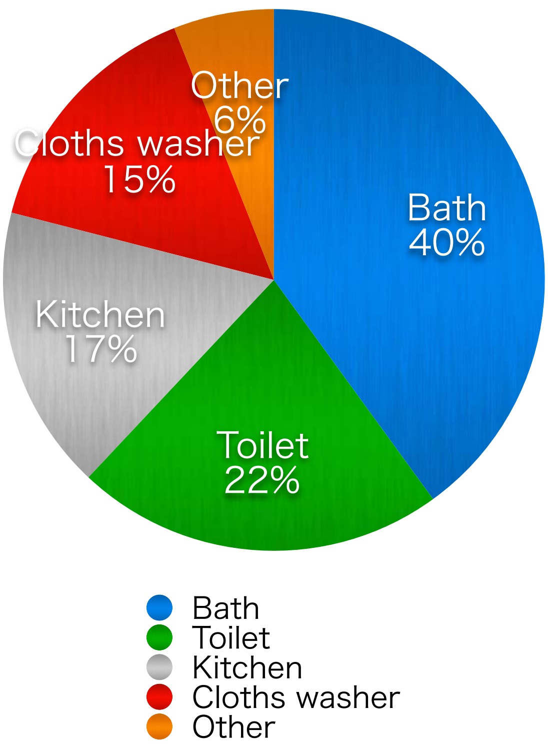
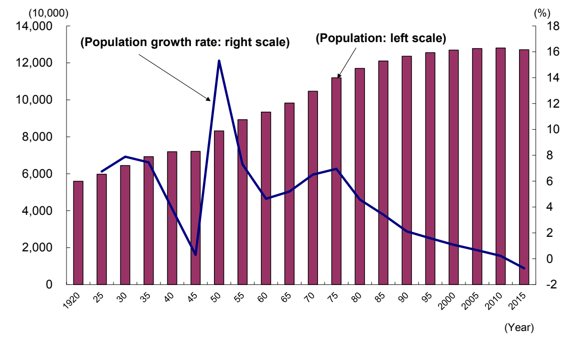
Water in Daily Life



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

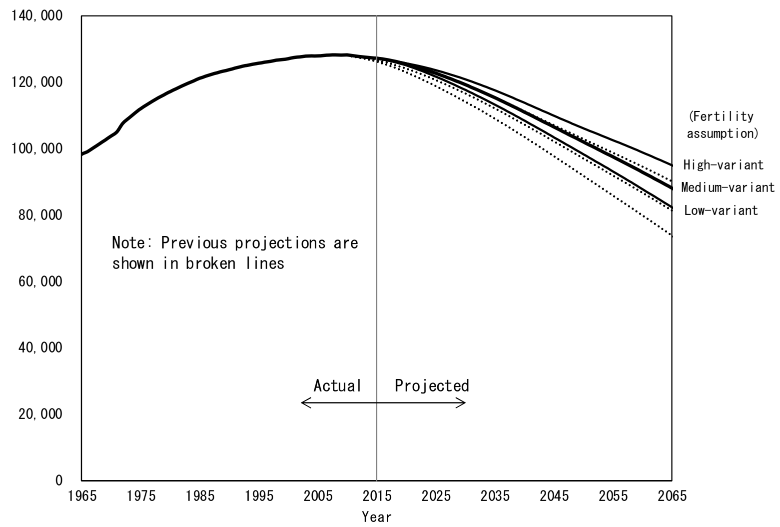
Tokyo Metropolitan Waterworks Bureau

Japan's Depopulating Society

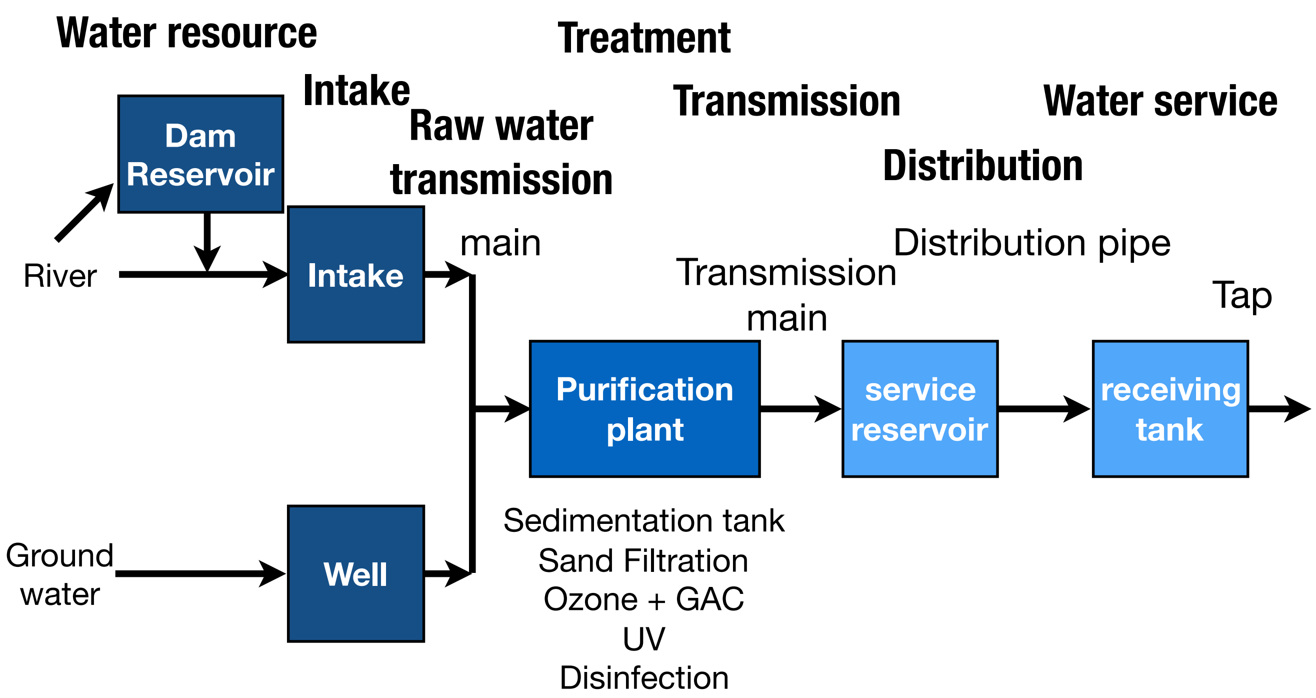


Changes in Japan's population and population growth

Actual and projected population of Japan

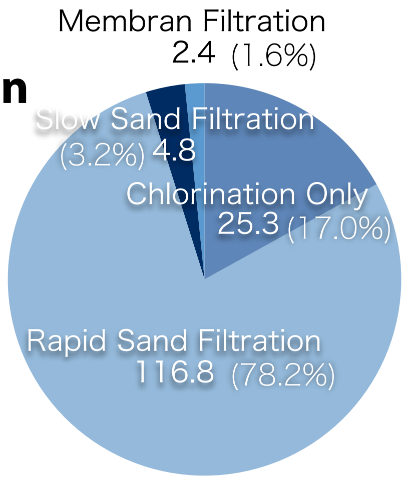


Water supply system



Basic Water Purification Process

Annual fresh water Volume:
14.93 billion cubic meter

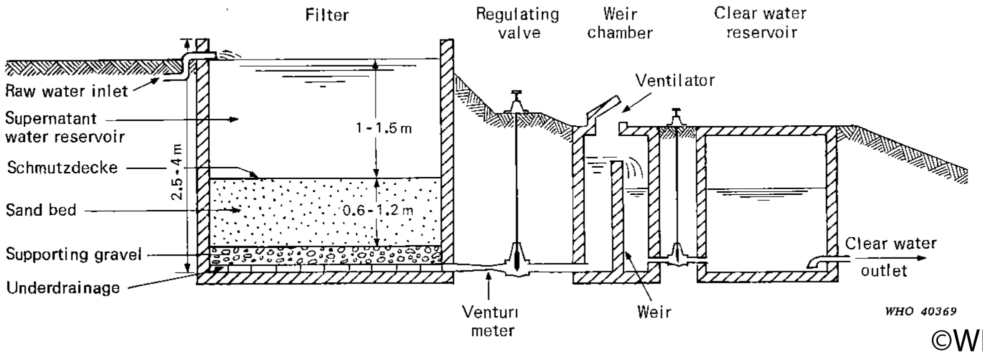


- **Removal of turbidity & disinfection**
- **Process**
  - Slow sand filtration
  - Rapid sand filtration
  - Membran filtration
  - Chlorination only
  - Advanced water treatment (ozone+GAC(Granular activated carbon))

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.



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

Pre-Treatment: Coagulation-Flocculation → Rapid Sand Filtration → Post-Treatment: Chlorination

- 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.

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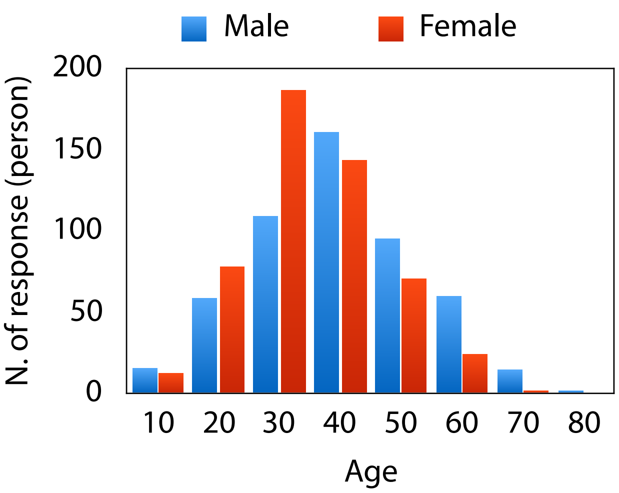
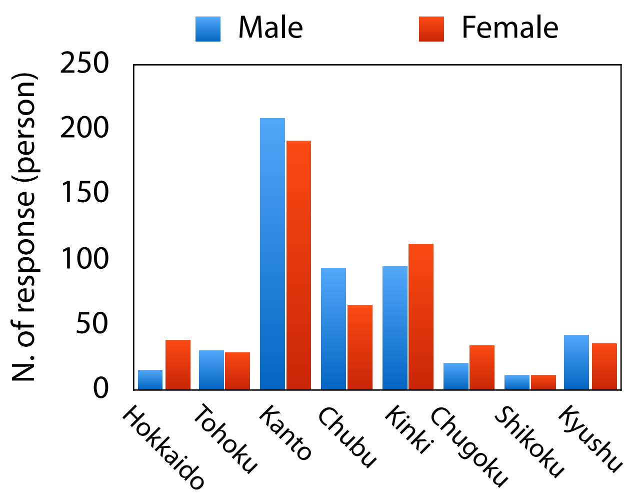
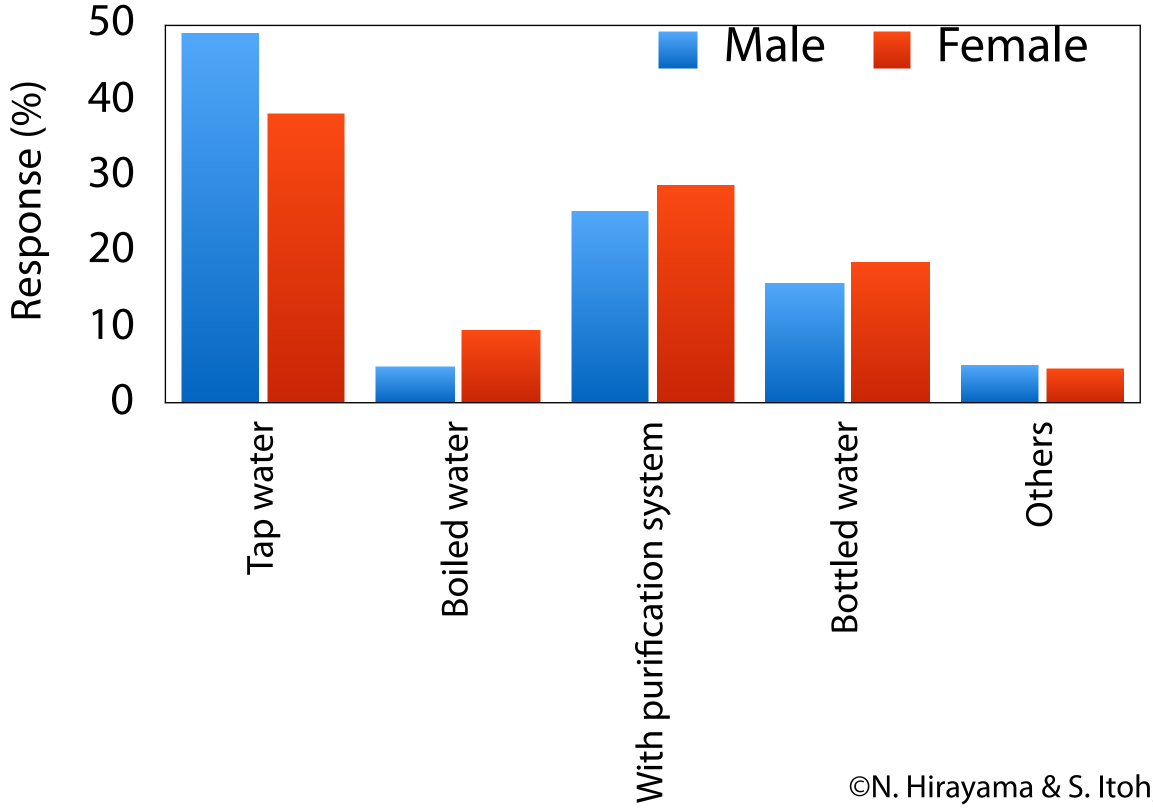
Questionnaire Survey

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





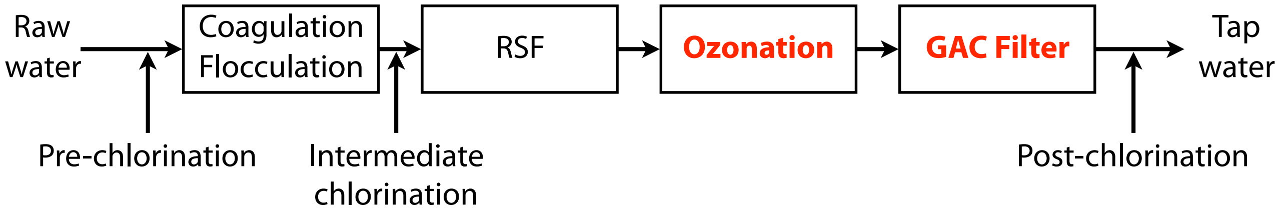
Alternative Drinking Tap Water



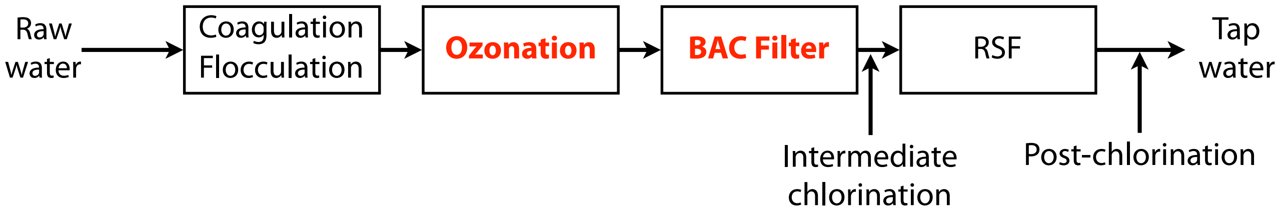
Advanced Treatment Process (Ozone+GAC/BAC)

- **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)

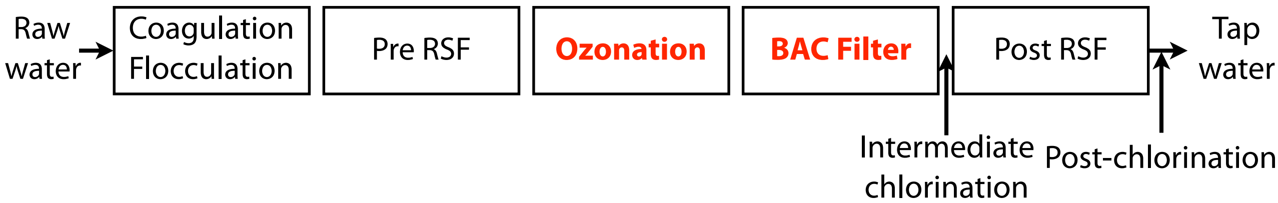


Treated water quality ◎ Cost of construction △ Cost of operation △

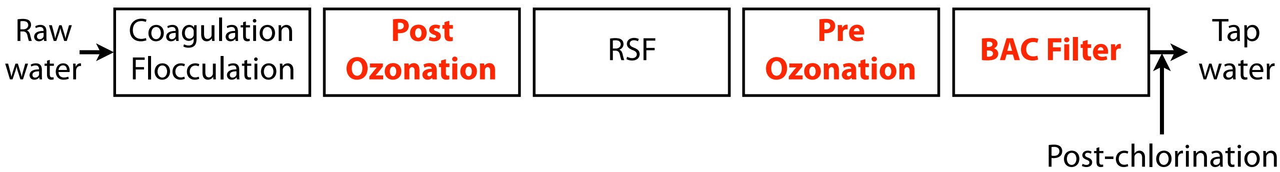


Treated water quality ◎ Cost of construction △ Cost of operation ○

Advanced Treatment Process (Ozone+GAC/BAC)



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



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

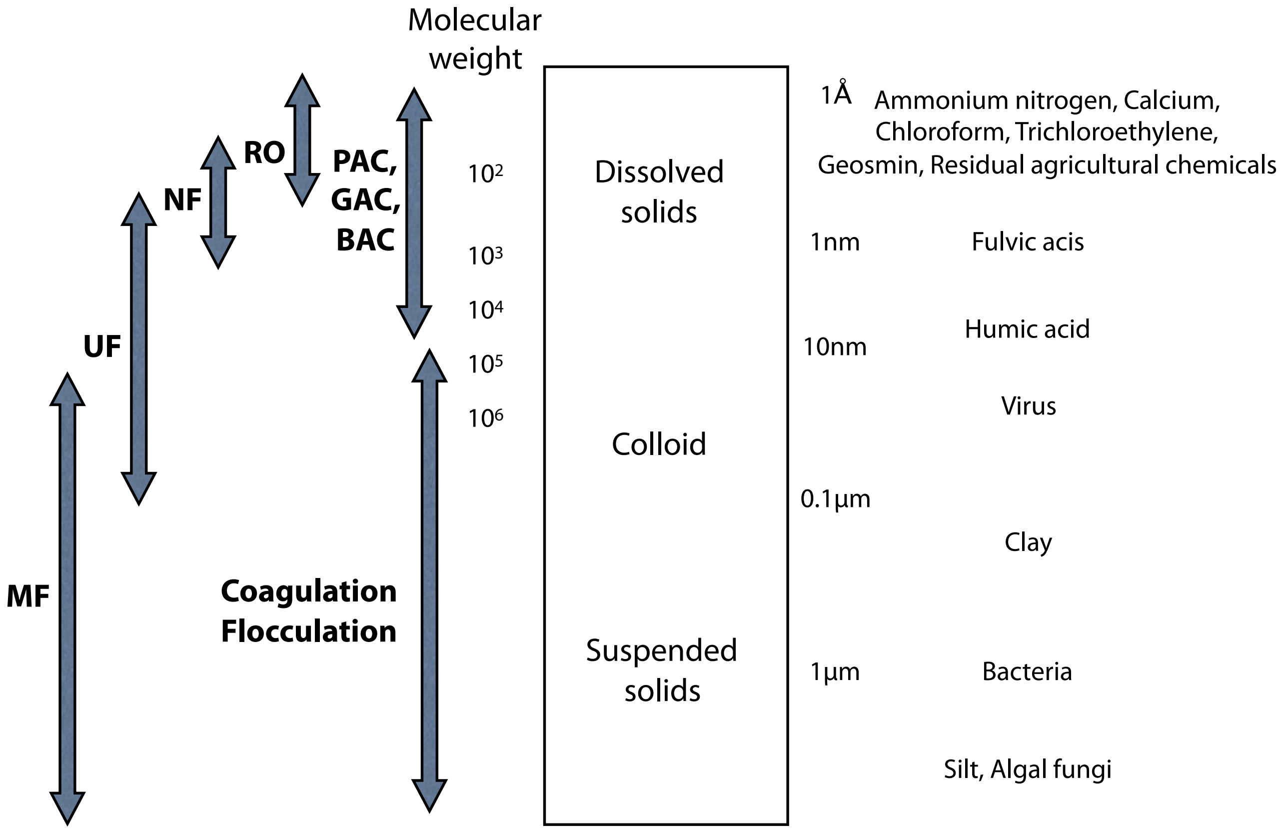
Membrane Process

- 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



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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 〃

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**".

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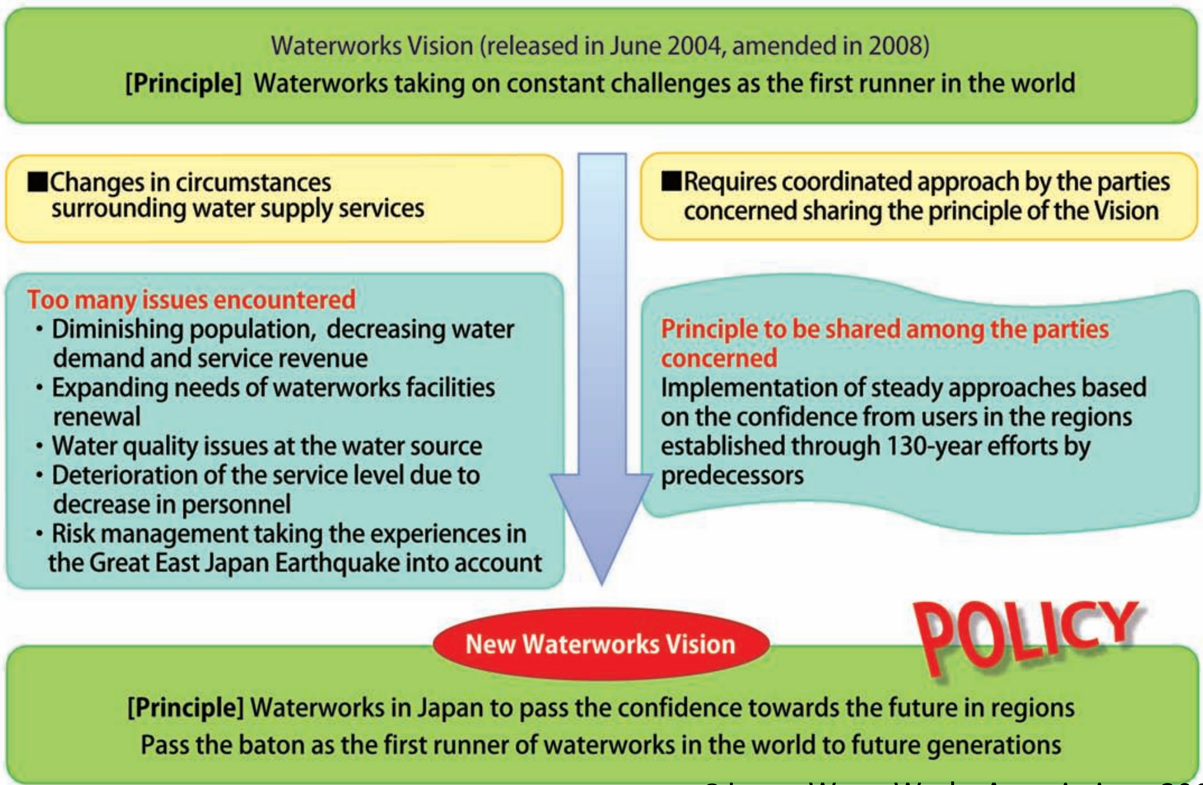
Principles of New Waterworks Vision



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

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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