25. Global and Environmental Considerations in Drinking Water Supply

(Climate Impact / Energy Savings)

Presenter

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1. Need for Global and Environmental Consideration

115 years have passed since Japan's first modern water service system started in Yokohama City, to improve public health and upgrade people's living environment. Today, covering nearly 97% of the country's population, the waterworks has become an infrastructure indispensable to hygienic and comfortable daily life. Recent statistics show that 123 million people consume 17 billion m³ of tap water per year. In other words, the average amount of water supply per person is 380 liters per day, a 3.6% drop from the figure ten years ago; 394 liters.[1)]

Japan's population growth is expected to reach its peak within a few years and then start to gradually decline afterwards. Looking at the situation surrounding drinking water supply, supply-demand relationship is also on the drastic turning point, as represented by industrial water decline caused by recycling and rainwater use, growing water-saving consciousness, and sluggish household water consumption.

Figure 1 symbolically illustrates the role played by the domestic waterworks. In the 1960s, the public water networks expanded rapidly, resulting in a remarkable drop in the prevalence of waterborne infectious diseases (dysentery, cholera, typhoid, and paratyphoid). In addition to overall enhancement in public health, the waterworks greatly contributed about 2-log elimination in the incidence.

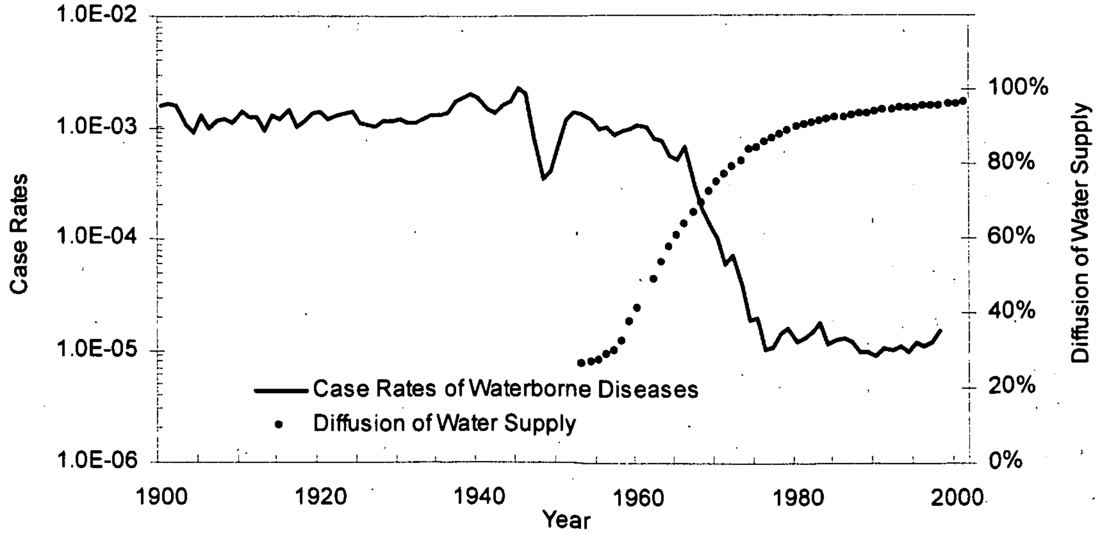

Figure 1 Changes in waterborne diseases and domestic waterworks coverage

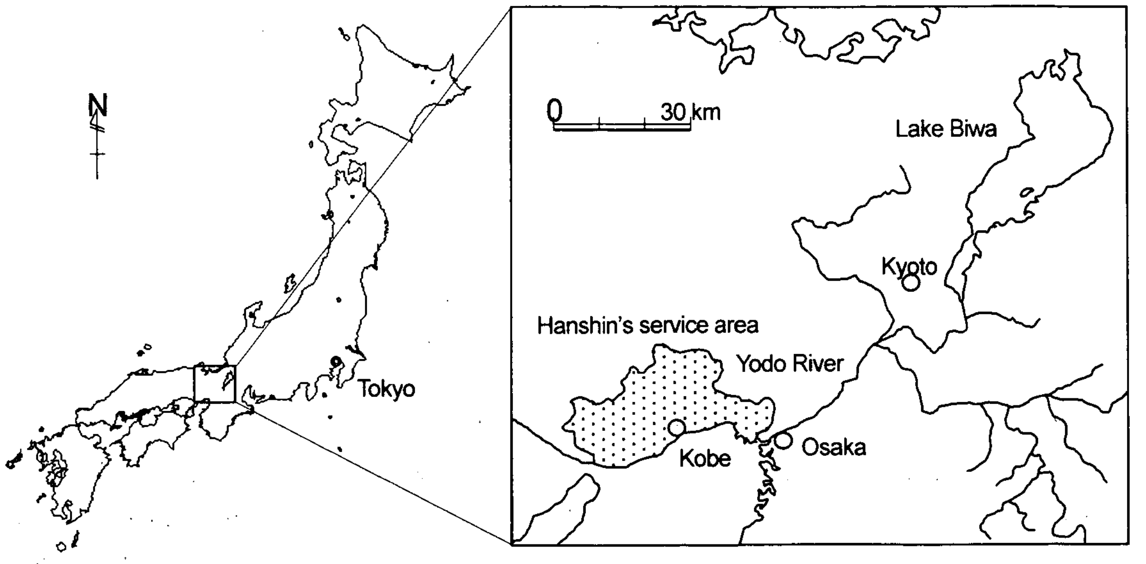

Figure 2-a Outline of Lake Biwa - Yodo River system and Hanshin Water

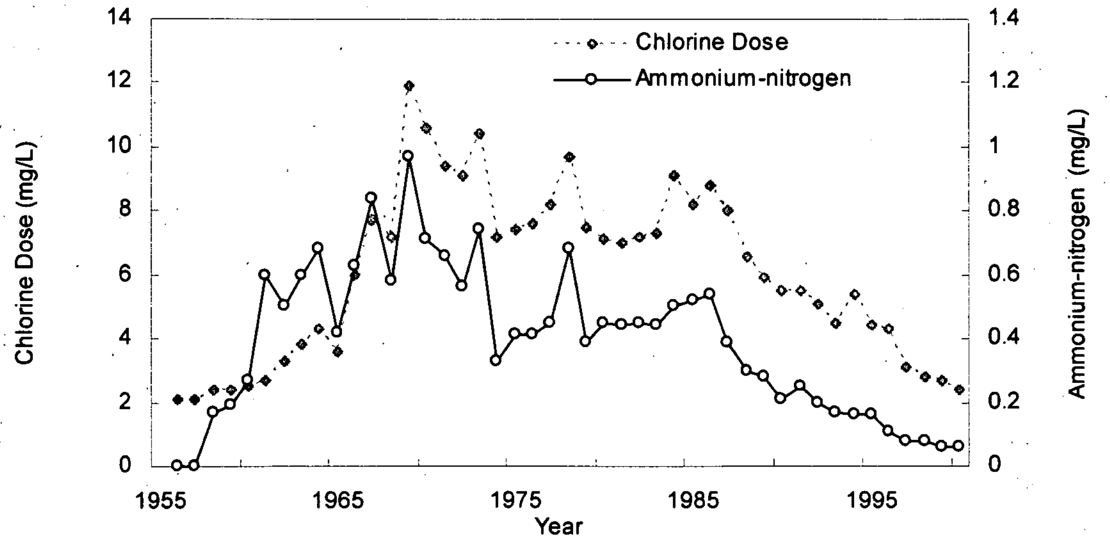

Figure 2-b Changes in raw water quality and chlorine Dosage

Figure 2-a and 2-b indicate annual changes in water quality of the Yodo River, one of representative rivers in Japan, and the average chlorine dosage by the Hanshin Water Supply Authority. Lake Biwa, Japan's largest lake, and the famous city of Kyoto are located at upper reaches of the Yodo River. Therefore, the Yodo River is subject to eutrophication and domestic wastewater, which situation is typical of urban rivers. Around 1960, the ammonium nitrogen began to increase rapidly in the Yodo River, keeping pace with the Japan's rapid economic progress. In 1969, the annual average chlorine dosage reached 12 mg/L. Later, the spread of sewage systems and progress in wastewater treatment technology regained the water quality of pre-deterioration, as far as ammonium nitrogen and chlorine dosage are concerned.

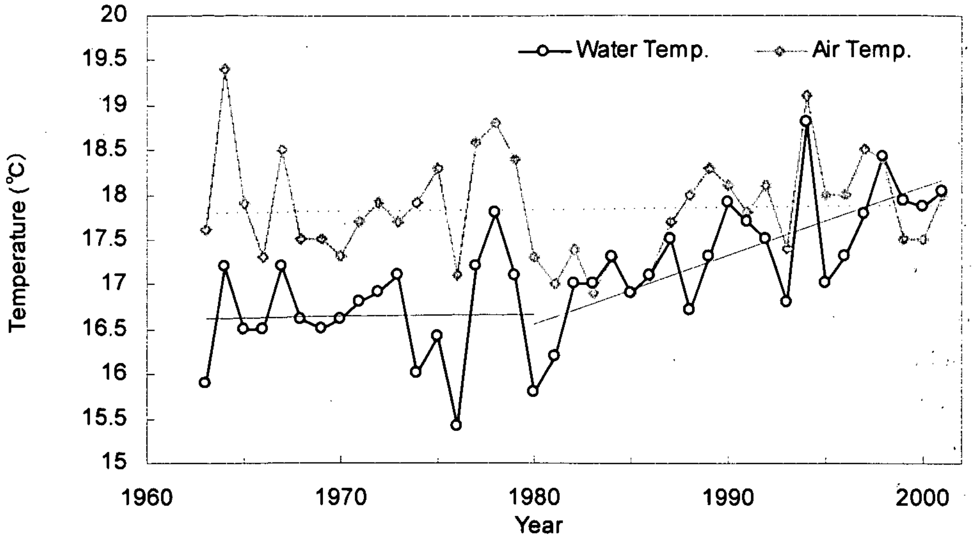

Figure 3 Changes in water and atmospheric temperatures

Figure 3 shows water and atmospheric temperatures over the last 40 years at the Hanshin Water's Inagawa water treatment plant (WTP), which suggests the unprecedented changes in hydrologic cycle in the Yodo River basin. The atmospheric temperatures remain unchanged on the whole except for slight fluctuations, whereas the water temperatures have a tendency to increase over the periods. Dividing the periods into 20-year sub-periods will make it clear. Water temperatures are relatively static in the first 20 years, while they marked 1.5°C increase during the last 20 years. Climbing water temperature itself is of great significance as a sign of global warming, however, attention should also be directed to the difference between water and atmospheric temperatures. Although ranged from 1 to 2°C until around 1980, the difference has been disappearing in recent years. The author assumes that some sort of unnatural hydrologic cycle causes short circuit, which flows ground surface susceptible to the atmospheric temperature. Short circuit flow can, simply put, trigger drought or flooding.

In the face of diversifying socio-economic structures, creeping global warming, and unnatural hydrologic cycle, the water service system, which has fulfilled its initial missions, should pay attention to global environmental considerations as a matured infrastructure. This is because tap water is nothing but the most accessible water to people today edging away from natural waterside. Based on mutual partnership, the water suppliers and customers should share the common understanding on climate impact and importance of energy saving via tap water, as well as creating new strategies to conserve source water quality, sustain water resources, and re-establish natural hydrologic cycle. In this paper, Chapters 2 and 3 respectively introduce the Hanshin Water and other utilities' efforts concerning global environmental consideration, followed by Chapters 4 in which the author intends to find out a clue to future orientation.

2. Efforts of the Hanshin Water

The Hanshin Water is a drinking water supply utility serving 2.5 million people in four cities, including Kobe. It is the oldest wholesome authority of this kind in Japan. The authority intakes from the Yodo River to its two water treatment plants: the main Inagawa WTP (916,900 m^3/d) and the Amagasaki WTP (373,000 m^3/d) with leading-edge technology. From 1993 to 2001, to better cope with diversifying source water quality, advanced water treatment technology were introduced, mainly featuring mid-ozonation and granular activated carbon-fluidized bed (GAC-FB) adsorption. Aqueducts and transmission mains stretch 183 km, and a large amount of water is pumped up to nearly 100 m.

In this chapter, the author presents environmental measures taken by the Hanshin Water, such as energy conservation, carbon dioxide (CO_2) discharge reduction, recycling of wastes during treatment processes, and environmental-oriented designing.

2-1. Energy conservation

(1) Transmission and distribution facilities

Among the water supply processes, water transportation consumes much of the total energy, 80% of which is used for pumps. Since pump motive power depends on the cubed revolving speed, controlling the revolving speed is highly effective in reducing energy consumption. The Hanshin Water has been active in introducing revolving speed control pumps since the 1960s. More recently, in the wake of progress in the revolving speed control, the utility has been switching from conventional Scherbius system to the inverter system, which is superior to the former in energy and space savings, and working environment.

As for conduits, pipeline loss is reduced by parallel operation of existing and newly laid pipelines. Systematic remote control of pumps from a central control center, as well as effective use of nighttime electricity utilizing reservoirs' capacity, contribute to leveling and cutting back on power consumption.

(2) Water treatment facilities

Ozonation facilities make up the largest percentage of electricity consumption for water treatment process. Since 1993, the Hanshin Water has commenced operation of ozonation facilities, with the target residual ozone at 0.2 - 0.3 mg/L.

During initial phases of operations, continuous residual ozone meters were not sufficiently reliable; consequently, operators manually measured the concentration, and they set the ozone dosage after each analysis. Later, the utility itself got involved in creating highly reliable meters, and succeeded in developing automatic continuous measurement and feedback control of residual ozone. As a result, the variation coefficient of residual ozone concentration has improved dramatically, as illustrated in Figure 4 and Table 1, and over 30% reduction has been realized in power consumption per unit water.[2)]

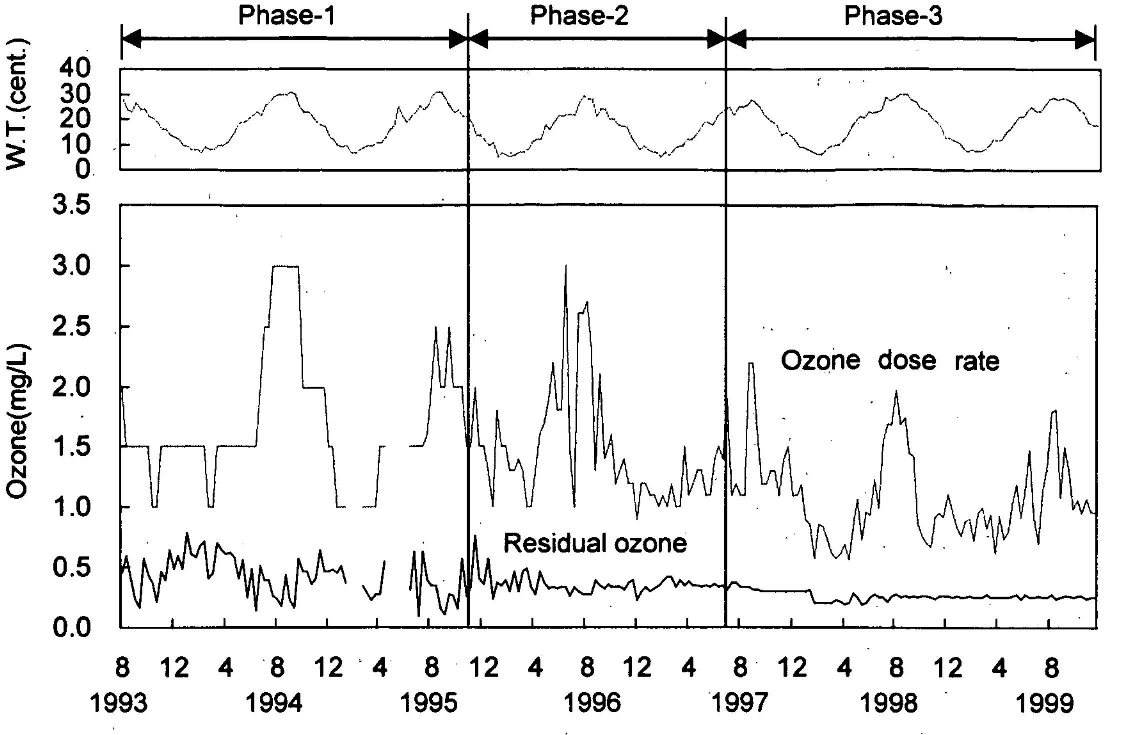

Figure 4 Changes in ozone dosage and residual ozone concentration

Table1 Variation coefficient of residual ozone concentration

	Residual Average	Standard deviation	Coefficient of variation
Phase 1	0.40 (mg/L)	0.177 (mg/L)	45%
Phase 2	0.35 (mg/L)	0.093 (mg/L)	26%
Phase 3	0.25 (mg/L)	0.028 (mg/L)	11%

(3) Change in unit consumption

Figure 5 indicates annual changes in water supply and basic unit. Despite the addition of advanced treatment such as ozonation and activated carbon treatment, unit consumption of electricity has been kept around 0.6 kWh/m^3 since 1960, which resulted from such following energy saving measures as pump renewal, effective water transmission, and ozone dosage control.

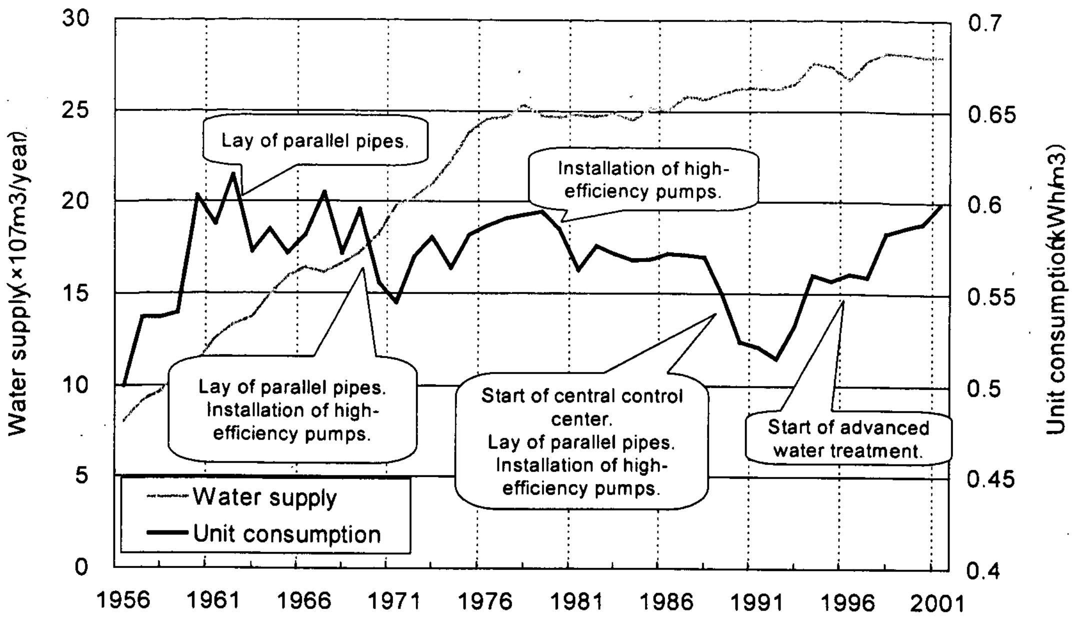

Figure 5 Changes in quantity supplied and basic unit

Table 2 CO_2 discharge reduction in Amagasaki WTP

	Co-generation system	Single generation system
Electric energy (kWh)	※ 5,767,140	
Heat utilization (MJ)	※ 13,961,902	
Gas consumption (m^3)	※ 158,862	393,804
CO_2 emissions (kg-CO_2)	3,415,535	4,820,241

※ 2001.4 ~ 2002.3 result

CO_2 conversion factor [Natural gas : 2.15 kg-CO_2/m^3, Electricity : 0.689 kg-CO_2/kWh (thermal power)]

2-2. Chlorine dioxide discharge reduction

In March of 2001, the Hanshin Water has completed a project reconstructing the Amagasaki WTP, with the aim of introducing cutting-edge treatment technologies and renovating after the Great Hanshin-Awaji Earthquake ("Kobe earthquake" of 1995). It resumed its operation with optimized water treatment technologies coupled with integrated environmental technology.[3)] A co-generation system (CGS) characterizes its environmental technology, adopted to secure an emergency power and to meet growing thermal demand.

The CGS runs on a gas engine fueled by a natural gas, whose CO_2 discharge is 60% of coal and 75% of petroleum, thereby cutting back on environmental load. This system provides electricity to transmission and distribution pumps both as regular and emergency power. Thermal energy co-generated is used as a heat source inside the WTP to heat sediment sludge, dry dehydrated cake, cool ozonizers, and run air-conditioning equipments. Table 2 and Figure 6 digest CO_2 discharge reduction and an outline of the CGS, respectively. As compared to the case in which CGS is not installed, this system generates less CO_2, by 1,400 tons per year, that is, a reduction rate of about 30%, as shown in Table 2.

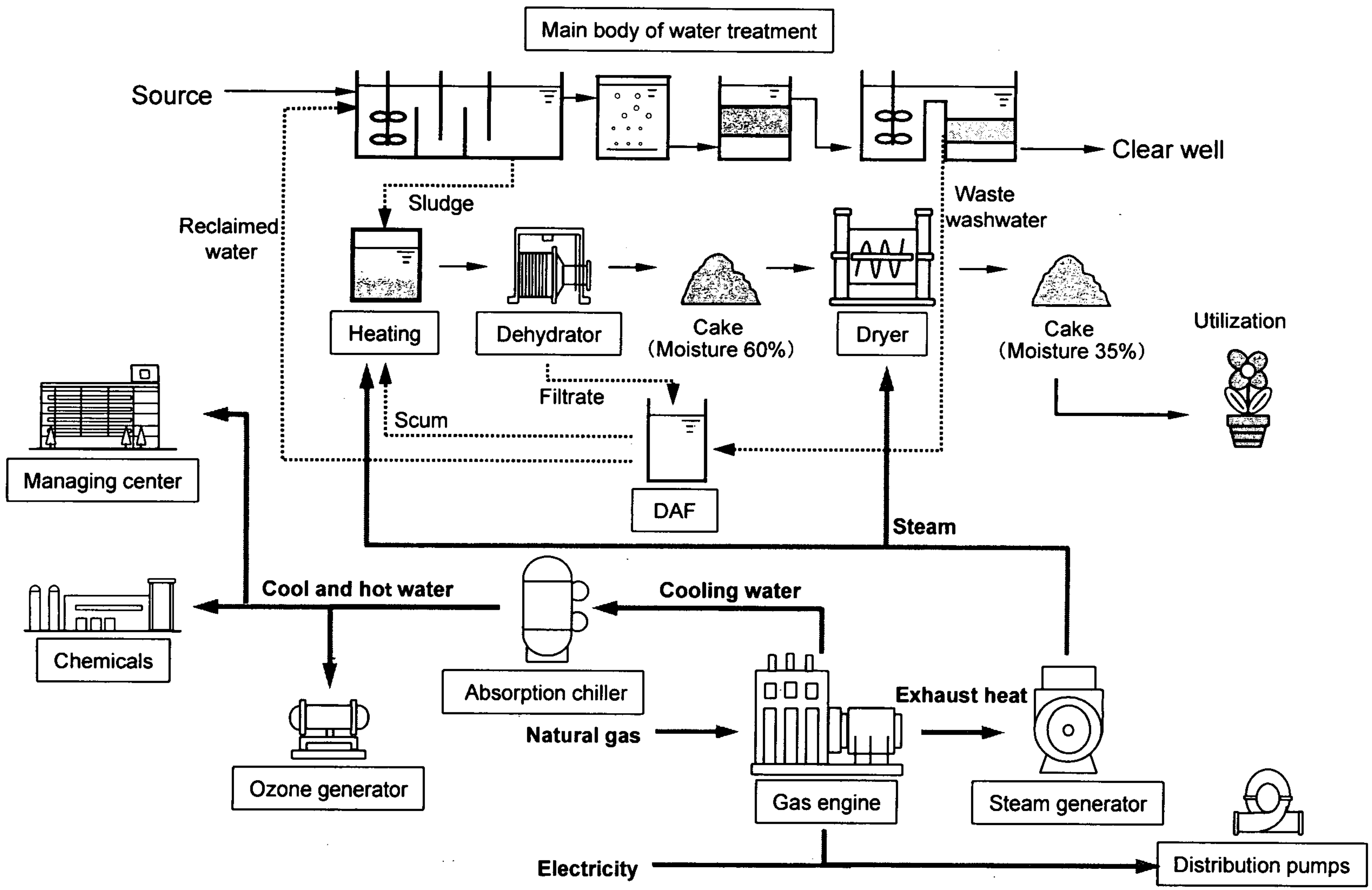

Figure 6 Outline of CGS in Amagasaki WTP

2-3. Recycling of waste materials

Wastewater from each treatment facility is reclaimed as raw water within the plant's closed loop, to follow effluent standards of the Water Pollution Control Law and utilize water resource. Solid materials separated during treatment process mainly derive from sediment sludge and filter backwash water. The majority of sludge is mechanically dehydrated.

At the Amagasaki WTP, exhaust heat from the CGS is utilized for heating sludge before dewatering, to raise the sludge temperature for the purpose of enhancing dehydration efficiency. Plate-shaped cakes from a dehydrator are kneaded and ground up into 0.3 to 5 mm cakes by a pelletizing-drying equipment (drying temperature: 170°C) using steam from the boiler, as shown in Figure 7.

Since the finished cake has an appropriate hardness, as well as extinguishing weed seeds and bacteria by heating, it can be used as alternate material for agricultural and horticultural soils without modification. The sludge is characterized by its high phosphate absorption coefficient and high cation exchange capacity. The former requires additional fertilization, on the other hand, the latter ensures excellent fertilizer retention.

These factors make it possible to add commercial value to the cake and sell it on the spot. Now the utility has achieved 100% utilization or recycling of waste materials at the plant. In addition, spent activated carbon disposed by a constant amount every year has also commercial value as material for agricultural and horticultural soils for its high deodorizing effect.[4)]

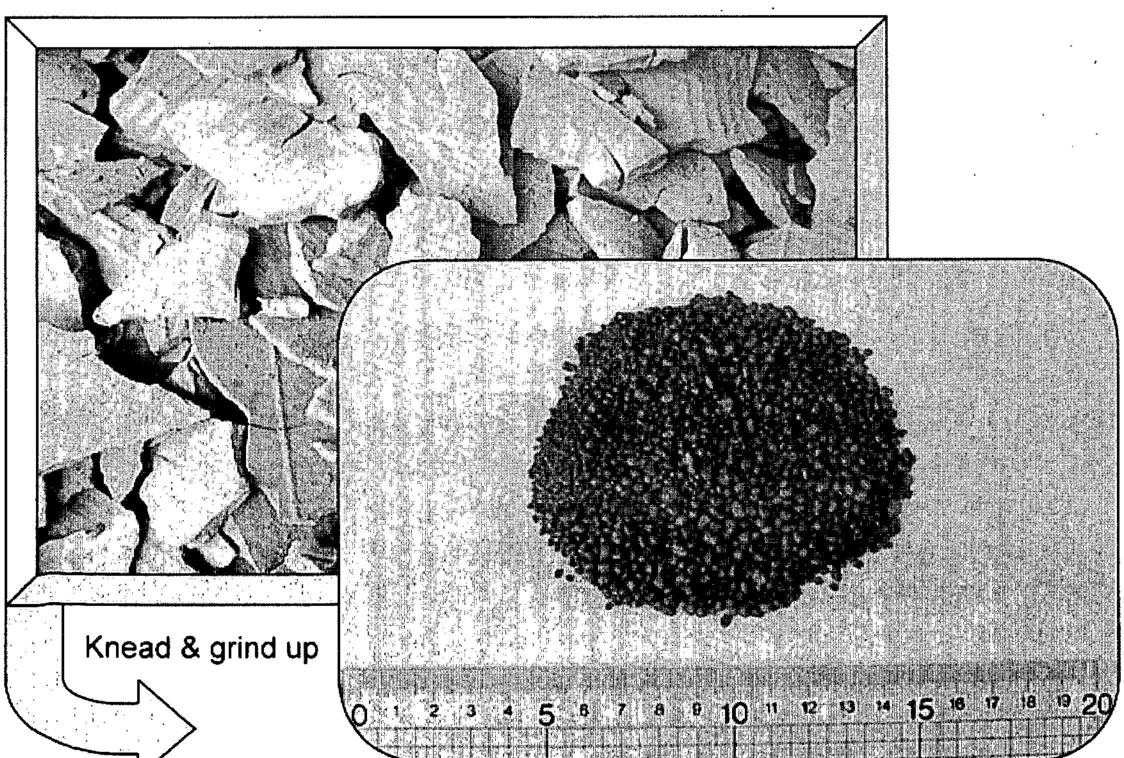

Figure 7 Plate-shaped cakes and palletized cakes

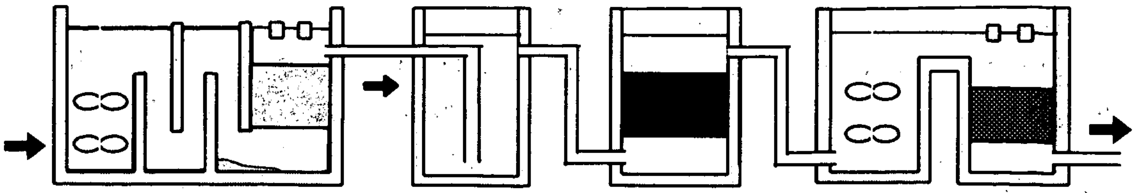

Figure 8 Treatment flow of Amagasaki WTP

2-4. Environmentally-oriented design

Figure 8 shows the main body of treatment flow at the Amagasaki WTP. The basic concept is the Multiple-barrier, which places emphasis upon maintaining a balance between microbial risk and chemical risk of the finished drinking water.[5] The facilities are marked by the effective use of upward flow and structures in the vertical direction, which are different from the conventional lateral flow and structures. The design concept combines a space-saving design with the idea of viewing gravity as an even resistive body in the vertical motion. As a result, the Plant has a large T_{10}/HRT value [10% mass of tracer outflow time / hydraulic retention time], realizing both facility compactness and treatability enhancement.

Upward-flow sedimentation basin provides an example. As compared to the conventional horizontal-flow type, while the new basin is one-third in volume, the turbidity of its treated water shows a major improvement from 0.6 mg/L to 0.1 mg/L (actual data). The U-tube ozone contactor can raise the T_{10}/HRT value up to 0.7 - 0.8 (estimated) and makes it possible to easily secure a required reaction time. As for the GAC-FB adsorber, the total head loss is only 0.5 to 0.6 m, much less than the conventional downward-flow filtration method, since the carbon bed fluidizes upward.

3. Representative Cases of Other Water Utilities

In Japan, global warming control has become a major challenge. At the same time, energy conservation, which is closely related to the warming, is further growing in importance. In such a situation, laws and regulations have gone into effect concerning the promotion of global warming control and rationalization of energy use. In the preceding chapter, environmental measures taken by the Hanshin Water have been discussed. In the field of water supply, other water utilities are also implementing programs in their way. This chapter presents some examples of environmental protection measures and energy saving carried out by each water utility and corporation. Their websites are helpful to gather information.

3-1. Tokyo Metropolitan Waterworks

Tokyo Metropolitan Waterworks is promoting environmental measures including the management of water source forests and the creation of water-saving lifestyles, as well as efficient energy utilization and the recycling. It manages the forests systematically to maintain a variety of important roles such as water conservation, water quality purification, and CO_2 absorption. Promotion of water-saving lifestyle includes the development of independent water-saving tap device and effective water use like rainwater.

To promote efficient energy utilization, power generators have been introduced that run on natural gases, solar energy, or elevation head at intake points, and experiments are being conducted on fuel cells-based generators. As for the recycling, the Bureau promotes reuse of materials left in construction works, low-depth installation of pipelines, and the reuse of soil and granular activated carbon from water purification. As a program covering the entire Bureau, an investigation is also under way concerning life cycle assessment (LCA).[6)]

3-2. Osaka Prefectural Waterworks

Osaka Prefectural Waterworks is promoting energy conservation, the utilization of natural energy resources, wastes reduction, and recycling. To promote energy conservation and natural resource use, power facilities fueled by natural gases have been introduced, covering 30% of electricity consumed at water treatment plants. At the same time, exhaust heat is utilized to heat dehydrated cake. Power generators are also installed that make use of surplus pressure from transmission pumps and the elevation head at water treatment facilities with hierarchical structure. Moreover, heat exchange between inflow and outflow gas reduces the power consumption by the heater at the exhaust ozone gas decomposer. At sedimentation basins, solar energy panels are mounted on anti-algae shades to utilize natural energy.

To reduce waste material generation and to recycle resources, production is minimized and used as alternate material for athletic field soils. By heating, granular activated carbon is regenerated and reused.[7)]

3-3. Kobe City Waterworks

Kobe City Waterworks is implementing measures for the utilization of natural energy resources, as well as energy conservation including efficient pump operation. Natural energy resources, such as solar and hydraulic energy are harnessed to run small-scale power generators used for a telemeter system that controls water distribution management. In case of an accident, the generator serves as an emergency power source.

Making use of the City's topographical characteristics, the Bureau is trying to reduce the unit power consumption for transmission, thorough systematic pumping station renovation and efficient distribution control. Direct water supply that doesn't go through receiving tank is adopted for small-scale two-story buildings to harness water pressure in distribution pipelines, while a direct boosted water supply is employed for buildings with ten floors or so, thereby reducing the power cost borne by consumers.[8)]

3-4. Japan Water Works Association (JWWA)

Commissioned by the Ministry of Health and Welfare (MHLW; present Ministry of Health, Labor and Welfare), the JWWA has conducted LCA and other surveys to prepare reports on environmental action plans in the field of water service. The results are compiled in a survey report to formulate guidelines for global warming control.[9)]

3-5. Japan Water Research Center (JWRC)

Commissioned by the MHLW, the JWRC has studied measures to promote the reduction and reuse of waste materials. The study includes questionnaire surveys clarifying the current status of waste materials at waterworks facilities and their treatment.[10)]

4. Future Orientation

Japan's drinking water service is in the process of shifting from expansion to maintenance. Facilities built during the Japan's rapid economic progress now require fundamental renovation. The annual water supply of 17 billion m^3 mentioned at the beginning is equivalent to twice as much or more as annual domestic cargo volume of 6.4 billion tons, on the other hand, the power consumption for waterworks is about 8.0 billion kWh/y, only 0.8% of the country's total power consumption of 978.3 billion kWh/y. However, further energy conservation in water service is necessary, considering the fact that the motive cost constitutes a large percentage of the total water supply cost. Meanwhile, wastewater treatment in WTPs annually produces about 360,000 tons of dehydrated cake, only 37% of which is utilized on a national scale. From the standpoint of environmental load reduction, or promoting a recycling-oriented society, greater recycling and reuse are inevitable. Water utilities have limitation to consider global environment within the framework of repair works covered by operating costs. Therefore, it is important to fully grasp each opportunity of facility rehabilitation to integrate environmental technology. Progress should be achieved step-by-step through specific policies, from consideration to guidelines, and then to action plans.

The utilities can afford to ensure accountability for consumers on water treatment technology, which forms the basis of water service, by clarifying the balance of materials including pathogenic microorganisms and disinfection by-products in each treatment process, as well as paying attention to maintain risk balance in finished water. Also with regard to energy consumption and waste materials at treatment plants, it is necessary to introduce environmental technology based on the concept of material balance. Extremely speaking, accomplishing accountability on material balance can lead to the solution of environmental problems.

In this 21st century, more focus will be placed on water-related issues, which include difficulty of restoring natural hydrologic cycle and maintaining global balance in water supply and demand. As stated above, for many people in industrialized countries including Japan, the most familiar water in our daily life is the tap water. By taking a close look at tap water, each consumer is expected to gain a better understanding of the current status of water resources, water treatment technology, water transportation, energy consumption, and waste materials, and then, to take actions against global environmental problems. Water supply and sewerage utilities, constituting part of the hydrologic cycle, have a responsibility to promote information management and action plan for realizing sustainable environment and economy.

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