SOURCE WATER PROTECTION OF YODO RIVER AND WATER QUALITY MANAGEMENT IN OSAKA MUNICIPAL WATERWORKS

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WATER CYCLE IN YODO RIVER SYSTEM

For hundreds of years, Lake Biwa and the Yodo River system has been the primary water source for residents in the Kyoto-Osaka-Kobe area, located in the central part of Japan. This area has prospered as the center of politics, economy and culture since ancient times. The Yodo River basin flows across 6 prefectures in Kansai area and the catchment area is 8,240 Km^2. Five million people live in the upstream of the catchment area. From this area, domestic drainage and industrial wastewater is eventually returned to the Yodo River via sewerage treatment plants. The average effluent amount of sewerage and human waste treatment plants in the upstream area is around 18 m^3 per a second (2001) which amounts to one tenth of the average downstream water flow rate of the Yodo River (172 m^3/sec : average at Hirakata in 2003). On the other hand, more than eleven million people in the downstream area use the same river water for water supply. Therefore the Yodo River system is considered to be one of the most visible case of unplanned indirect water reclamation in Japan.

We learned that our life and human activities are based on a natural water cycle system and loading pollutants beyond the environmental capacity of the system will contribute to a continual increase in pollution. We have an instructive experience that the water quality of the Yodo River had seriously deteriorated during the 1950s and '70s due to rapid urbanization and increasing industrial activities in the upstream area as a result of economic growth. In this paper we would like to show the various water quality management countermeasures and hope our experience gives a clue to sustainable water utilization.

WATER QUALITY DETERIORATION DUE TO POLLUTION IN THE CATCHMENT AREA AND COUNTERMEASURES

Figure 1 represents approximately a hundred year transition of potassium permanganate ($KMnO_4$) consumption value and bacterial standard plate count of raw water at the Kunijima purification plant of Osaka Municipal Waterworks Bureau (OMWB), located in the lowest part of the Yodo River. In the 1950s, the water quality of the Yodo River deteriorated rapidly due to increasing contaminant load from domestic and factory sewage.

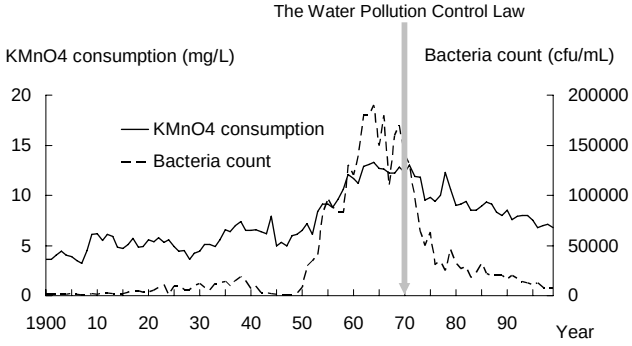

Figure 1. Transition of water quality of raw water at Kunijima purification plant

In the following 30 years, however, the quality has been improved dramatically, owing to the efforts of national and local governments and other relating administrative organizations to implement countermeasures for environment water conservation on various aspects such as establishing a national regulations and administrative monitoring and conducting tests on drainage water quality flowing into public water bodies.

Legislative preparation for source water conservation. For the purpose of protection of national health and preservation of living environment, national government prepared The Basic Law of Environmental Pollution Control in 1970 and revised this upward The Basic Environment Law in 1993. Under this law, the Environmental Water Quality Standards were set for protection of human health and conservation of living conditions. To achieve the compliance of standards, The Water Pollution Control Law with a clause of penalty and enforceable The National Effluent Standards were set in 1970, which covers about 300,000 factories. In addition, The Sewerage Law also reviewed to define sewage works as primary facilities for conserving water quality of public water bodies and to require that national and local governments should work together to promote the improvement of sewerage systems. Accordingly, the coverage of sewerage system in Kyoto City area has risen from around 40% in 1960 up to 99% in 2000.

Water quality conservation activities within Yodo River basin. Promoting the coverage rate of the sewerage system in the upstream basin has contributed greatly to improving water quality of the Yodo River by decreasing total biological oxygen demand (BOD) load to the Yodo River basin which was determined on the basis of data obtained at the Hirakata observation point in the middle basin of Yodo River (See Figure 2). While the load began to decrease in the '70s and recently, it has dropped to a level of 1/3 of that in the '60s, the chloride ion load, which does not decrease in sewage treatment, gradually increased (See Figure 3). These facts suggest that sewage treatment decreased BOD, while BOD load into sewage treatment increased like chloride ion.

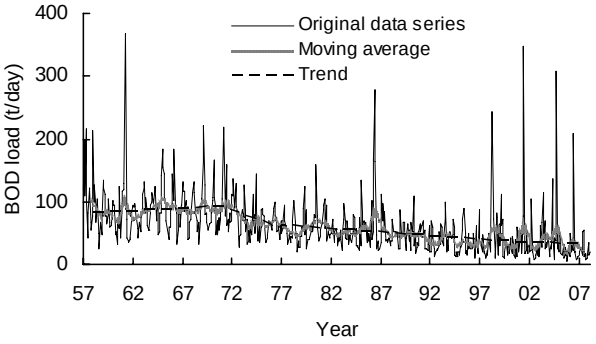

Figure 2. Changes in BOD Load

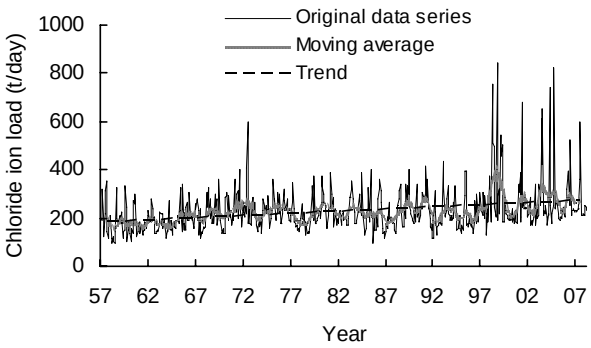

Figure 3. Changes in Chloride Ion Load

The national government determines the strategic policy of the environment and each local government implements concrete countermeasures accordingly. Almost all waterworks in Japan are organized on a municipal basis and are not executive authorities. This means that the governmental countermeasures would not always be satisfied to ensure supply safe water. When more effective countermeasures are expected, close coordination between the related administrative organizations and waterworks is essential.

To promote water quality conservation and to provide a systematized communication and coordination against water pollution, the Yodo River System Liaison Council for Prevention of Water Pollution was founded in 1958, comprising of the administrative organizations including the regional bureau of the Ministry of Land, Infrastructure, Transport and Tourism, environmental divisions of local governments in the region, and waterworks located in the basin.

In 1965, ten water authorities in the basin including OMWB have jointly established the Yodo River Water Quality Consultative Committee (YRWQCC) to conduct source water quality monitoring, research and investigation, lobbying to the administrative bodies concerned, and maintaining an emergency liaison network for handling crises such as unexpected pollution. One of the fruits of these activities is a fact that there are no effluents from sewerage and human waste water treatment plants flowing into the midstream of the Yodo River basin because of changing their discharging routes.

On its own, OMWB has conducted independent monitoring of quality of the source waters and industrial effluents directly discharged to upstream. If a violation of the regulations was detected, the administrative bodies are notified to improve the wastewater quality. Before 1970, the BOD level in the effluent was more than a few hundred mg/L in a dyeing factory and has once exceeded a thousand mg/L in yearly average in a brewery. But after 1970, those BOD levels have decreased to less than ten mg/L (see Figure 4).

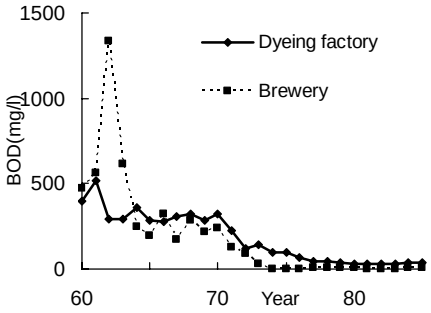

Figure 4. BOD Change of Industrial Effluents

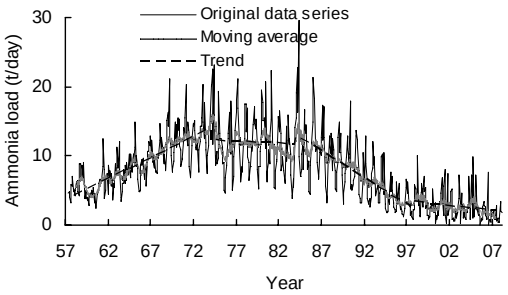

Figure 5. Changes in Ammonia Load

Figure 5 shows the change of ammonia load into the Yodo River. The ammonia load increased according to progress of sewage treatment coverage. Ammonia is not considered a toxic substance in natural environmental water and is included neither in the environmental standards nor in the effluent standards until 2001. Ammonia, however, is a very annoying substance to the waterworks, since it reacts with chlorine and consumes it. Therefore, we have strongly requested a reduction of ammonia in sewage treatment and human waste treatment plants in the upstream areas by YRWQCC lobbying activities. Accordingly, introduction of circulated denitrification system and long time aeration into the treatment plants has been promoted, and the ammonia load has been remarkably decreased.

Introduction of advanced water treatment. Around 1930, OMWB employed slow sand filtration system, and 30 years later, switched to rapid sand filtration system following chemical coagulation and sedimentation due to increasing water demand and raw water quality deterioration. We also adopted break point chlorination for enhancement of oxidizing contaminants and disinfection. Since the 1970s disinfection by-products (DBPs) problem and musty odor occurring in Lake Biwa have became our major concerns. It was found that musty odor substances and DBPs cannot be sufficiently reduced by conventional treatment.

Therefore, the advanced water treatment (AWT) including intermediate/post ozonation and granular activated carbon (GAC) treatment has been introduced into our purification plants from 1998 to 2000. The AWT has completely removed musty odor and lowered the level of DBPs by decreasing the formation potentials

(DBPFPs). Besides this, dissolved organic carbon in the finished water was also decreased to almost 40% and effectively removed other contaminants. The AWT contributes to ensuring greater safety and improved drinking water quality.

PRESENT AND FORWARD MEASURES IN ORDER TO ENSURE THE SAFETY AND SECURITY OF RAW WATER

Source water quality has been improved in organic pollution during the past 30 years. However, the relationship between the upstream and the downstream of the Yodo River cannot be changed. We should always consider that our water source is continuously exposed to potential contamination by harmful chemicals in the upstream basin by high pace industrial activities. OMWB has been conducting various approaches to manage these potential threats using the following measures:

Research of the reduction of harmful chemicals potentially occurring in raw water by AWT. We are conducting foreseeing researches on the issues of concerned contaminants potentially occurring in raw water. According to the latest research, most of the contaminants investigated are confirmed to be effectively removed by the treatment (Table 1).

TABLE 1 Contaminant removal efficacy of AWT

Contaminant	Removal by AWT	Analytical method
Mutagenisity	Effective #	Ames assay (TA98, TA100)
Pesticides (99 chemicals)	Effective	GC/MS, LC/MS
Endocrine disruptor	Effective	Yeast two-hybrid assay, LC/MS/MS, GC/MS
Pharmaceuticals	Effective	LC/MS/MS GC/MS
3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX)	Effective	LC/MS/MS

also after disinfection

Safety hazard analysis of raw water by the Kansai Waterworks Research Association to support introduction of the Water Safety Plan. The Kansai Waterworks Research Association (KWRA) is a research group launched by 8 waterworks including OMWB and academic experts from the Kansai area for the purpose of logical argument about present issues from various aspects of Kansai area, making it reflected in policies for providing better water service. The research on water source management for supporting the Water Safety Plan was conducted in 2006 and 2007. It consisted of collecting the basic information about the river basin such as its geology, flow regime and basin condition and the source of contamination, identifying raw water safety hazards, assessing the possibility of hazards to reach at intake point, and presenting an appropriate figure of the water source. The risk assessment of the hazards of raw water can be carried out by the estimation of the total discharged chemical amounts in the basin based on the national data base of the Pollutant Release and Transfer Register, while adding the potential risk of chemical spill by factories in the basin. The member waterworks of KWRA are utilizing this procedure of the risk assessment when they develop their own Water Safety Plan.

Enhancement of raw water contaminant monitoring. Based on the statistical results of the latest three years monitoring data on source and raw water quality, we review monitoring frequency for every next year. In addition, to be sure early warning system for unexpected raw water contamination by toxic substances, we provide necessary equipments such as bio-assay systems by monitoring fish activity and nitrobacteria respiration. We are going to carry out an intersectional workshop for investigation and establishment of further sophisticated monitoring system.

Implement of Osaka Municipal Waterworks' edition of the Water Safety Plan on the basis of the international standard of the Food Safety Management Systems (ISO22000:2005). ISO 22000:2005 is the international management systems consists of the quality management system with continual improvement and the HACCP system in the production process. So it is the best method in which all activities carried out including implementation of the Water Safety Plan and drinking water quality managements are jointly coordinated in this ISO standard, because the whole water supply system can be considered a kind of food distribution. We are going to make every effort to ensure the safety and security of raw water by carrying out all measures mentioned above under ISO 22000.

CONCLUSION

To conserve the water environment in the basin, administrative organizations to manage water pollution, sewage works and waterworks have played each own role which actually contributes to control and reduce the risk of safety hazard in the watershed. In addition, to make further improvement in water quality of the river basin and sustain the utilization of the limited amount of water, more strengthened communication, coordination and cooperation not only among waterworks, but also in many different organizations concerned in the basin are necessary. This is considered as the royal road to establish the desirable conservation system for water supply in which any possible hazard cannot reach at the intake point, even if toxic substance flows into the upstream basin.

Source Water Protection of Yodo River and Water Quality Management in Osaka Municipal Waterworks

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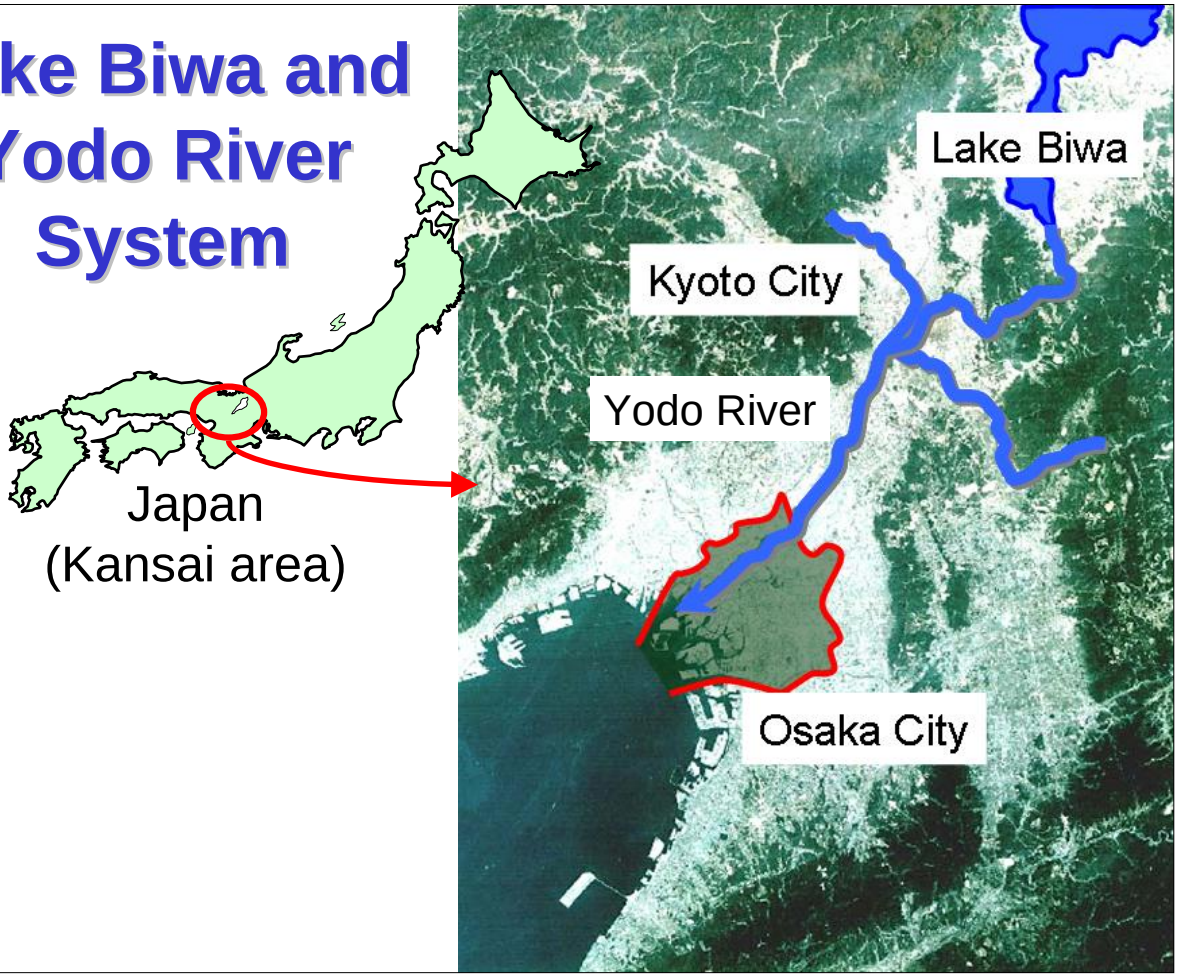
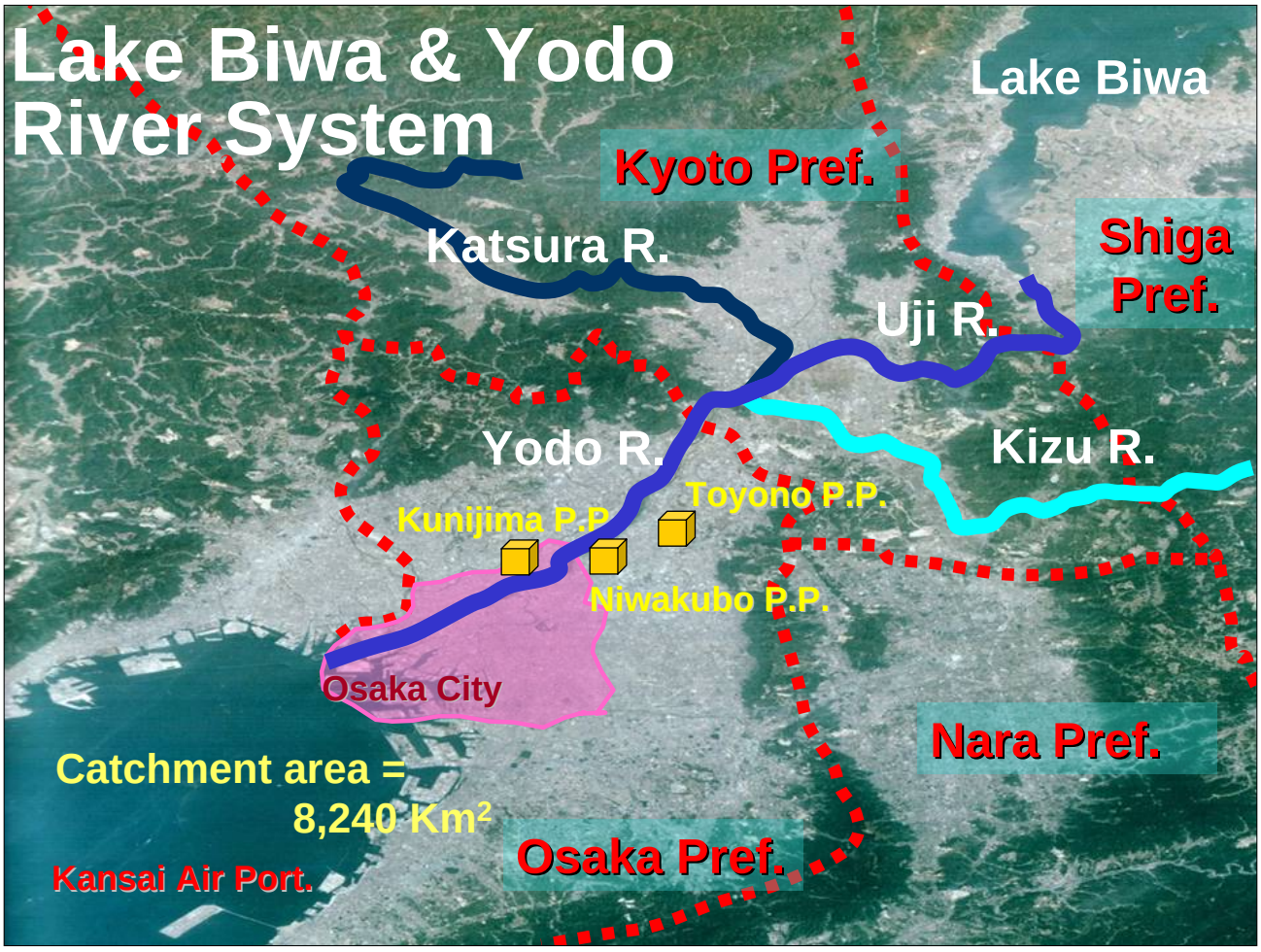
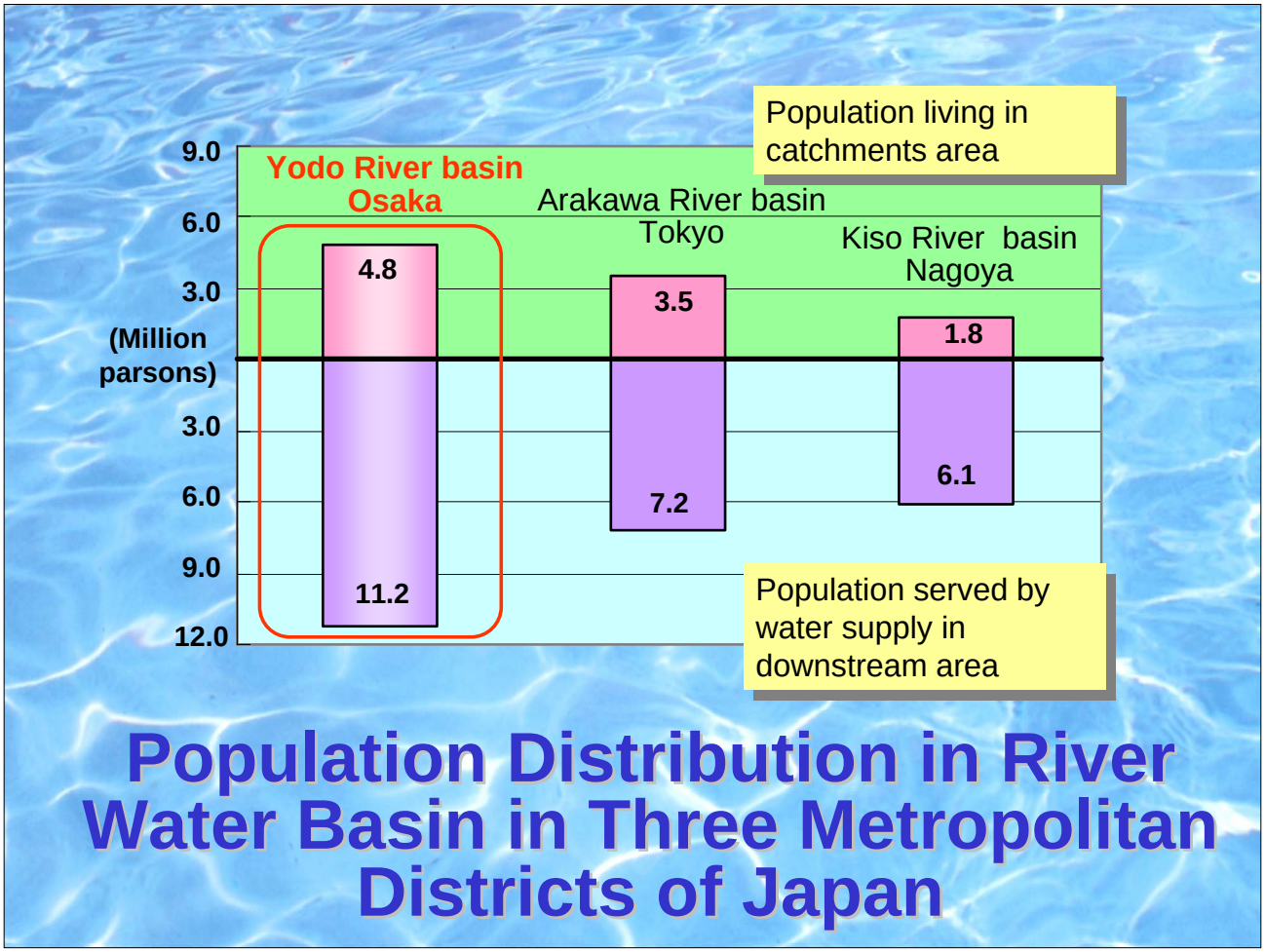
Japan-U.S. Joint Conference On Drinking Water Quality Management and Wastewater Control

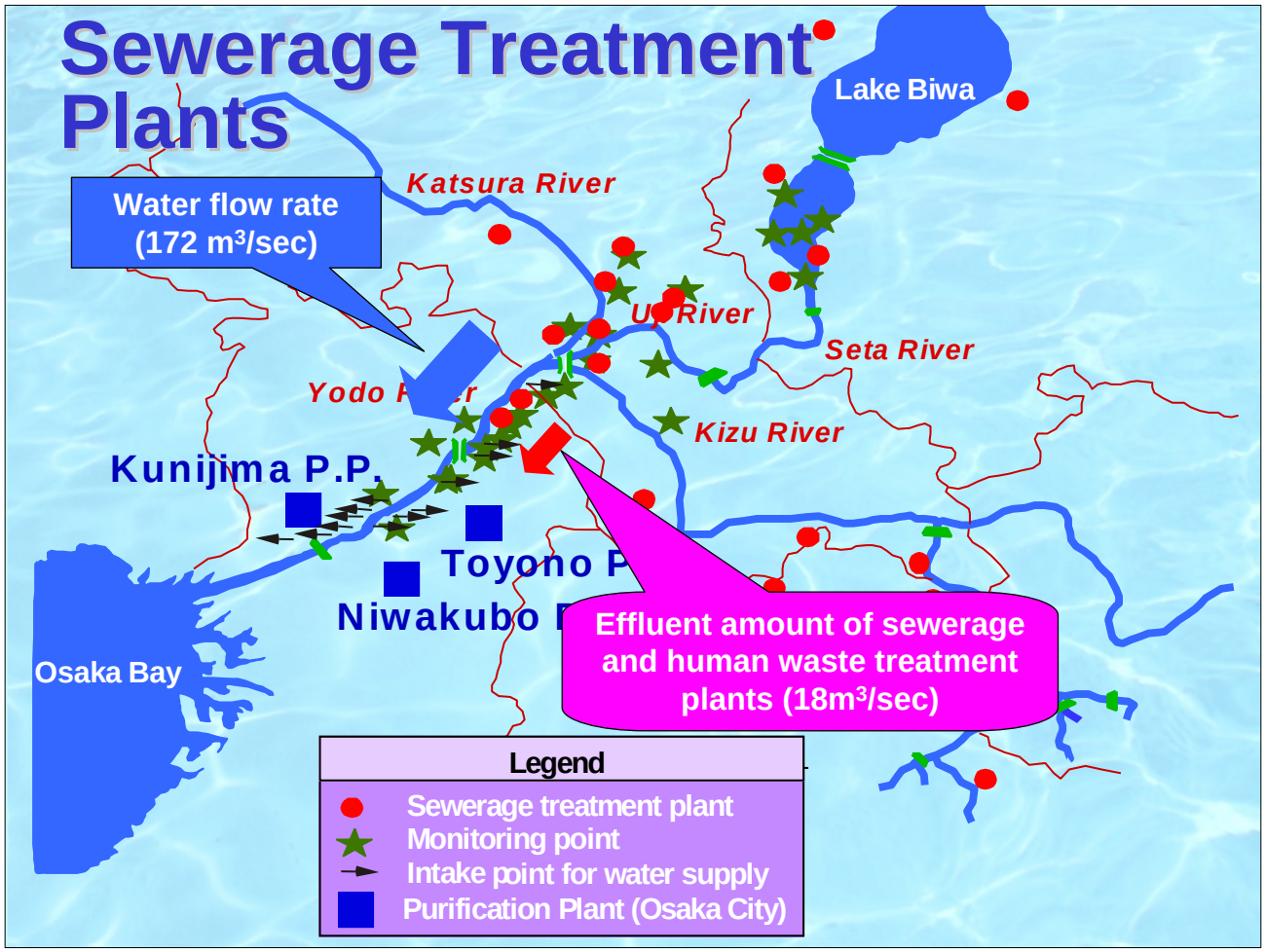
Lake Biwa and Yodo River System

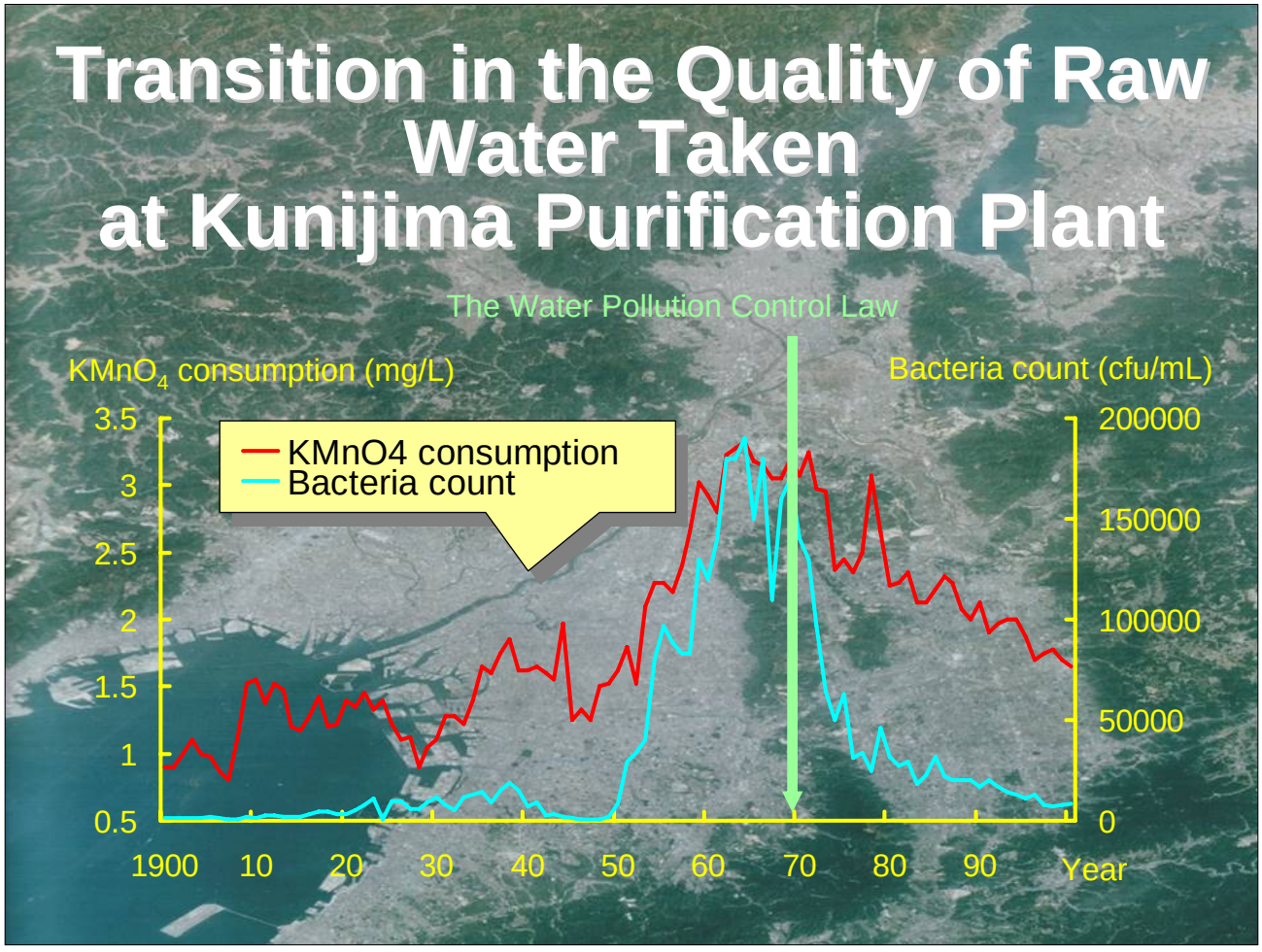






Population Distribution in River Water Basin in Three Metropolitan Districts of Japan


Sewerage Treatment Plants
Lake Biwa
Katsura River
Water flow rate (172 m³/sec)
Seta River
Kizu River
Kunijima P.P.
Toyono P
Niwakubo P
Osaka Bay
Effluent amount of sewerage and human waste treatment plants (18m³/sec)
Legend
Sewerage treatment plant
Monitoring point
Intake point for water supply
Purification Plant (Osaka City)


Transition in the Quality of Raw Water Taken at Kunijima Purification Plant
The Water Pollution Control Law
KMnO4 consumption (mg/L)
Bacteria count (cfu/mL)
KMnO4 consumption
Bacteria count
3.5
3
2.5
2
1.5
1
0.5
200000
150000
100000
50000
0
1900
10
20
30
40
50
60
70
80
90
Year

National Policy and Overall Coordination on Conservation of Water Environment

Ministry of the Environment

Conservation of Water Quality in Public Water Resources
- Environmental Quality Standards
- Factory Effluent Control
- Household Waste Water Control

Ministry of Land, Infrastructure and Transport

Master Plans for River Environment Management

Diffusion of Sewerage System and Advanced Sewerage Treatment

Measures for Conservation of Water Quality

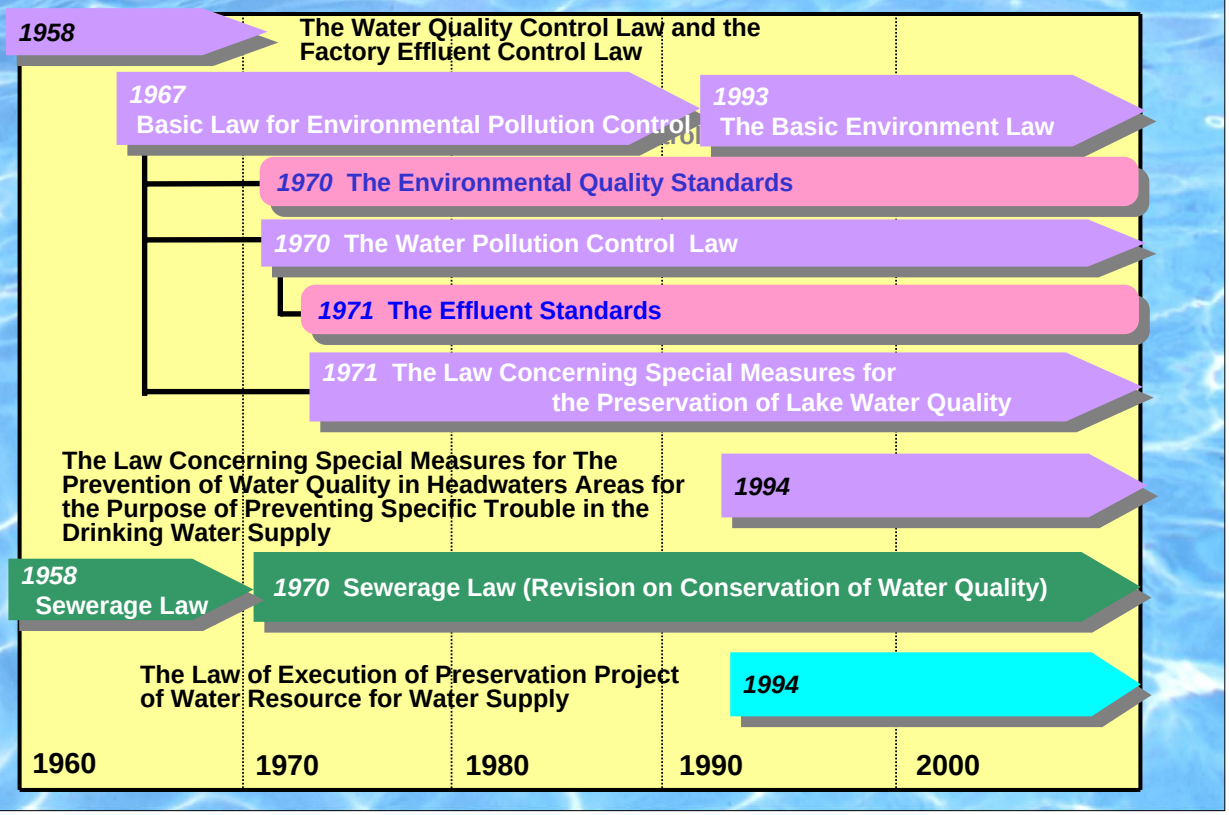
Ministry of Health, Labour and Welfare

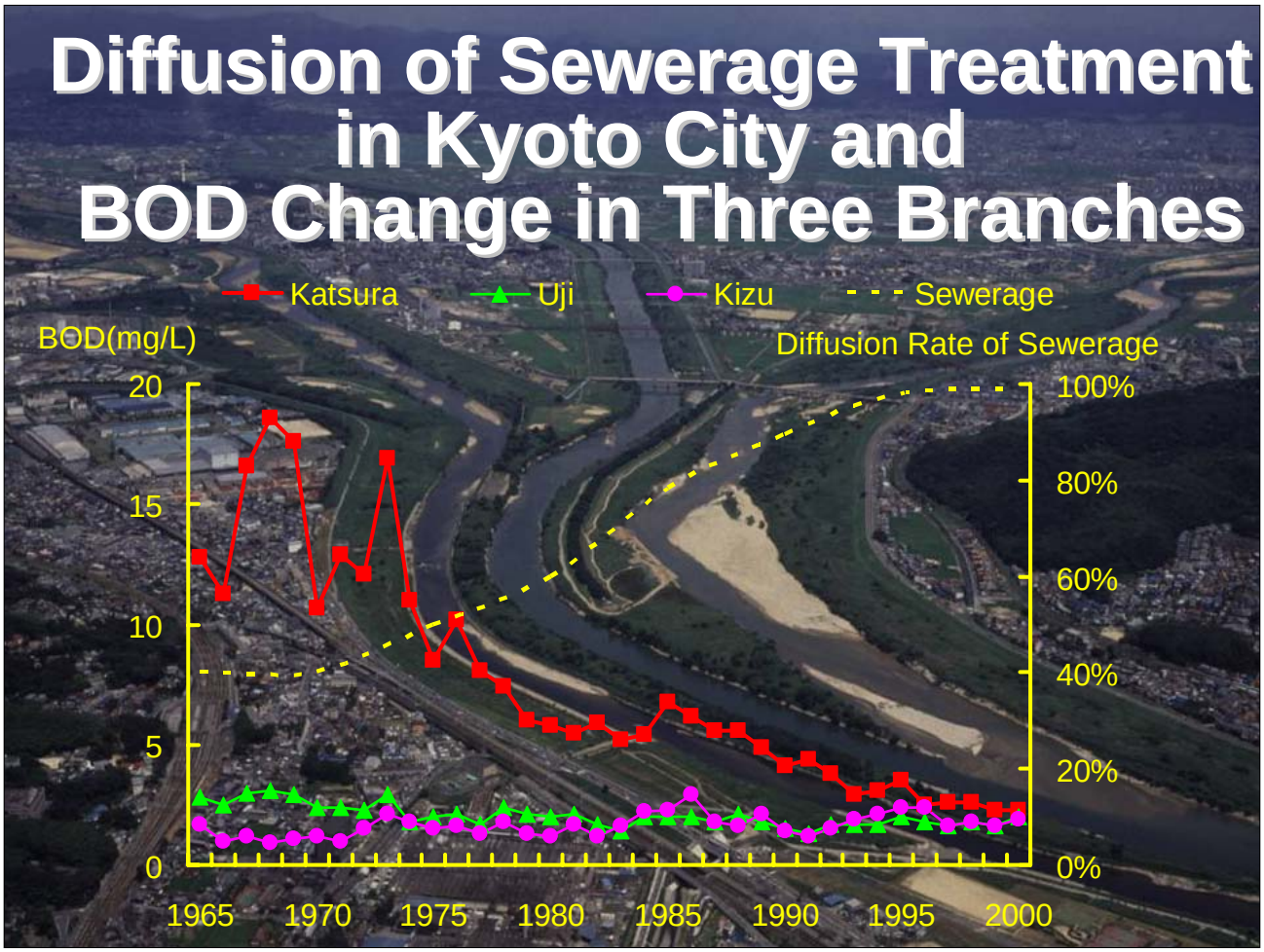
Execution of Preservation of Water Resource Quality for Water Supply

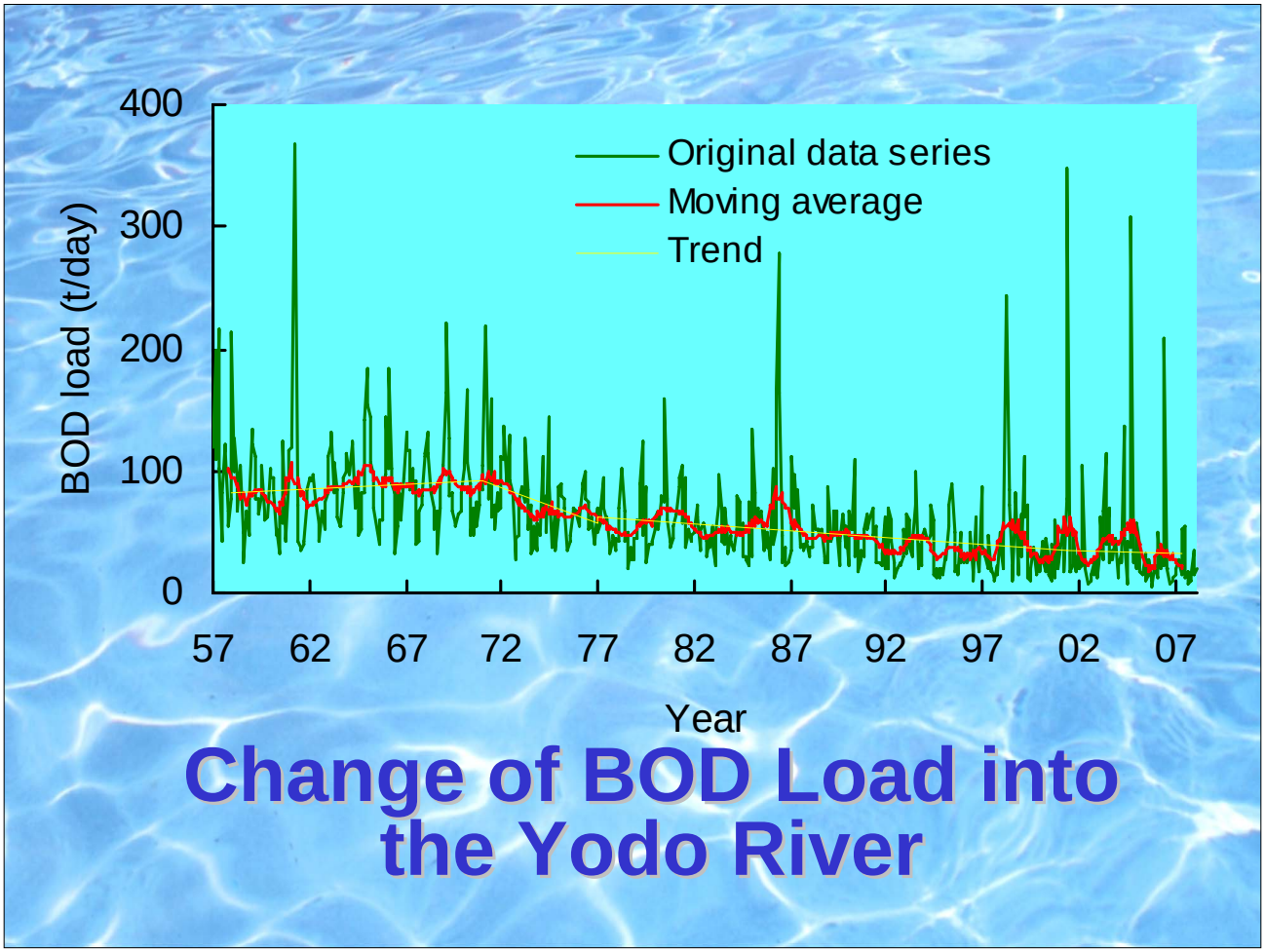
Ministry of Agriculture, Forestry and Fisheries

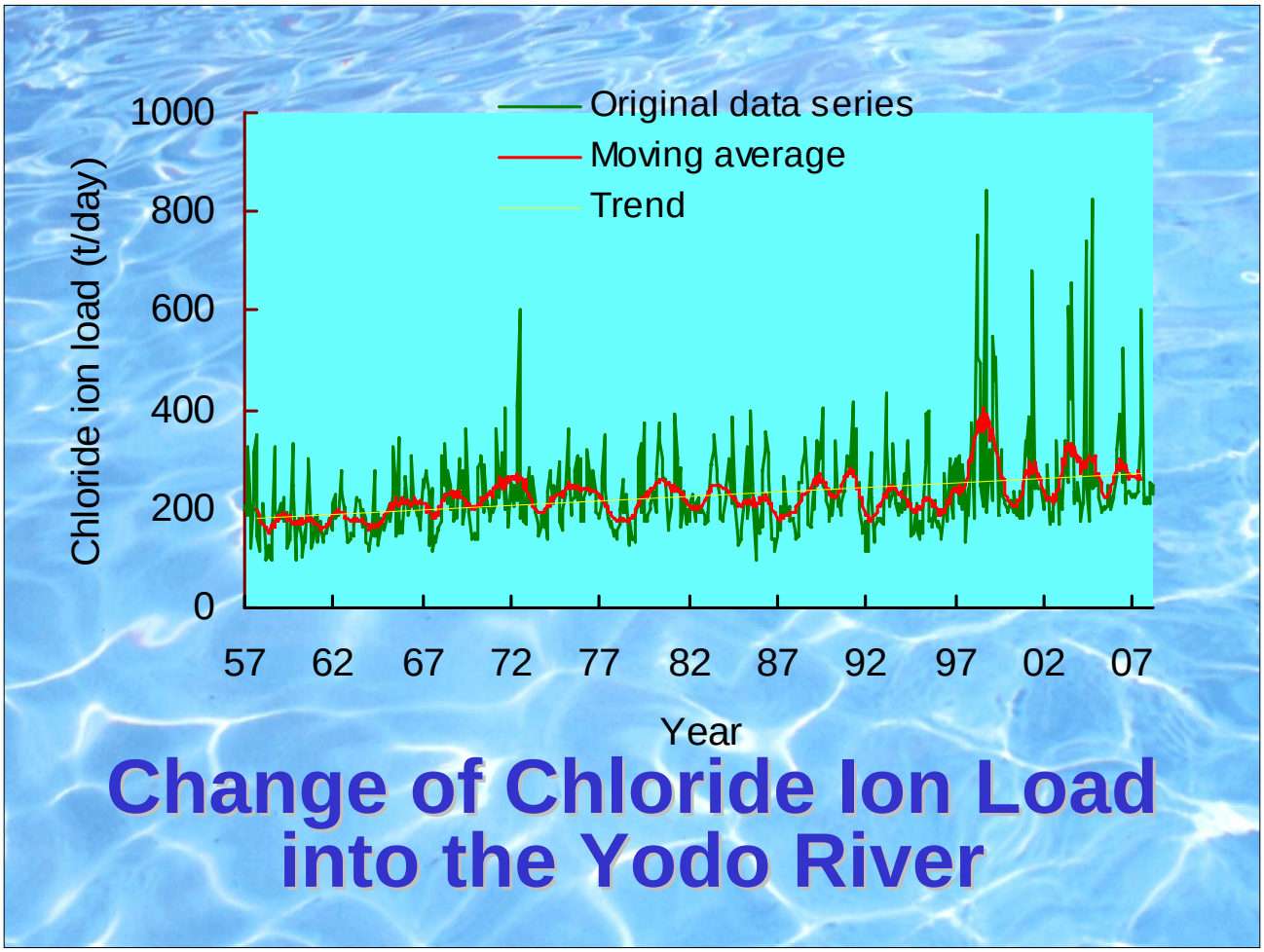
Conservation of Water Quality in Public Water Resources
- Rural Community Sewerage
- Conservation of Forest

Legislative System on Conservation of Water Quality in Public Water Resources




Diffusion of Sewerage Treatment in Kyoto City and BOD Change in Three Branches
Katsura
Uji
Kizu
Sewerage
BOD(mg/L)
Diffusion Rate of Sewerage
20
15
10
5
0
100%
80%
60%
40%
20%
0%
1965
1970
1975
1980
1985
1990
1995
2000


Original data series
Moving average
Trend
BOD load (t/day)
400
300
200
100
0
57
62
67
72
77
82
87
92
97
02
07
Year
Change of BOD Load into the Yodo River



Change of Chloride Ion Load into the Yodo River

Measures for Conservation -A Case of OMW-

[1] Lobbying Activity (Administrative Bodies)

- To Promote Construction of Public Waste Water Treatment Plant

Including subsidizing for the source water conservation in Lake Biwa area

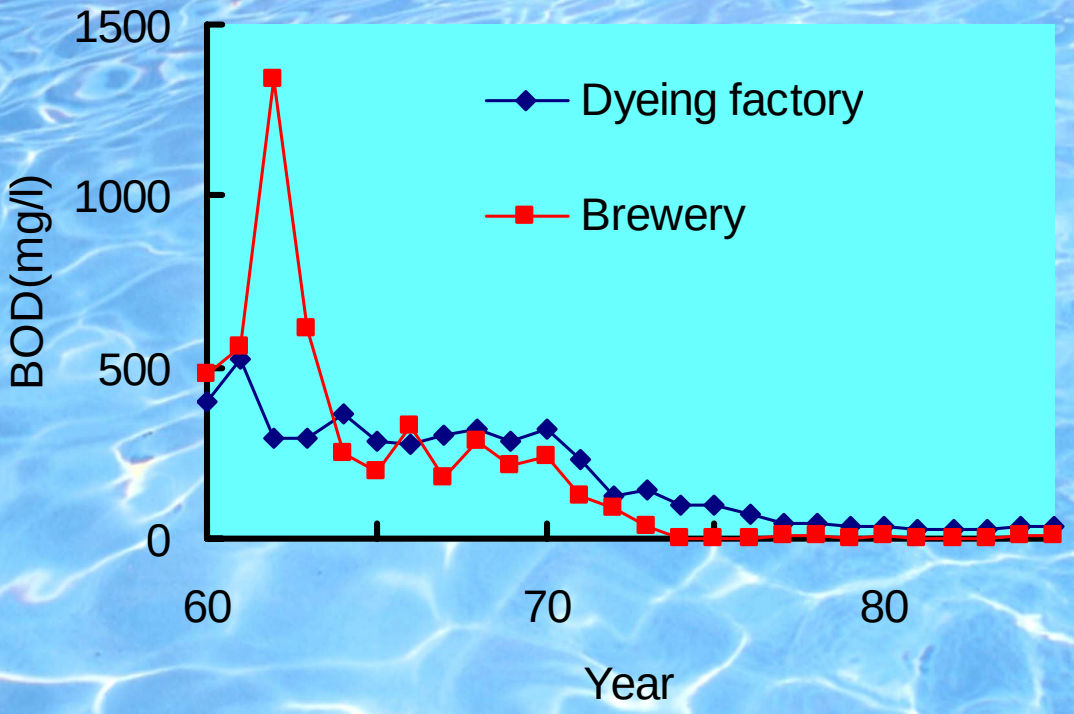
- To Improve Effluent Water Quality from Sewerage Treatment Plants

Reduction of ammonia concentration

Measures for Conservation -A Case of OMWB-

[2] Water Quality Monitoring in Water Sources

- Monthly Monitoring at Fixed Stations through the Yodo River
- Overall Parameters for Drinking Water Quality Control
- Report the Data to Public and the Administrative Bodies



BOD Change of Industrial Effluents

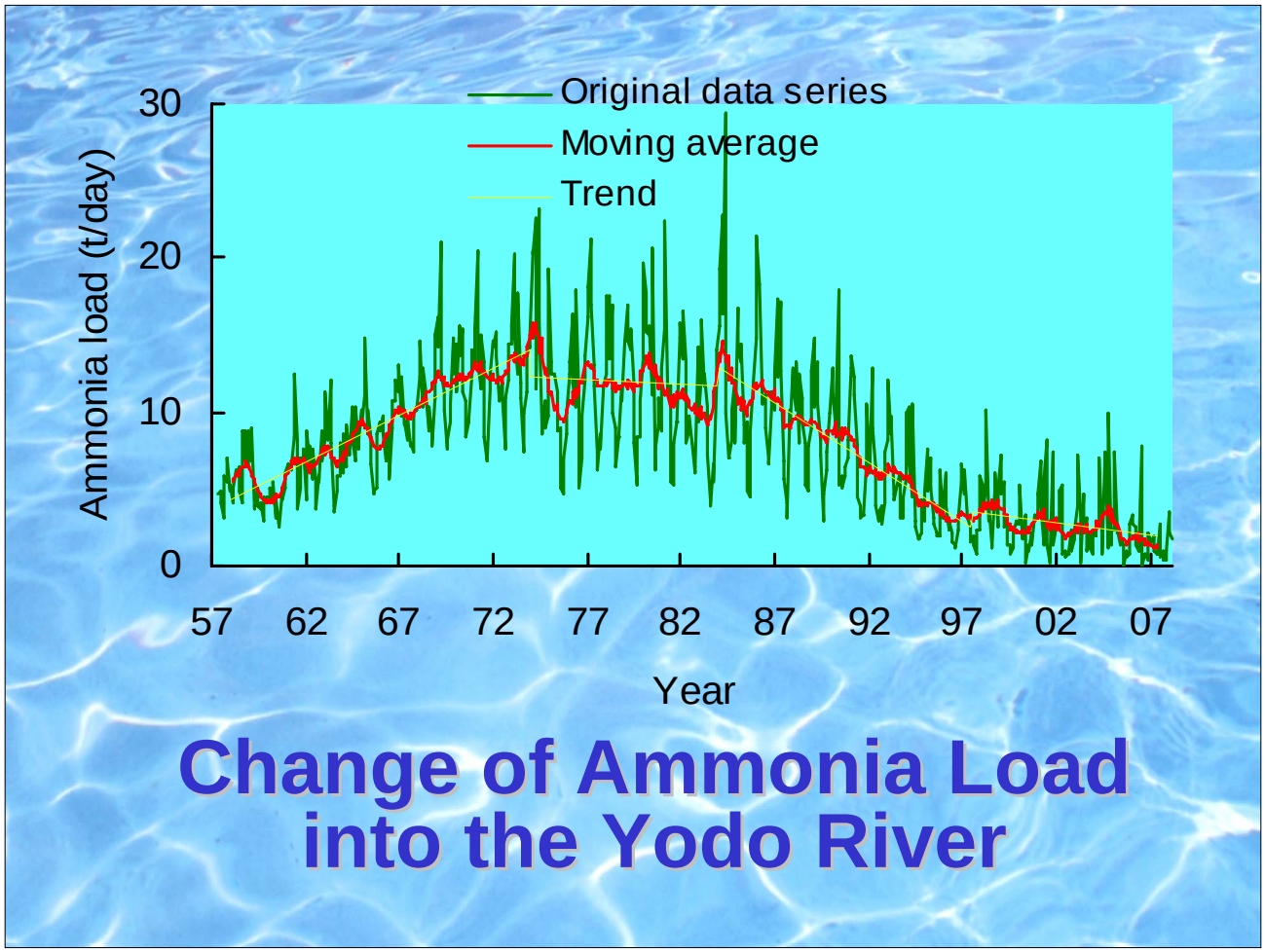
Measures for Conservation -A Case of OMWB-

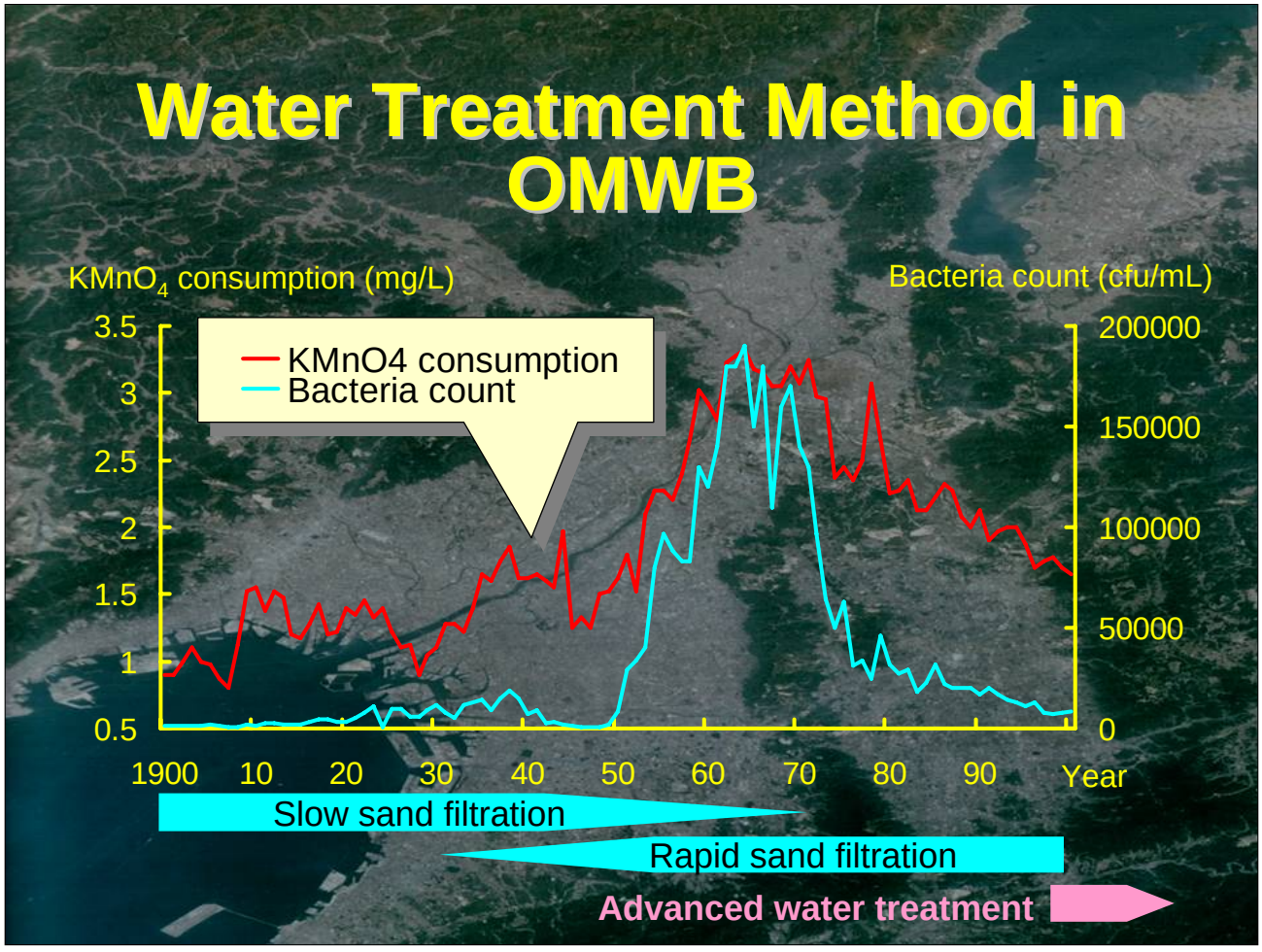
[3] Regional Association on Water Quality Conservation

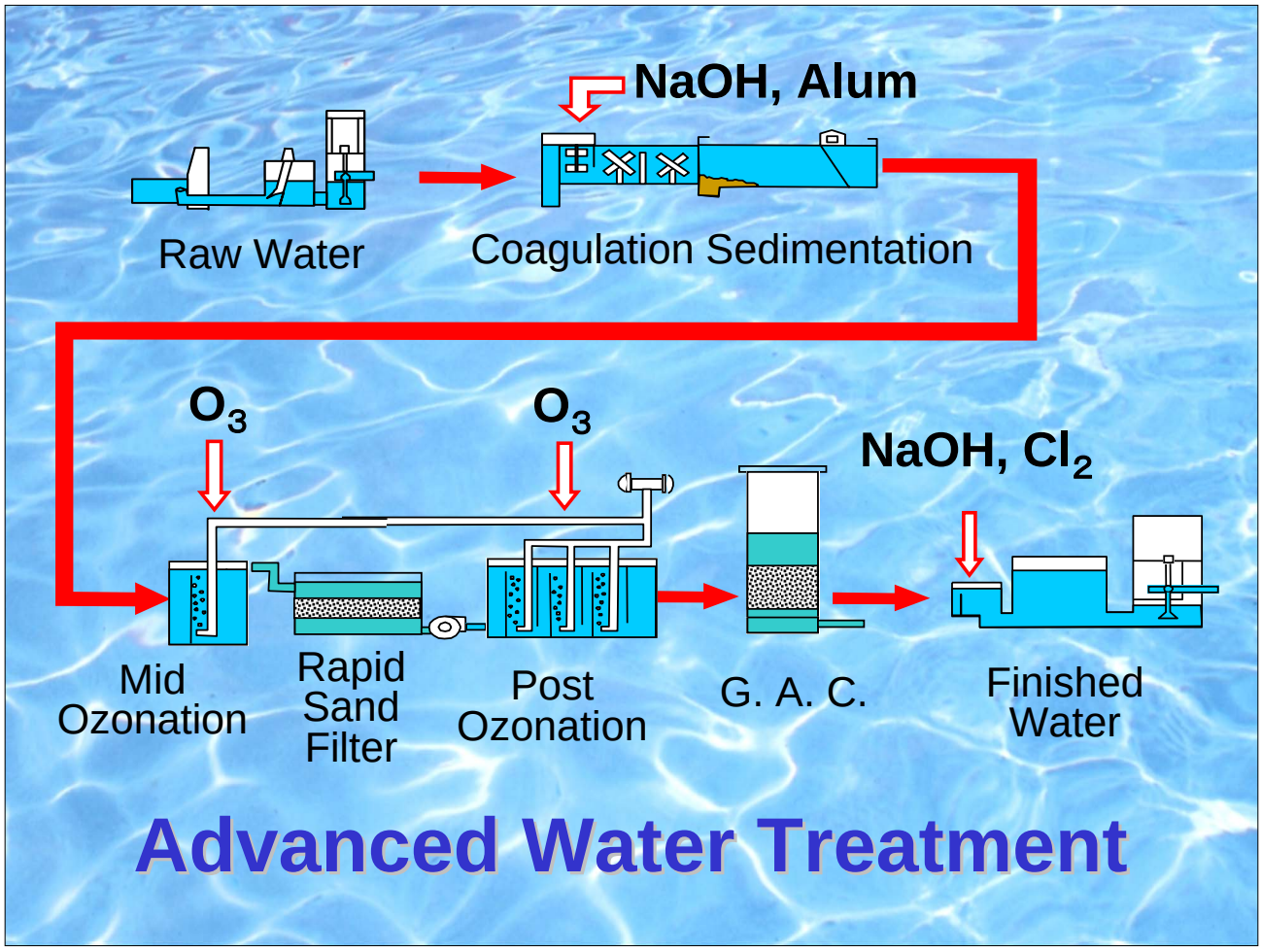
- Participation in the Yodo River System Liaison Council for Prevention of Water
- Participation in the Yodo River Water Quality Consultative Committee (YRWQCC)

Water Utilities of YRWQCC

Name	Water Supply Capacity (m^3/D)
Osaka Municipal Waterworks	2,430,000
Osaka Prefectural Waterworks	2,330,000
Hanshin Water Supply Authority	1,128,000
Moriguchi City Waterworks	103,500
Hirakata City Waterworks	191,317
Neyagawa City Waterworks	129,000
Amagasaki City Waterworks	351,486
Suita City Waterworks	208,000
Nishinomiya City Waterworks	275,691
Itami City Waterworks	94,600


Original data series
Moving average
Trend
Ammonia load (t/day)
30
20
10
0
57
62
67
72
77
82
87
92
97
02
07
Year
Change of Ammonia Load into the Yodo River


Water Treatment Method in OMWB
KMnO4 consumption (mg/L)
Bacteria count (cfu/mL)
KMnO4 consumption
Bacteria count
3.5
3
2.5
2
1.5
1
0.5
200000
150000
100000
50000
0
1900
10
20
30
40
50
60
70
80
90
Year
Slow sand filtration
Rapid sand filtration
Advanced water treatment



Measures for the Improvement of Water Quality Management in OMWB

[2] Risk assessment and management of the hazards

- **Evaluating contaminant removal efficacy of AWT**
- **Hazard analysis in raw water**
- **Enhancement of raw water contaminant monitoring**

Bio-assay systems by monitoring fish activity and nitrobacteria respiration

- **Introducing Water Safety Plan**

HACCP system and ISO 22000:2005

Contaminant removal efficacy of AWT

Contaminant	Removal by AWT	Analytical method
Mutagenisity	Effective #	Ames assay (TA98, TA100)
Pesticides (99 chemicals)	Effective	GC/MS, LC/MS
Endocrine disruptor	Effective	Yeast two-hybrid assay, LC/MS/MS, GC/MS
Pharmaceuticals	Effective	LC/MS/MS, GC/MS
3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX)	Effective	LC/MS/MS

also after disinfection

Risk assessment procedure based on the PRTR* data

Estimating the total daily volume of designated chemicals transferred in the basin

As the components of waste in the upstream area of the Yodo River

↓

Estimating chemical concentration in downstream

Total volume / daily downstream water flow rate (m^3)

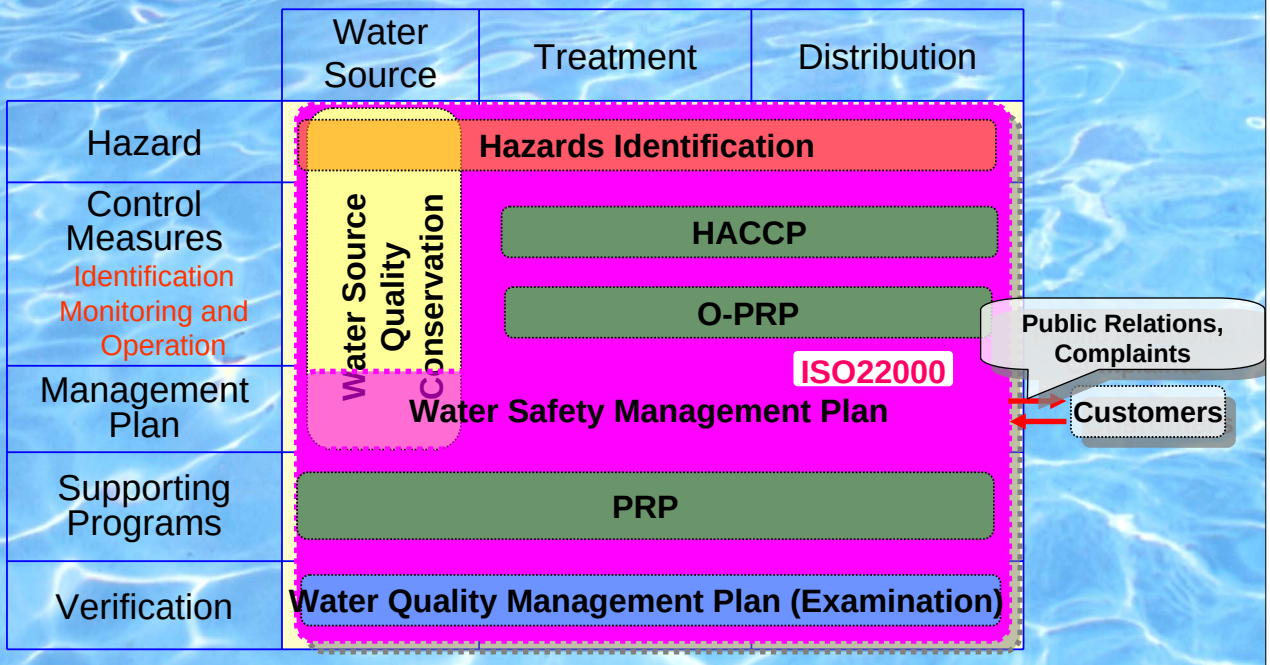
↓

Assessing the possibility of hazards to reach at intake point

Based on the Drinking Water Quality Standards

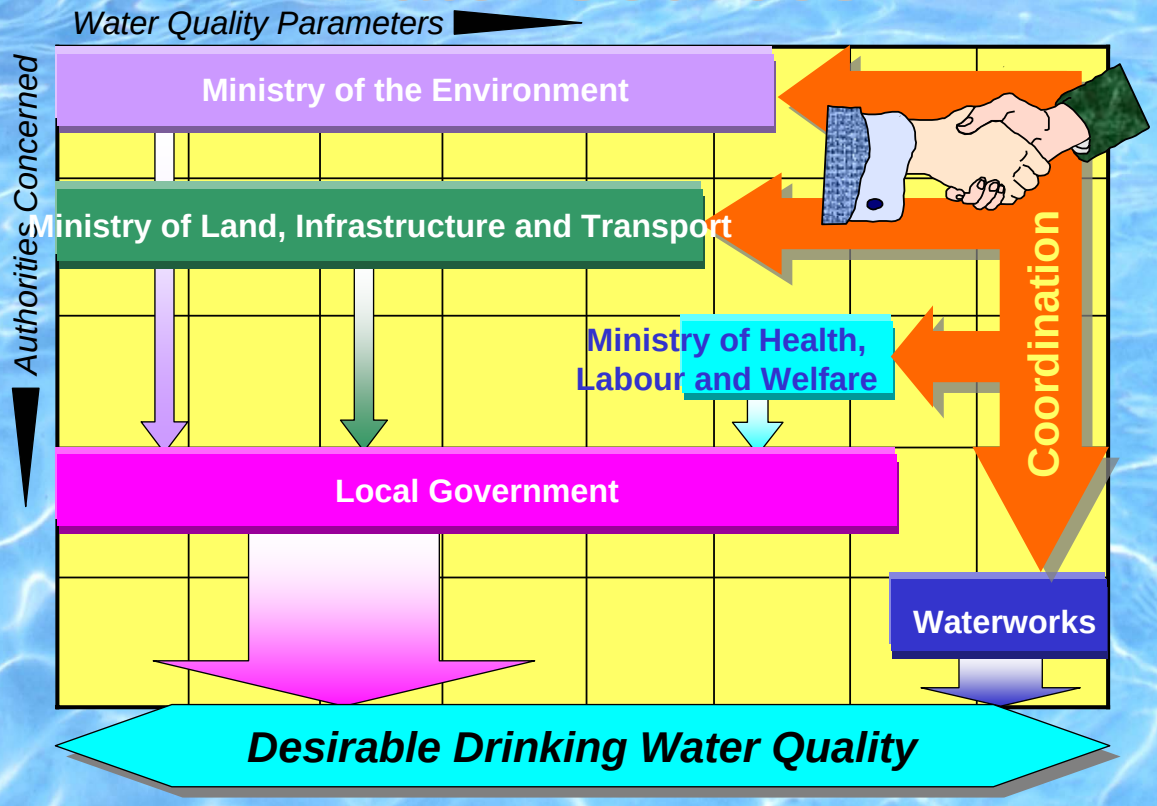
*PRTR : Pollutant Release and Transfer Register

Outline of the WSP in OMWB



O-PRP: Operation Prerequisite Programs
PRP: Prerequisite Programs (infrastructure, management, service, etc.)

Conservation of Drinking Water Sources




Clean Tap Water
• Safe
• Inexpensive
Whoever
• Sufficient
Wherever
Whenever