New water supply technology and development of water utility management in Japan

Yasumoto Magara, Yoshihiko Matsui and Koichi Ohno

Yasumoto Magara

Graduate School of Public Policies, Hokkaido University, N-13,W-8, Kita-ku, Sapporo, Japan

Tel: +81-11-706-7278

E-mail: magara@eng.hokudai.ac.jp

Yoshihiko Matsui

Koichi Ohno

Graduate School of Engineering, Hokkaido University, Japan. Kita-ku, Sapporo, Japan

Tel:+81-11-706-7280

E-mail: matsui@eng.hokudai.ac.jp, ohnok@eng.hokudai.ac.jp

ABSTRACT

The Japanese government has published "The Water and Sanitation Broad Partnership Initiative (WASABI)" on March 2006. This initiative was based on the policies that Japan will support the self-help efforts of developing countries on water and sanitation, establishing broad partnerships with international organizations, and the other donor agencies, etc. Because water resources are very limited, it is necessary to develop the emergent water treatment technology which can supply a safe drinking water from unsuitable polluted source water with a reasonable cost.

In order to anticipate a sustainable development of water service the Japanese Ministry of Health, Labor and Welfare has published "The Water Works Vision" so as to restructure the water utility management system in 2004. The vision asks to reform the water utility management system so as to mobilize every resource including public private partnership. Therefore, it is necessary to develop an audit system by a third party for the risk

communication among the stakeholders.

Key words | audit system, cancer risk, ISO/TC224, nano-filtration, public private partnership, The Water Works Vision

INTRODUCTION

Water is essential for human life and health, as well as for economic activity and the preservation of the ecosystem. The UN Millennium Development Goals (MDGs) (WHO 2005) include improved access to safe drinking water and basic sanitation as a target. This reflects that water is an extremely important element in achieving other MDGs such as the eradication of poverty and hunger, health, education, gender equality, and environmental sustainability.

While the proportion of the population using safe sources of drinking water in the developing world rose from 71% in 1990 to 79% in 2002, 1.100 million people are still using water from unimproved sources. Particularly in sub-Saharan Africa, progress is slow, and high population growth is making the situation even more difficult. On the other hand, while sanitation coverage in the developing world rose from 34% in 1990 to 49% in 2002, 2.600 million people still lack toilets and other forms of improved sanitation.

Water-related disasters disproportionately affect developing countries and are increasing. Furthermore, it is predicted that the water shortage will aggravate structurally around the world due to such factors as population growth, economic development, urbanization, and climate change. As a result, there is a possibility that tensions may increase over water resources and water environment among nations and people who share water resources in

rivers and aquifers.

The Japanese government has published "The Water and Sanitation Broad Partnership Initiative (WASABI)" on March 2006 (Ministry of Foreign Affairs 2006). This initiative was based on the policies that Japan will support the self-help efforts of developing countries on water and sanitation, establishing broad partnerships with international organizations, and the other donor agencies, etc. Among the published major tasks, the provision of safe drinking water and sanitation is targeted from two aspects from rural communities and urban areas. For the measures in rural communities, the tasks will be implemented with consideration to local conditions and capacity development. For urban areas, the tasks will be implemented with the utilization of private sector funds to meet large-scale funding needs.

The water environment is one aspect of water circulation on the earth. Fresh water, precipitated water, has a constant amount of circulation: 150×10^{12} m^3, which circulates within a period of one week to 10 days. However, the available fresh water resource is the amount of water which reaches rivers and lakes and this is very much limited. The available fresh water resource is estimated to be about 55,000 km^3/year. 6,000 million people are now using 55,293 km^3/year of this fresh water, 8,000 million people will be using it before long, and 100,000 milliom people will be using it by the middle of the 21st century. The problem of fresh water resources lies in their unequal distribution on the earth. Therefore, it is the emergent to develop new water treatment technology as well as comprehensive water resources managing systems for meeting the ever increasing water demand, especially in scarce water resource areas.

The water supply covering ratio in Japan has reached 98% in 2005 and most people have

access to water through the water supply system. However, the water utility management is going to face a serious situation. Because many water supply facilities built in the 20th century are becoming old now we are in the early 21st century, rebuilding these facilities is an important issue. The 21st century will be a century in which we experience large-scale renewal and restructuring of water supply facilities for the first time. In addition to the fact that we are entering a period when the previous steady growth in population will cease and start to decline, assignment of roles between the private and public sectors and between national and local governments are being reexamined. Furthermore, globalization, mergers of municipalities and other moves to reorganize municipal frameworks, and a decrease in the number of young engineers working for water suppliers are all having an effect. It is clear that the environment surrounding the water supply service is changing significantly even in the domestic water services.

Accordingly, now is the time to take new steps to provide an improved water supply service to the population. In order to anticipate a sustainable development of the water service the Ministry of Health, Labor and Welfare has published " The Water Works Vision" so as to restructure the water utility management system in 2004 (Ministry of Health, Labor and Welfare 2005).

EMERGENT WATER TREATMENT TECHNOLOGY

The role of a waterworks is first and foremost the maintenance of public health, encompassing the supply of water necessary for the various activities of a city. With one single pipeline supplying water for various purposes, ranging from water for domestic life to water for urban activities, waterworks now have to continuously maintain a level of service that must meet the demands of volume and quality. Bearing in mind water for public use in

the form of raw water, the condition of groundwater, and the capacity for regulating the water quality at existing waterworks facilities, the structure of water purification treatment facilities should be made redundant, and endowed with a multi-barrier function in order that people in the 21st century can have access to a good quality supply of water, with few inconveniences and no sense of discomfort. For example, Figure 1 illustrates the flow chart of purification treatment one is likely to see in the future, in terms of the relationship with the selection issues.

As shown by the WHO guidelines (WHO 2004) on the quality of drinking water, the role of waterworks with regard to measures to tackle infectious diseases is of the utmost significance. Moreover, if an anoxic condition occurs in stagnant water bodies, such as reservoirs, dams and so forth, reducible inorganic substances like iron and manganese come into existence. Therefore, as a measure against such occurrences, oxidative conditions within purification systems must be created. Although oxidizing agents such as chlorine are in use, the reducing substance with the highest chlorine demands is ammonium nitrogen, and in cases where there is a large fluctuation in its concentration, it is very difficult to control the oxidizing conditions. Furthermore, there are many soluble organic substances in raw water with high levels of ammonium nitrogen. These soluble organic substances form a complex with the aluminum-based coagulants (which are widely used as coagulants), and this retards the coagulation process. This can be inconvenient due to the fact that the aluminum complex remains in the purified water. With these kinds of contaminated raw water, it is necessary, through biological treatment, to reduce ammonium nitrogen and soluble organic matter in as far as it is possible. In addition, due to the fact that, amongst other factors, compared to aluminum-based coagulants, ferrous coagulants are more effective at removing soluble organic matter, the benefit of changing them to ferrous coagulants is a great one. Regarding

the conventional coagulation and sand filtration process – a solid-liquid separation process to remove colloids and turbid contaminants – in order to remove hazardous inorganic substances such as arsenic and since an oxidizing agent needs to oxidize from arsenite to arsenate so as to remove it effectively, it becomes necessary to carry out the oxidation treatment using an oxidizing agent such as chlorine.

MF/UF filtration, which takes the place of the conventional coagulation and sand filtration process, is a technology which is capable of separating chlorine-resistant organisms, such as *cryptosporidium* and pico-plankton, as shown in Figure 2. In the case of the conventional coagulation and sand filtration process maximum removal ratio of cryptosporidium is anticipated as high as 3 log. On the other hand MF/UF filtration can remove them completely at 5 to 6log, therefore this technology should be adopted as a general-purpose water treatment technology.

Sand filtration and MF/UF filtration are solid-liquid separation processes, and one cannot practically expect them to be effective in the treatment of soluble organic substances. Due to the fact that substances with an unpleasant taste and odor like Geosmin and 2-MIB, produced by phytoplankton and so on, are still produced even when biological wastewater treatment such as the activated sludge process is used, there is a high possibility that difficulties will arise in water bodies of water in which water resources are repeatedly used. Due to the fact that agrochemicals such as pesticides and herbicides are used on a seasonal basis, during periods of use there is a high concentration of them in raw water, and although health risk management objectives have been established, from the perspective of chronic effects, because agrochemicals are used every year, regulation is necessary, taking into account seasonal fluctuations.

Figure 3 shows the overall total of the carcinogenic risk of tap water for each local authority based on the respective carcinogenic risk of carcinogenic substances, within the water quality standard laid down in the Water Works Law. In addition, Figure 4 shows the composition of those carcinogenic substances (Ohno *et al*. 2006). Regarding the carcinogenic risk of tap water, although the risk level for each individual carcinogenic substance is fixed at 10^{-5} by the water quality standard, as Figure 3 shows, the tap water with the highest carcinogenic risk is in the order of 10^{-4}, with approximately 80% of that carcinogenic risk being covered by disinfection by-products. Because of this, in the case of raw water where disinfection by-products has a high generative potential, soluble organic matter such as humic substances, which are known as a precursor, must be removed using ozone/activated carbon absorption treatment. If bromide ions exist in raw water, bromate with strong carcinogenicity is generated as a result of the ozone treatment. Due to this fact, in such cases an advanced oxidation treatment (AOP) such as the application of hydrogen peroxide with ozone, should be applied, in which bromate is not generated.

In order to control unpleasant taste and odor, agro-chemicals, disinfection by-products, soluble organic substances etc., as well as by-products that are generated through the treatment process, advanced water purification systems such as ozone/activated carbon absorption must be introduced. However, there is an extremely high possibility that water treatment systems based on nano-filtration (NF) membranes will be introduced as an alternative to those systems. NF membrane filtration is a treatment technology using a membrane which combines the characteristics of a reverse osmosis membrane, used for seawater desalination, with those of UF membrane filtration, and with just one process can remove both soluble organic matter and inorganic ions. With operational management, due to the fact that straightforward automated control is possible, as with MF/UF membrane

filtration, it is thought that it will be introduced first to small-scale purification plants, where there is a limit to the human resources available. However, its introduction may be considered in large-scale purification plants too, as an advanced purification treatment facility, taking the place of ozone/activated carbon absorption. NF membrane filtration is a technology used in the bottled water production process, and furthermore, it is being used for an on-site dual water supply system, developed in one part of China, supplying ready-to-drink tap water and tap water for everyday use. This technology has reached a level where costs allow the possibility of applications in public water supply system As a result, this is a technology from which one can expect an even greater degree of innovation.

It is certain that chlorination will continue to be an effective measure against infectious organisms. Having said that, due to the fact that chlorine based agents are highly reactive oxidizing agents, they convert organic matter in raw water into low-molecular organic matter, generate organic matter with a high level of assimilative organic carbon (AOC), causing re-growth of bacteria in the water supply system such pipes, and also generate organic matter containing health risks, such as halogenated organic substances. Moreover, the addition of chlorine's distinctive odor to tap water is one of the reasons for its unpleasantness. Excessive algal growth due to eutrophication in stagnant water bodies such as dam reservoirs and lakes, means a high proportion of raw water contains organic substances due to phytoplankton. Moreover, if a situation arises in which raw water is affected by domestic miscellaneous wastewater due to delays in development of domestic wastewater treatment facilities, such as public sewerage systems located up-stream and mid-stream of rivers, then inevitably there is a rise in the amount of chlorine consuming substances, and chlorine dosage control becomes increasingly difficult. As a result, not only is there an increase in the concentration of residual chlorine, and a deterioration in tap water quality, but at the same time, there is also an increase

in the concentration of chlorine disinfection by-product matter. Because of this kind of occurrence, as is shown in Figure 1, in addition to the building of barriers within water purification systems, sufficient to combat infectious microorganisms, combined chlorination will be introduced, in the form of a disinfection technology with water supply system risk management, and which leaves no sense of discomfort in terms of chlorine odor.

CURRENT STATE OF WATER UTILITY MANAGEMENT

In recent years when most people have access to tap water, their main concern is whether the water supplied is safe to drink and easily available. However, according to the results of on-site inspections of water suppliers nationwide conducted by the Ministry of Health, Labor and Welfare (Ministry of Health, Labour and Welfare 2005), there are many cases where management of water supply systems is inadequate. In addition, safe water is not yet available to all because of the deterioration in water quality at the source, loss of water quality at connecting points between the public water supply system and private water supply facilities such as the customer's water storage tanks and so on. Significant differences among areas are also present in terms of the availability of drinkable water; specifically, poor taste and odor, the presence of chlorine, color, and turbidity. In order to solve these problems, it is necessary not only to exercise strict control over water quality based on the Waterworks Law but also to correlate the processes from the water source to the tap from a wider point of view.

It is important to provide people with information on where the water they drink and use comes from and how it is purified and distributed. Providing this information raises public awareness and acceptance of the water supply service. In order to supply people with safe water in a stable manner, it may be useful to develop risk communication strategies. In a risk communication program, water suppliers implement appropriate water quality control based

on contamination risks in the area from every process from water intake to supply at the tap. They then draw up and publish water quality management plans and disclose their progress, taking customers' wishes and intentions into consideration, and establishing standards for the water supply service based on a shared understanding. This movement is becoming a global trend and is present in the Water Safety Plan proposed by the World Health Organization (WHO 2004).

The water supply system is required to provide water to people so that they can live and survive even during emergencies such as earthquakes and other natural disasters, water quality incidents, and terrorist attacks. Therefore, it is necessary to ensure the security of major water supply facilities, guarantee a supply of water to important facilities, and establish a system in which rebuilding work is started as soon as possible if facilities are damaged.

However, the percentage of main facilities (purifications plants, service reservoirs, etc.) resistant to earthquakes stands at 23% nationwide and for main pipelines (transmission pipes and distribution mains) this is 13%. In addition, only 34% of water suppliers have drawn up an emergency water supply plans. Nationwide preparedness both on the hardware and software sides is hardly satisfactory. Rather, the vulnerability to earthquakes is increasing as facilities come to the end of their useful service lives.

Water supply facilities in Japan were intensively developed around 1975, and since about 1990, and their total appraisal value, the accumulation of past investments is estimated at more than 37 trillion yen. Annual cost for renewing existing facilities is about 0.5 trillion yen and it will be 1.5 times more in the decade starting from 2018. Nevertheless, recent investment in the water supply system is on a declining trend. If this trend continues, the cost

for renewal will be bigger than the investment and renovating facilities may make little progress in the future. If the amount of investment in construction and renovation of water supply facilities becomes 1% lower than that in the previous year, it is estimated that both the cost for renewal and the investment will stand at about one trillion yen a year after some two decades, and after that, the cost of renewal will exceed the investment, as shown in Figure 5.

PUBLIC PRIVATE PARTNERSHIP IN WATER UTILITY MANAGEMENT

Today, there is a move towards deregulation and the use of business approaches employed by private companies. Outsourcing the management of water purification plants is being encouraged based on the revised Waterworks Law in 2001 (Ministry of Health, Labour and Welfare 2001). Other systems, such as the participation of local independent administrative corporations in the management of the water supply and appointment of superintendents for public facilities, are also being introduced.

Facilities developed so far will need renovation in the near future and the costs of rebuilding are expected to increase enormously. However, since future increases in water demand are not expected to equal those of the past, collecting the funds necessary for rebuilding facilities is not always easy. With the so-called triple reform now being discussed, which is reviewing terminating and reducing the amounts of subsidies to public-works projects and other big projects, transferring the sources of tax revenues from the central government to local governments, and allocating budgets to local governments, it is necessary to ensure the efficient development of facilities by cutting costs and actively diversify the financing mechanisms in the long and medium term.

Since the water supply service is funded from the revenue from water rates collected from

customers, precise response to customer needs will help to develop future business. It is important for water suppliers to provide their customers with a variety of information on subjects ranging from water quality to water rates and facilities and to obtain their agreement and support.

Management of the water supply service has been discussed at the Council for Regulatory Reform and other occasions with an eye to the possibility of privatization. Various actions have been taken recently, including establishing the Law Concerning the Promotion of Public Facilities Development by Using Private Funds (PFI Law), the introduction of outsourcing systems following the revision of the Waterworks Law, the introduction of a superintendent appointment system for public facilities following the revision of the Local Autonomy Law, and the establishment of the Law Concerning Local Independent Administrative Corporation.

These actions have helped water suppliers to collaborate with other suppliers and private companies in various forms, as shown in Figure 6. As each of these forms of collaboration have their own characteristics, a wide-ranging review on how to choose the best management system to address problems of water suppliers is required from the viewpoint of customer service.

Fundamentally, water suppliers who are responsible for water supply management in their areas should manage and administer the water supply service by themselves. With this in mind, we will encourage water suppliers and water wholesalers to integrate their operations and expand their service areas beyond municipal boundaries. We will also encourage collaboration between prefectural and municipal governments and private companies to make the most of their individual advantages and know-how. The synergistic effects of these efforts

will improve the effectiveness and efficiency of the service as well as enhance customer satisfaction.

Water suppliers should always actively develop facilities, improve management systems, and improve technologies. At the same time, they are required to set the most desirable service level and water rates based on the conditions of the area through a dialogue with customers, because they supply water in exchange for payment. They must attain a high level of customer satisfaction through their strong will and unrelenting efforts.

The national, prefecture, and municipal governments will regulate, monitor and advise water suppliers and installers of private water supply systems and induce them to provide higher levels of water supply service because of its monopolistic business in the service area. At the same time, they will positively promote measures to improve the quality of the water supply service through wide-area collaboration among water suppliers and facilities and cooperation with relevant private sectors and entities in fields other than the water supply service, as shown in Figure 7

The private sectors in Japan have developed in parallel with the development of water supply systems in Japan and are at a high technical level. They are required to further strengthen their collaboration with water suppliers and installers and play a more important role than ever to tackle the lack of engineers and financial vulnerability. They will be able to provide high-quality, high-performance equipment, develop new systems and technologies that meet on-site needs, provide water suppliers with advanced construction, operation, and maintenance skills by commission, and make proposals to strengthen the base of the service.

It is necessary to fully examine what management style can be opted in order to properly manage the water supply service based on the situation in each area from both the managerial and technical perspectives. In order to involve the private sectors, it is necessary to evaluate objectively whether business operations carried out by the private sector can achieve their goals, and obtain the agreement of customers.

Therefore, it is also necessary to develop the third party audit system which includes the evaluation and the recommendation towards better performance, including the sustainability, of water services. Although the water supply service level is characterized by it sociological, cultural, economical, natural and environmental background, the minimum service level that intends to fulfill the human dignity right in the 25th article of the Japanese government constituent, that is regulated by the Water Works Law. Therefore, the audit system should be composed from the basic points such as protecting public health to the sophisticated points such as aesthetical satisfactions to the water services. And the implementation of the audit to each water service utility should be done by a de facto domestic standard so as to publish the evaluation and the recommendation for the effective tool to develop consumers' agreements of the stakeholders of its water service utility.

The manual, as a de facto standard to the audit institutes, of the evaluation and the recommendation to the water service utility is going to be developed by the research activity of the graduate school of public policies of Hokkaido University as a joint research activity with academic, administrative, private financial and engineering sectors. The audit of water suppliers will be implemented from the view points of safety, stability, management and environment in order to evaluate the satisfaction of customers, capability of facilities, competence of employees, appraisal of assets and balance sheet assessment, as shown in

Table-1. The ISO/TC224, that will be ISO/WD24512, and Water Service Guidelines registered by Japan Water Works Association in 2005 will be referred to in the manual, because they have standardized the performance index (Japan Water Works Association 2005).

CONCLUSION

The world population is expected to increase to 8 billion by 2015. Most of the cities in the world are scattered around a fresh water resource. These cities and villages have their own interests and they constitute a power order. Therefore, we have been trying to harmonize these cities and villages in the usage of fresh water resources and the discharging of wastewater as well, by using an engineering means of water treatment. However, fresh water resources, which are essential to our lives, have a constant amount of circulation with a period of one week to ten days.

The water environment's science and technology should recognize the limit of fresh water resources for the sustainable development of society, because the water service industries are the essential infrastructure of the community. In order to implement an appropriate risk management it is necessary to identify the goal of environmental management considering the social, natural and economical conditions. The energy dependent science and technology should be reconsidered in order to response the ever increasing demand to reduce energy and carbon dioxide emission relating with the suppression global climate change. Therefore, it needs to develop the emergent water treatment technology so as to meet the ever increasing demands of customers and environmental conservation.

However, because of the huge demands of funds for the renovation of existing facilities which

will be terminated by the service life, it is necessary to promote public private partnerships for sustainable service of water. In order to evaluate the risk of water utility management it is necessary to develop a de facto standard to audit the water supplier.

Various globalization movements have been visible recently in the water supply service, including progress in international standardization for water supply and sewage treatment systems in connection with ISO/TC224. Under these circumstances, we can advance international cooperation in water supply services and strengthen our competitiveness by promoting bilateral and multilateral exchanges and adopting an aggressive stance on globalization that will benefit Japan.

REFERENCES

Japan Water Works Association (2005) Water Works Management Guideline.(Japanese) Japan Water Works Association. Tokyo

Ministry of Foreign Affairs (2006) *The Water and Sanitation Broad Partnership Initiative*. (WASABI) http://www.mofa.go.jp/mofaj/gaiko/oda/bunya/water/initiative.html

Ministry of Health, Labor and Welfares (2005) *The Water Works Vision*.(Japanese) http://www.mhlw.go.jp/topics/bukyoku/kenkou/suido/vision2/vision2.html

Ministry of Health, Labor and Welfares (2005) The report of on-site inspection of water suppliers. (Japanese)

http://www.mhlw.go.jp/topics/bukyoku/kenkou/suido/vision2/dl/one2-03.pdf

Ministry of Health, Labor and Welfares (2001) The Water Works Law (Japanese) http://law.e-gov.go.jp/htmldata/S32/S32HO177.html

Ohno, K., Kadota, E., Kondo, Y., Kamei, T. & Magara, Y. 2006 Estimation of geographical variation of cancer risks in drinking water in Japan. *Water Science and Technology: Water*

Supply **6**(2), 31-37

WHO. (2004) Drinking Water Quality Guidelines 3rd edition.- Volume 1. Recommendation. WHO press.Geneva

WHO(2005) Health in the Millennium Development Goals. http://www.who.int/mdg/goals/en/index.html

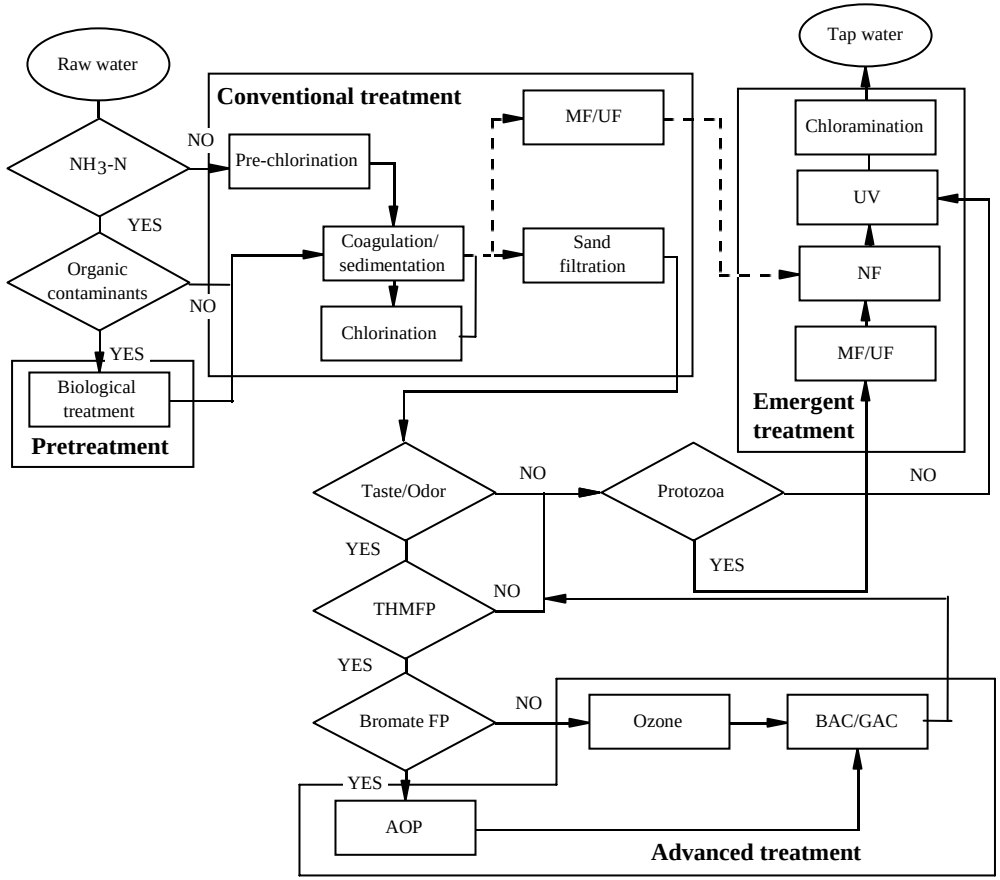

Figure 1.Flow chart of the development of water purification system

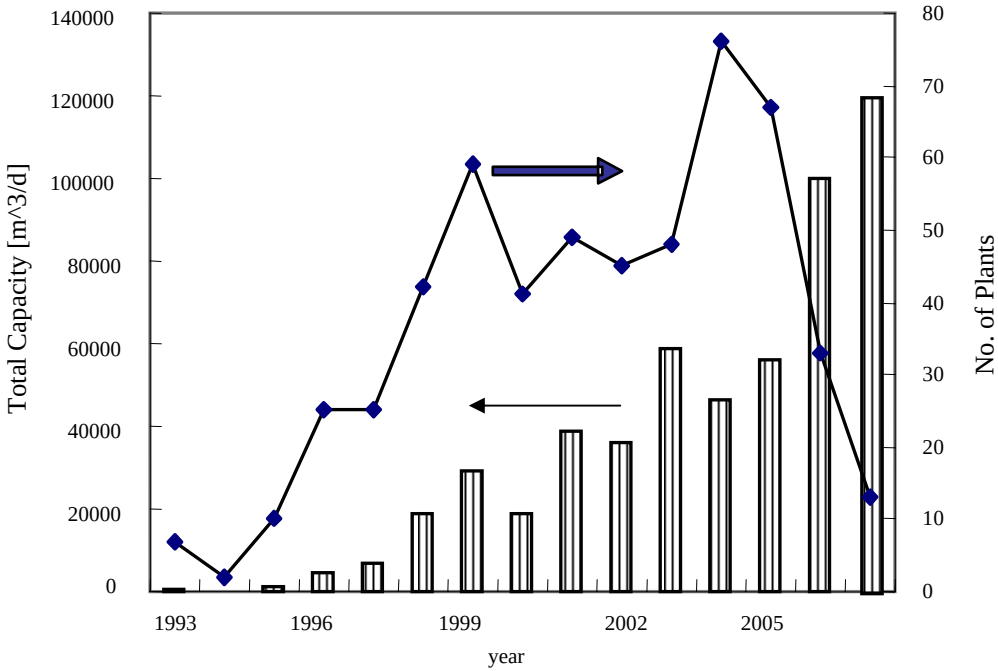

Figure 2. The development of MF/UF water purification plant in Japan

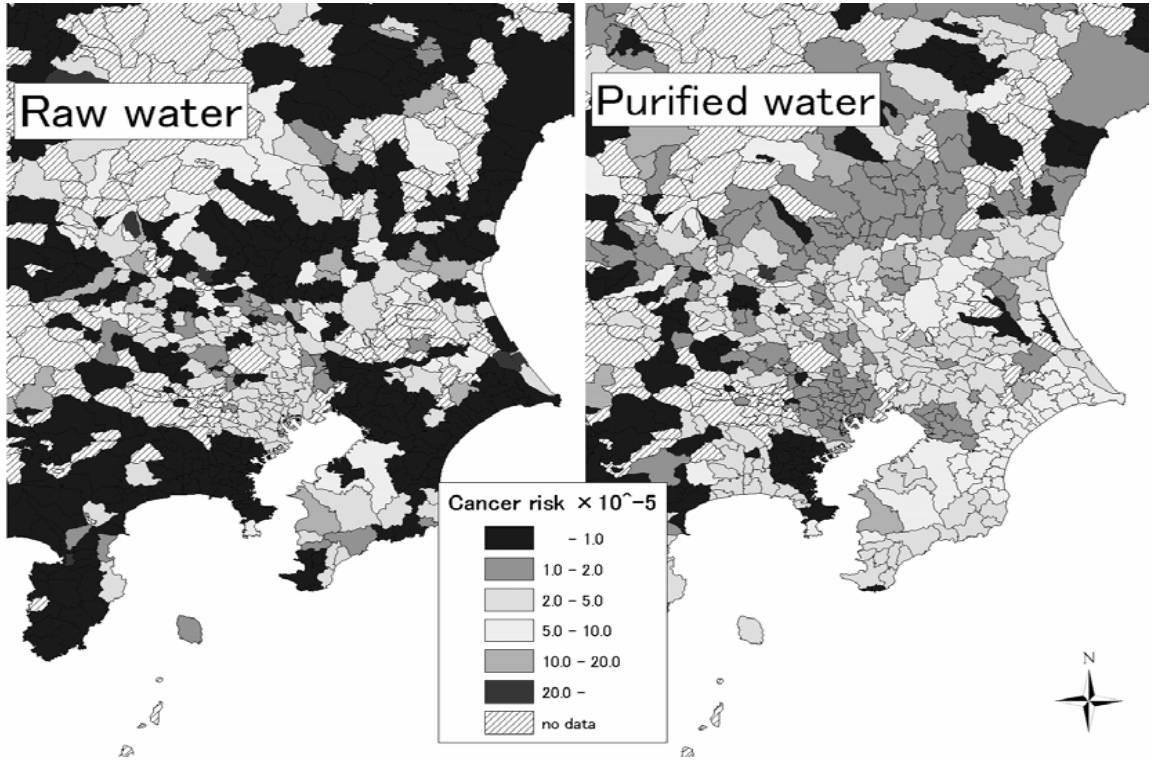

Figure 3 Distribution of cancer risk of raw water and purified water in Tokyo metropolitan area

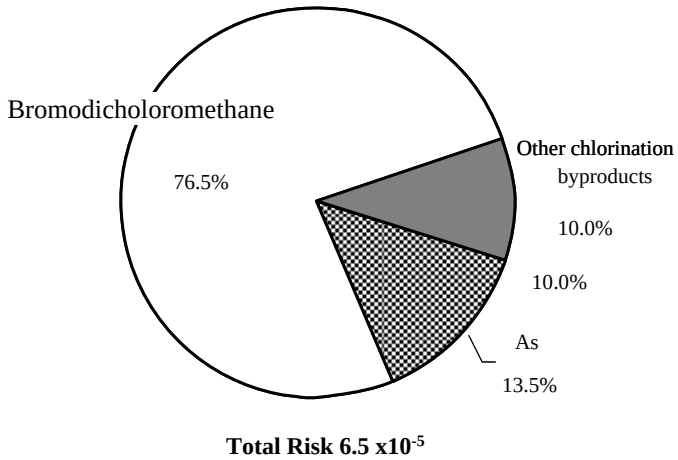

Figure 4 The composition of carcinogenic chemicals in purified water

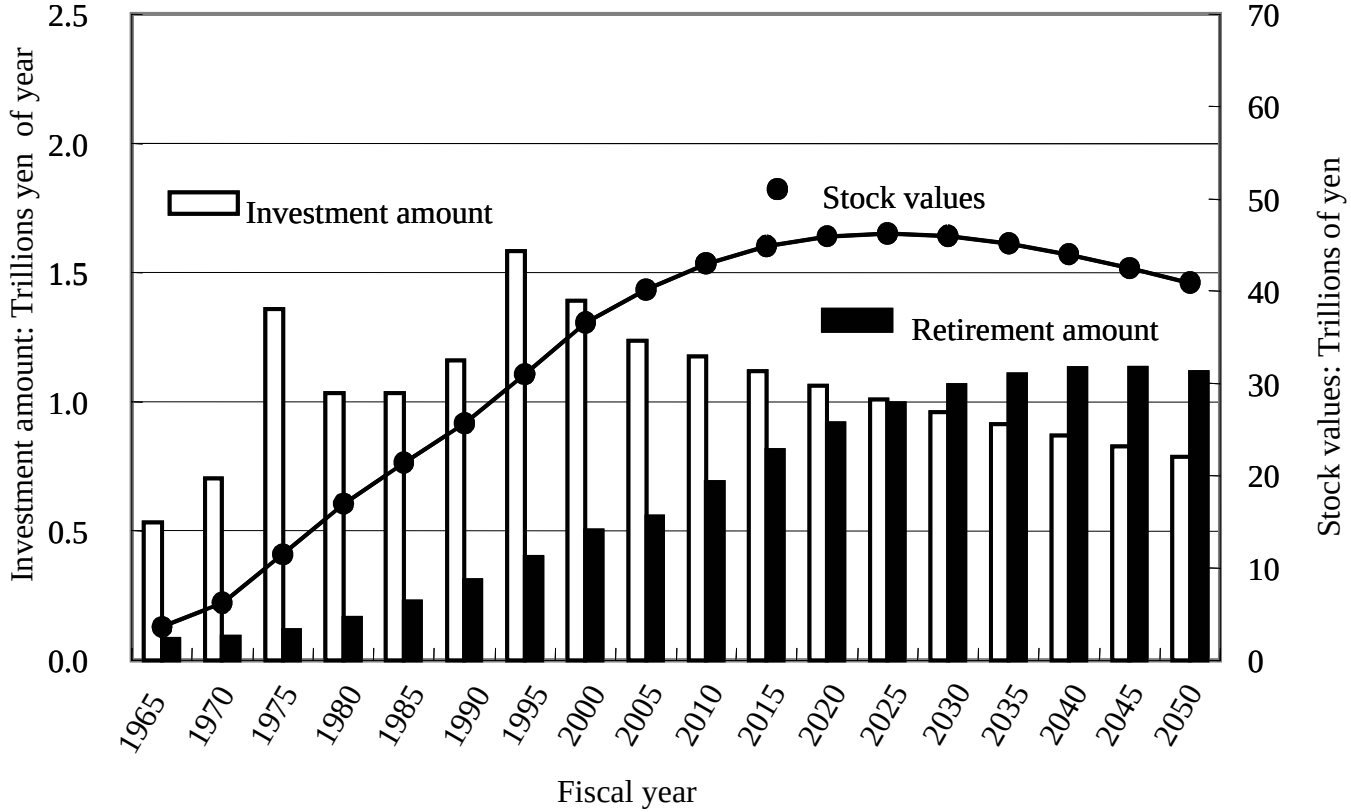

Figure 5 The trends of investment and retirement amount with the total stock of facilities

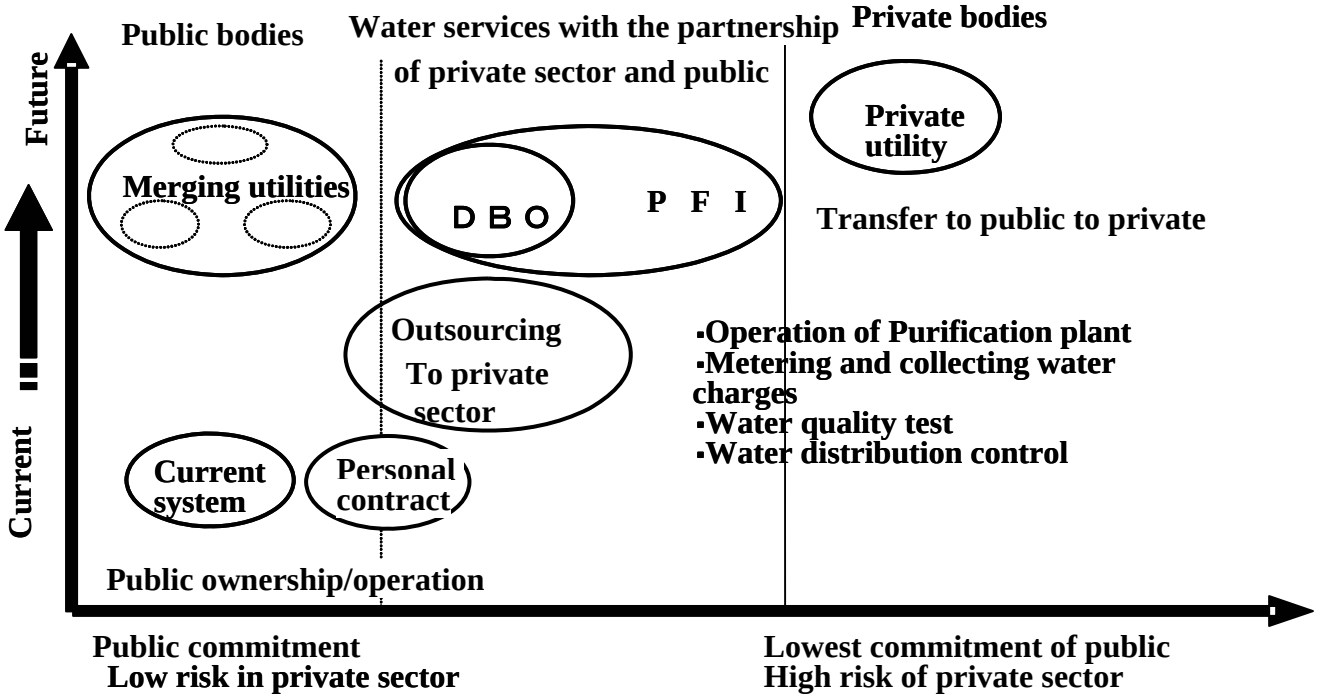

Figure 6. The models of public private partnership in water service business

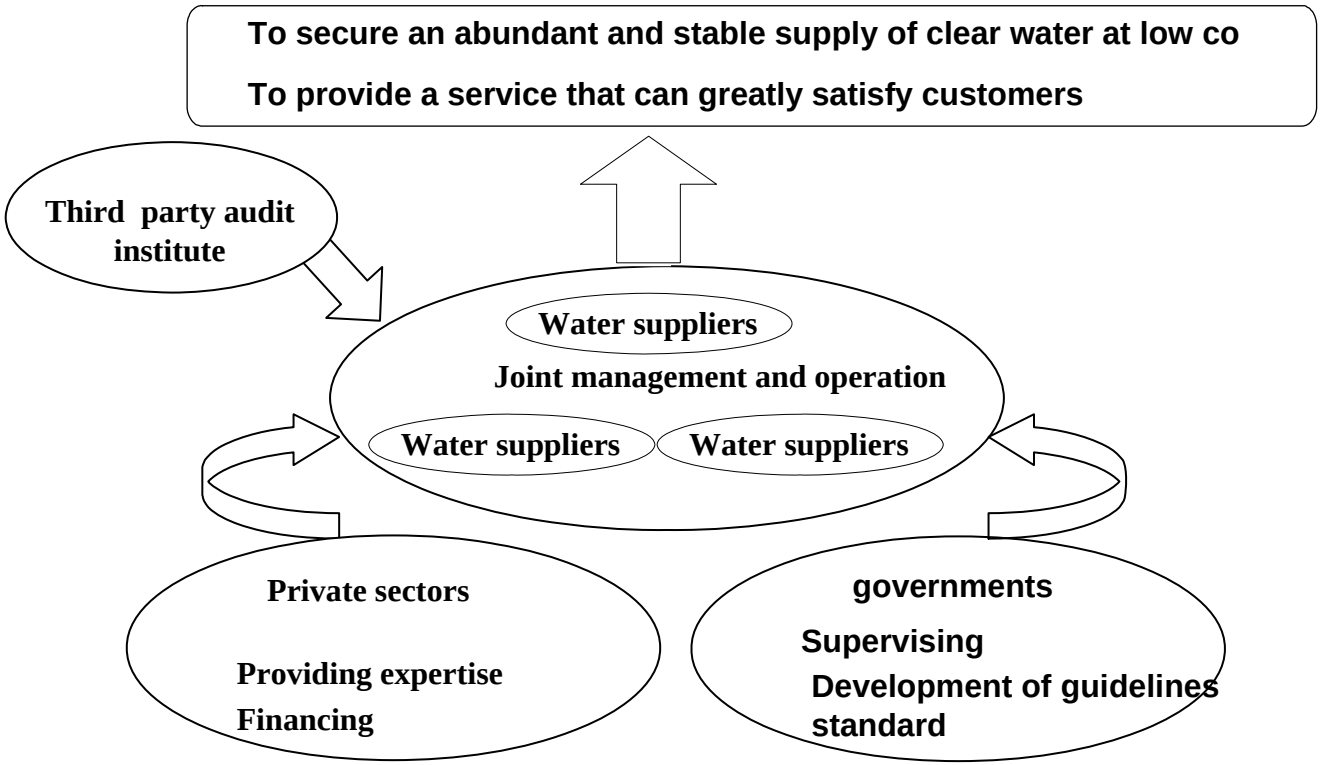

Figure 7. New scheme of public and private partnership for the sustainable water service

Table 1. The matrix of the components to be audited by the third party

	Safety	**Stability**	**Sustainability**	**Management**	**Environment**
Satisfaction of customer	●	●	○	●	○
Capability of facilities	○	●	●	●	○
Competence of Employee	●	○	●	●	○
Appraisal of asset	○	○	●	●	●
B/S assessment	●	○	●	●	○

● :High priority　　○ :Secondary priority