are also trying to create new testing methods. As a result, we found that phthalic acid esters in a dioxin detection system respond at a low concentration level and are easy to understand. In terms of immune toxicity, it has significant toxicity. Also, looking at liver disorders or the impact on Daphnia, we can begin to understand which combination would bring us more accurate evaluations of chemicals.

In other words, we can say that testing raw water with bioassay using toxicity or the hazardous impact as a new index mean is the integration of a new concept.

I'll now show you how to introduce this in the management of the environment and raw water. First, we test to find out the toxicity in raw water using this evaluation method. If the toxicity is low, it can be used as tap water after conventional treatment. On the contrary, if it is hazardous, we must decide on a target chemical, or introduce a treatment method to reduce the toxicity. We see if it is volatile or ionic according to the treatment process, then analyze it again with bioassay. If it is volatile, aeration can easily diminish toxicity. Then you must verify the results at a pilot plant before integrating the new method into the water treatment process. Thus, we establish a methodology to secure safer water. If we can set up such a system, it would be quite beneficial.

As you see, we are developing a new concept. Unfortunately, we do not have any English version, but you can see the details on our homepage. If you are interested, please access our web site.

In closing, let me show you one other slide. Those who are involved in research will stay overnight in Fukuoka to have a study meeting. This is the scene of our discussion. We have committed ourselves to secure safe tap water, and our efforts have resulted in great improvements. We should inform people of this fact. On the other hand, we recognize that tap water contains dubious substances and a new methodology is necessary to reduce them. Efforts in this area should also be made known to the public. To secure safe tap water, we need more information. Tap water is indispensable, not only to the healthy, but to the sick, elderly and other people. I hope all of us present here will join forces and be able to supply safer and more satisfying tap water. Thank you for your kind attention.

(Applause)

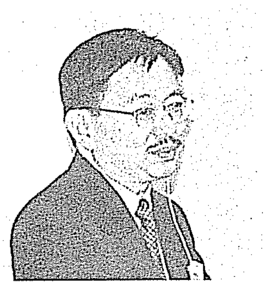
Presentation

Mr. Wong Kee Wei
Superintending Engineer
Public Utilities Board, Singapore

Chairperson (Mr. Hiroto Oda)

We would like to move on to the next case study presentation. The first presentation is from Singapore. Mr. Wong Kee Wei of Singapore, please.

Mr. Wong Kee Wei (SINGAPORE)



Thank you Mr. Chairman. Good morning, ladies and gentlemen. My name is Wong Kee Wei from the Public Utilities Board of Singapore. It is my pleasure this morning to present this paper on the integrated approach to the provision of a safe water supply in Singapore.

This paper is jointly prepared with my colleague Mr. Tan Nam Seng. The paper describes how Singapore develops and manages its limited water resources to provide safe drinking water to meet a rising water demand and support the country's economic growth. It traces the radical changes in water resources development from protected catchment areas to unprotected catchment areas and eventually to urban water collection systems.

The importance of an integrated approach in land use planning to safeguard water resources, the changes in treatment processes and plant design to upgrade the efficiency of water treatment and comprehensive water accounting and conservation measures to effectively utilize precious water resources are also highlighted in the paper.

Now in this morning's presentation, I will touch on five main areas. They are: the development of water resources, safeguarding water catchments, expansion of transmission and distribution networks, application of computer-based technology, and water demand management.

First, a little bit on Singapore. Singapore is an island city-state with a population of about 3.9 million. Our land consists of many islands and the land area is very small indeed. Actually, there are only about 650km^2. But the demand for potable water is about 1.3 million m^3 a day. And the growth rate of the demand for last ten years has been more than 3% per year, which is considered to be on the high side.

The Public Utilities Board of Singapore (PUB) is the water authority and regulator of the electricity and piped gas industries. As the water authority, PUB is responsible for the development of water resources, treatment, and the supply of potable water.

Now, on to the first topic. The development of water resources began with central catchment reservoirs, then went to estuarine reservoirs, and finally to urban storm water collection systems. With this development, raw water quality has changed. And the changes in the treatment process and plant design were also in the process of development.

With a high population density, we need to exploit limited water resources as effectively as possible in order to meet the increasing demand from domestic, non-domestic and industrial sectors. Initially, our supply was obtained from the forested central catchment reservoirs. This slide shows a map of Singapore, and the Central Protected Catchments are colored at the centre of the island. This is a forested, protected catchment and, therefore, water quality collected in these catchments is quite good. But following the droughts and water rationing in the 1960s, the capacity of the water reservoirs was enlarged in the 1960s and 1970s.

This slide shows you a photograph of the Upper Peirce Reservoir, which was expanded in 1969. Under this development scheme, the capacity of the reservoir was increased by 35times. The natural run-off was augmented by water pumped from eight streams adjacent to the reservoir. Correspondingly, the treatment capacity of the Woodleigh Waterworks was also increased by three times.

There is another scheme, called the Upper Peirce Water Supply Scheme, which was completed in 1975. As shown in the slide, under the development, we built a dam across the former Peirce Reservoir. The dam is of a height of 20m, and therefore raises the water storage capacity on the upper ridge of the reservoir by 20m. As a result of this expansion, the storage capacity was increased by10times. And under the scheme, we also built the Chestnut Avenue Waterworks with a capacity for a 275,000m^3/day production rate.

From the Central Protected Catchments, development continues into the unprotected catchments in the coastal area. We call the unprotected catchments estuary reservoirs. As you can see on the slide, four water supply schemes were implemented under this coastal area. First, the Kranji Scheme at the northwestern site, then the Western Catchment Scheme covers the western site. Then we have the Seletar Reservoir and the Bedok Reservoir at the eastern site. And we also have a development scheme at an offshore island at the northeastern site. Now these estuary reservoirs are impounding reservoirs created in the tidal estuaries.

This slide shows the completed Kranji Reservoir. On the far end, is the reservoir; the near end of the lower side of the slide is actually the sea.

The Kranji Reservoir Scheme was completed in the late '70s. The next slide is the Western Catchment Reservoir Scheme. This was completed in the early '80s.

To develop estuary reservoirs, we need to have stringent pollution control measures in catchment areas. Additional treatment processes were introduced. Obviously, incompatible activities and polluting industries had to be relocated out of the water catchment areas.

The Lower Seletar/Bedok Water Supply Scheme was completed in 1986, and it was the last water supply scheme of indigenous sources of water developed in Singapore. The unique feature of the scheme is that we have the Urban Storm Water Collection System. The Urban Storm Water Collection System basically catches storm run-off from urbanized areas where all premises have sewers from separate systems. Singapore is an equatorial country. Our annual rainfall is about 2,400mm characterized by relatively high-intensity rains and short-duration storms of small area distributions. In the system design, only the cleaner part of the storm water is abstracted and pumped into reservoirs. This enables us to capture about 70% of the rainfall that falls in the catchments.

We need to have stringent control on land use in the catchments through a coordinated and integrated approach to the urban town planning. This involves working closely with the various governmental agencies during the planning and development. These agencies are the Urban Redevelopment Authority, which is responsible for planning and conservation, the HDB, or the Housing and Development Board Public Housing Authority, and also the Ministry of the Environment, which is responsible for pollution control in Singapore.

As the development of water resources progressed from protected catchments to unprotected catchments and from the central inland reservoirs to estuary reservoirs, changes in treatment processes and plant designs also had to be made. Because of water deterioration, the treatment process has employed dual media filters, an aeration system to aerate the raw water before treatment. And ozone is used for primary disinfection in the catchment of these estuary reservoirs. They were originally farming areas, which included pig farms and animal rearing. Of course, with the introduction of these additional treatment processes, the treatment cost goes up correspondingly. If you compare this water with the treated water from the central catchments, the cost is about two to three times higher.

The next topic on which I want to touch is that of safeguarding water catchments. Two areas are important for the successful implementation of a water scheme with unprotected water catchment. One is to control land use and also the legislation for it. The other is water quality monitoring and pollution control.

In developing the new water supply schemes, the catchment areas have to be safeguarded to ensure that the run-off will be of a good quality. The measures taken included legislation so that we can actually control the land use. The legislation helps us in implementing the water supply scheme in coastal areas.

In the area of water quality monitoring and pollution control, we provide a green belt in the periphery of the reservoirs. Animal farming, for example, pig farming and rearing other hoofed animals within the water catchment area, are prohibited. Modern sanitation for all premises was implemented within the water catchments. And the control of trade effluence within the catchments had to be implemented, and separate sewerage systems were built for premises within the catchments. We also control the building density in the development of a new town. Polluting industries originally in the catchment areas had to be relocated.

This slide shows you the Bedok Reservoir, which is actually located within a housing estate. And from there, you can see the green belt created in the periphery of the reservoirs.

The third area I would like to touch on is the expansion of transmission and distribution networks. In tandem with the development of water supply schemes, transmission and distribution systems were expanded accordingly. This includes the development of the zone-based water consumption information system, transmission network planning, distribution network planning, service reservoirs, water towers, and booster station construction.

The zone-based water consumption information system was developed to guide the network expansion. It is an up-to-date information system based on geographical distribution of demand. It involves the details of each category of demand, such as domestic, manufacturing, etc. So in the process of development, close liaison is maintained with other government departments and agencies, and major developers. Information about this development will affect the water demand in the related area; and the information obtained is used to update zonal demands.

Transmission network planning is arranged as several interlocking loops to provide a secure supply should one source fail. It is based on the geographical distribution of demand and the location of the treated water sources. It is reviewed and upgraded periodically based on the zone-based consumption information system that we have developed.

Next is distribution network planning, organized as smaller loops within transmission loops, which provides adequate pressure. This is insured through high-level tanks and low-level tanks with a booster pump system in high-rise buildings. One of the typical layouts is shown in this slide. Water first enters the low-level tank and is then pumped up to the high-level tank. The pressure is good enough to supply to the lower floors of the high-rise flats; but we also have a separate system where water is fed directly to the lower floors of buildings.

As part of the network expansion, service reservoirs and water towers were built to regulate peak demands and to minimize interruption of the supply. One of the typical service reservoirs is this Floral-Astromar Service Reservoir, which is located on high ground, on a hilltop. But there are areas where we do not have such hills for us to build such service reservoirs. Booster stations were built to transport water from a lower pressure zone to a higher pressure one. The Woodleigh Booster Station is one such system.

As the production centre increased and the network expanded, to maintain an efficient and reliable water supply system, application of computer-based technology or automation became necessary. We have so far developed two systems: the Remote Monitoring and Supervisory Control System, and the Automated Information Mapping System.

The Remote Monitoring and Supervisory Control System covers the upstream raw water resources, the treatment process, and downstream treated water distribution network. At the moment, we have six systems in use. At the waterworks level, the treatment process is automated, and for controlling production, it also helps in dispatching water from the various centers to the network.

We have a centralized control center, which we call Woodleigh System Control

Centre-in short, WSCC. The center coordinates the operation of all the production centers, as well as the demand in the various zones of the network. We have the Regional Control Centre at waterworks linked to the WSCC and the data is transmitted through a real-time data link.

The Automated Information Mapping System maintains a comprehensive inventory of all network facilities and the key service connection. The applications include hydrant information and a Facility Maintenance System. This system has enabled better tracking of activities and improvements in productivity. It is now being used extensively to obtain information on the transmission and distribution network.

Now I would like to touch on the fifth area, which is water demand and supply management. Rapid economic, industrial, and social developments in Singapore have resulted in a sharp increase in our water demand; and this has placed a great strain on our limited water resources. Our primary concern is to keep the growth of the water demand down to a sustainable level. Therefore, demand management is very important to us, and is achieved through three main areas. First is water accounting; second is main replacement and rehabilitation; third is water conservation.

For water accounting, we do 100% of the metering of the entire water supply from waterworks to all our customers' premises, where, at the moment, we have slightly more than one million customer accounts.

We also use the best available meters. For example, in the waterworks facilities, we use electro-magnetic flow meters, and at the customer end, we use ISO Class C meters, most of which have a caliber of 15㎜. Now, the other concern about water is the unaccounted-for water defined as total output of waterworks minus total output metered at customers' premises and other accounted-for water, such as the water used for flushing water mains, fire fighting and washing of the service reservoirs, etc. With all these measures taken, we have been able to keep our unaccounted-for water down, and we have managed to maintain it at around 5% in 1998. This slide shows the trend of unaccounted-for water over the last ten years.

One of the factors contributing to unaccounted-for water is leakage in water mains. In past years, complaints of poor water quality or discolored water were mainly due to corrosion of old and unlined cast-iron mains, galvanized iron pipes. Hence, in 1980, we decided to stop the use of unlined galvanized iron pipes, and from then onwards, only corrosion-resistant, more durable types of pipes have been used.

We also embarked on a main rehabilitation and replacement program in the early '90s. This 10-year replacement program replaced all unlined galvanized iron pipes with stainless steel or copper pipes. We also replaced unlined cast iron mains with cement-lined ductile iron mains. So in the program, we replaced about 70,000 unlined cast-iron or unlined connecting pipes and about 180㎞ of unlined cast-iron mains at the cost of about

S$56 million. There are mains and connections that belong to PUB, so at the same time, we also advised our customers to replace galvanized iron connections at their premises.

And with the program implemented and other measures taken, we have seen a rather drastic reduction in complaint cases. From 1985 to 1998, complaints of leakage were reduced by more than 75%. In terms of discolored water, they were reduced by more than 90%, and for poor pressure, complaints reduced by more than 90%.

In Singapore, like in Fukuoka, we face water shortages as well. So we emphasize water demand management quite a bit. And various water conservation measures have been implemented to check the growing demand-one of which is publicity and education. We hold publicity and education programs from time to time to educate our consumers, particularly our younger group. We also conducted water audits and advice for our large customers to ensure that water is used effectively. We also encourage the reuse and recycling of water, and the adoption of water conservation measures. We have introduced. the installation of thimbles and other water saving devices. So for public areas, the installation of water saving devices is mandatory.

We also introduced tariff revisions and a conservation tax. We found that this is one of the effective measures in curbing the excessive growth of water demand.

In conclusion, I would like to say that Singapore adopts an integrated approach in the development and management of its water supply through radical changes in water resources development, timely network development and upgrading, using computer-based technology, and comprehensive demand management approach.

These enable the provision of a safe water supply to meet the rising water demand and support rising economies.

This is the end of my presentation. Thank you for your attention. (Applause)

Discussion

Chairperson (Mr. Hiroto Oda)

Thank you very much, Mr. Wong Kee Wei of Singapore. The presentation from Singapore was about changes in water resources development, network development, application of computer-based technology and demand management approach. The common problem for many cities is to meet a rising water demand, develop water resources in a limited natural environment and manage them effectively and efficiently. As the presentation is completed, we will now have questions and comments. Are there any questions, please?

Mr. Haryadi Priyohutomo (JAKARTA)

My name is Priyohutomo from Jakarta, Indonesia. You said that publicity and education to raise public awareness is one of the plans for water conservation. So I would like to know how you are implementing this policy and what kind of publicity and education you have for the younger generation or for the whole community to build public awareness.

Chairperson (Mr. Hiroto Oda)

Mr. Wong Kee Wei of Singapore, please.

Mr. Wong Kee Wei (SINGAPORE)

In fact in our programs to educate the public on conservation measures, we have nationwide programs and packets for the younger generation, especially for schoolchildren. As for the nationwide program, we have a safe water campaign. And perhaps some of the delegates here may know that in Singapore we have various types of campaigns to get messages across to the general public.

For example, in recent years, we have conducted safe water campaigns, one in '95, one in '96, and another one in '98. Under the campaign, we have various activities centered on the areas where we want to make the general public aware that water is precious. To the general public, it is very simple. The more you turn tap, the more supply you expect to get. To them, a water supply should be there as much as they want it. But in our program, we are trying to educate them through the program to remember that in Singapore we have limited land, we have limited water resources; therefore, we should use it as a strategic resource and use it effectively. We are not asking people not to use water, but to use it only when they need it. Therefore, in the latest campaign, we visited local areas to tell people, "Turn it off when you don't need water." The slogan is: "Turn it off." That means after you use the water, remember to turn it off. The message we want to get across is to use water only when you need it; otherwise, turn the water off to conserve it.

For schools, we have conducted a visit to a waterworks facility. This is to give an idea to the younger generation or schoolchildren, that water supply is not as simple as just turning on the tap. We need to go through a comprehensive, complicated treatment process. To let them see this process will be much more convincing in showing them that water is precious than for them to understand just a slogan: "Water is precious." And this is a year-round program. We invite schoolchildren from primary schools and secondary schools to visit our waterworks.

On top of that, we also invite schools to attend our conservation centre to see the exhibition, to find various ways of conserving water in their daily life-that means at home, at school, or at public places.

And we also have another program for very young children. We give them stickers so that their schoolteachers or kindergarten teachers can support and implement the program.

These are the main measures we have taken for the past several years.

Chairperson (Mr. Hiroto Oda)

Thank you very much. I hope that answered your question, Mr. Priyohutomo. Any other questions?

Mr. Shin Sung-Kyo (PUSAN)

My name is Shin Sung-Kyo from Pusan. Looking at the whole of Singapore, the picture showed that the catchment areas comprise more than 50% of the land area of the whole city. Therefore, the lives of the people in those areas may be regulated under water quality control.

If land use is regulated correspondingly, it is very likely that there would be various complaints from the people of the area. General regulations of land use alone, however, will not effectively achieve the actual goal. Please let me know if there are any supporting measures for the local people in the area where land use is regulated.

Also, I understand that more than 50% of the water used in Singapore is taken from the western part of Malaysia. I would like you to tell me if there is any agreement or arrangement between Malaysia and Singapore related to water use in terms of area control in particular.

Chairperson (Mr. Hiroto Oda)

Thank you very much. Mr. Shin Sung-Kyo of Pusan has asked about incentives, and if there is any agreement on conveying water from western Malaysia. Mr. Wong Kee Wei of Singapore, please.

Mr. Wong Kee Wei (SINGAPORE)

As Mr. Shin Sung-Kyo from Pusan said, more than half of the island is a water catchment area. As I mentioned earlier, originally we started our water supply in the central area. So in the '70s, we started to convert the coastal area into a water catchment area, as well. This area was predominantly a farming area or an undeveloped area, but with small industries scattered about. You might have noticed that, in my presentation, I said that to ensure the successful implementation of this water supply scheme, we needed a law. The aim is to carry out the relocation of those activities incompatible with drinking water sources away from the catchment.

In Singapore, we have limited resources. We need to make the best use of our resources, and therefore we have to make it work right. So, of course, this is closely coordinated with other government agencies, such as the Urban Redevelopment Authority, the Housing and Development Board, and the Ministry of the Environment. Now in this process, basically we have been redeveloping the area. Those who were living in the catchment area were relocated to the high-rise buildings you can see in the slide.

So since the '70s, this program has been going on. And by now, almost all of the people who once lived in this coastal area have been relocated into those multi-story flats built by the Housing and Development Board. And currently, in Singapore, 85% of the population are living in multi-story flats. And the conditions of living in these multi-story flats are much better than those on the original premises located in the water catchment area. Of course, in the process, the people have to make changes to adapt to a new environment. For example, if they were originally doing farming activities within the catchment area, they can not do such work until the redevelopment is completed. So the people involved in those farming activities would have to switch their professions.

As we also have industrial development, some of the people have switched their professions from farming to other industrial activities. And, of course, we have so-called high tech farming for which its effluence is strictly controlled. And, therefore, those areas are located in certain places and the waste produced in the process is properly channeled and properly treated.

As to your second point, about half of our water is imported from Johore. This works well under the water supply agreement with the Malaysian government. This agreement has been working since the '40s, and we have kept a good relationship with the Malaysian authorities. We built a facility in Johore, and conveyed water. We also supply part of it to Johore, and some of the rest is delivered to Singapore. Over the years, this has been working very well. There is no problem with this.

Chairperson (Mr. Hiroto Oda)

Thank you very much. Did that answer your question, Mr. Shin of Pusan? Are there any other questions?

Ir. Hj. Mohmad Asari Daud (KUALA LUMPUR)

I would like to address this question to Mr. Wong. Regarding your unaccounted-for water, which is very impressive, having 10.6% in 1989 and now 4.7%, could you please elaborate further on your key success factor? And could you please actually break it down further into the components of unaccounted-for water? Furthermore, which part is considered the most strategic in tackling in order to reduce unaccounted-for water?

Chairperson (Mr. Hiroto Oda)

Mr. Wong Kee Wei, please.

Mr. Wong Kee Wei (SINGAPORE)

I think one of the factors which helps us to improve our performance in terms of unaccounted-for water is that our system basically covers a smaller area compared with many of your systems you are providing to your customers. We have about 4,500km of pipeline supplying water to customers, and we are using good-quality steel pipes for our transmission. Older mains, those built 50-70 years ago, or smaller mains built before 1950, were cast-iron mains. And we found that cast-iron mains are susceptible to leakage due to various traffic loading and defects in the joints. So we have identified this problem and we have replaced the older mains.

Although I have mentioned that we completed the scheme in 1993, in fact, after the scheme we continued our annual routine replacement program. That means whenever we identify a main which is leaking frequently or if there is a kilometer of main leaking three times a year over a period of 12 months, we single it out and get it replaced according to the guidelines. So this program has been ongoing.

Of course, the other area is connections. Connections sometimes are so small that you may not be able to detect them and the leak continues without anybody knowing it. So we have replaced our connections with the more durable stainless steel or copper pipes. So this is another area that has helped to reduce leaks.

We also have a leak detection program where the whole island is divided into about 250 zones, and every zone is tested once a year. If a particular zone is found to suspect there is a leak, then it can be zeroed down and identified. Therefore, we can carry out repairs or even replace a particular section of the main.

The more important area is, perhaps, the accuracy of metering. So if the water produced is properly metered and also the water being sold to the customers is also properly metered, that could account for this deviation, I think. Our water meter at the waterworks is checked by tests. In other words, every month, we stop water and pump it to a clear tank for a period of time to calculate how much water is actually pumped in compared to the electro-magnetic meter. From there, we can tell whether there is a difference. If there is a difference, the flow-meter can be adjusted accordingly.

Generally in Singapore, because of housing development, as I just mentioned, 85% of the population are living in estates. And these estates are relatively new. Most of them were built after the 1960s. In other words, they are about 30 years. So in a way, the pipes are rather new, and the chances of leakage from these pipes are less. So I think that is a significant fact which contributes to our low unaccounted-for water.

Chairperson (Mr. Hiroto Oda)

Thank you, Mr. Wong Kee Wei. Did that address your point, Ir. Hj. Mohmad Asari Daud of Kuala Lumpur? Then, I would like to conclude the presentation by Mr. Wong Kee Wei. Thank you very much.