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Commission 3

Enhancing and maintaining water quality for metropolises

METROPOLIS 2002 SEOUL

Metropolis

COMMISSION 3

'ENHANCING AND MAINTAINING WATER QUALITY FOR METROPOLISES'

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CHAIRMAN'S FOREWORD

Water is a basic need and a precious resource. As the world's population increases and becomes more urbanised the need for water as well as competition between users is growing. At the same time communities around the world are increasingly demanding good supplies of clean, safe water and non-polluting wastewater services.

Balancing these demands, and finding ways to equitably share the world's scarce and precious water to provide secure and sustainable supplies of water now, and in the future, is a challenge facing many cities, particularly those in the developing world. A challenge that must be met if cities are to prosper, grow and be safe, healthy places to live in.

There is much to gain by sharing information on how cities are dealing with these complex and demanding issues. I hope that the findings of this study will assist the Metropolis members and others to meet these challenges.

I would like to acknowledge the contribution made by all the participants and thank the Melbourne-based working group that assisted with this study for their dedication and expertise.

John Thwaites
Former Minister for Planning
Government of Victoria
Melbourne, Australia

EXECUTIVE SUMMARY

While some cities have ample water resources to meet future demand, almost half of the cities in the study have plans that will be implemented over the next 10 years to ensure they have secure, long-term supplies of water. For a few, these demands will be met by using non-traditional sources of supply such as reusing reclaimed or recycled water. Many more cities, particularly those in the industrialised and developed countries, are seeking efficiency gains, more economic use of drinking water, the introduction of demand management systems and exploration of potential sources of supply that do not require major new infrastructure such as dams.

Many cities reported that they have reformed their water services over the past 10 years although approaches to this varied. The study demonstrates continuing impetus to reform water supply systems. The main objectives of this appear to be to create the conditions for greater involvement of the private sector in cost reduction and quality improvement strategies. Private sector involvement is also being used to facilitate the entry of new technology and funding, and to improve services through competition. Customers in cities with privatised water services are generally required to pay for a level of profit although this may be capped by legislation. Privatisation was not the only way used to gain the efficiencies and quality improvements. Some cities have demonstrated alternative approaches such as competition through benchmarking, out-sourcing non-core activities and through regulatory controls.

Most of the cities indicated they obtain their raw water supplies from a mix of sources with the most coming from rivers, dams and lakes. Within their distribution systems, the majority of cities have two or more sources of water, which they regard as critical to minimising interruptions and maintaining supply. Ten of the cities indicated that land use within their water catchments was mixed with varying amounts of forested and grassland areas, industry, agriculture and residential development. In some, these activities are significant. Some cities need to transfer their water long distances with water sources being 150 kilometres from a city being quite common.

Actions to protect water supplies are directly related to how and from where water is sourced. Most cities do not have enclosed and protected water catchments and the majority of these cities protect their supplies by regulating discharges and activities in the water catchment areas. While some cities are developing new strategies to protect their water catchments some appear to rely solely on treating their raw water supplies to protect the health of their residents. Two cities in the study always advise the community to boil their drinking water because of poor infrastructure and reticulation services.

All cities monitor their water quality and governments in all cities in the study are responsible or have a direct involvement in the supply of drinking water. All the cities publicly own and manage their wastewater treatment plants. More than three-quarters of the cities have regular water conservation campaigns.

All cities indicated water losses from their system although the rate of unaccounted-for-water varies considerably. Most have experienced losses between 15 to 30 per cent, with some unable to account for more than half their water. The best performing city reported just three per cent losses.

Responses from the majority of cities in the study indicate that the need for environmental flows in rivers for their health and ecology is not considered as a priority water use with many appearing to consider they do not have this option. Recognising the need for environmental flows was mainly confined to cities from the more affluent countries.

Water pricing is generally the responsibility of government. Those cities that operate on significant government subsidies seem to have quite arbitrary pricing structures.

In many developing countries wastewater services are not particularly well provided for and, in a number of cities collection networks are almost non-existent. The inadequate collection and treatment of wastewater in developing countries is the cause of major environmental pollution, low levels of hygiene and increased health risks.

Conversely, it is not surprising that the study highlights that it is the cities in the developed world that have higher per capita water consumption, better-maintained infrastructure and more comprehensive and safe wastewater treatment and disposal.

Thirty cities participated in the study, representing every major continent and the developed and developing worlds. While the study benefits from this diversity, there were significant differences in the way the study questionnaire was interpreted and answered resulting in some inconsistencies in the data that were collected. Some cities did not respond to all questions. During the preparation of this report these issues have been taken into account.

INTRODUCTION

Water is the growing world population's most basic need. Governments, policy makers and planners are faced with the challenge of supplying adequate water to all and ensuring that water is not wasted or contaminated. While cities need ample, secure, uninterrupted supplies of safe, clean drinking water for their residents, this demand must be balanced with the equally important requirement of water for agriculture, commerce and industry, recreational uses and the environment.

In many parts of the world water is increasingly becoming a major political and environmental issue as countries, cities and communities balance competing demands and claims for the world's fresh water. Demand for water has increased as city populations increase. Competition for water has become more acute, not only between cities and their hinterlands but also between nations. In many nations, cities must also compete with environmental demands with the restoration of damaged ecosystems and preservation of endangered species requiring greater volumes of water to be left as in-stream flows, limitations on groundwater extraction, and prevention of further withdrawals or water infrastructure expansion.

Approximately 1.3 billion people around the world do not have access to safe drinking water, almost all of whom are in developing countries. Additionally approximately 57 per cent of human populations living in these countries, or 2.6 billion people, are without access to adequate sanitation.[1] There is clearly a relationship between these two statistics. The need to address the problem of domestic water supply will likely intensify in the near future.

In some parts of the world there is evidence that urban and rural developments are restricted by access to adequate water supplies. Disputes over water are not uncommon and the quantity and quality of surface and groundwater resources are under threat through inefficient use and contamination. Even countries and regions with good water resources could have problems in the future as demand for water increases and climate change continues. It has been predicted that major disputes or wars of the 21st century may well be fought over access to water.

How cities supply water to their communities is closely linked to how they are governed and managed, as well as their local climate and geography. Each city's history, economic, cultural, political and social circumstances, as well as settlement patterns, have fundamental impacts on the availability, quality and distribution of water resources.

PURPOSE AND METHODOLOGY

This Metropolis study was undertaken to encourage authorities to identify the critical sustainability aspects of water supply in their cities; provide decision makers in developed and developing countries with some indicative benchmarking information; and to give water authorities information about the experiences of participating cities. All participants completed a questionnaire that covered water supply issues in terms of government policies; sustainability of water resources; security of supply; economic considerations; treatment and monitoring of water quality; wastewater services; and infrastructure requirements. Additional information was sought through a supplementary questionnaire, but responses were received from only 11 cities.

There were differences in the way the questionnaires were interpreted and answered. Issues that are important in one part of the world are not necessarily so elsewhere resulting in some inconsistencies in the data

1. UNDP, 1999, human development report 1999. Oxford University Press, Oxford.

Figure 1: Location of participating cities

that were collected. Also, not all cities answered all sections of the questionnaire. However, the study does provide some important information for Metropolis members and other participants.

The report has been written taking account of the difficulties with the response data. To augment the data from the questionnaire, published research related to the issues addressed in the report has also been used.

PARTICIPATING CITIES

The 30 cities that participated in the study are dispersed geographically. Every major continent is represented, as are cities from the developed and developing worlds. The population of the participating cities ranges from 347,000 in Wellington to 10.9 million in Paris-Ile-de-France.

The range of cities is starkly demonstrated by the per capita daily water usage figures: the lowest daily consumption was approximately100 litres per person and the highest over 1,000 litres. Average daily per capita usage for all cities was 410 litres per day. Also indicative of the variations between the cities is the number of people served per property connection. This ranges from 15.1 in Riyadh to 1.6 in Lisbon with and overall average of 4.4 persons per connection.

Figure 2: Water sources and ownership

CITY	POPULATION	WATER SUPPLY SOURCE	%	QUANTITY SUPPLIED IN 98/99 (MEGALITRES)	OWNERSHIP
BARCELONA	3,100,000	Surface Underground	85 15	320,000 ML	State/Local Govt
BELO HORIZONTE	2,200,000	Surface	100	116,600 ML	
BERLIN	3,400,000	Surface	100	224,000 ML	State
BUSAN	3,763,000	Surface	93	524,040 ML	Local Government
CASABLANCA	3,500,000	Surface	100	181,000 ML	State
DENPASAR	385,478	Surface (River) Underground	70 30	17,492 ML	Local Government
DENVER*	1,066,000	Surface	100	323,560 ML	Federal government
DOHA (QATAR)	600,000	Surface (MSFdistillation) Underground	90 10	130,678 ML	State
DOUALA	484,870	Surface	85	21,800 ML	State
DUBLIN	1,200,000	Surface	100	164,250 ML	Local Government
GENEVA	408,000	Surface Underground	80 20	60,200 ML	State
GUANGZHOU	6,850,000	Surface Underground	n/a	1,236,000 ML	Local Government
HANOI	700,000	Underground	100	138,276 ML	State
HARARE	2,200,000	Surface	100	152,200 ML	State
LISBON	517,650	Surface Ground	90 10	62.225 ML	State
LOS ANGELES	3,800,000	Surface Underground	85 15	798,000 ML	State
MANILA	6,400,000	Surface Underground	97 3	1,101,205 ML	State
MELBOURNE	3,300,000	Surface	100	494,000 ML	State
MEXICO	8,300,000	Underground Surface	81 19	830,400 ML	Federal government
MONTREAL	1,500,000	Surface	100	1,779.7 ML	State
PARIS**	10,926,000	Surface Underground	70 30	850,000 ML	State/Local Govt
PORT ELIZABETH	1,250,000	Surface	n/a	68,360 ML	Joint State, LG & Private
RIYADH	3,855,758	Desalinated Ground	65 35	506,483 ML	State
RIO DE JANEIRO	1,486,768	Surface	100	n/a	State
SEOUL	10,321,000	Surface	100	1,654,291 ML	State
SYDNEY	3,995,000	Surface	100	599,692 ML	State
TEL AVIV***	1,500,000	Surface	100	n/a	State
TORONTO	3,000,000	Surface	100	540,000 ML	State/Local Govt
WELLINGTON	347,000	Surface Underground	61 39	54,900 ML	Regional/Local Govt

* Denver Water customers only, not total metropolitan population
** Paris-Ile-de-France region.
***Tel Aviv, partial response received.

1. POLITICAL AND ECONOMIC CONSIDERATIONS

1.1 POLITICAL IMPERATIVES

Water is a basic need. Because of its importance in every aspect of life, water is also a political issue. Governments cannot ignore the role they have in ensuring their communities have water for drinking and for hygiene, or that the water needs of industry, agriculture and the natural environment are met.

Governmental strategic planning and water policy is expressed in legislation and regulations that cover ownership, water supply and quality, water use, resource development, planning for long-term supply, wastewater treatment and disposal, and water for environmental flows.

The legislative frameworks adopted by countries and cities to govern their water resources and supply are often complex and reflect, among other issues, the current and historical political systems and government structures in which they operate. Legislation and regulations are set at national, state and local levels of government as was evident in the study. Legislation affecting many cities is often piecemeal, overlapping and is sometimes outdated.

Governments also have the responsibility of ensuring that residents can afford the water they need and a number of cities, although not all, indicated that their water charges include consideration of an obligation to the community to provide concessions on their water charges.

1.1.1 Meeting obligations to customers

Out of 11 responses to the supplementary questionnaire three cities said they had no obligations to their customers, eight reported that they do. For these cities, the obligations generally specify the level of service that is to be provided and include minimum water quality standards, water pressure and response times to address disruptions to supply.

However, most cities have a system in place for customers to complain and generally these complaints are recorded and acted on. Seoul identified that if its services do not meet the specifications of its obligations, fines are imposed. Melbourne's retail water companies have a customer charter stipulating the obligations they must meet and this is provided to their customers.

With an increased awareness of their rights, and of the cost that they are paying for water, residents in some cities are becoming more service-oriented and have a lower tolerance for disruptions to supply. Melbourne has noted a change over the past 10 years with improved marketing of service levels and customer rights. Its customers now expect improved service with fewer interruptions and reduced outage times. Berlin reports that complaints are expressed earlier and it is likely that this is a situation common to a number of cities.

With increased water and service charges, and an increased awareness among the community of 'value for money' Port Elizabeth's residents are reported to expect an immediate response when there are disruptions to supply. The expectation of an immediate response when there are disruptions to supply has been increased by the installation of water meters at previously unmetered sites.

1.1.2 National Government role

The responsibility of national government focuses on establishing a framework under which cities operate to provide drinking water. Particular mention was made of water resource management and standard setting.

In eight of the eleven cities that responded to the relevant question, local government had responsibility or a direct involvement in the supply of drinking water. In Toronto and Melbourne this is a state (provincial) government function.

1.1.3 Water reform since 1990

Water reforms reported by many of the cities in the study over the last 10 years are varied. Common themes included:

- development of public and private partnerships to introduce private enterprise to the supply of water;
- implementation of strategies to drive business improvement;
- increased awareness of water conservation and environmental impacts; and
- revised and enhanced compliance standards for drinking water supply.

In cities such as Dublin, Geneva and Riyadh, water reform has not occurred.

Providing water more efficiently by gaining maximum output while reducing costs has been a driver in many cities. The main incentive in place for continuous improvement is through comparison with other businesses, together with annual reporting on performance. Denver reported having employee awards that recognise and encourage innovation and improvements. Only Port Elizabeth and Mexico reported no incentives for productivity improvements.

In Australia, water reform has been driven by the Council of Australian Governments' 1995 decision to address the competition for water between environmental and human uses.

Doha, which sources its potable water almost entirely from three desalination plants, has transferred responsibility for water supply from its Ministry of Electricity and Water to a water corporation. This is the first step towards privatisation and some of the production facilities have been transferred to a private company. Following full privatisation the water corporation's role will be confined to purchasing water for distribution.

> Melbourne has disaggregated its water industry into one wholesale and three retail businesses. Increased efficiency has been gained through competition by benchmarking, utilising private competitive contracts to provide maintenance and construction services and encouraging a commercial approach to the conduct of its business. Clarity in obligations was obtained by issuing licences to retail businesses and through regulatory arrangements established through an Office of Regulator General.
>
> Source: Melbourne Water

1.1.4 Water reform over the next 10 years

Further reforms envisaged over the next 10 years include those resulting from: technological advances; the introduction and development of competitive principles; application of alternative sources of supply; further private sector participation; improved service and efficiency in performance; institutional reform; water conservation and environmental protection.

Berlin, where recent reforms have privatised 49.9 per cent of its water resources, plans further privatisation although the extent of this is unclear.

Generally, the study demonstrates continuing impetus to reform water supply authorities. The main objectives of this appear to be to create the conditions for greater involvement of the private sector as cost reduction and quality improvement strategies. Private sector involvement is also being used to facilitate the entry of new technology and funding, and to improve services through competition. Privatisation can also have the effect of distancing government from pricing reforms and pay-for-use regimes.

1.1.5 Planning for long-term supply

As cities have grown, many have had to access their additional water supplies from increasingly distant sources. Twentieth century water resources planning and development relied on population projections, per-capita water demand, agricultural production, and levels of economic productivity. Because each of these has always been projected to rise, water needs have been expected to rise.

Prior to the 1980s, planners assumed that projected shortfalls would be met through new physical infrastructure such as new dams to create reservoirs for water storage, and new aqueducts and pipelines for inter-basin transfers. This approach of relying on physical solutions, such as new dams, continues to dominate water planning but is facing increasing opposition. More and more water suppliers and planning agencies are beginning to explore integrated water resources planning (IWRP), a more holistic planning approach that seeks efficiency improvements, demand management and alternative sources of supply. Demand management becomes a key element of meeting future needs by freeing up existing supplies through conservation to meet incremental demands of the growing number of customers.

Past investments in physical infrastructure have provided undeniable benefits. Water supplies in most developed countries are clean and reliable, eliminating many of the water-related diseases rampant in Europe and North America in the late 1800s. This infrastructure has required an enormous economic investment. But there were other costs. Infrastructure projects to provide raw water also destroyed ecosystems, dislocated human populations, inundated cultural sites and disrupted sedimentation processes. These were the hidden costs of 20th century water development.

Relying on more and more dams and reservoirs to capture and store large volumes of freshwater run-off is becoming less attractive for environmental, economic, and social reasons. Costs of water supplies are rising because the real cost per unit of supply for new engineering projects is frequently two to three times those of existing sources. Moreover, new water supply systems have increasingly become expensive compared with non-structural alternatives. With relatively high levels of inefficiency in water delivery and water use, current demand can be reduced relatively cheaply through water conservation technologies, water user behavioural change, and leak detection and repair. These enable existing water supplies to meet the needs of new users. Also, in the past almost all water-related development was subsidised or paid for by governments and international financial organisations. More recently, many government budgets are under pressure and there are constraints on funds for major water projects making non-structural alternatives a necessity. Worldwide, the average cost of most new projects to supply water to consumers is expected to be two to three times that of existing investments.[II]

Some new dams, aqueducts, and water infrastructure will be built, particularly in developing countries where

II. Serageldin I., 1995. Toward sustainable management of water resources. World Bank Directions in Development Series. Washington D.C.

the basic water requirements for humans have still not been met. However, meeting a city's demand for water over the next century will increasingly depend on non-traditional sources of supply including systems to reuse reclaimed or recycled water and, in some limited circumstances, desalinated brackish water or seawater[III]. This approach is in line with calls by the UN Conference on Environment and Development, Rio de Janeiro,1992.

Of the cities that participated in the study, almost half have plans that will be implemented over the next 10 years to ensure secure, long-term supply of water. Approaches to achieving this are varied. Generally the response in the more industrialised and developed countries is to seek efficiency gains, make more economic use of drinking water, introduce demand management systems and explore the potential of alternative sources of supply that do not require major new infrastructure such as dams. Nevertheless, cities such as Denpasar, Doha, Dublin, Hanoi, Harare, Manila, Mexico City, and Busan have plans for major new infrastructure developments.

1.2 ECONOMICS

1.2.1 Ownership of water resources

Large cities frequently have legal rights to use water without actually owning the water resources or catchments as this rests with government at the federal or state level. Water resources are in government ownership in cities such as Berlin, Casablanca, Denpasar, Denver, Douala, Geneva, Harare, Mexico City, Melbourne, Seoul and Sydney. Paris's water resources are 'part of the national communal heritage'. Port Elizabeth's resources are owned by a mix of public and private organisations. In both Manila and Busan three per cent of water resources are in private ownership. The Regional Council and four city councils own Wellington's water resources. While cities might have legal rights to use government-owned water, they may be obliged to meet efficiency standards in their allocation of water and/or be subject to public trust-type legislation that might affect future withdrawals, for example, to meet environmental goals or to deal with regional droughts or longer term supply shortfalls. In some cases, water rights systems may allow cities to sell excess water to other providers through water markets.

Where cities do not own the water catchment or wellhead areas, they get their supplies from a third party such as a larger government entity, from another city/utility (that acts as their wholesaler), from a private interest (such as a desalination plant owner), or from some combination of these.

Town water supply resources are owned by government either at a federal, provincial or state level in 19 cities. In one city, a private concession has been established. Two countries, Canada and the United States, own Lake Ontario from where Toronto draws its water. Once Doha's program of privatisation of its desalination plants is finalised, the private sector will own and operate the city's three desalination plants that supply more than 90 per cent of its potable water.

1.2.2 Private sector involvement in water supply services

Debate over private sector involvement in water services is ongoing and there are strong arguments and proponents for and against this. Providing sustainable water supplies is a complex process in which the objectives of sustainability are attached to economic and political questions. Rethinking appropriate and efficient roles for government, the provision of equitable pricing, funding the expansion

III. P.H. Gleick, Pacific Institute for Studies in Development, Environment, and Security, Meeting basic water needs as a human right, conference paper, Xth World Water Congress, Melbourne, March 2000.

and repair of ageing urban systems, and meeting growing demand from finite and often overcommitted water sources are all drivers in the global trend towards private sector involvement in urban water supply and management.

However, the debate revolves around the extent of private sector involvement in providing potable water services to urban communities. There are four broad degrees of private sector involvement as services providers and investors in infrastructure.

- Management Agreements: Through a management agreement, the operation and maintenance of a service are contracted out to a private company for a predetermined period without the private company or consortium financing the asset. Instead, the public sector finances both fixed asset and working capital.
- Lease agreements: Through a lease agreement, a private company leases, operates and maintains a State-owned asset for a prescribed period. The public sector retains the responsibility for financing the investments in fixed assets.
- Concessions: Through a concession agreement, a private operator is responsible for developing or rehabilitating and operating a State-owned asset or service for a prescribed period. Concessions include agreements such as build-operate-transfer or rehabilitate-operate-transfer schemes.[1]
- Privatisation: Through privatisation, State-owned assets are sold to a private company or consortium and these assets are owned and managed by the private operation in perpetuity.

Issues at the core of the debate over privatisation of water services include:

- how the needs of the community for affordable, safe and sustainable supplies of water can best be met;
- whether or not a profit motivated private sector can, or should, be responsible for providing this basic need;
- the cost of water services infrastructure and impact on government economies; and
- the place of the free market in the provision of essential community services such as water supplies.

Where privatisation of water services has occurred it appears to be universal that the private operators are subject to government scrutiny and the setting of appropriate tariffs and operating conditions to protect the population from any potential abuse of monopoly powers. In the United Kingdom, the Office of Water Services tried to limit monopoly powers, regulate spending which included ensuring adequate investment in infrastructure and service improvements, and prevent excessive profit taking and asset stripping to benefit shareholders. In the US, Public Utility Commissions usually adjudicate over rates in which private suppliers make a rate case which presents costs and estimated profit margins embedded within proposed tariff structures.

Eight cities indicated that their water businesses are in public ownership with private sector involvement in areas that benefit from market competition. In Berlin 49.9 per cent is in private ownership. Manila's town water reservoirs, treatment plants and reticulation assets are wholly government owned. However, a private company through a 25 year concession operates them. Melbourne has a mix of a corporatised, publicly owned wholesale water supply and sewage disposal business, and three publicly owned water retailers. Riyadh has a completely government run utility, Toronto the same but with ancillary services widely outsourced to private sector. In Tel Aviv the central government wholesales to local government and in Lisbon the regional government-owned authority retails to the public.

1. Southern African Development Bank.

The study does not indicate any correlation between levels of privatisation and water scarcity, economic conditions, city size or infrastructure condition. Privatisation appears to be largely determined by political history and influences quite separate from natural resource management considerations.

Privatisation of sewerage services is not evident anywhere in the cities that participated in the study. Melbourne, with its three retail companies, is the only city where disaggregation of the retail and wholesale functions includes water supply and sewerage services. Both are still wholly owned by government. (section 2.5 has information on wastewater services.)

1.2.3 Public funding and accountability

Many cities did not respond to this question. However, it is evident that cities generate income to fund their water services in a variety of ways. They can recover expenses by charging consumers for the water they receive as a commodity, by charging for their service connection, and/or by levying different fees to cover special expenditures like distribution system upgrades. Public sector suppliers usually operate to cover their long-run operating costs, although some of their costs may be borne by larger government agencies through taxpayer funded grants or through international development assistance in the case of developing country cities. They may run short-term fiscal deficits or surpluses but these tend to be eliminated over the longer term.

Consumers in cities with privatised water systems will generally pay for a level of profit on operating costs although these may be capped by legislation. Large capital projects are usually financed by some kind of bond measure or through commercial or federal, state or provincial loans. In developing countries, funds may be provided by international donors in the form of grants or loans, often with a low interest rate.

Approximately half of the cities in the study reported that their operating income is largely derived from water sales and sewage disposal charges. The other half identified government grants as their major income sources.

Investment capital is raised though private banks, public bond issues, government grants and loans and private/public partnerships. The study demonstrated that cities use a variety of approaches to funding their infrastructure requirements. Berlin and Sydney indicated these are government funded. Los Angeles uses a combination of monies from rates and bond issues, Barcelona's funds come from a 50-50 split between the regional government and the regional public corporation while Denver relies solely on debt financing and neither 'gives nor gets monies from the City or the County of Denver'. International funding aid is a source of capital in developing countries and Harare uses internally generated funds, loans from the government as well as banks such as the World Bank and the African Development Bank. However, despite these variations, there is a consistent and strong level of government involvement in financing expansion and new development programs. Total water authority self-funding was reported by two cities, including Melbourne.

The study demonstrated an increasing trend towards public financial reporting and accountability to government regulators for meeting contractual targets. However, open public reporting appears to be rare with most reports, while technically being publicly available, tending to be provided to the government or responsible authority. At least one city, Los Angeles, seems to deal with accountability by building customer satisfaction through customer education and Melbourne provides publicly available environment and public health reports.

1.2.4 The cost of water

The setting of water prices is a responsibility of government for the overwhelming majority of cities. Water prices may be based on the volume used, known as commodity pricing, only where water meters are installed and read regularly, usually monthly or bimonthly. Where meters are not installed, cities must use a system of flat fees or base their prices on some kind of proxy data for consumption, for example the diameter of the connection, the size or assessed value of the serviced property, or the type of industrial facility. Commodity pricing can adopt various fee structures, for example constant rates, declining rates (based on some concept of economies of scale), or the increasingly more popular inclining rate structure, often known as conservation pricing – the more you use, the more you pay.

Most of the cities charge for water based on a formula that incorporates a metered volumetric usage charge and a service fee. However, many cities did not provide any financial data relating revenue to costs. In Mexico City, price is set by the authority following specified directions, which is then approved by State Congress. Cities, such as Riyadh, that generally operate on significant government subsidies appear to have quite arbitrary pricing structures. This may indicate that many water authorities have not assessed the cost of delivering water against the price to consumers or do not have the accounting data to do so. These circumstances must present serious planning and system management difficulties especially if supplies become scarce or under pressure from competing uses.

Survey responses from Seoul, Melbourne, and Geneva show that their water corporations produce surplus funds that are available for re-investment in new development. In the case of Melbourne's water businesses surpluses are paid to their shareholder, the Government of Victoria. This is done partially to meet competition requirements for tax equivalence and partially to provide the government with funds as the water businesses are expected to be commercial operations. The responses from Harare and Riyadh show that water is delivered to consumers below the cost of production and delivery.

This is not the case in Tel Aviv. Here, a government-owned company sells water to the city's municipalities for approximately what it costs to harvest and deliver. The municipalities then sell water to customers at a profit. Tel Aviv's response did not specify what these profits were used for and may merely reflect the costs for administering the city's cost for such things as billing and local infrastructure. The actual cost is fixed by the municipalities and approved by the Minister of the Interior. Enacting such pricing regulations puts a financial burden on the lower socio-economic groups in the community.

While most cities base their water charges on a mix of volume used and a service fee, Wellington and Montreal are obvious exceptions to this. In Wellington, where very few properties have water meters, water is paid for as part of annual property rates. Montreal's tariffs are based on property values and small consumers, including households, are not metered. About 1,100 large industrial consumers are metered and they are charged extra if their consumption exceeds their property value-based allocation

It is interesting that, apart from Port Elizabeth, Riyadh, and possibly Hanoi and Mexico City (responses to the questionnaire from these two cities were not clear), no other city uses pricing to directly help control water use during times of shortage. However, they use other methods, such as education and restrictions to conserve water during times of shortage.

In Los Angeles, special drought and water shortage contingency measures allow for special rate structures where each unit volume of water consumed above a given threshold becomes increasingly expensive. The city also has a rebate system that encourages water conservation, for example, providing financial assistance for those installing low-flush toilets or other approved devices. Rebates are funded through a surcharge on the water tariff that is also used to provide assistance for those on low incomes.

The study indicates that pricing is rarely related to scarcity. Riyadh's pricing structure, for example, delivers water at below the cost of production despite the high cost of desalinisation. Scarcity is handled by reducing supply rather than managing demand through pricing. While not evident from the study, frequently, when potential demand outstrips supply and prices are not used to bring demand into line, water suppliers resort to measures such as reducing system-wide pressure or intermittent service to “ration” water. This can skew per capita use toward wealthier customers as a typical response to intermittent supply is the construction of large household water tanks that can be filled on the days water is flowing. Those who can afford the biggest tanks thus get the largest volume of water.

Water charges in many cities incorporate concessions as a community service obligation (CSO). Nearly all CSOs are absorbed internally and funded by charging slightly higher fees to the broader customer base to provide lower cost services to the minority, such as low income households. This is particularly the case where water is provided by public institutions, be they cities or utilities. Those receiving CSO rates are usually given the opportunity to consume below a given minimum level of service at a below-average cost. In the USA and the UK CSOs are commonly found. They require acceptance of the concept that water is a social good and a basic necessity that should be provided.

2. WATER QUALITY AND REGULATORY CONTROLS

2.1 ACTIONS TO PROTECT WATER SUPPLIES

The actions taken by cities to protect their water supplies are directly related to how and from where their water is sourced. In Melbourne and Wellington, which have primarily enclosed and protected water catchments, actions are directed at managing these areas to exclude activities that may adversely impact on water quality. Development is strictly prohibited and public access restricted.

Undoubtedly these cities are aware that they are among a handful worldwide that have large, forested and protected catchments and the advantage this provides their citizens.

Protecting water supplies is more difficult in two cities. In Manila rapid urbanisation and squatter communities are problematic. To ensure that its water supplies are protected, security patrols are routinely deployed to deter illegal settlements within the catchment and along the right-of-way of the raw water aqueducts. Port Elizabeth also indicated that, while its water catchments are fairly well protected, they are coming under increasing pressure from informal settlement.

Most cities do not have enclosed and protected water catchments for their water supplies. For these cities, actions to protect supply are directed at regulating discharges and activities in the catchment areas that may pollute the surface waters. Approaches to achieving this vary.

For Barcelona, *The Waters Act* restricts discharges into public waterways from activities such as piggeries to protect surface and underground waters from pollution. Appropriate sanitation and/or wastewater treatment for villages above the water intakes is being developed. The surface water supplying Denver is protected by the United States *Clean Water Act* that regulates sewage and other discharges into receiving bodies from point sources and increasingly includes provisions for controlling non-point source pollution in watersheds.

Some cities are developing new strategies to better protect their water catchment areas. Sydney is developing a regional plan for drinking water catchments that will control activities in the catchment areas. This will include strategies for the collaborative improvement of the management of catchments through best management practices, land and water capability assessment and catchment restoration plans.

In Belo Horizonte, where catchments and river basins are affected by silting as a result of clear felling and sewage discharges, the state has introduced a *Drainage Guide Plan* that includes a geographic information system (GIS) hydraulic modelling in a bid to control wastewaters and improve monitoring of water quality.

Other cities, such as Denpasar and Harare did not indicate that they have any restrictions or controls over activities in their water catchments and rely solely on adequate treatment of their raw water supplies to protect water quality. Denpasar also has local government regulations to manage development in the catchment areas. The effectiveness of these may be questionable, as there are inconsistencies in the way they are applied.

Protection plans to safeguard the quality of source water are in place, or being developed in 18 cities. This applies to both surface and groundwater supplies. Many cities include ongoing monitoring programs and treatment processes as measures to protect their sources although these approaches are fundamentally different from input controls, alerting attention to water quality deterioration and implementing output control measures for contaminant removal. In addition, in developed countries where water is from non-protected catchments, additional management options are used inclu-

ding negotiating with farmers to reduce pesticide use and the development of alternative water supplies such as in Paris-Ile-de-France.

2.2 WATER TREATMENT PROCESSES AND MAINTAINING WATER QUALITY

All cities actively treat their water before it is supplied as drinking water. Conventional multi-staged treatment is used by 15 cities. The water treatment used by cities relates to the stringency of their water quality guidelines or standards and their technical and financial capacities. However, treatment is also influenced by the source of the raw water with more comprehensive treatment being required for the more compromised supplies.

Most surface supplies, with the exception of Melbourne, are fully treated by conventional treatment processes of pre-chlorination, flocculation, sedimentation, filtration, pH correction and disinfection. Only Wellington uses the dissolved air flotation process, although the process is being investigated in some other cities. Direct filtration is used where water quality is suitable. Ozone is quite commonly used as a means to disinfect water supplies.

Melbourne avoids the need to fully treat its water supply by maintaining barriers to protect water quality. These barriers include strongly protected catchments, large catchment reservoirs with long detention times, additional retention time in seasonal storage systems, disinfection of water before it enters the distribution system, closed distribution systems and a comprehensive monitoring program. Where source water is from an unprotected catchment, it is comprehensively treated.

For almost every city the by-products of disinfection by chlorination are a major issue and it is anticipated that the World Health Organisation will introduce stricter guidelines to control these. The degree to which this is a problem varies from source to source depending on the presence of chemical by-products from decaying organic materials. Protected catchments and sources with low levels of eutrophication and aquatic vegetation are much less likely to suffer from disinfection by-products such as trihalomethanes. Consideration of this issue needs to take into account the trade-offs associated with under-treated or untreated water with little or no residual disinfectant and that the risk posed by chlorination by-products. In many parts of the world, the risks from chlorination by-products are lower than those associated with under treated or untreated water. However, despite their water treatment regimes, Denpasar and Hanoi, always advise their residents to boil their drinking water because of poor infrastructure and reticulation services.

Most cities have a cleaning program for their water supply tanks and reservoirs, usually every three to five years.

2.2.1 Water quality guidelines and monitoring

Most cities in the study have water quality guidelines that apply nationally. Other cities use standards that have been developed at an international level. In Paris and Barcelona, the European Union's water quality standards apply and Doha relies on World Health Organisation standards. Water quality guidelines are in use in Dublin, Los Angeles, Melbourne and Sydney. The water quality criteria are selected by the Department of Health in Barcelona, Dublin, Geneva, Hanoi, Manila, Mexico, Rio de Janeiro, Sydney and Wellington.

Water quality monitoring is undertaken in all cities, typically by the Department of Health but occasionally by other government departments such as the Environment Protection Agency (Los Angeles). Geneva, Paris, Port Elizabeth and Melbourne use independent

laboratories. The monitoring is used to provide evidence of the integrity of the distribution and reticulation systems and that water treatment processes are functioning.

The number of water samples obtained varied. Generally the cities take between 3,000-55,000 samples annually from the distribution system depending on population size. Sample numbers in the low hundreds are taken from raw water supplies or treatment plants in Denpasar, Hanoi, Paris and Sydney. The health department in 16 cities makes an assessment of water quality following laboratory analysis, the water authority in six and the laboratories analysing the data in one city. Of those cities that responded only Doha, Casablanca and Mexico City did not publicly report the testing results.

The Australian Framework for Management of Drinking Water Quality

The Framework for Management of Drinking Water Quality integrates quality and risk management principles, and emphasises the need for a comprehensive preventive management approach throughout the water supply system to optimise drinking water quality and protect public health. The Framework will be incorporated into the Australian Drinking Water Guidelines during 2001/02.

Regulatory structures have relied heavily on monitoring finished water in the distribution system to manage drinking water quality. Compliance monitoring limitations include the shortcomings of sampling and analytical techniques; inadequate consideration of events that can impact on drinking water quality; and failure to provide an effective response to contaminants without a prescribed numerical guideline value or established method of analysis. Also, the time between water sampling and test results often means that non-complying water reaches consumers before a corrective response can be initiated and tends to promote a reactive management approach.

The focus of the Framework is on understanding the drinking water supply system, establishing and optimising barriers and control measures to minimise risks, monitoring the effectiveness of these controls, and implementing management actions to prevent or correct variations from established criteria before water reaches the consumer. The Framework also addresses non-technical aspects of water supply such as corporate commitment and relationships with other stakeholders and with consumers.

The Framework complements management systems already used in the water industry, and provides additional guidance on a number of aspects fundamental to water quality management but not addressed by any single existing quality management system.

Dr Martha Sinclair, member of the Australian National Health and Medical Research Council– Drinking Water Quality Management Working Party

2.3 REGULATORY CONTROL OF WATER SUPPLY

National and state governments in all but one of the participating cities are responsible for establishing regulations, laws and guidelines to protect public health and set water quality criteria. (Doha indicated it has no legislation to protect and manage its town water supply.) In most cases, it is the municipal government that is involved in the supply of water and the government public health authority that assesses attainment of guidelines or public health related standards. In some cities, such as Melbourne and Sydney state government owned instrumentalities assume total responsibility for town water supply and distribution.

Overwhelmingly, the regulating body reports to the ministerial level of government. In the USA and Canada, these requirements are established by the EPA and enforced by the health department and other federal and regional authorities such as state water resources control boards. It is of concern that Harare reports that the organisations (state and local government) responsible for regulating the public health aspects of the city's water supplies are not meeting their obligations. This is said to be due to staff and equipment shortages.

The use of standards rather than guidelines did not appear related to whether a private or public company controlled the supply. A more complex set of political reasons appears to drive the movement towards standards.

Permits, licences or approvals to extract water are required in 17 cities while five report that there was no such requirement.

In Melbourne, the bulk supplier is government owned and responsible for the supply and treatment of bulk water with direct supply and distribution to customers controlled by three publicly owned retail companies. Government in cities such as Denpasar, Busan, Geneva and Rio de Janeiro have maintained responsibility for bulk water supply, treatment and distribution. In others, such as Montreal, Harare, Wellington and Dublin, while the government has maintained responsibility for harvesting and regulating water supplies, municipalities have an involvement in the distribution and the sale of water to consumers. In Montreal, the municipal government owns the distribution networks.

2.4 PUBLIC HEALTH ISSUES

A recent history of illnesses caused by poor quality or contaminated water was not an issue in any of the cities that provided the relevant data. However, five cities indicated that over the past five years their communities had been advised to boil their drinking water. Two of these cities, Denpasar and Hanoi, always advise their citizens to boil their drinking water. In Denpasar this is due to the quality of the source water and in Hanoi the treatment is not sufficient to make the water safe for drinking. In the other three cities, Manila's residents are advised to boil their drinking water after heavy rain, Busan's during outbreaks of water borne diseases and Mexico City's as a mechanism to control cholera.

For those cities that provided microbial indicators they typically had >99.9 per cent compliance for *E.Coli* and >98 per cent and often 99.9 per cent compliance for total coliform and plate counts.

In late May 2000 the community of Walkerton in Canada experienced an outbreak of illness that was linked to the municipal water supply. Residents were advised to boil their drinking water from May 21 until December 5, 2000. The overall estimated number of cases of gastroenteritis associated with the outbreak was more than 2300 people, out of 5000.

"Almost one year after a deadly E.coli outbreak claimed seven lives, made thousands ill and turned the lives of Walkerton residents upside down there are signs of both returning normalcy and ongoing trauma in the community.

Nearly six months after the lifting of a seven-month long boil water advisory, many residents still make regular stops at the local Water Distribution Centre to pick up bottled water.

The fact that some residents continue to make use of the distribution centre, while others now place their trust in a new Ultrafiltration system and other improvements to Walketon's water supply, illustrates the varying degrees to which local residents have recovered from what Concerned Walkerton Citizens (CWC) spokesperson Bruce Davidson called "the most disastrous year you could ever imagine."

The CWC formed initially to provide a citizens perspective at the Walkerton Water Inquiry, Davidson said the group has broadened its mandate in response public demand for "advocacy of a variety of concerns."

He said the group is currently working on preparing a position paper opposing moves toward the privatization of water.

"The big concern is accountability. The private sector is very selective about what markets it targets and what resources it expends on any project. Those who can't afford first rate service will be left in peril," said Davidson.

Davidson said the group's other focus will be promotion "best practices legislation," for water in Ontario." The Walkerton Herald-Times, 15.5.2001

The Walkerton incident was fully preventable. A risk management approach such as the Australian Drinking Water Framework would have provided early detection of system failures and, with proper monitoring, should have prevented this incident. In addition, it highlights the need for due diligence at all levels of control within the water distribution supply from the regulator to the water supply management to the technical staff collecting samples for the laboratory.

2.5 WASTEWATER SERVICES

All the participating cities publicly own and manage their wastewater treatment plants. In developing countries this service is not particularly well provided for and in many of these countries, wastewater collection networks connected to wastewater treatment facilities are almost non-existent. Marginal communities tend not to be connected to sewer networks and thus excreta disposal is achieved through some other mechanism, varying

from highly effective on-site sanitation such as septic tanks and leach fields and pit or pour-flush latrines, to inadequate and unhygienic open-air defecation.

The inadequate collection and treatment of wastewater in developing countries is the cause of major environmental pollution, low levels of hygiene and increased health risks. Even when sewer networks are extensive, in over 90 per cent of developing world cities they discharge directly to receiving bodies such as intra-city water courses, or adjacent lakes and oceans. In the most impoverished cities, attenuation of wastewater may be achieved through the establishment of a sewer network, improvement to existing systems to eliminate leaks and blockages, and treatment of effluent by simple and economic techniques such as oxidation lagoons and, where appropriate, surface spreading. Where sewer networks are technically or economically unfeasible, expanded sanitation coverage to city residents through construction of ventilated improved pit latrines or other on-site excreta disposal system is preferable.

Not all cities in affluent countries have adequate wastewater treatment capacity, with some clearly under-equipped. Aging sewer networks, sometimes linked to stormwater drainage systems, may impact on of the capacity of treatment plant. In some cases, sewage is given only primary treatment leaving considerable concentrations of pathogens and nutrients in the effluent, the main cause for environmental and health problems/risks. Priorities for these cities are the upgrading of aged equipment, improvements to treatment by removing nitrogens and phosphates, and the systematic purification of sludges for agricultural use.

2.5.1 Wastewater treatment and disposal

Wastewater disposal plays a major role in public health. Cities must adequately treat their wastewater before discharge to receiving bodies to minimise their potential adverse impact on public health and the environment. City authorities also need to manage their wastewater services efficiently, particularly with regards to cost.

A Metropolis 1996[IV] study found that wastewater treatment was not as well provided as the supply of potable water. This is still the case and the 2001 study highlights the strong disparities between cities in the treatment of wastewater. For various reasons – notably infrastructure costs – wastewater treatment systems in cities in developing countries are poor and provide an inferior service when contrasted with those in the more affluent cities. In many cases, failure to include wastewater treatment systems into sewer networks as they have grown has made retrofitting of plants into dense, highly populated communities extremely expensive and technically challenging.

Three categories of cities emerge from the study: those undertaking poor, moderate or satisfactory treatments of wastewater. This categorisation of cities relates primarily to the volume of the wastewater collected that is treated and the percentage of the population with connections to the sewer network.

2.5.1.1 Cities with poor wastewater treatment facilities

Some cities treat only a small proportion of their collected wastewater. Rio de Janeiro, with a precarious sewer network and insufficient equipment due to lack of investment, treats a minute part of its wastewater, and discharges the rest to the environment, including 30 per cent to the ocean via an outfall sewer at Ipanema.

Casablanca pre-treats half of its effluent before discharging it into the ocean four kilometres offshore. The remaining 50 per cent is discharged, untreated, directly

IV. Metropolis for the People: Seeking solidarity among world citizens – Metropolis'96 Congress, April 1996

into the ocean. In Hanoi, wastewater treatment will improve with completion of two purification plants. In Belo Horizonte, about 85 per cent of properties are connected to the sewer, but only 35 per cent of the collected wastes is given primary treatment.

The lack of wastewater treatment results in little or no production sewage sludge, increasingly referred to by the wastewater industry as biosolids, a by-product of purification. Barcelona, Denver, Hanoi, Harare, Lisbon, Los Angeles, Manila, Melbourne, Paris, Sydney and Toronto indicated the tonnages of sludge used in agriculture. Only five cities indicated that the use of sludges in agriculture is regulated.

In the absence of a comprehensive sewer network, septic tanks and cesspools are used extensively in cities such as Douala and Denpasar. While these are effective in dispersed locations, they cannot substitute for a centralised sewer network connected to wastewater treatment plants in dense urban areas. The cost of such infrastructure is the limiting factor for cities of limited resources.

2.5.1.2 Cities with moderate wastewater treatment facilities

Although Busan, Bangkok, Guangzhou and Mexico City have collection networks and treatment systems, the extent of these need to be improved to increase coverage to include the whole city. The number of households connected to the collective wastewater treatment network in these cities ranges between 50 per cent in Busan to 94 per cent in Mexico City.

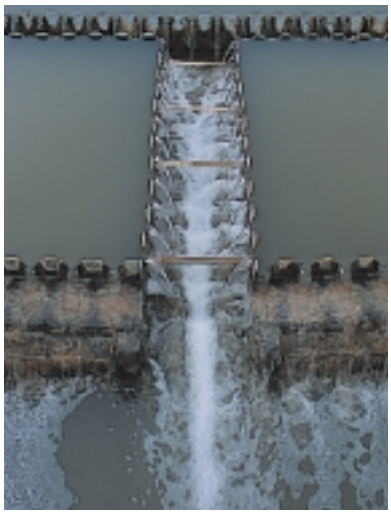
Treatment plants in Busan and Bangkok purify 70 per cent of the total effluent collected by pre-treatment, activated sludge and sand filtration. Guangzhou treats 93 per cent of its industrial wastewater, but only 27 per cent of domestic discharges. It plans to raise this to 70 per cent with the construction of four new purification plants. Mexico City treats only 17 per cent of its collected wastewater by combining biofiltration and activated sludge lagoon treatment. For wastewater not collected, these cities resort to septic tanks.

All cities, except Guangzhou, produce sludges, which are mostly used in agriculture after a short storage period. In Port Elizabeth 97 per cent of biosolids go to brick making. In Berlin, Geneva, Mexico, Montreal and Busan sludges are incinerated. However, there are some concerns over the disposal of sludges in agriculture, particularly with regard to the failure of standard primary and secondary sewage treatment to remove many of the more toxic constituents in wastewaters. A potential alternative to agricultural use or dumping of sludges as waste is the production of biogas as an energy source. Many wastewater plants now have facilities which harness methane gas from sludge plants and biodigestors to create thermal or electrical energy for their own use or for sale.

The priority for cities with moderate wastewater treatment facilities is to extend their wastewater collection networks to provide adequate treatment capacity using low-cost techniques suited to their geographic location. In developing countries agricultural uses of purified sludge, within the framework of a regulatory health system, would provide the best economic and environmental outcome.

2.5.1.3 Cities with satisfactory wastewater treatment facilities

Cities with satisfactory wastewater services are Barcelona, Berlin, Denver, Dublin, Harare, Lisbon, Los Angeles, Melbourne, Montreal, Paris, Port Elizabeth, Sydney, Toronto and Wellington. All these cities have connection rates to the sewer networks of close to 100 per cent. The level of treatment varied in cities, depending upon regulatory requirements. Although a number of the cities have some limited use of septic tanks at the urban fringes. These cities treat the collected effluent and discharge the treated wastewater to rivers or the ocean. Dublin, Barcelona, and the urban areas of Lisbon and Paris indicated an insufficient treatment capacity of between 10 per cent



and 30 per cent. These cities require additional capacity to enable them to control their treatment networks.

2.5.2 Sewer connections

The study highlighted that Bangkok, Denpasar, Douala, Hanoi, Manila, Rio de Janeiro and Casablanca need to make substantial progress in the number of their households connected to the sewer system. With the exception of Casablanca and Rio de Janeiro, the sewer connection rate is low. Denpasar, a city of more than 390,000, has no wastewater collection and treatment system.

The situation has not improved much since the Metropolis 1996 study and uncontrolled discharges to septic tanks, cesspools and the environment are major contributors to pollution. The Metropolis 1996 study mentions the wastewater pollution of the Pasig River in Manila. This was reinforced by another study, which makes the point that in Manila–

> "the main cause of water pollution is the discharge of waste waters into waterways, representing two-thirds of the pollutant load. The second cause of pollution can be attributed to waste waters from industrial activity."[v]

2.5.3 Sludge production and disposal

Biological treatment by the activated sludge process dominates in the vast majority of purification plants. Some cities, such as Denver, Paris and Sydney (in some plants) use a complementary partial tertiary treatment of their effluent by denitrification and phosphorus elimination prior to discharge to the environment. In Denver, this includes chlorination and dechlorination to kill residual pathogens and algae. Harare, Melbourne and Paris – Ile de France, utilise lagoon treatment plants in their rural areas, with Melbourne treating approximately half this way. Montreal is the only city that seems to limit itself to a physico-chemical treatment of its wastewater.

In some cities there are large volumes of sludge produced. Poorly controlled disposal can be a source of environmental pollution. As noted earlier, for these sludges to continue to be used in agriculture some quality issues, notably heavy metal content, must be addressed to overcome the health risk to populations and animals.

In the majority of cases, the thresholds for heavy metal content for sludges are fixed by national regulations.

Figure 3: Average heavy metal contents of sludges (in mg/kg)

TME	MONTREAL	TORONTO	DENVER	GENEVA	SYDNEY	BERLIN	PARIS US	PARIS DS	LISBON	LOS ANGELES	PORT ELIZABETH	MELB W	MELB E
Cd	10		6	2.1	5	1.3	4	8.8	3	-	4	18	19
Cr	108	145	66	12.8	250	35	57.5	123	23	102	2200	763	193
Cu	472	1100	519	288	375	600	487.7	846	66	906	261	744	660
Hg	1	2	2.2		4	2	3.3	6.6	0.7	3.12	0.027	2.4	2
Ni	32	30	31	18.6	125	325	36.6	48.5	15	79.2	85	126	105
Pb	125	75	78	21.5	150	60	473.4	418.1	53	76.1	266	604	228
Se	4	3	3.1		8			3.88		7.51	0.035	0.02	-
Zn	596	2	684	490	700	850	906.8	2218.3	460	1100	1356	1885	1110

TME = Trace metal elements
Paris us = sludge from upstream station - Paris ds = sludge from downstream station
Melb (W) = Sludge from Western Treatment plant
Melb (E) = Sludge from Eastern Treatment Plant

V. Urban planning and development in Metro Manila – Metropolitan Manila Authority and Japan International Cooperation Agency, 1996.

Regulatory controls vary from one country to the next. Sludge is spread and composted in Barcelona, Berlin, Denver, Dublin, and Paris. Sludge releases fewer pollutants to the air and water if incinerated or buried, which is included in the treatment processes in Berlin, Montreal, Paris and Port Elizabeth. Minimum standards for storage times for sludge also contribute to reduced contamination risks. Melbourne mixes digested sludge from its Eastern Treatment Plant with other materials to reduce contaminant levels before use as soil conditioner.

2.5.4 General sewerage improvement

The priority for cities with massive wastewater treatment plants is equipment maintenance and cleaning and upgrading aging sewer networks and treatment plants. More economic alternative treatments such as lagoons can also be investigated depending on climatic and spatial conditions. Barcelona, Dublin and Paris are considering supplementing their treatment capacity. Systematic agricultural development of purified sludges is being researched.

Figure 4: Wastewater treatment systems

CITY	POPULATION	TYPE OF SYSTEM	% - TREATED WASTEWATER
BARCELONA	3,100,000	Active Sludge and physico-chemical treatments	100
BELO HORIZONTE	2,200,000	Primary Treatment	30
BERLIN	3,400,000	Sewerage Treatment Plants Septic Tanks (2%)	98
BUSAN	3,763,000	Gravity Sedimentation, Activated Sludge Treatment & Sand Filtering (53.4%). The balance is discharged directly to the environment untreated.	53.4
CASABLANCA	3,500,000	Sewerage Treatment Plants (untreated sewerage dumped directly to the ocean. Septic tanks (40%)	50
DENPASAR	385,478	Septic Tanks 100%	
DENVER	1,066,000	Return-activate Sludge Treatment (100%), plus tertiary treatment of 50% of wastes	100
DOHA (QATAR)	600,000	Not specified	100
DOUALA	484,870	Septic Tanks & Sumps (99%) Purification Plants (1%)	1
DUBLIN	1,200,000	Activated sludge process Septic Tanks (10%)	90
GENEVA	408,000	Sewerage Treatment Plant	100
HANOI	700,000	Open sludge fields Septic Tanks (10%)	70
HARARE	2,200,000	Primary and Secondary Lagoon Treatment	100
LISBON	517,650	Activated sludge and Tertiary treatment	78
LOS ANGELES	3,800,000	Activated Sludge Treatment Plant	100
MANILA	6,400,000	Activated Sludge Treatment Plant, Aerated Lagoon. (Untreated wastewater discharged direct to environment - 94%)	6
MELBOURNE	3,300,000	Lagoons & Land Treatment Systems (60%) Return Activated Sludge treatment plants (40%)	100
MEXICO	8,300,000	Lagoons, Activated Sludge - 17% (Untreated wastewater discharged direct to environment - 83%)	17
MONTREAL	1,500,000	Removal of solids and phosphates	100
PARIS	10,926,000	Purification Plants (Metro - 100%; Rural 80%), and septic tanks (rural 20%)	80
PORT ELIZABETH	1,250,000	Sewerage Treatment Plants (86%) Septic Tanks (0.5%), Conservancy Tanks (0.5%) & Buckets (13%)	86
RIO DE JANEIRO	1,486,768	Untreated wastewater discharged direct to environment - 100%	0
RIYADH	3,855,758	Activated sludge and Tertiary treatment Septic tanks (65%)	35
SYDNEY	3,995,000	Sewerage Treatment System (Septic Tanks & Pump-Out Systems - 2.5%. Untreated wastewater discharged direct to environment - 0.5%))	97
TORONTO	3,000,000	Secondary treatment plants plus disinfection	98
WELLINGTON	347,000	Sewerage Treatment System. Septic Tanks (1%)	99

3. RESOURCE MANAGEMENT AND SUSTAINABILITY

3.1 WATER SUPPLY SOURCES AND LAND USE IN WATER CATCHMENTS

Drinking water is sourced from surface waters, groundwater and desalinated supply. Surface water sources such as rivers, dams and lakes are the most common source of supply. The majority of the cities have a mix of sources of supply.

Drinking water in seven cities, including Denpasar, Douala, Geneva, Guangzhou, Los Angeles and Wellington, comes from a mix of surface and groundwater, some from deep secure aquifers. Lake Geneva, a natural alpine lake supplies 80 per cent of Geneva's water with the remainder coming from groundwater that is partly artificially recharged with treated river water. Berlin and Hanoi use groundwater for 100 per cent of their water supplies. In Berlin 14 per cent of the groundwater is artificially recharged into the system. Toronto draws all its water from Lake Ontario. Belo Horizonte relies solely on river waters while Los Angeles primarily uses local groundwater that is supplemented by imported surface water from the Eastern Sierra Mountains.

Doha's three desalination plants produce more than 90 per cent of its potable water. This city is in a region of low rainfall with no lakes or rivers. Water for agriculture and a small amount of potable water is taken from underground aquifers.

Two cities, Melbourne and Wellington, have forested surface water catchments that are protected as a source of drinking water. These catchments are claimed to be almost completely free from human impact and supply up to 97 per cent of the cities' drinking water. In Paris-Ile-de-France, national regulations control land use and human activities around water sources.

Ten of the cities reported that the land use within their catchments was mixed with varying amounts of forested and grassland areas, industry, agriculture and residential development. In some such as Barcelona, Harare, Montreal, and Rio de Janeiro these activities are significant.

The reported changes to the source of supply within the next five years focused on harvesting additional resources and improved water treatment capability. Some cities report that they do not envisage any changes over this period.

3.2 SUSTAINABILITY

Questions related to sustainability were not answered clearly in almost half the responses. Where adequate responses were given, it was clear that the cities had good secure supplies of raw water and this was not of concern. Two cities indicated that their supply of water that had been treated could be limited by operational failures such as electricity shortage.

3.2.1 Sustainability and security of supply

A fundamental objective for cities is that they have secure supplies of raw water for their present and predicted populations. A number of cities provided data on current water consumption volumes, together with sustainable yield from their current water supply infrastructure. Respondent cities are on average using 72 per cent their sustainable yield. However, the variation between some of the cities is quite significant. For example Berlin and Lisbon use less than 25 per cent of their sustainable supply, whilst others (such as Los Angeles, Riyadh) use over 90 per cent of their sustainable supply.

Projections of estimated water consumption and sustainable yields in 2020 were also provided. Based on currently planned infrastructure, average water consumption as a percentage of sustainable yield will rise from 72 per cent currently to 85 per cent by 2020. The rise however will not be uniform, with Sydney for example anticipating that its percentage will fall as a result of implementation of planned demand management programs.

Figure 5: Percentage of available supply consumed 1998/99

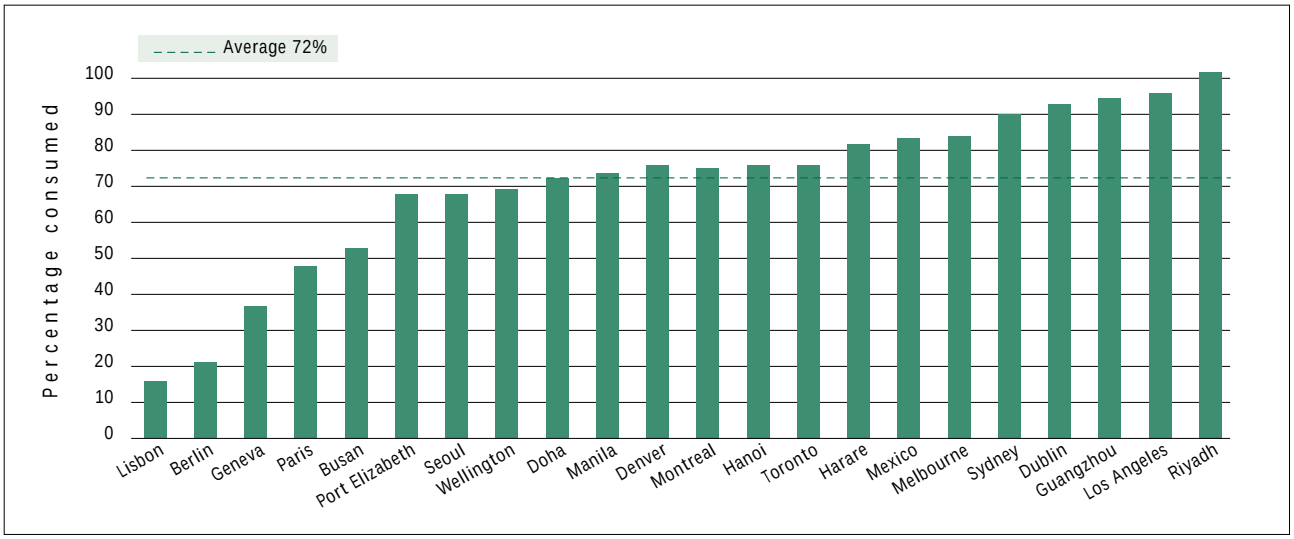
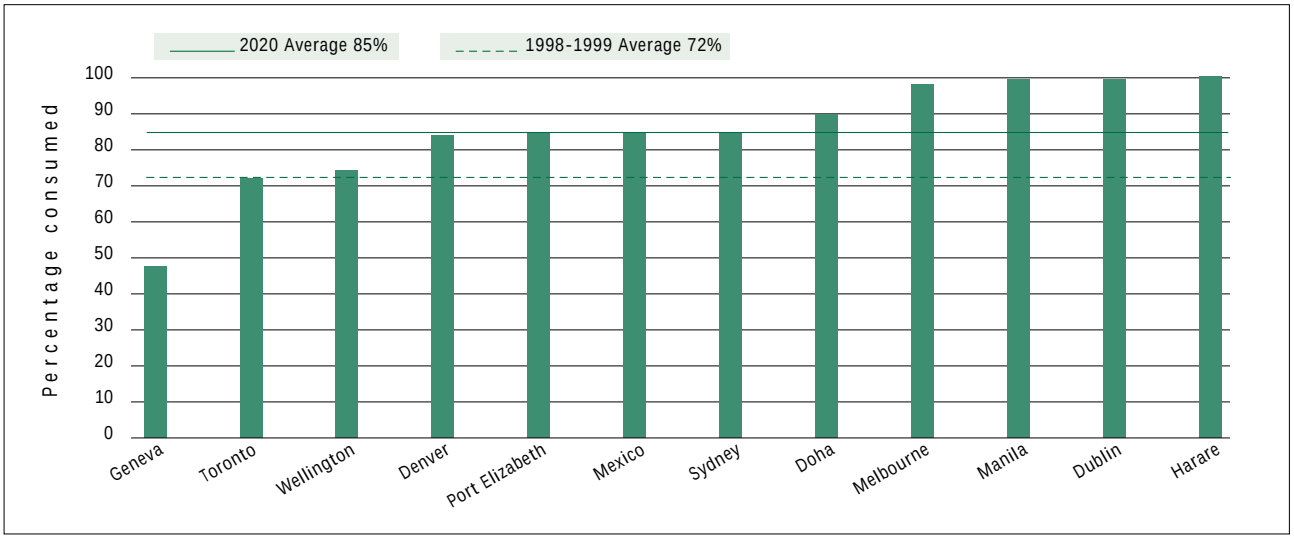


Figure 6: Percentage projected consumption in 2020



Apart from environmental factors such as climate change and drought, population growth and increased per capita water usage are challenging the future sustainability of water supplies for individual cities.

Figure 7: Population changes 1999-2020

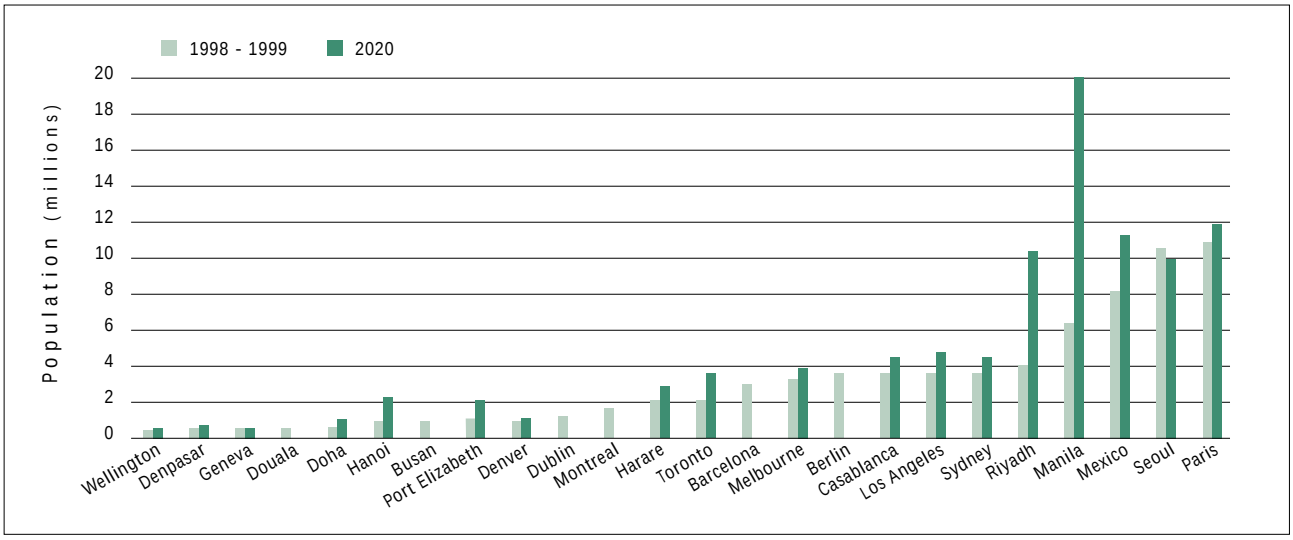
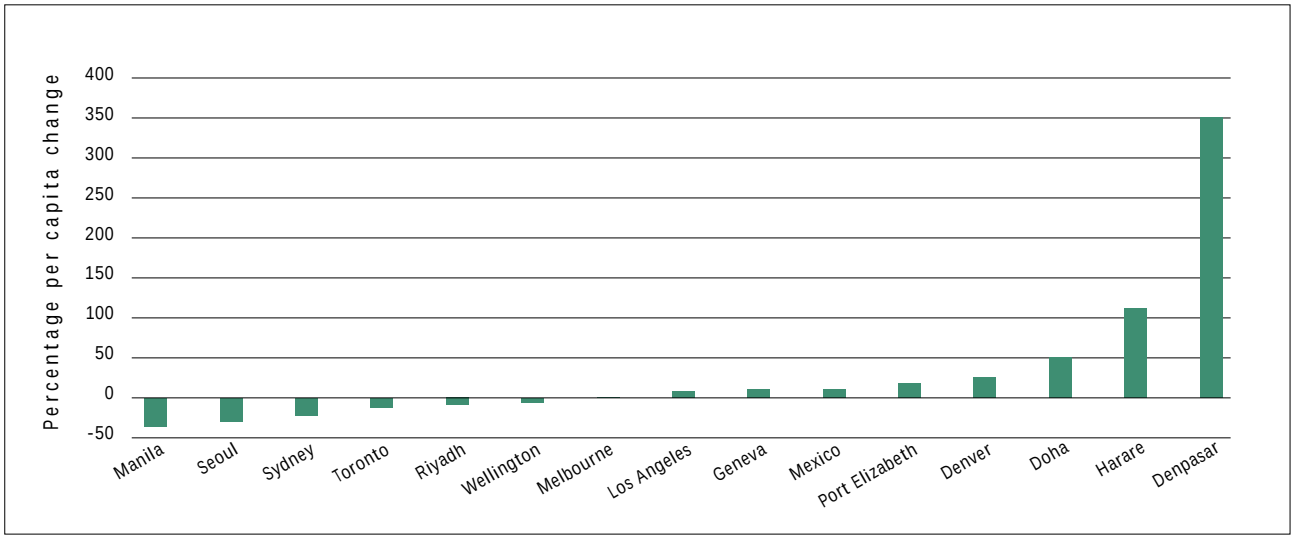


Figure 8: Anticipated change in per capita water consumption by 2020



Manila's expected 38 per cent decrease in per capita water consumption, would appear to be a result of the massive population increase expected in the next 20 years and the inability of the water supply system to keep pace.

Some cities identified issues that would need resolution to maintain sustainability of their water supplies although there was little commonality between the participating cities. Some of the individual issues were:

- restrictions on groundwater use resulting from competing demands from industry and commerce in Denpasar;
- replacing potable water used by irrigators with treated effluent in Doha;
- significant growth in supply to urban and adjacent rural areas in Hanoi;
- high unaccounted-for water losses in Harare;
- rehabilitating pipes and covering reservoirs in Dublin; and
- meeting peak supply demands in Geneva.

3.2.2 Climate change and drought

Little scientific doubt remains that global climate change is occurring, that the earth is becoming warmer and this could have serious impacts on water availability and quality. However, the actual climate change effects and distributions remain uncertain and this is a major impediment to planning.

Reduced rainfall and increasing frequency of drought will exacerbate stresses caused by pollution as well as by the demands of growing populations and economies. Higher rainfall and rainfall intensities will increase erosion and flood risks and their attendant water quality problems. Shifting patterns of agriculture and intensification of irrigation are likely effects in many regions. Long-term climate change may influence the recharge of groundwater supplies. Coastal aquifers could also be affected by being invaded by saline waters from rising seas. Through its effects on vegetation, agriculture, health, and environment, climate change is likely to add to economic and political tensions, particularly in regions that already have scarce water resources.

Some cities that have not been exposed to drought conditions and water shortages in the past may need to commence planning for these conditions. Many measures that respond to climate change are consistent with strategies for ecologically sustainable development and essential whatever actual climate change occurs.

At the time of writing this report a severe long-term drought was affecting Melbourne's water supply and its reserves fell below 50 per cent for a period in 2001. The city has voluntary restrictions in place and due to the effect of its drought response plan will manage the quality and quantity of supplies should the drought continue. The city will need a return to average rainfall conditions and time for its water storages to recover fully. The State Government is developing a Water Resources Strategy to ensure that Melbourne continues to have a safe, reliable, and cost-effective supply of raw water that is environmentally sustainable in the long-term.

Prolonged drought is also affecting Barcelona's water reserves, which are currently at 30 per cent of capacity. While this is causing concern, the conditions are not without precedence as rainfall in the area is highly irregular with most coming at the start of summer and in the autumn. Even without drought conditions, the city has experienced situations when its water resources have been precarious. With a "foreseeable increase in demand, it is absolutely essential to transfer resources from other hydrologic systems in order to ensure supply to the population." Water is likely to be taken from the Ebro Valley although there is a major controversy about this option.

Los Angeles has sufficient water resources but security of supply is determined by rainfall in northern California. Large storage reservoirs throughout the State ensure water supply in drought years. The severe 1987-92 drought prompted Los Angeles to adopt a new ordinance prohibiting wasteful water use and introducing strict conservation measures.

Busan indicated that drought was affecting source water quality through lower flows in catchments and catchment pollution. New dams are required to provide additional reserves.

3.2.3 Water consumption

The average daily per capita water consumption in the cities in the study is 410 litres per day. Consumption is highest in Montreal with a per capita consumption of 1190 litres per day and lowest in Hanoi where the population has a daily allocation of 100 litres. (In some cases there were large discrepancies in the responses to the questionnaire between stated per capita water consumption and the rates calculated from population and volumetric data.)

Figure 9: Per capita daily water consumption

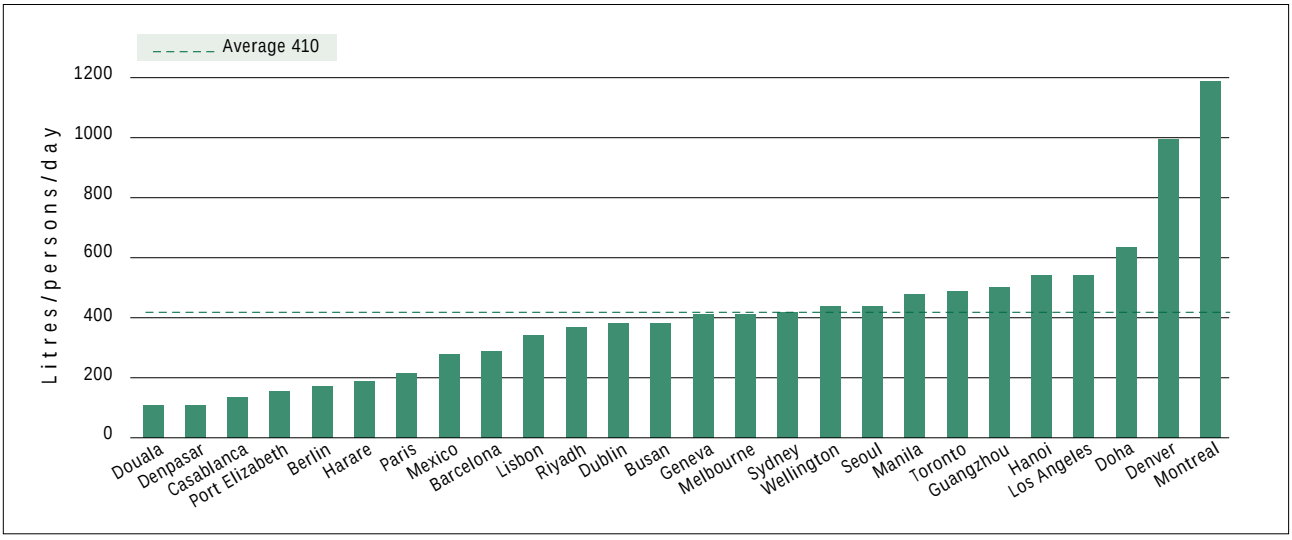
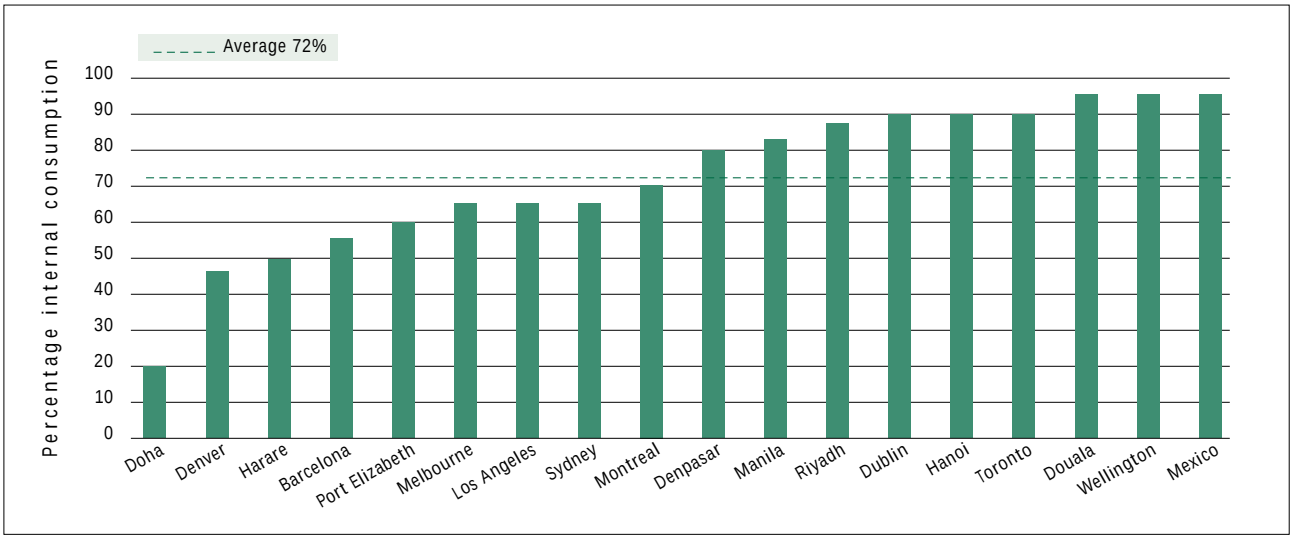


Figure 10: Percentage of water used for internal residential consumption



The use of water varied considerably between indoor and outdoor use. Overall average indoor use accounted for 72 per cent and outdoor use 38 per cent. Usage was evenly balanced between indoor and outdoor use in Melbourne, Barcelona, Denver and Harare. In the other cities it was mostly internally, the exception being Doha where 80 per cent of water use is primarily for external purposes.

The form of urban development affects the opportunities for a reduction in water consumption and increased water reuse. In Sydney, primarily a sprawling low-density city, about 66 per cent of metered water use is for households with almost one quarter of this for gardening, which is equal to the amount used for showers.

The consumption of metered water within cities with good rainfall could be reduced if rainwater was harvested from roofs and systems to recycle the water used in laundries, baths and showers were introduced. One of the biggest single uses has historically been for toilet flushing, many toilets using around 25 litres or more per flush. Switching to ultra-low flush (ULFT) models with a 5-6 litre tank can yield major savings. Alternatively or additionally, wastewater could be treated to a higher effluent standard, enabling reuse for non-potable purposes, assuming a dual carrier distribution system could be constructed. The latter option is already implemented in Israel, which has a national dual carrier system and in United States cities like Denver, ULFT refitting has been aggressively pursued as a key demand management option.

Although small-scale water harvesting and recycling 'greywater' as alternative sources of supply is on the water policy agenda among those in the industry, Busan was the only city in the study that indicated this was included in their plans for new water resources. However, recently it was announced that a new suburb in Melbourne would include water reuse systems.

A new suburb is to be developed at Epping North on Melbourne's urban fringe. The suburb will be developed over a 15-year period and will have approximately 8000 new homes accommodating 25,000 people.

With limited existing capacity to accommodate sewage from this new outer suburb, a large local sewerage plant will be built to treat sewerage from the development. The limited capacity of the existing sewerage system will be used for sludge disposal.

Water captured through the treatment process will be recycled through the new suburb in a secondary water reticulation system. Providing water for toilet flushing and garden watering, it is anticipated that water demand from the new suburb could be reduced by 40 per cent.

The initiative is cost neutral in comparison to traditional approaches to funding of total water cycle infrastructure.

Source: Urban and Regional Land Corporation, Victoria, Australia

3.2.4 Water losses

Water that is delivered to the distribution network but not registered on a meter as having been used is defined as unaccounted for. All cities have some degree of water loss from their system although the volume of unaccounted-for-water varies considerably. Reasons for cities having unaccounted-for-water include pipe leakages, under-registering of meters, hydrant flushing, illegal connections and fire fighting.

Most cities have between 15 and 30 per cent of unaccounted-for-water, with some unable to account for more than half their water. Manila loses 59 per cent of its treated water, Hanoi 55 per cent and Harare 37 per cent. These cities all have comprehensive strategies in place to reduce these losses. These include detecting illegal connections to the system in Manila and Harare where there are heavy penalties for illegal connections. Hanoi and Manila are introducing district-metering zones to help detect the location of water losses. In some cities the loss is more likely due to undetected pipe failures whereas in highly metered systems, losses are more likely related to water theft.

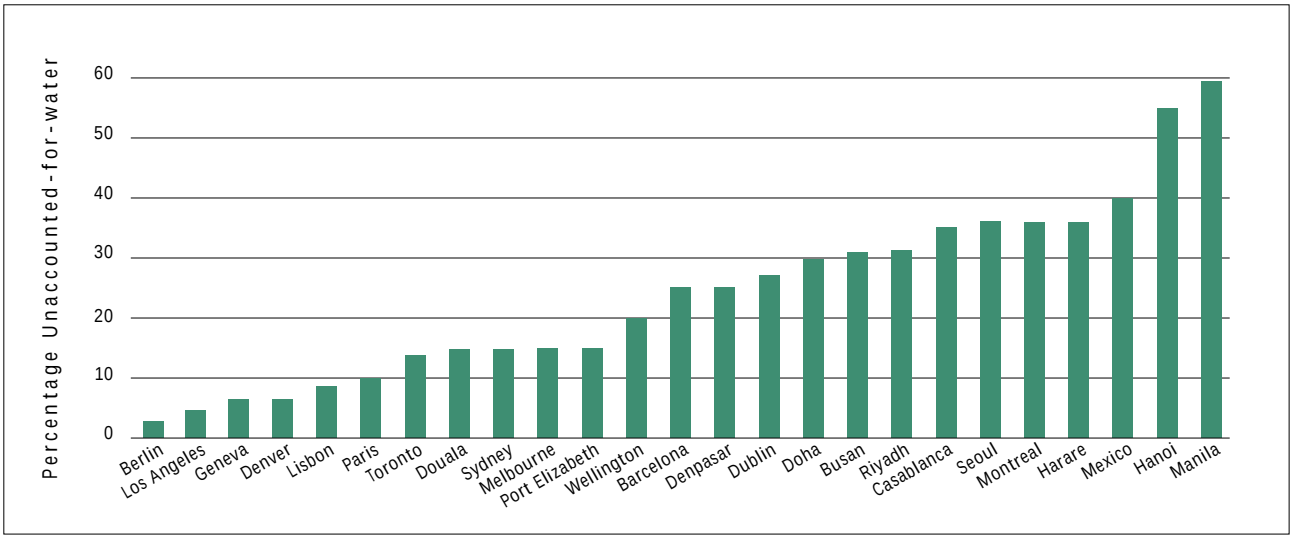
Dublin has been actively addressing its water losses. When the city introduced a £37 million *Water Conservation Strategy* to tackle this problem, 42 per cent of its water was unaccounted for. This loss has been reduced to 28 per cent and is still falling. Berlin, with just three per cent water loss, is the best performing city and it considers that this loss is too low to warrant strategies to combat it. However, Denver with an average loss of just six per cent between 1993 and 1999 has a range of strategies to reduce this, including an incentive program for its field representatives to discover illegal connections. Geneva also has six per cent of its bulk water unaccounted for. The city follows the minimum flow rate at night and has regular campaigns to detect leaks for repair.

3.2.5 Competition for supply

Few of the cities in the study are confronted by competing demands for water internally or externally. For more than 80 per cent of the cities, the source of their water was solely under their discretion. However, three cities indicated they face external competition for their water.

- Harare expects to face more competition for supply with further growth and development.
- Manila gets only about a third of the water it desires because of the need to share the resource with power generation, irrigation and water for other municipalities. This is being partly addressed by the construction of a new dam.
- Busan shares its water with other cities and will require new water resources.

Figure 11: Unaccounted-for-water



Harare and Manila are also experiencing competition for their water from industry and agriculture. Government is involved in managing these demands and in both cities town water is given priority.

The need to maintain environmental flows in rivers for their health and ecology does not appear to be a major issue especially for developing cities. The study shows that this is very patchy and mainly confined to relatively affluent and democratic countries. Many large cities in the world appear to not place high priority on the need to maintain environmental flows in streams and rivers.

Denver, Los Angeles, Melbourne and Wellington were the only cities that indicated that the need for environmental flows was a consideration.

> "Litigation equating environmental uses of water with urban uses has brought awareness of the need to incorporate environmental considerations into water resource management." (Los Angeles questionnaire response)

Over the last decade, Los Angeles fought and lost a major battle against environmentalists seeking to cease its legal diversion of water from tributaries to the Mono Lake basin into its aqueduct bringing water from the Owens River Valley. Environmentalists successfully persuaded the California Supreme Court to enact the public trust doctrine to restore flows to the ecologically valuable saline lake that is a critical habitat for migrating water birds on the route to and from South America and a water body of outstanding natural beauty. As a consequence, Los Angeles has had to invest aggressively in water conservation as well as seeking alternative sources of supply to meet its long-term needs.

Wellington was the only city that indicated it has a restriction on the maximum amount of water that it can take for public water supply. This is regulated under the Regional Council's *Fresh Water Plan.*

3.2.6 Conservation measures and water restrictions

More than three-quarters of the cities have regular educational water conservation campaigns in place. The approaches to these campaigns included school education kits, newspaper, radio and TV advertisements and information supplied with invoices.

Denver's water conservation program, from the data provided, appears to be particularly comprehensive. It includes a schools program, sonic leak detection, promoting drought resistant plant species, ultra low-volume toilet rebate program, mass media advertising, commercial and industry audit and incentive programs, a parks computerised irrigation system, a conservation hotline, family and low-income audit and retrofit programs, and an irrigation efficiency program. The need for aggressive conservation was in large part a consequence of the failure of the City to secure permission from the federal government to build the controversial Twin Forks dam, which would have inundated one of Colorado's most pristine trout rivers. Environmentalists successfully persuaded authorities that the city did not need additional supplies but instead could meet future supplies from demand management.

Los Angeles severe drought between 1987-1992 forced the city authorities and its residents to acknowledge the need to conserve water. Following the drought in the city, a plumbing retrofit was mandated requiring water conservation devices in all properties and water-efficient landscaping for all new buildings. Low-flow showerheads and ultra-low-flush toilets must now be installed in all buildings prior to resale. The city also has programs to help organisations such as golf courses and some industrial users to use recycled water where possible. Other programs include educational programs for the public and schools and bans on daytime garden watering.

Four cities indicated they did not have regular water conservation campaigns but for vastly different reasons. Berlin indi-

cated it does not need to as it has plentiful water and had already achieved a 40 per cent reduction in water use over the past 10 years through reduced industrial use and the lower amount of water used in modern washing machines. Doha and Busan simply restrict supply to conserve water. Douala introduces fees for water from public water-hydrants.

Drought is acknowledged as a potential for 12 cities. The general response to coping with this was to introduce initial voluntary restrictions followed by compulsory restrictions, most often only on external water use. Interestingly though, no city appears to directly use pricing to help control water use. For those cities that can be affected by drought eight indicated that the trigger point for introducing compulsory restrictions related to their reserves of water storages whether this be in terms of days of supply or percentage of capacity. For example Dublin uses 120 days of supply, Barcelona three months supply and Melbourne approximately 50 per cent of storage capacity, depending on the month of the year.

Mexico City, which has had irregular water conservation campaigns, does not restrict water under normal conditions but in some districts residents are only able to rely on water supplies on some days of the week.

3.3 RECYCLING OF WASTEWATER[2]

While the majority of cities in the study have no plans to increase their use of treated wastewater over the next

Figure 12: Reuse of treated wastewater

CITIES	POTABLE REUSE		NON POTABLE REUSE			
	PLANNED INDIRECT POTABLE REUSE	UNPLANNE INDIRECT POTABLE REUSE	AGRICULTURE	RECREATIONAL	INDUSTRY	URBAN
HARARE	(1)		(2)			
LOS ANGELES		(3)				
BUSAN						(4)
ISRAEL						
RIYADH					(7)	
DOHA						
BARCELONA			(6)			
MELBOURNE		(5)				
SYDNEY						
MEXICO						
PORT ELIZABETH						
LISBON					(9)	
TORONTO						
MONTREAL						
PARIS			(8)			

(1) and (2): around 40 per cent of the treated wastewater.
(3): 18 per cent of the treated wastewater especially for agricultural and recreational purposes.
(4): Recycling loops in several buildings for flushing and cleaning.
(5): Less than 0.25 per cent.
(6): Volume is between 2 per cent and 80 per cent.
(7): Cooling purpose
(8): Sewage farming uses nearly 4 per cent of the Paris's untreated wastewater effluent.
(9): Primarily recycling loops in the sewage plants for cleaning and watering.

2 In this report the terms 'recycling' and 'reuse' are interchangeable.

five to ten years water recycling, especially for non-potable purposes is on the agenda of many cities around the world. It is becoming as important as controlling leakage and demand management and integral to conservation strategies and the development of new resources as a means of balancing water supply with demand.

3.3.1 Current reuse of treated wastewater for potable purposes

None of the cities in the study directly exploits treated wastewater for potable use. It seems that Windhoek, Namibia is the only city in the world that does and there are no reports that this is harmful to human health. Some countries, such as the United States of America, the United Kingdom and South Africa have included some indirect treated wastewater into their water supply systems. It may be that cities are reluctant to increase their use of treated wastewater as both direct and indirect sources of supply due to sanitary considerations and consumers negative perceptions.

Among the 15 cities that claim they use treated wastewater, Los Angeles and Melbourne indicate they have extremely small, indirect inputs of wastewater into their raw water sources. In Melbourne, this comes from treated effluent that is discharged to surface waters and in Los Angeles into the surface aquifer. The amounts are insignificant. In Melbourne it is estimated to be less than 0.25 per cent and not more than 2.5 per cent in Los Angeles.

Planned indirect potable reuse is included in Harere's water supply. Wastewater is discharged into the river that feeds into the water reservoirs for treatment. The city estimated that this forms less than 5 per cent of its supply.

Geneva, which discharges its treated wastewater into the Rhone River, makes the important point that the river is the source of raw water for downstream cities and that as the river flows to the Mediterranean, water from the Rhone is used many times. Multitudes of cities worldwide are in the situation of indirectly using wastewater that is discharged into rivers that then supply raw water for downstream cities.

Barcelona, Harare, Los Angeles, Melbourne, Montreal, Sydney and Tel Aviv use treated effluent for agricultural and industrial purposes. For most cities this is on a small scale, except in Tel Aviv where 66 per cent of its treated wastewater is used for agricultural purposes and Harare with 40 per cent. Los Angeles uses 50 million megalitres annually for agricultural, industrial and recreation activities. This accounts for 18 per cent of its wastewater. Port Elizabeth reuses five per cent of its wastewater. In the USA, there are several thousand water recycling schemes. Worldwide, recycling is practiced in Australia, Belgium, Canada, France, Hong Kong, Israel, Japan, Jordan, Latin America, Netherlands, Saudi Arabia, South Africa, and Spain.[VI]

The Chelmer Augmentation Wastewater Reuse Scheme

A combination of circumstances championed effective wastewater re-use for human consumption in the county of Essex, in the south-east of England: 1) limited water resources, 2) the droughts of 1990 and 1996 in one of the drier regions of England, and 3) population growth due largely to the proximity to Greater London. The 1.7 million population's daily demand of 410,000m^3 is met by local sources (the Chelmer, Blackwater and Stour rivers) and by water

VI. www.environment-agency.gov.uk/modules.

imported from other counties. It is project to rise to 480,000m^3 by 2025.

To meet the short-term demand, and with the support of the National Rivers Authority and the Environment Agency, Essex and Suffolk Water (ESW) has diverted 30,000m^3 daily of purified wastewater from the Chelmsford treatment plant to the Chelmer River which feeds into the Hanningfield reservoir used for potable water. Recycling was undertaken in two stages:

Stage 1, transitory (July 97-December 98), during which the diverted wastewater underwent UV treatment before being pumped into the waters of the Chelmer River. At the end of this period, no measurable deterioration in the quality of drinking water or of that of the ecosystems was detected.

Stage 2 was approved in June 2000 for a 10 years period. The technical solution adopted differs from the first stage in so far as the wastewater extracted from the treatment plant undergoes a tertiary processing (reducing nitrates and phosphates) before being pumped upstream into the Chelmer River before it runs into the Hanningfield reservoir. In normal climatic conditions, recycling of wastewater will be undertaken during April to October, but could extend all the year round during drought.

The success of the project is largely due to extensive studies carried out in the four years before the introduction of Stage 1, on the quality of wastewater as well as medium and possible long-term effects on human health. The project was also very instructive in understanding people's perceptions and how to deal with public opposition in other similar projects.

Source: Colloque Catchwater de Noirmoutier, France. Workshops Proceedings, September 2001)

3.3.2 Future recycling of water for potable and non-potable uses

It is difficult to predict the future of treated wastewater reuse for potable supplies. Technological developments in the recycling of wastewater, or other concerns that might trigger a more urgent consideration of wastewater as a source of supply, are unknown at this point. However, there is evidence to suggest that the costs of recycling and desalination are becoming less than the cost of transporting pure water over long distances.[VII] It is also interesting to note that the cost of producing drinking quality water from treated wastewater using reverse osmosis technology is usually less expensive than desalinating seawater with the same systems, although clearly, public perception and acceptance of the final product may differ markedly.

Port Elizabeth currently reuses five per cent of its wastewater for non-potable purposes and hopes that this will rise to 40 per cent by 2010. The city expects that by 2020 about 30 per cent of its potable supply will be recycled water.

Reusing water for other than potable supplies is on the agenda in a number of cities. Denver, which apparently uses very little of its treated wastewater, is in the final

VII. Les enjeux internationaux de l'eau volume 3, June 1999. Ministry of International Relations, Quebec, Canada.

design phase of a system to use two to five per cent of its treated wastewater for non-potable supplies. Mexico City will develop a system to treat its wastewater to a level suitable for industrial use and for refilling depleted aquifers.

Busan intends to introduce regulations to ensure more buildings are constructed with systems to capture and recycle the building's 'grey water'.

Los Angeles foresees reusing more than a third of its wastewater for purposes other than human consumption by 2020 while Melbourne is aiming to reuse 20 per cent of its wastewater by this date.

> "Development of new water resources over the next five years will include increased use of reclaimed water and greater conservation efforts. The Department of Water and Power plans to use recycled water to recharge the groundwater basin and is also examining the potential to increase the use of stormwater for the same purpose. All groundwater extracted for distribution must meet State drinking water requirements prior to entering the distribution system." (Los Angeles)

A number of other cities in the study also indicated they were considering using treated effluent to recharge their groundwater acquifers.

The Dan Project: an example of successful integrated water management

Dan is the largest Israeli wastewater purification plant. It treats and recycles 330,000m3 of wastewater daily, generated by eight agglomerations with a total population around two million, and includes the Tel Aviv-Jaffa region. Operational since 1989, the project required an investment of 227 million Euros for treatment and distribution costs of 0.12 and 0.4 €/m^3 respectively.

Following traditional techniques of activated sludge, nitrification, denitrification and transfer to purification basins, water is sent into four filtration sites from which they are returned to the coastal ground watertable (Soil Aquifer Treatment, SAT). The advantage of this system is that water percolates slowly through sand, supporting adsorption, biological degradation of nutrients and the exchanges of ions. Waters remain an average of two months in the ground before being pumped and transported by pipeline to the Negev desert, 87km south of Tel Aviv, and stored in six reservoirs with a total capacity of 510,000m^3 before being used for irrigation (15,000 ha). The combined treatment plant and SAT processes eliminate over 99 per cent of suspended matter, biological oxygen demand, and chemical oxygen demand, and achieves nitrogen and phosphorus abatement rates of 83 per cent and 99.7 per cent respectively. Concentrations of faecal coliforms and streptocoques in recycled wastewater meet prescribed Israeli regulatory standards of less than 10 faecal coliforms per 100ml for unrestricted use in irrigation. Importantly, it has been demonstrated that chlorine levels in the water used for irrigation do not have any negative impact on vegetation.

Although the largest, Dan is only one of a number of projects reusing wastewater for irrigation.

Source: Colloque Catchwater de Noirmoutier, France. Workshops Proceedings, September 2001)

3.3.3 Drivers and barriers to reusing wastewater

Reuse has a place in countries where water resources are scarce. Some countries in Africa, the Middle East and Asia do have recycling processes in place and some cities in Australia, South Africa and the USA foresee the development, or increase, of reuse in the longer term. A number of water providers in the USA have extensive wastewater reuse systems such as the City of Irvine and the Orange County Water District, both close neighbours of Los Angeles. Israel has a nationwide system of wastewater reuse and a second reticulation system to distribute it to users. Mexico City's proposed use of recycled water is being driven by raw water shortages.

The low volumes of wastewater being reused and the number of cities actively reusing their wastewater can, in part, be explained by the absence of financial incentives for these projects. Los Angeles and Port Elizabeth are exceptions to this.

Los Angeles offers a 20 per cent discount for long-term contracts to supply reclaimed water for irrigation. Not only are the lower water bills a financial incentive but also customers taking advantage of the discounts are assured supply under drought conditions. Port Elizabeth also charges less for recycled water for industrial users and irrigation although the level of the discount was not provided.

Berlin, Douala, Manila, Sydney, Toronto and Wellington indicated that they have abundant raw water resources and they had no need to look to reuse for additional supply.

Treating wastewater to meet the water quality standards required for a potable supply is problematic and not only because of the costs of the additional infrastructure involved. A major barrier is the community's perceived health risk associated with the use of treated wastewater.

Developments in purification technology will enhance the possibility of reuse. However, more would be achieved with improved public awareness and education about wastewater reuse.

3.4 DISTRIBUTION AND WATER SUPPLY INFRASTRUCTURE

As would be expected, the large majority of cities use pipes, with some using open aqueducts and pipes, to transfer their bulk water for distribution. Cast iron and ductile iron is the most common pipe type and is used in more than 50 per cent of cities. Asbestos cement pipes are extensively used by Mexico City, with 98 per cent of its pipe network of this type and Port Elizabeth with 70 per cent. Harare, Doha and Denpasar indicate they have been using asbestos cement in the past five years. Poly vinyl chloride and polyethylene plastic piping are used relatively little, except in Douala and Hanoi.

Transferring water over long distances, some up to 150 kilometres are quite common. Mexico City, which already sources some of its water 120 kilometres from the city, is planning for new supplies that are about 150 kms from the city, although transporting water this distance is acknowledged as a troublesome proposition.

Maintenance of the distribution network in a number of cities, notably those in the developing countries, relies on replacing pipes only after they have failed

with little or no preventative actions taken. Other cities use surveys to detect problems. A common concern is lack of funding for preventative maintenance as experienced by Port Elizabeth, Denpasar and Harare.

Mexico City has no current asset or network maintenance program at all, although it recognises the need for one. Manila is constrained in developing a comprehensive maintenance program by inaccurate maps, old assets, damage by third parties, poor quality of materials and ground movement.

Some of the cities in the more industrialised countries have sophisticated maintenance programs in place that mix preventative and replacement programs to ensure good service to their customers. These asset maintenance systems are based on good knowledge of the assets and real time information management systems. Other cities, such as Doha and Manila, indicated that they are planning to introduce such systems over the next 10 years.

Denver's use of technology provides insights into the city's long-term replacement responsibilities by looking at them based on the quantities and dates that the assets were installed, their estimated life expectancy and decay patterns, and current unit cost replacements. Over the past 10 years Melbourne's maintenance program has progressed from focusing on asset management to considering performance of the system with customer service requirements to prioritise a mains replacement program.

The major advantages of a systematic, informed routine maintenance program are many. Perhaps the most important are that budget can be identified and allocated, disruptions to supply are minimised and a works program can be clearly defined. Many cities around the world are developing computerised GIS databases of pipelines and models that can help determine critical areas for replacement and upgrading based on past failure history, age and physical characteristics, and other such critical attributes.

Target water pressures varied widely across the cities, from 3m in Hanoi to 50m in Geneva. Generally water pressure is maintained between 15m and 25m. Issues mentioned in maintaining pressure and flow include controlling water main bursts and power failures. Most technical development involved increased GIS and SCADA (System Control and Data Acquisition) technology to isolate and deal with faults.

The majority of cities regard having two or more sources within the distribution system for their water supplies as critical to minimise interruptions and maintaining supply. Average response times to restore supplies following disruption were, for most cities, between one and eight hours.

Most cities indicated that, over the past 10 years, residents had demonstrated an increased level of awareness and desire for information when water supplies are disrupted. The most frequently cited problem in maintaining supply was the lack of funds to replace systems and to update equipment.

3.5 RISK MANAGEMENT

Most cities perceived risks to their water supplies as localised. Events such as earthquakes, major contamination of supplies, power failure, a reduction in catchment areas and power failure were all seen as risks. The majority of cities reported that they have emergency response plans in place or are part of a state emergency plan.

For Paris, the risk of a major, catastrophic flooding as was experienced in 1910 is perceived as a major threat. A study is underway to enable the development of a plan for the use of bores in the Albien watertable to provide a secure supply.

Doha and Riyadh, who depend largely on desalinated water, are able to divert supply from one zone to another, in the event of failure in one of the desalination plants. Similarly, interconnected supply systems are used in Geneva and Toronto.

For Manila, preventing dams overflowing after heavy rains and flooding downstream municipalities is a major concern. Before floodwaters are released, an emergency action plan is implemented by the water authority in consultation with the local governments.

4. EMERGING ISSUES

Water business management and water pricing

The survey data strongly suggests that many cities have only vague estimates of how much water they harvest, where it is used and how much it costs to harvest, treat and distribute. The management and planning limitations this imposes on water utilities must cripple their ability to plan and develop effectively, to implement cost-related and equitable tariffs and Community Service Obligations or to know their environmental impact.

Demand management

The survey results also indicated that work to manage demand is still relatively weak. Although an unselective demand management tool, water pricing is rarely related to scarcity among all the member cities and few cities reported efforts at improving water use efficiency or reducing system leakage or other losses. Augmentation remains the strategy of choice.

Reuse

There is a limit to the volume of water that can be gained through increased efficiencies and the supply of good quality drinking water is likely to become a major issue for many cities over the next 10-20 years. However, very few cities appear to be seriously considering treated wastewater reuse as a viable option as a source of additional supply. Issues that will need consideration include the cost-effectiveness now, and in the future, of using treated wastewater, the community's perception and acceptance of reuse for potable water supplies, and public health issues.

Ecological sustainability

There is a need to ensure adequate environmental flows for ecology as well as downstream users. This was not mentioned by most cities. The survey data indicates that economic and institutional reforms in the water industry are taking place to some extent in most member cities but appear to be largely determined by political history and political/economic influences. Natural resource management considerations and the aims of ecological sustainability still do not appear to be driving change to any significant extent, especially in developing countries.

Treatment and disposal of wastewater

In many cities untreated sewage continues to be discharged to the environment polluting receiving river and ocean waters and presenting considerable health risks to human populations. Where this is occurring there is a need for the sustainable treatment and disposal of wastewater. Due to costs, this is not achievable in a number of countries. However, this raises some fundamental sanitary and hygiene issues that should be addressed by international organisations such as the World Health Organisation and the World Bank.

Privatisation

In line with many industiries (e.g. transport, medical care, airlines, electricity) there is a global trend for privatising the water supply and wastewater industries. So far benefits appear to be increased economic efficiency. However, close government scrutiny and appropriate legislation will be needed to continue to maintain service standards, infrastructure, public confidence, adequate treatment of wastewater and the quality and quantity of water delivered.

5. CITY SNAPSHOTS

BARCELONA

Background

Barcelona's population exceeds 3 million. The Ter and the Llobregat Rivers provide about 90 per cent of the city's water, with the rest coming from underground aquifers. About 1,300,000 properties are connected to the water supply system that provides 320 million litres annually. The average daily consumption is 300 litres per person.

The Ter River catchment area is forested and sparsely populated, and its waters require only conventional physico-chemical treatment. However, the Llobregat River flows through highly industrialised and densely populated areas and its waters need an intensive treatment process. Three plants treat the city's water.

Resource management and regulatory control

The management of water resources in Barcelona is the responsibility of a regional government instrumentality. Water resources are owned by the government and are managed by public companies, leaving the distribution network to local government through private enterprise. Licenses are required to extract water.

Protection and control of the water supply is guaranteed through Regional Acts and a Metropolitan Order regulates the cost of domestic water.

The Spanish Ministry of Health is responsible for regulation and establishing water quality standards. Monitoring is carried out through licensed companies employed by the local councils of EMSHTR. The EMSHTR is also responsible for managing the wastewater collection and treatment systems on behalf of the Catalan Water Board.

Political and economic issues

Following reforms between 1988 and 1990, the regional government has the responsibility for the water supply system, which includes harvesting, treatment and distribution to the municipal networks. Licensed private companies distribute water. No further reforms are envisaged at this stage.

High-level infrastructure investments are shared on a 50/50 basis between the regional government and a publicly owned distribution company. Both companies finance investments through levies and tariffs collected directly from users. Investment and operation of low-level infrastructure (reticulation to end-users) are financed through charges made by each licensed company and approved by the EMSHTR. Users receive no reports on the annual financial status of their supply company.

Sustainability issues

A prolonged drought has reduced the city's reservoirs storage to 30 per cent of capacity. This, and a projected increase in demand, has forced authorities to urgently identify additional water sources, and a controversial plan is being considered to transfer water from the Ebro Valley into the Llobregat River.

Drought mitigation measures are imposed when reserves cannot meet three months demand. These include reducing water pressure, limiting the use of fountains and the watering of gardens, some restrictions on industrial and commercial uses, and domestic limitations. To encourage efficient and wise water use, tariffs are based on a sliding scale that penalises high water consumption.

Recycling of wastewater is not considered a viable alternative because of the necessary infrastructure and treatment costs and community perceptions of the quality of treated wastewaters.

Infrastructure

Cast iron pipes are used to transfer waters from source to the distribution networks. The water distribution system is divided into pressure compartments that ensure adequate pressure to every household regardless of its location.

Wastewater treatment

All hospitals in the metropolitan area, and almost 100 per cent of households and industries, are connected to the sewerage system. A negligible number of households rely on septic tanks. Presently, 70 per cent of wastewater is treated before being discharged to the environment. It is envisaged that in the next two years all of the wastewater from the metropolitan area will be treated.

Wastewater is treated using a conventional biological process (activated sludge) and physico-chemical treatment. Tertiary treatment is planned for the future. A public corporation established under the auspices of the municipal councils owns the treatment plants. The 75,000 tonnes of sludge produced annually is used in agriculture, compost, and regeneration of forests and quarries.

BELO HORIZONTE

Background

Belo Horizonte is the capital of Minas Gerais, Brazil, and has a population of 2.2 million. Over 99 per cent of its inhabitants are connected to town water, and they consume 116,600 megalitres of water annually. The Velhas, Serra, Azul and Manso rivers meet most of the city's demand for water.

The city is in the process of implementing an *Urban Drainage Guide Plan.* This is based on an exhaustive study of the city's infrastructure, land use activities in urban margins, flooding and soil erosion around watercourses, and water pollution, to assist in developing an integrated drainage system. The plan will be implemented over four years. It will introduce improved water and wastewater management techniques and will be assisted by GIS and hydraulic modelling in a bid to control water flows and improve monitoring of water quality.

Ownership and regulatory control

Water resources are owned by the state. The Minas Gerais Sanitation Company, through a city concession, is responsible for construction and maintenance of the drinking water distribution network and sewerage system. The Belo Horizonte City Hall is responsible for drainage. The introduction of the *Urban Drainage Guide Plan* will integrate the sanitation and drainage systems under the control of the city.

Funding of water, drainage and sanitation projects is the responsibility of the municipality. Traditionally, the federal government provided funding for major works of national interest. But with the decrease in federal funding the city is burdened with financial responsibility for developing and maintaining a flood prevention sys-

tem and is having difficulties in meeting the high cost of new projects.

The state run concessionary determines the tariff structure. Water charges are based on volumetric consumption.

Catchment management and water quality

The Velhas River basin has an area of 29,173km^2 and a population close to four million. The catchment, rich with mineral resources and an important economic activity centre in the state, is affected by extensive mining, industrial and urban activities. Water quality in the river is further degraded by silting as a result of clear felling, and discharges of raw sewage from metropolitan Belo Horizonte.

All waters undergo comprehensive treatment before distribution. The state run concessionary and the municipality are responsible for monitoring water quality and regularly test water samples against federal government standards.

Wastewater treatment and recycling

In line with Brazilian practice, the municipality is responsible for collection and treatment of sewage. About 85 per cent of the properties are connected to the sewer, but only 35 per cent of the collected wastewater go through primary treatment before final discharge. Secondary treatment will be introduced in 2002.

Water is not recycled, and there are no plans to introduce reuse of wastewaters.

BERLIN

Background

Berlin has a population of 3.4 million. The city has abundant groundwater resources that meet its demand for water. Consumption figures over a ten-year period indicate a downward trend of about 40 per cent, largely attributed to a drop in industrial use and the lower water requirements of modern washing machines.

Because of the abundance of water resources and reduced consumption there are no programs or education campaigns to manage demand. In fact, water charges do not differentiate between residential, industrial or business uses. A flat rate of 3.5 DM per cubic metre applies.

Ownership and regulatory control

Under the *Berlin Water Act* the community owns the water resources and the Government of Berlin administers water rights. Until 1999 the Berlin Government owned the Berliner Wasser Betriebe (BWB), a public company which harvests, treats and distributes water. BWB is now in joint public/private sector ownership, with a majority government ownership of 50.1 per cent. It is expected that privatisation of the water supply system will continue, with a reduction in the number of water treatment plants. The government is responsible for the legislative and regulatory environment

Catchment management and water quality

The water catchment area has forest, grassland, and rural uses as well as urban residential and industrial activities. The city's water comes from four aquifers under Berlin. Wells into these supply 11 water treatment plants. Four protection zones with defined restrictions on the type of development around the wells

are in place. The water does not require chlorination but undergoes simple treatment, aeration and fast filtration.

The 1990 state department regulations set out the health criteria for drinking water quality. The Berlin Government and BWB carry out water quality testing through their accredited independent laboratory or another independent laboratory. In 1999 the BWB laboratory tested 7109 water samples. The state is responsible for assessing and publishing test results. However, neither the Berlin government not the BWB keep records of complaints from customers regarding the quality of water.

Infrastructure maintenance and replacement

In Berlin the transfer system is practically non-existent since the treatment plants also serve as mains to the distribution network. Over 74 per cent of the pipes in the distribution system are made of some type of cast iron, followed by steel (9.7 per cent) and asbestos cement (12 per cent). The use of concrete and PVC is negligible. The reticulation system is 7760km long.

A long-term rehabilitation program using statistically analysed databases to identify problem areas has replaced routine cleaning of the distribution network. This may explain the 3 per cent reading for unaccounted-for-water, making Berlin the best performing city in this category of this study. Most pipe bursts occur as a result of their age, ground movement, drastic changes in temperature such as frosts, and construction works by third parties. Average response time for restoring supply is less than eight hours.

Six pumping stations ensure continuity of supply and pressure. Standard water pressure is between 4.5 and 5.5. bar. The government finances all water supply and maintenance programs.

Wastewater treatment and recycling

Over 98 per cent of the properties linked to town water are connected to the sewerage system; the rest rely on septic tanks. Seven treatment plants treat all the sewerage before discharging it to the surface water system. Plants are owned and operated by the government, except for two that are owned by private companies. Overall management is under BWB authority.

A total of 298,000 metric tons of sludge are produced annually, of which 43 per cent is composted and used in landscaping, 46 per cent incinerated, 10 per cent used for experimental energy production, and 1 per cent goes to land-fill. Composted sludge must comply with government regulations.

Wastewater is not recycled because of the abundance of water. No financial incentives have been offered to encourage recycling and there are no short or long-term plans to introduce recycling.

BUSAN

Background

Busan has a population of approximately 3.9 million. Average daily water consumption is 381 litres and 98 per cent of residents are connected to the town water system. The Nakdong River provides 93 percent of the city's water with the balance coming from forested catchments. In 1999 the population consumed about 524,040 megalitres of water, which was primarily used indoors.

While Busan's population and water consumption remained static over a five-year period increased competition from abutting municipalities has forced the city to identify new water sources and plan the construction of new dams. Although water resources meet current demand, its quality is being compromised by a long period of severe drought. During floods or severe drought water supply may be stopped for several hours in some areas and bans imposed on garden watering and car washing.

Ownership and regulatory control

The national government owns the water resources except for the forested catchments, which are owned by Busan City. The city owns the treatment and distribution systems and is responsible for harvesting, treating and distributing water. No permits or licenses are required to extract water. Busan is considering future partial privatisation of the system.

A number of national acts regulate public health and water quality. The Ministry of Environment is responsible for the development of water quality standards. A Waterworks Authority monitors water quality, testing it daily and assessing and publishing the results.

Tariff structures are based on volumetric consumption and include a sewerage disposal charge. Different rates apply for domestic and business supply, but the pricing structure does not encourage efficient water use.

Resource management and water quality

Land use in the Nakdong River basin includes residential and farming activities. The forested catchments are designated protected zones. River waters are subjected to comprehensive treatment. Measures used to reduce river pollution range from expanding treatment facilities, separating sewer and drainage facilities, monitoring effluent discharges into the river, constructing community treatment facilities for livestock farms, and the introduction of central government legislation for water quality management.

Residential and industrial activities generate algal blooms in the upper river basin that impact on water quality. The Water Authority regularly advises residents to boil water during periods of diarrhoea outbreaks that are related to reduced water quality.

Infrastructure maintenance and replacement

The water supply system has four treatment plants. Water is transferred from source to customers primarily in ductile iron and coated steel pipes.

Aging treatment plants and distribution networks are the main causes of reduced water quality. Unaccounted-for-water is around 31 percent and is attributed to leakages and other reasons. Busan is planning to replace the old distribution and reticulation networks and complete major, advanced treatment facilities by 2002.

Wastewater treatment and recycling

The Environment Management Company, a public agency, manages the treatment plants on behalf of the city. Only 53 per cent of properties are connected to the town sewerage system. Some residents have septic tanks but about 30 percent discharge their wastewater directly to drains and streams. Sewerage that is collected is treated by gravity sedimentation, activated sludge and sand filtering before discharge to the ocean via urban rivers. In 1999 four treatment plants produced a total of 115,411 tons of biosolids, of which 10,693 tons were incinerated and the rest dumped to the ocean after 3-6 days storage.

Although a number of buildings are equipped with wastewater recycling systems and the treated water used for cleaning and flushing toilets, Busan does not provide incentives to encourage the use of recycled water.

CASABLANCA

Background

Casablanca is Morocco's largest city and its population of 3.5 million consume about 119 million cubic meters of water annually. Surface sources provide 98 per cent per cent of the water, with the balance coming from spring water. Surface water is stored in dams, more than 80km from the city, before being transported to plants for comprehensive treatment. Spring water is chlorinated only.

Projections for 2010 indicate that Casablanca's population will rise to 4.5 million with an increase in water consumption to about 150 million cubic meters annually. The current and projected needs of the city are expected to be met from current resources.

Catchment management and water quality

The Ministry of Public Works is responsible for water resources and catchment management. This includes developing and implementing government policy over the planning and construction of dams, creating catchment management agencies, issuing of licenses and permits to harvest and treat water, and water quality standards.

The National Office for Drinking Water (ONEP) and the Oum Er Bia Water Board (SOER) operate treatment plants, which are also responsible for water sampling and testing. ONEP also has responsibility for water allocation.

Water quality criteria are set out in Moroccan Standards that set out minimum standards and the frequency and number of water samples to be taken annually by the distributing agencies. In 1999 ONEP took 42,700 samples, well in excess of the required 24,150 samples.

Water quality studies show a 99.7 per cent compliance with the standards, as well as a reduction in the number of "red water" zones. The distributing agencies are required to produce an assessment of water testing, but these are not publicly available.

Ownership and regulatory control

All water resources are owned by the national government, while the municipality owns the distribution infrastructure. In 1997 the municipality contracted Lyonnaise des Eaux de Casablanca to manage water distribution, and established a small unit to monitor the contractor's performance.

In 1995, legislation was introduced empowering the Ministry for Public Works to administer the distribution of water between the various uses (domestic, industrial, agricultural). Legislation, introduced in 1997, enables privatisation of the distribution systems. Under this legislation private contractors are responsible for investment and maintaining and upgrading the systems.

The Ministry for Health is responsible for policy and regulatory control regarding public health aspects of water supply, which are implemented by local municipalities.

Casablanca uses a fixed tariff structure for different consumption rates:

- Tier 1 – for consumption below 24m^3 the sale price is lower than the purchase price. This tier is also identified as the 'social bracket' designed to meet community service obligations.
- Tier 2 – for consumption between 24-60m^3 the sale price equals the purchase price.
- Tier 3 – for consumption over 60m^3 the sale price exceeds the purchase price, and it is designed to promote efficient water usage.

Infrastructure maintenance and replacement

The water storage system consists of 36 reinforced concrete tanks and towers with a one-day consumption storage capacity. Water is transferred from storage dams using primarily PVC and cast iron pipes. The length of the network is 3294km. Routine maintenance undertaken to ensure water quality includes filters at entry and exit points in water tanks, installing sensors to detect chlorine levels, and annual cleaning of water tanks.

On average, about 4-5 breakdowns per 180km occur on a monthly basis. These are attended to immediately.

The harvesting and treatment plants supply 181 million cubic meters of water annually, but 34 per cent of the city's water is unaccounted for. With better detection of leakages, immediate repairs, replacing water meters and an inventory of customers this could be reduced.

Over the past 10 years extensive renovations and repairs of the distribution network have been done to prevent leaks and improve the network. As well an annual refurbishment program based on multi-criteria studies such as age of infrastructure and frequency of leaks, is in place.

Wastewater treatment and recycling

Only 60 per cent of users are connected to the town sewerage system. The rest rely on septic tanks or filtration pits. About 50 per cent of the collected wastewater is pre-treated before being discharged to the ocean, 4km from the coast. The untreated wastewater is dumped directly into the ocean, also 4km from the coast.

Presently the city does not recycle its wastewater, although it is exploring possibilities for using recycled water for irrigation purposes or for replenishing the watertable.

DENPASAR

Background

Denpasar is the capital of the Indonesian province of Bali. About 70 per cent of the city's water supply is from rivers with the balance from subterranean wells. Denpasar's population is about 400,000. The total number of properties is 64,246, but in 1999 only 73 per cent were connected to town water. During that year the Denpasar Water Supply Company supplied about 17,500 megalitres of water to its customers.

To meet the anticipated rise in demand, a new treatment plant is planned for 2010, at the cost of Rp 30 billion, and another will be constructed by 2020, at the cost of Rp 50 billion.

Ownership and regulatory control

The Bali Province owns Denpasar's water resources. Water catchments are in government and private ownership. Water is harvested, treated and distributed by the Denpasar Water Supply (DWS), which was set up by the central and municipal governments and is owned by the City of Denpasar. Under central government legislation the city sets the regulatory framework for water supply and is responsible for monitoring the performance of the water company. Licences to harvest water are issued by the Indonesian (Bali Province) Mining Department.

At present DWS uses contractors to service connections, for repairs and to expand the distribution network. Proposed reforms to management over the next 10 years include privatisation of the DWS. Privatisation will largely depend on DWS's ability to increase profits, raise water quality, service levels, and reduce the volume of unaccounted-for-water.

The four different water tariffs for domestic, institutional, commercial and industrial uses are based on a combination of volumetric consumption, usage charge and service fee. Revenues generated meet only 75 per cent of the cost of supply. Water prices are reviewed every two years.

Resource management and water quality

Land uses around the water catchments vary from forest, urban and intensive agriculture (rice paddies). Human activity is a cause of water pollution. While local government regulations are in place to control development in the catchments, their application is inconsistent.

River water is comprehensively treated. Treatment of well-water varies between wells, but usually consists of pH adjustment, chlorination and sometimes aeration. Even so, customers are regularly advised to boil water.

The Drinking and Clean Water Quality Standard 1990, prepared by Indonesia's Health Department, provides the framework for identifying acceptable water quality criteria. Testing of water is done by both DWS laboratory and an independent laboratory with 360 routine samples collected annually. Test results are assessed by the Department of Health.

Infrastructure maintenance and replacement

DWS has one treatment plant and 11 wells with pumping systems. Treated river water is stored in a 10,000m^3 enclosed concrete reservoir before distribution. Distance from the treatment plant to the distribution network is 8km. The combined length of the transfer and reticulation networks is 1100km, using predominantly asbestos cement and PVC pipes. Key indicators for asset management include the number and frequency of pipe failure, asset age, water pressure, water quality and customer complaints.

The water treatment plant is cleaned weekly, but the reservoir, transfer and distribution mains are cleaned when needed. Desired water pressure targets of 8m for domestic users and 10m for commercial and industrial uses are difficult to maintain because of leakages (20 per cent unaccounted-for-water) and treatment plant failures. Current monitoring and restoration of the distribution system is on 'as needs' basis. Operational procedures in the treatment plant are not adequate to maintain water pressure and service levels.
Improvements would require developing specific policies and regulations, upgrading staff skills, routine monitoring of the network, and restoring the existing distribution system as well as its expansion.

DENVER

Background

The Denver metropolitan area has a population of about 2.3 million. However, Denver Water[3] supplies water to roughly half of the metropolitan population. Denver Water gets its water from three rivers. Current supplies are adequate to meet the projected demand over the next 20 years. In 1999 Denver Water supplied a total of 323,492 megalitres. Although the number of its customers has risen by 20 per cent over the past 20 years, water consumption rose by only 5 per cent. Domestic water consumption is 46 per cent for indoor and 54 per cent for outdoor uses.

Ownership and regulatory control

The Federal government owns most of the water catchments, although there are some in private ownership. Denver Water owns water rights and owns and operates all the supply and distribution systems in its part of the Denver metro area. Contractors are used by Denver Water for design and construction of facilities only.

All operations, maintenance and capital works are paid for through water charges or special contributions to aid construction (eg. system development charges, participation charges) and through the ability to debt-finance most major construction works. Denver Water does not receive financial contributions from either the City or the County.

Various Federal acts and regulations regulate water rights, water quality, sewage and other discharges into the catchments. The Colorado Department of Public Health and Environment regulates all public health aspects of water supply and sets out water quality standards and assessment criteria.

3. Information in this report relates only to the area supplied by Denver Water.

Resource management and water quality

Land uses around the catchments include national forest, logging, grazing, and mining as well as urban and recreational purposes. To ensure water quality, regulations will need to be tightened to protect watersheds from pollution and to encourage efficient use of water resources. Already strategies that promote water conservation are in place and include education campaigns, metering, low-flush toilet rebates, and efficient park irrigation programs. Denver Water has also introduced a 'summer lawn-watering calendar', a voluntary system which utilises the last two digits of the property address to provide outdoors irrigation on a roster system. A sliding scale for tariff penalises high water consumption. Drought response measures are introduced when water storages drops below 60 per cent capacity.

Denver Water takes 7,000 samples annually to monitor water quality. These are assessed and results are made public.

Maintenance of the transfer and distribution systems includes two-yearly cleaning of reservoirs and routine flushing of the distribution system. Significant renovations of the water treatment system are underway and will improve water quality.

Infrastructure maintenance and replacement

All water is stored in enclosed reinforced concrete tanks. The average distance from source to the distribution system is about 21km. Major pipes used are cast iron (49 per cent), ductile iron (17 per cent), and other materials to a lesser degree, although ductile iron, PVC and steel are preferred to expand the system and replace old pipes. The network has a total length of almost 4,000km. Water pressure at point of supply is 28 m.

The main reasons for interruptions to water supplies are leaks in the system and wild fires when debris clogs filters. The rate of main bursts is 17.9 bursts per 100 kilometres of pipes annually, which is higher than the city's goal of less than one break per 10 miles. The response time to water interruption is about six hours. Overall asset management includes repairing leaks as soon as they are detected, replacing pipe segments if two leaks occurred in one year or there is a previous leak history, and monitoring and analysis of water pressure complaints to determine future replacement priorities. About 1,300km are surveyed annually as part of a leak detection and system restoration program.

Wastewater treatment and recycling

Almost all properties are connected to the sewer system, and industrial users must comply with strict pre-treatment permits that prohibit discharging of toxins and pollutants into the sewer. All wastewater is treated. Although the stormwater system is not connected to the sewer, the Metro District has agreed to accept limited quantities of contaminated stormwater from specific locations such as Denver International Airport.

Secondary treatment is used. About half of the 160 million gallons of wastewater treated receives advanced tertiary treatment. All treated effluent is chlorinated before it is discharge to the river.

A regional treatment agency owns and manages the sewerage treatment system. The Metro District produces 26,461 metric tons of dry sludge, of which 98 per cent is used in agriculture and the rest is composted and sold to the public under State and Federal sanitary regulations.

The end of 2003 will complete the first stage of treatment facilities to recycle wastewater for industrial and outdoor uses. The system will delay the need to develop new water sources. The system, which is expected to be fully operational in 2012, will cost $140 million and will deliver water to customers via a separate reticulation system. Tariffs for recycled water will be lower than for potable water.

DOHA

Background

Doha is the capital of Qatar, an arid state with negligible rainfall and no natural surface water. Nearly the entire state's population of about 600,000 lives in Doha. Doha is very unusual as 90 per cent of its potable water comes from desalinated seawater with the balance from wells. Only 10 per cent of the water is used by industry. About 80 per cent of residential consumption is used outdoors, with the remainder used indoors. Although Doha's population is expected to increase by about 56 per cent by 2010, water consumption is likely to increase by 115 per cent, causing some challenges in terms of sustainable water use.

Ownership and regulatory control

The Qatar General Electricity and Water Corporation (QGEWC), a government owned body, owns and operates the distribution system as well as two water desalination plants. The QGEWC has been established as a first step towards privatisation of all water production facilities, with the state retaining responsibility only for the reservoirs and distribution networks. Virtually no legislation of any kind exists to control the activities of QGEWC, but this is likely to change as Qatar is keen to use international best practice. QGEWC is not required to provide annual financial reports. The government funds community obligations.

A simple tariff based on consumption is used, but not all properties have meters. In fact, no records are kept of consumption and revenue per property, or of revenue against operating cost per megalitre supplied. Changes to the system are now under consideration.

Resource management and water quality

Three power and water production plants provide about 130,000 megalitres of water daily, meeting 95 per cent of the demand, and are supplemented by well water treated in reverse osmosis plants. Potable water is produced by re-mineralising the distillate from multi-stage flash evaporators and disinfecting with chlorine. As water storages have only three-day supply capacity, pumping of water into the distribution system may be stopped for a few hours per day to manage demand.

Networks are regularly flushed to ensure water quality, but programs for cleaning of reservoirs and water tanks are yet to be developed. Using World Health Organisation standards QGEWC takes about 100-120,000 samples to assess water quality. The results are not published, and there is no monitoring to gauge customer satisfaction.

Infrastructure maintenance and replacement

Desalinated and re-mineralised water is stored in reinforced concrete reservoirs. The criteria adopted for sizing of reservoirs is to ensure three days supply, the maximum period required to repair worst breaks in the transmission mains. Distance from the reservoirs to the distribution is system is 20km, and water is transferred in enclosed pipes. The predominant material used in the transfer and reticulation networks is ductile iron. Minimum pressure of 1 bar (10m) is maintained. Routine pressure measurements are carried out in areas with frequent low-pressure complaints.

Asset management indicators include the number of pipe bursts, size and age of pipe, and the physical condition of the pipe. Most interruptions to supply result from the failure of old assets or insufficient hydraulic

capacity. The 30 per cent rate of unaccounted-for-water is directly related to the age of assets.

Issues for the future

Future challenges for Doha relate to efficient uses of water. Priority areas include reducing water losses, using treated wastewater for irrigation, installing meters in all properties and introducing cost recovery based tariffs. Extensions to existing production plants and construction of a new power and water plant will add a further 60-70 MIGD to the current capacity.

DOUALA

Background

Although not the capital, Douala is Cameroon's most significant city. It has a population of almost 1,000, 000 of whom about 50 per cent have access to domestic reticulated water. The rest of the population gets its drinking water from public water mains.

Subterranean springs supply the city with15 per cent of its water with 85 per cent coming from two rivers. The main source is the Dibamba River but the water is brackish. Fresh waters from the Chenal River and the springs are used to offset the salinity problems. While activities around the spring basins are traditional handicrafts and fertiliser-free subsistence cropping, urban development affects the Chenal River as it travels beside the edge of the metropolitan area. All surface waters are comprehensively treated.

Like the rest of West Africa, Douala has abundant water resources, sufficient to meet demand even with an expected tripling of the population over the next 20 years.

Ownership and regulatory control

The State owns the spring basins and the entire water supply system including the catchments, treatment plants and storage facilities. Management of the water supply system is administered through contractual conditions in the concession to distribute drinking water to Douala and a statute that covers various issues including water rights as well as development and operating licenses.

The State Ministry of Mines, Water and Energy (MINMEE) is responsible for regulatory control and price set-

ting. The National Water Agency of Cameroon (SNEC) implements these as part of its responsibilities for catchment management, treatment, storage and distribution of drinking water. Operating licenses for the extraction, treatment, distribution, and sampling of water are issued by MINMEE. Together with the Pasteur Institute, MINMEE is responsible for setting water quality criteria. Regular physico-chemical and microbiological water testing is done and MINEE monitors these for compliance with these standards. Test results are only published on request from municipalities. SNEC's central laboratory carries out regular water quality studies to assist in improving water treatment.

Tariffs, education and social obligations

To encourage sensible water use the tariff structure is based on consumption using a sliding scale that penalises consumption when it exceeds 10m^3.

Until recently people without reticulated domestic water were able to get water at no cost from public mains. Fees have now been introduced for water from these sources to encourage water conservation. During drought periods municipal inspectors are deployed to manage the sale of water from public mains.

Limited financial assistance by way of concessions is provided by SNEC (with funding from external financial organisations). SNEC employs a targeted campaign to notify individuals of their eligibility for concessions.

Infrastructure maintenance

The treatment plant for the subterranean spring is under-utilised since eight of the 12 bores have been out of use for various reasons. The spring is a renewable resource, but neglect of facilities and equipment at the bore sites may lead to their closure. Lack of funding for repairs and to upgrade production facilities is a major obstacle to protecting and improving water quality. The predominant material used in the distribution network is PVC (90 per cent). Pipes are repaired on an 'as needs' basis. Over the past five years a combination of PVC and reinforced concrete have been used to replace old pipes. Replacement of pipes is undertaken as part of road network maintenance. Major reasons that the system fails are wilful breakages, ground movement and power surges.

A 24-hour emergency repair service is available to restore service immediately. However, when power surges are responsible for interruption to services, repair may take longer.

The distribution networked is purged and sterilised on a yearly basis. When customer complaints about water quality have been proven by analysis of water samples, purging operations are done in the affected zones.

A discrepancy of 15 per cent between total supply and actual billing is attributed to illegal sales, or water theft, of bore water.

Water reform and plans for the future

The State is considering institutional reform to allow a private operator to harvest and distribute water. This will require new legislation. There are plans to exploit a new source that will be capable of meeting the entire demand for water. However, this depends on raising funding to operate the proposed plant.

Other key priorities for Douala are establishing electronic systems to manage consumer records and improving the system's overall performance. These will assist in stepping up the struggle against defrauding in the dis-

tribution network. SNEC also intends to tighten natural water protection to control pollution and minimise water treatment costs.

Wastewater treatment

Only three neighbourhoods in Douala with about 4,500 households and 18,000 inhabitants are connected to the town sewerage system. Thus, less than 1 per cent of wastewater goes through purification plants, with the majority being discharged to septic tanks and sumps.

DUBLIN

Background

Dublin, with 1.2 million inhabitants, has a third of Ireland's population. The city is on the banks of the River Liffey. The Liffey, the Varty and the Dodder Rivers meet Dublin's water demand of about 140 litres per person per day. While the water catchments are not protected and agricultural, and urban and industrial activities take place within them, most of the water is harvested from high quality upland sources.

Existing resources are adequate to meet the current daily demand of 450 million litres. A total of 545,000 properties – 439,000 domestic and 106,commercial – are connected to the town water supply. About 90 per cent of domestic water is used indoors.

Ownership and regulatory control

The local authorities own and operate the water supply systems and are responsible for harvesting, treating distributing, and monitoring, under central government legislative and regulatory provisions. Similarly, local authorities are responsible for all health aspects of the water supply system under delegation from the central government Departments of Health and Environment. This includes selecting water quality standards, developing guidelines, and monitoring. The local authorities conduct about 2 million microbiological tests annually, which are assessed and monitored by the Environment Protection Agency. The results are made public.

Presently, the central government funds maintenance of the systems, but the Dublin Corporation is examining new initiatives using public/private partnership models for future development of resources and distribution systems.

For historical and political reasons different tariffs were being applied by the six councils to different groups of customers to recover the cost of water, mostly based on property values. The *1996 Greater Dublin Water Supply Strategic Study* (GDWSS) recommended, on economic and financial grounds, that a single tariff policy be introduced to manage demand and recover costs. It recommended a flat rate charge for domestic customers based on average annual domestic consumption multiplied by the measured volume.

Resource management and water quality

Six local authorities in Dublin supply water, but only two are licensed to produce water. Water is supplied to the local authorities through a collective regional agreement.

River management plans with detailed catchment protection and monitoring requirements are in place to protect water quality. Water treatment includes flocculation, sedimentation, filtration, pH adjustment, and chlorination. However, treated water is stored in open reservoirs that are also home to large roosting gull populations, causing an unacceptable health risk. Bacteriological tests in the Dublin distribution system indicate a high level of coliform and *E.coli* readings. The GDWSS recommended that either the storages are covered or further treatment before reticulation.

Infrastructure maintenance and replacement

The water distribution system primarily consists of cast iron and lead pipes, much of it dating from the end of the 19th century. A passive policy to repair pipes only when leaks were detected resulted with a very high rate of water loss. The £37 million Water Conservation Project, implemented following the GDWSS, has succeeded in reducing water loss from 42 per cent to 28 per cent. Leakage detection and control are now integral components of supply management.

As well as assessing present levels of services, the GDWSS sets out the framework for developing and improving the network in the region over 20 years. During that period every element in the harvesting and supply systems will be upgraded. Proposed infrastructure works over the next five years are expected to cost £450 million.

Wastewater treatment and recycling

Not all properties in the Dublin region are connected to the sewerage system. On the urban fringe and in rural areas septic tanks are still in use. By 2002 it is expected that 90 per cent of properties will be linked to town wastewater systems. New municipal treatment plans, using activated sludge processes, have been installed to treat wastes. It is expected that by 2002 all effluent will be treated before discharge to the environment. Sludge is thermally dried and used as biosolids.

The local authority owns and operates the waste treatment plants with one exception where the largest treatment plant has been contracted to a consortium for a period of 20 years.

Dublin does not recycle its wastewater and it is not a priority for the next 20 years.

GENEVA

Background

The Canton of Geneva has a population of 408,000 who consume 60,200 megalitres of water annually. Lake Geneva, a natural alpine lake, meets 80 per cent of the demand with the remaining 20 per cent from ground water sources that are artificially recharged with treated river water. Although Geneva is rich in water, the capacity of the treatment plants to meet demand during summer and winter may be constrained.

Between 1990 and 2000 water consumption dropped by 15 per cent in spite of a 6.7 per cent increase in the population. This may be attributed to public awareness campaigns to conserve water and the willingness of the population to cooperate.

Ownership and regulatory control

Under Federal legislation the state government owns the water resources and is responsible for their protection. The Industrial Works of Geneva (SIG[4]) harvests, treats and supplies the canton with water. SIG is a publicly owned independent company with an operating budget of 100 million Swiss Francs, of which 55 per cent is provided by the Canton of Geneva, 30 per cent by the City of Geneva, and 15 per cent by other municipalities within the Canton. The company is under pressure to provide quality service and be financially responsible, and is required to publish annual financial and performance reports.

The canton implements federal legislation over water quality standards and monitoring requirements to regulate public health aspects of water supply.

Catchment management and water quality

Land use activities within the Lake Geneva catchment range from forest, agriculture, uncultivated ground, and urban and recreational uses. The International Committee for the Protection of Lake Geneva, CIPEL[5], whose objective is the restoration of water quality in the lake, has been developing strategies since 1952 to enable coordination of French-Swiss water policies.

Potable water quality is assured through comprehensive treatment of lake water and river water for recharging of aquifers. About 7,000 microbiological test are conducted annually by the SIG laboratory. These are assessed and the results are provided upon request. In spite of high levels of phosphorous in Lake Geneva and of 'red water' because of rusted pipes, water quality standards are high. SIG keeps records of customer complaints about water quality – about 70 annually.

Infrastructure maintenance and replacement

Three lake water treatment plants and 10 groundwater pumping stations are interlinked using wide diameter pipes, to ensure continuity of supply when one of the plants or stations is off. A new water treatment plant that will replace two existing ones will be commissioned in 2004, at a projected cost of 60 million Swiss Francs. Depending on water consumption trends, an additional plant may be required by 2002 to ensure adequate supplies when treatment plants are decommissioned for maintenance work.

Treated water is stored in concrete reservoirs.

Maintenance work includes yearly cleaning of reservoirs and flushing of pipes on an 'as needs' basis. The length

4. SIG - Services industriels de Genève.

5. CIPEL - Commission internationale pour la protection des eaux du Léman.

of the distribution network is 1213km, using primarily cast iron and ductile cast iron pipes with lesser use of PVC, asbestos cement, concrete and fibreglass pipes.

Water pressure of 5 bars in urban areas and 3.5 bars in rural areas and elevated reservoirs with two hours capacity and fitted with emergency diesel pumps, ensure continuity of supply.

An effective asset management mechanism used by SIG is the replacement of at least 1.5 per cent of pipes per year, in conjunction with public works in streets. As well, a leak detection program with regular leak control campaigns ensures a low rate of unaccounted-for-water.

Wastewater treatment

Almost all sewage generated in Geneva is treated before it is discharged into the river system. The sewage treatment plants are owned and managed by the State and each year produce about 7,200 tons of sludge, which is incinerated.

GUANGZHOU

Background

The metropolitan area of Guangzhou takes in 10 urban and two rural districts with a combined area of 7434km^2. By the end of 1999 the total permanent and transient Guangzhou population was close to 8.7 million. Most of the city's demand for water is met by surface sources that are supplemented by small quantities of ground water. In 1999 eight treatment/distribution plants supplied 1,236,000 megalitres of water, using a supply network 4991km long. Consumption figures indicate that 15.5 per cent of the water is used for domestic activities, 62 per cent industrial, and 22.5 per cent rural.

Resource management

The water supply is divided into four sectors: the first is the North Liuxi River, the Baini River, and the Pearl River East Waterway which account for 58 percent of the metropolitan water supply. The second is Pearl River front and back channel, supplying 11 percent. The third is the northern trunk of the Dong River, the Zeng River and Xifu River, accounting for 14 percent. The fourth is a southern source, which includes the Shawan and the Jiaomen waterways, making up 17 percent of the total supply.

Wastewater treatment and environmental protection

Since the 1970s, the Guangzhou Municipal Government has focused on reducing pollution in the water system, and has undertaken measures to control industrial wastewater discharges. By the end of 1999 more than 92 per cent of all industrial wastewater was treated and contamination from industrial wastes markedly decreased.

However, the main area of concern is domestic sewage. Two large-scale treatment plants with a combined daily capacity of 520,000 tons per day (28 per cent) have been brought into use. By the end of 2002 new treatment plants will bring total treatment capacity to 1.6 million tons, which will treat about 70 per cent of domestic sewage.

Future resource exploitation and water quality

With economic and social changes, Guangzhou will face serious challenges in meeting the demand for water. The Liuxi River is still the most important source of drinking water. However, the northern trunk of the Dong River and the southern Shawan and Jiaomen waterways will increasingly play a greater role in water resource utilisation. To meet those challenges these resources should be protected through the following measures in the Guangzhou Development Strategy:

1. Construct the Nanzhou water plant and install river diversion works.
2. Reduce water consumption by industry and increase recycling of industrial wastewater from 76 per cent to 80 per cent by 2005.
3. Strengthen measures for treatment of industrial wastewaters, and extend the sewerage system to increase treatment capacity for domestic sewage.
4. Protect river catchments by creating natural reserves and conservation areas.
5. Enforce State Standards on concentrations of pollutants from industrial sources, and strengthen control over agricultural pollution, particularly with regard to the use of pesticides and fertilisers.

HANOI

Background

Hanoi, Vietnam's Capital, is located on the bank of the Red River, and its boundaries extend into rural areas. Approximately 800,000 residents or about 65 per cent of the metropolitan population have access to treated town water. Average daily consumption is 395,000m^3 per day. Nearly 100 per cent of the water supplied to urban and rural areas is ground water from a series of wells. Some wells in the rural areas are still fitted with hand pumps.

There are plans to exploit surface sources, from the Red River and Black River, which will add 500,000m^3 of water by 2005, as current output is not sufficient to meet demand during summer. Measures to ration water use during summer include cutting off supply on a rostered basis, and using mobile water tanks to deliver water to the undersupplied areas.

Catchment management and water quality

Regulations to protect the well catchments are in place. These prohibit residential and industrial land uses in a 50m radius from the wells, but with many of the catchments in urban areas, these measures are not enforceable. Nevertheless, the quality of the raw water does not show signs of pollution. Water extracted from wells undergoes filtration and chlorine disinfection before it is pumped into the distribution network.

Various water quality criteria have been introduced by the National Ministry of Health Care and the municipality. Water quality is routinely tested in the laboratories of the water supply companies. The Hanoi Institute of Hygiene and Epidemiology monitors water quality with samples taken monthly from the wells, after treatment,

and from the distribution network. The results are assessed by the Institute and Hanoi Health Care. Water quality reports are made public.

Because only 50 per cent of the desired volume is available in summer the municipality has introduced restrictions banning the use of clean water for washing motorbikes, as well as higher charges for business use and for watering parks. It also undertakes education campaigns to encourage water conservation.

Ownership and political administration

All water resources are owned and managed by the state. The National Ministry of Agriculture and Rural Development controls the granting of exploitation rights and licences. The Hanoi Municipality controls the harvesting, management and supply of ground water in Hanoi as well as the construction, operation and maintenance of the water supply system.

Recent decisions have ratified plans for future development of water supply systems at the national and municipal levels. These are designed to improve water quality, improve the management and operation of water resources and networks, and extend the water network to reach everyone in the urban areas.

Infrastructure maintenance and replacement

The municipality has 13 water harvesting and treatment plants with a maximum sustainable yield of 420,000m^3 per day, sufficient to meet current demand, except during summer. But with a projected population of 1.67 million in 2005 and 1.76 for 2010 the municipality is upgrading infrastructure to connect all urban consumers to the network, allowing 160 litres/person/day. The cost of this is estimated to be US$435.9 billion.

The water distribution system comprises 137km of transfer pipes and 490km of reticulation pipes made of cast iron and plastic. Maintenance of the network includes 3-6 monthly inspections, repairs to leaks and purging of pipes. But the system is old and run-down and 55 per cent of water is unaccounted for, which is unacceptably high. The city has introduced a number of strategies to assist in identifying water losses that include increased metering and splitting the network in separate zones to better measure unaccounted-for water in those areas.

Wastewater treatment and recycling

Approximately 70 per cent of town water users are connected to the sewer, of those not connected, only 10 per cent are connected to septic tanks. Currently all effluent is transferred, untreated, to sludge fields. Three of Hanoi's 36 hospitals have their own low-grade treatment facilities. The state is presently building two effluent treatment plants in Hanoi. These will be managed by the Hanoi Municipal Government and operated by a contracted sewerage and drainage company.

Wastewater recycling is not a priority and no financial incentives are offered by the government to encourage recycling. A pilot project implemented by the city in 1988 to recycle water used for washing filters at the water treatment plants was not successful.

HARARE

Background

Harare's 2.2 millions inhabitants are all connected to the water supply system and in 1999 they consumed about 152,200 megalitres of water, 49 per cent for internal uses, and 51 per cent for outdoors. Comparisons of consumption rates over a 10-year period show that, although the population increased by 83 per cent, water consumption was up by only 49 per cent. But even so, long-term projections indicate that, with increased population and competing agricultural demands, current sources will meet only 76 per cent of the demand.

Ownership and regulatory control

The government owns the water resources and is responsible for the regulatory framework. Licensing agreements for the extraction of waters are granted to local authorities through the Zimbabwe National Water Authority (ZINWA). The City of Harare owns and operates the treatment plants and distribution system, but private contractors provide some maintenance and construction works. Legislation ensures resource management and permit systems, water quality and with discharges of effluent to rivers.

The Harare City Health Department is responsible for regulating and monitoring public health issues, but this is not enforced due to staff and equipment shortages.

The price of water is based on cost recovery. Water supply projects are financed through capital development funds generated from water revenue, and external sources such as the World Bank and the African Development Bank. Financial statements are produced annually and are publicly available.

Most significant water reforms over the past decade have been the establishment of the Zimbabwe National Water Authority in 1999, consolidating resource management at catchment basin level, and the introduction of the 'polluter pays' principle. Future reforms will be focused on privatisation of water and sewerage systems.

Resource management and water quality

Four surface water sources meet the demand for water. Less than 0.1 per cent is from private bores. Exiting resources are sufficient to meet the demand, but when storage levels fall below 21 months supply, compulsory restrictions are enforced banning watering of gardens, filling swimming pools and washing cars. Awareness campaigns warn consumers of penalties for excessive water use.

Catchment areas are fully developed with urban, recreation, agriculture and other rural uses. Since treated wastewater is discharged to rivers and lakes in the catchment, all water undergoes extensive treatment. Typical microbiological tests are 99 per cent of samples <1 faecal coliforms per 100ml.

Infrastructure maintenance and replacement
The storage system consists of 87 reservoir with a combined capacity of 792.7 megalitres. The water distribution network is totally enclosed, using primarily asbestos cement pipes. The total length of the network is about 4225km. Reservoirs and mains are cleaned once a year. Water pressure at supply point is 15 metres across the board.

Key performance indicators for asset management are the number and frequency of pipe bursts, water pressure and water quality. The high number and frequency of pipe bursts (80 bursts/100km, 35 bursts/1000 properties) is the main cause for interruptions to supply. Stand by

pumps, and around the clock monitoring of infrastructure and the availability of repair crews, have reduced response time for restoring supply to four hours.

Unaccounted-for-water is estimated to be about 37 per cent. Primarily due to the age of the decaying reticulation system, in part to water theft, and to a lesser degree to water pressure failure. Strategies in place to rectify the situation include monitoring of water pressure, penalties for illegal connections and pipe replacements.

Challenges for the future include upgrading storage facilities, transmission mains, and booster pump stations, introducing new technologies for water supply management and training of unskilled staff.

Wastewater treatment and recycling

Sewage treatment systems are owned and managed by the city. Three sewage treatment plants and five lagoon-type systems treat all effluent generated in the metropolis. All wastewater from the lagoons is used for irrigation. About 100 megalitres of treated water from the sewage plants is released daily to pastures for irrigation, and 90 megalitres a day to the rivers for recycling. Sludge is used for agriculture.

Wastewater discharged into the river for recycling is fed into water reservoirs before it is extracted for treatment. Less than 5 per cent of the town water supply is recycled water. However, recycling has high priority and Harare is phasing out conventional biological trickling filters and replacing them with biological nutrient removal treatment plans.

LISBON

Background

Lisbon, the capital of Portugal, has a population of approximately 520,000 and an annual water consumption of around 544,600 megalitres. River waters meet 90 percent of the demand and are supplemented by groundwater sources. While these sources provide adequate water for current demand alternative ground and surface sources will need to be identified to ensure security of supply.

Ownership and regulatory control

All water resources are owned by the national government. The National Water Institute is responsible for protection of water resources. A government owned agency oversees the regional water companies, whether publicly or privately owned. A regional company supplies Lisbon and other municipalities, and harvests and treats water before supplying it in bulk to distribution companies. A government license is needed for harvesting water.

The water pricing tariff structure is set up by the government and different rates apply for domestic, industrial and municipal users.

Resource management and water quality

The Ministry for Health and European Union directives set up public health standards related to water quality which include microbiological parameters, monitoring and frequency of sampling. About 5000 samples are collected annually and the results are made public.

Only one catchment is protected by legislation that restricts access allowing limited recreational activities and

provides guidelines and water quality standards. Surface water undergoes comprehensive treatment while groundwater is chlorinated only.

External competition for water resources is primarily from neighbouring municipalities and power generators, sometimes leading to conflicts particularly in relation to water quality.

During drought the city imposes restrictions on the availability of water for some period of the day. Education campaigns through press, media, schools and cultural exhibitions encourage efficient use of water.

Infrastructure maintenance and replacement

Two harvesting and treatment plants have a combined daily capacity of 740,000 cubic metres. The transfer pipes from source to the consumers are all made of reinforced concrete pipes. The ground water aqueduct is over a hundred years old and 114km long. The water harvesting and treatment system is equipped with online sampling and measuring devices. As well, there are 70 fixed sampling points for collecting and monitoring water quality throughout the entire distribution system. The distribution network is 1372km long.

Maintenance work to ensure water quality includes annual cleaning of reservoir and cleaning and disinfecting the transfer pipes and reticulation mains. Key indicators used in managing Lisbon's water supply include the number and frequency of pipe failures, asset age, water quality, and the number of unplanned, repeat interruptions to water supply. Pipe bursts are the main cause for interruption to services.

Unaccounted-for-water is between 5-10 per cent largely due to poor metering and leakages in the distribution network.

Over the next 10 years a major investment program will result in the construction of new reservoirs and the upgrade of treatment plants, the distribution network and metering system.

Wastewater treatment and recycling

A city-owned company manages and operates the sewerage system. Almost all properties are connected to the sewerage system, with only 2 per cent directly discharging to watercourses. About 80 per cent of wastewater is treated using the activated sludge method, tertiary treatment for removal of nitrogen pollutants, as well as sand filtration and ultra-violet disinfection for 40 per cent of wastes. Annual sludge production is around 27,000 tonnes, which is used in agriculture after a four-month storage period.

No significant recycling is carried out, mostly because of the lack of the necessary infrastructure.

LOS ANGELES

Background

The City of Los Angeles has a population of 3.8 million that uses about 798,074 megalitres of water annually. Local ground water and imported surface and ground water supply the city. Imported water from the Colorado River and Eastern Sierra Mountains are transported to the city in aqueducts. This is the city's first choice of supply because of the high quality of water and the low cost of gravity flow that also has hydropower generating capacity.

Although the city's population increased by more than 10 per cent over a ten-year period, water consumption fell by 3.7 percent. This may be attributed to water management reforms and greater public understanding of the need to conserve water resources. Projections for 2020 indicate a population increase of 26 per cent (to 4.8 million) with a 24 per cent rise in water consumption.

Ownership and regulatory control

The city owns its water resources. Under federal government legislation over public health and water management the state oversees water supply projects, including guidelines and regulatory controls for monitoring water quality. The Department of Water and Power (DWP) is responsible for harvesting, treating and distributing water to consumers. Licensed water rights and permits for extracting water are required.

The trend toward privatisation has forced the city to become more competitive and to contract out services. At the same time management is clear about its obligations to its customers and has a clear understanding that water supply and water quality issues can not be separated.

Water is charged on a volumetric basis, and tariffs are based on a two-tier structure that penalises high consumption. Water revenue exceeds operating costs, enabling the city to meet community obligations and fund rebates to customers to install low-flush toilets.

Catchment management and water quality

Local ground water is pumped from deep wells below highly urbanised areas. The water in the Colorado River is affected by agriculture, recreation, and lesser urban land uses. Open reservoirs in the city are not open to the public. Others in the catchment areas are open for recreational use, but are subject to stringent controls to ensure water quality. All water is treated by direct filtration. Local ground water is chlorinated and aerated at the wellheads.

Although water sources are sufficient to meet the demand, security of supply is determined by the amount of rainfall in northern California. Large storage reservoirs throughout the state ensure water supply during drought. Following the 1987-92 drought strict measures were introduced prohibiting wasteful water use, and a new ordinance adopted requiring the installation of low-flow plumbing devices in domestic and business premises. These measures are supported by intense education campaigns. Financial penalties apply for violations of these measures during drought.

More than 21,000 water samples are taken annually by DWP that must comply with standards established by the State's Department of Health Services. Test results are available to the public. Extensive research and DWP sponsored studies ensure that water quality is further enhanced.

Infrastructure maintenance and replacement

The water storage system has 105 tanks and reservoirs. Most are earth-fill dams but there are a few concrete-

lined dams. The entire distribution and reticulation system is 11,448km long. Maintenance works include tank cleaning every four years and the disinfection of distribution mains after repairs.

Regulator stations ensure that water pressure is maintained at 18 metres. Leaks in the supply system are recorded and monitored. The city has plans for remote monitoring of all regulator stations and control of chlorination stations. Surveillance using System Control and Data Acquisition and 24-hour maintenance crews ensure prompt restoration of water supply. Average response time is between one and four hours.

Unaccounted-for-water is between 4-6 per cent. Although low by comparison with most cities in the study, a strategy is in place to replace meters and to cement-line reservoirs.

Wastewater treatment and recycling

Almost 100 per cent of properties in the City of Los Angeles are connected to the town sewer. Some septic tanks are still in use on the city outskirts. The city owns and operates four treatment plants that process its collected wastewaters. Sludge produced is used in agriculture after a brief storage period.

As much as 18 per cent of treated wastewater is used for industrial, irrigation and recreational purposes, and this is expected to rise to 25 per cent in 2010 and 31 per cent in 2020. A negligible amount of treated wastewater is used to recharge aquifers. Financial incentives to encourage reuse include discounted long-term contracts, exemptions from water rate adjustments and subsidies. However, the cost of infrastructure and public perceptions are key issues to overcome to increase the use of treated effluent.

MANILA

Background

In 1999 Manila's population was approximately 9 million. Only 6.4 million were connected to the town water supply and they consumed a total of 1,101, 205 megalitres of water. About 97 per cent of the city's water supply is from surface sources with the balance from deep wells. Manila's population is expected to reach 16 million by 2010. It is also anticipated that, by then, the total population will be connected to town water services and consume 1,664,035 megalitres of water annually. The Laiban Dam project to construct a dam, treatment plant and transfer system, at a cost of US$646.3 million, will be completed by 2010 and add 693,500 megalitres of water to the system annually.

An area of concern for Manila is flood management in downstream municipalities and preventing dams overflowing after heavy rain. Before floodwaters are released, the water authority advises local governments and an emergency action plan is implemented.

Ownership and regulatory control

Water resources and the supply systems are government owned. The Philippines Department of Environmental and Natural Resources and the Department of Health set the regulations to monitor performance and service obligations. These are administered by the National Water Resources Board (NWRB) through a joint venture company. The Manila Waterworks and Sewerage System (MWSS) allocate raw water. Two private sector concessionaires undertake treatment and distribution and they must comply with the Philippine National Standards for Drinking Water. The terms of the agreements oblige concessionaries to invest in the system to connect the enti-

re metropolitan area, ensure continuous water supply and meet quality standards. The Regulatory Office monitors compliance.

The NWRB grants water rights (permits). These rights may be leased or transferred to other agencies or persons with NWRB approval. The NWRB may modify, suspend, or revoke permits.

The tariff structure is consumption based and includes different service charges for domestic and commercial uses, a penalty charge for over-consumption, a maintenance service charge, an environment charge and a sewerage charge for customers connected to the sewer. Plans for the future include a pricing policy based on cost recovery.

Resource management and water quality

Development in the catchment areas is strictly prohibited. Although the catchments are protected from urban, agricultural or industrial activities, water treatment includes screening, mixing, flocculation, sedimentation, filtration and chlorination. The 3 per cent of groundwater from unprotected catchments is chlorinated only. In spite of the protected catchments and comprehensive water treatment, consumers are advised to boil water during floods and when maintenance work is being done. Water quality is a priority for Manila as its poor quality is forcing people to purchase bottled water, resulting in hardship for already impoverished sections of the population.

In 1999 a total of 18,181 water samples were tested. Typical performance is >98 per cent samples <2.2 MPN/100ml. The Department of Health assesses compliance and the results are published monthly. An area of concern in protecting water catchments and water quality, is unlawful settlement in the watershed.

Increased competition from neighbouring municipalities, particularly for power generation, irrigation and increased industrialisation are placing great pressure on potential water sources, necessitating the construction of a new supply system. There is also internal competition between rural and urban customers. Awareness campaigns are used to encourage water conservation. Compulsory restrictions imposed during drought periods favour domestic consumers.

Infrastructure maintenance and replacement

Aqueducts and open channels carry water from the sources to the treatment plants. Water is stored in 11 open reservoirs with a combined capacity of 644 megalitres. Distance from source to customers is approximately 46km. PVC and asbestos cement pipes are used predominantly in the distribution system, followed by cement-lined cast iron and steel pipes. Storage reservoirs and filtration beds are cleaned and disinfected at least twice yearly.

Desired water pressure of 11m is difficult to maintain because of the frequency of breakages in the supply system, mainly due to ground movement, asset age, damage by third parties and inferior valves, resulting in 59 per cent of water being unaccounted-for, which is unacceptably high. . Average response time for restoring water services is 72 hours. Approaches to asset management include monitoring the frequency of burst pipes, and twice yearly surveys to detect leaks.

Challenges facing Manila include improving water quality, reducing water loss, upgrading the distribution and reticulation networks, enhancing hydraulic models, and improving its GIS and telemetry/SCADA systems capacity.

Wastewater treatment and recycling

The MWSS owns the sewage treatment system. Treatment plants are operated by private concession under a 25-year agreement. Of the 840,453 properties connected to town water supply, only 9.5 per cent are linked to the sewer. The rest use septic tanks or discharge effluent directly to street drains and creeks. Hospitals have their own wastewater treatment plants. Sewage is treated using activated sludge treatment and aerated lagoons. Sludge is dried and stored for 20 days in digesters then composted or directly used in agriculture. Treated effluent is discharged to water bodies. Only 10 per cent of stormwater is treated before discharge to the environment.

Manila does not recycle its wastewater, neither is it a priority for the near future.

MELBOURNE

Background

Melbourne has a population of more than 3.3 million. Annual water consumption is about 482,000 megalitres, with an average daily consumption of 410 litres per person, of which 49 per cent is for internal use and 51 per cent for outdoor use. Melbourne is dependent on rainwater, with 90 per cent of the demand met by reservoirs with fully protected catchments, and 10 per cent from catchments that are not protected. Melbourne reservoirs have been constructed to provide long-term storage capacity taking into account natural climate variability. Due to a record five year period of dry weather, water levels now stand at 58 per cent of capacity and failing substantial rainfall water restrictions are likely to be introduced. However, the built in capacity to manage this level of climate variability has seen the metropolis through the period of drought, and restrictions will only be needed if below average rainfall continues.

Catchment management and water quality

Most reservoirs are outside the defined metropolitan area, with the largest reservoir being 125km from Melbourne. To protect water quality catchment management includes a prohibition on public access with farming, industrial and urban land uses not allowed in the protected catchments. Water supplied from unprotected catchments is fully treated before entering the supply system.

With the exception of water supplied from unprotected catchments that are fully treated, the bulk of the water only requires chlorine disinfection, fluoridation and lime pH adjustment following lengthy detention in large storage reservoirs. Quality standards and monitoring of water are enforceable through Victorian government regulations and licences issued to water companies.

The result of the closed catchments and stringent standards is that Melbourne's water quality is among the highest in the world. Regular studies of these catchments and the annual report of the Regulator confirm high performance and continued improvement trends.

Ownership and regulatory control

All water resources, reservoirs and treatment plants are state-owned. The state government is responsible for regulatory control through various acts and regulations which govern water supply management, public health, and water treatment. In 1995 the existing Melbourne Water Corporation was broken down into one wholesale and three retail water companies. Melbourne Water Corporation, the wholesale company, is responsible for harvesting and treatment of water and its responsibilities include planning and constructing dams and water treatment plants. The retail water companies are responsible for customer service and management of the distribution network.

The retail water companies operate under licences that stipulate the operating standards that include water quality, pricing policy, and community service obligations such as pensioner concessions, rebates for non-profit organisations as well as hardship and relief schemes. Water consumption is charged on a volumetric basis (approximately 70c per kilolitre), and is founded on a cost recovery principle reflecting the full cost of harvesting, treatment and distribution of water.

Infrastructure maintenance and replacement

The transfer system from source to distributor is mainly via closed pipes, of which 50 per cent are made of cast iron, 30 per cent cement lined cast iron, and 15 per cent PVC. Based on past experience the life of the infrastructure is about 70 years.

The total length of the distribution and reticulation network is 19,500km. Presently, water pressure at point of supply is 15m for residential customers and 20m for commercial and industrial users. Key performance indicators for asset management are asset age, number and frequency of pipe failures, repeat interruptions to supply and water quality. In the case of unplanned interruptions service is restored within five hours in 99 per cent of the cases. The main reasons for system failure is asset age and ground movement due to changes in soil moisture content.

Challenges for the next 10 year include maximising asset life, improved understanding of customer expectations, and developing an accurate hydraulic model with integrated wholesale and retail systems.

Wastewater treatment and recycling

Essentially all Melbourne properties are connected to the sewer system. Sewerage, stormwater drainage and water reticulation systems are compulsory components of urban subdivision. The sewer system and treatment plants are owned and managed by the State government. Most of Melbourne's effluent is treated in two major treatment plants, either in lagoons (54 per cent) or through an activated sludge treatment plant (40 per cent). The remainder is treated in small local treatment plants. Most treated wastewater is discharged to the marine environment.

Wastewater recycling is currently minimal with approximately one per cent recycled largely due to the low cost of town water and the lack of infrastructure for distributing recycled wastewater. However there is a target to increase the amount of wastewater recycled to 20 per cent by 2010.

MEXICO CITY

Background

Mexico City has a population of nearly 20 million. Three subterranean sources provide 81 per cent of the city's water. Two of the wells are in rural areas and one is within the urban zone. The remaining 19 per cent per cent come from surface water, which travels up to 120km to reach users. The aquifers are over-exploited and this is likely to be exacerbated over the next 20 years given projected population growth, necessitating reliance on alternative peripheral distant sources that are costly to harvest and transport.

Most aquifers do not have protected catchments, but in an effort to improve water quality, the Federal National Water Commission (NWC) has proclaimed a number of green zones around some aquifers.

Resource management, ownership and regulatory control

The federal government owns the water sources and exploitation rights in all the territories. The NWC harvests and treats the water before its wholesale transfer to the states. The states supply the water to local municipalities, who are responsible for distribution to customers, metering consumption, billing and hydraulic services. A number of privately owned wells meet individual demands mainly in industry and agriculture.

Various national measures are in place to regulate water and wastewater quality, water rights, and standards for urban services. These are contained in acts that define water management, discharges to drainage systems, standards to regulate discharges of wastewater, and a requirement to treat all urban wastewaters before their discharge to water bodies. The State of Mexico's Institute of Health monitors town water quality. On average, 1500 water samples are taken annually.

However, in reality, the only obligation water companies have is to ensure that the minimum standards are maintained. In 1999, the NWC launched the *Clean Water Program* and the State of Mexico established an inter-institutional committee to fight the endemic problem of cholera.

Political and economic issues

Over the past 10 years a number of measures have been introduced to prevent over exploitation of water resources, control discharges to the environment and to monitor water quality. The state also has strategies to improve maintenance and reduce leakages in the distribution network, use treated wastewater for other than domestic purposes, and education campaigns to raise awareness of these strategies.

A financial code sets out the water pricing policy. The NWC fixes tariffs, which include exploitation agreements. The State Water Commission applies public fees that reflect the wholesale cost of water, exploitation agreements and operation costs. Councils and operating agencies apply the official tariff as prescribed in the financial code. In some instances the operating agencies apply their own public rates. Different tariffs are applied depending on volume and type of use. Discounts and concessions are available for early payment, pensioners, widows and aged people.

Competition between urban and rural uses of water has led to social conflicts that act as barriers to economic development. This should diminish with the promotion of treated wastewater for use in agriculture.

Infrastructure maintenance and replacement

The Federal government is responsible for providing and maintaining the extraction and treatment infrastructure,

while the States and municipalities are responsible for the operation and maintenance of the distribution networks. Storage tanks are cleaned and disinfected in line with Department of Health standards.

Concrete and asbestos-cement pipes are used in 95 per cent of the transfer and distribution networks. No asset and network maintenance programs are currently in existence. The systems are not designed for fire fighting.

A 10 MCA water pressure is considered adequate for any use, but this pressure is not uniform across the city, necessitating installation of water tanks in many buildings. It is hoped to rectify this by installing strategically located pumps.

About 40 per cent of water is lost in the distribution networks and in households, primarily due to deficient distribution and reticulation systems. Seismic activity and movement of clay soils contribute to water losses, as well as disruption of services. While inspections are carried out following earth tremors to look for visible leaks, actual maintenance is more corrective than preventative.

Modern equipment and new technology are sorely needed to reduce water losses, improve metering systems as well as billing and cost recovery, and to repair network damage caused by seismic activity.

Wastewater treatment and recycling

About 94 per cent of domestic and industrial users are connected to town sewerage systems. Forty-two systems operate within the metropolitan area with a capacity of 3.7m^3/s, but operating at 3m^3/s. Wastewater is treated in lagoons (13 per cent), activated sludge systems (80 per cent), as well as anaerobic and bio-filtration systems (7 per cent). In reality, the existing system can only treat about 17 per cent of the wastewater from the metropolitan area, with 83 per cent of the effluent discharged, untreated, to the environment. About 200 tons of sludge is generated annually which is used in agriculture or incinerated.

Ownership and operation of the wastewater systems is divided between the Federation, the States and local government, and a sprinkling of private operators.

A plan to recycle effluent for industrial and irrigation uses has been developed but is yet to be implemented. Apart from financial difficulties, the ability of existing water resources to meet the demand will be the main factor in whether recycling will be undertaken.

MONTREAL

Background

Montreal's 1.5 million inhabitants use close to 647,036 megalitres of water annually or about 1,772,700m^3 a day. The St Laurent River provides all the city's water. Current supplies are sufficient to meet the needs of the metropolis during normal conditions. Although drought related water shortage does not appear to be an issue, no watering of gardens and public parks is permitted between 8:00 and 18:00.

Ownership and regulatory control

The city's water resources are owned by the federal and provincial governments. The City of Montreal owns the intake facilities, the treatment plants and part of the distribution system; the rest of the distribution networks is owned by client municipalities. Permits are required for extracting water from the river. Regulatory control of drinking water is the responsibility of the municipality under federal delegation and provincial legislation establishing the water quality standards, monitoring and analysis requirements.

Tariffs are based on property values and domestic properties do not have water meters. About 1,100 industrial and large consumers are metered, and are charged extra if consumption exceeds their property value-based allocation.

Catchment management and water quality

The river catchment is not protected and water supply point is 610m from the riverbank. Water taken from the river undergoes comprehensive treatment in two plants before it is pumped directly into distribution network.

About 60,000 water samples are analysed annually in the City of Montreal's laboratory. Test results are assessed by the Quebec Ministry for Environment and made public. Over the past two years almost all of the treated water samples had less than 10 total coliforms (non-faecal). A five-year study into the health aspects of water quality and treatment works is nearing completion.

Infrastructure maintenance and replacement

The distribution network has 2,760km of mains, including 400km of large mains, and seven major service reservoirs with a total capacity 625,600m^3. The major mains are principally cast iron, steel or reinforced concrete.

Unaccounted-for-water is between 35-40 percent. Monitoring throughout the distribution and reticulation networks ensures minimum water pressure of 40 psi at all times.

Wastewater treatment and recycling

Almost 100 per cent of the 260,000 properties in the city are connected to the sewer, with a negligible number relying on septic tanks. All the collected wastewater undergoes physical-chemical treatment. The wastewater treatment plants are owned by the Montreal Metropolitan Government and managed by local municipalities and they produce 275,000 tonnes of bio-solids every year. Sludges are stored for four days before being incinerated.

Less than one percent of treated wastewater from the treatment plants is used as raw water for industrial purposes. There are no long-term plans to recycle wastewater.

PARIS ILE-DE-FRANCE

Background

Paris-Ile-de-France (Paris), with a population of almost 11 million inhabitants (17 per cent of France's population), is the country's prime economic region. Ten million people live the City of Paris and its surrounding suburbs, and the rest in rural centres around the periphery.

Water is abundant in the region and Paris and its suburbs consume annually almost 90 per cent of the 850,000 megalitres used in the whole region. This is less than half the total production capacity. Two-thirds of the region's water comes from rivers and a third from underground aquifers. Average daily consumption is about 215 litres per person, of which about 150 litres is used internally. Consumption has decreased steadily since 1990.

Catchment management, water quality and supplying security

Reticulated waster is of good quality. The Paris-Ile-de-France region has developed a system of potable water treatment plants capable of treating water of mediocre quality. The dozen or so plants which supply part of greater Paris are able to carry out physical treatment, biochemical treatment, physico-chemical treatment and by chlorination. Some plants use new techniques such as ultra-filtration, electro-chlorination and nanofiltration. The traditional treatment for water from underground aquifers is settlement and chlorine disinfection. This is increasingly being supplemented by treatments using nitrates and phyto-sanitary products.

To reduce the risks of pollution water upstream of the treatment plants is protected by having some areas where certain human activities are prohibited or restricted. Other actions include agreements with farmers to reduce contamination from nitrates and pesticides, diversification of supply, a network of river-based monitoring stations, and a measurement network to monitor surface and underground waters.

Although the risk of drought in the regions is small, Paris is fully prepared to deal with such an eventuality – additional potable water production centres, network interconnectivity, treated and untreated water reserves, storage dams, stocks of reagents in the event of serious pollution and a potable water supply plan. Paradoxically, it is flooding that poses the greatest risk as the majority of treatment plants would be physically immobilised in a catastrophic flood. Presently, emergency water needs of 10-20 litres per person per day are not guaranteed. An eventual recourse to deeper groundwater would be envisaged in this situation.

Ownership and regulatory control

Water resources belong to the nation. Responsibility for their management for human needs lies with local governments who are able to delegate to the private sector. Responsibility for water supply in Paris is shared with private companies where private producers and distributors manage 99 per cent of the city's water. The plants, reservoirs and networks belong to the communes (local municipalities), although some plants belong to private operators.

The national government legislates, regulates and controls water management. The Ministry for Health establishes the regulatory framework, ensures water supply quality and issues approvals for all potable water harvesting projects.

Infrastructure, maintenance and replacement

An interconnected network of water supply pipes serves almost all of Paris and its suburbs. The 2,400km of pota-

ble water network is constantly monitored by the water suppliers, particularly in greater Paris. About 95 per cent of the network is made of cast iron with half being more than 100 years old. Cast iron is being progressively replaced by reinforced concrete, steel and high-density polyethylene. Water is distributed through more than 8,000km of pipes, which were constructed at the beginning of the 1950s and are primarily of reinforced concrete and high-density polyethylene. Leakages in the network are estimated to be around 10-15 per cent.

Waste water treatment and Recycling

Most of the population in Paris and its suburbs is connected to the sewer, as are 80 per cent of the 2,700 industries in the city. In rural areas, the majority of users are connected to the sewer but it is estimated that about 500,000 people dispose of their wastewater to individual or collective septic tank systems.

Wastewater is treated by more than 500 treatment plants. A small amount is spread as manure or goes to lagoons. The total treatment capacity allows about 80 per cent of the effluent to be purified. Biological treatment by activated sludges is used predominantly. Investment programs are proposed to increase capacity and improve nitrogen and phosphorous treatment.

Of the 150,000 tonnes of purified sludge produced annually, 90 per cent is used in agriculture, the rest is incinerated or buried. This is done under a European Directive that prescribes conditions and standards for sludge spreading and content of toxic constituents.

PORT ELIZABETH

Background

The City of Port Elizabeth and six other local authorities make up the Municipality of Port Elizabeth, which has 1.25 million inhabitants. In 1999 they used 68,360 megalitres of water coming from surface water sources. An integrated system of rivers and dams ensures a maximum daily allocation of 70 megalitres. Consumption and population projections for 2010 indicate increases of 63 and 68 per cent respectively. Although current supplies are sufficient to meet the additional demand, it is anticipated that new water sources will need to be identified within five years.

Ownership and regulatory control

The government and the municipality share water resource ownership. The Municipality of Port Elizabeth is the regional water supply authority. *The National Water Act* sets the framework for managing the catchments and town water supply. Local government is responsible for the operation of the water supply system and for setting tariffs. Internal and external competition for water are managed through agreements between the government and the municipality.

Tariff structures are based on metered consumption charges, and fixed rates where properties are yet to be connected. The government funds a rebate scheme for low-income families. Water revenue is only marginally higher than operating costs.

Catchment management and water quality

Activities in the catchment areas are primarily agriculture and forestry, with little human interference. However, some of the catchments are coming under pressure

from informal human settlement. An important management issue is the need to rid the catchments of introduced foreign plants that absorb precious run-off, and restore the natural vegetation. New legislation will establish Catchment Management Authorities that will oversee activities, control development within the catchments, and ban the construction of new dams.

All waters undergo comprehensive treatment under criteria established by the South African Bureau of Standards and the Department of Water Affairs and Forestry. The municipality monitors water quality and routinely tests about 2000 samples each year, publishing the results in its Scientific Services Division annual report. Although the municipality is not required to report to either of the above bodies, there is a pro-active approach to maintain high-quality potable water and water quality problems are investigated and resolved immediately.

Infrastructure maintenance and replacement

The water supply system has nine dams with a combined storage capacity of 275,383 megalitres. These are located between 40 and120km from the city centre. The distribution and reticulation networks are totally enclosed, using primarily asbestos cement (70 per cent) and cast iron (15 per cent) pipes. The reticulation network is 2,700km long, supplying water to 109,000 metered properties. Another 40,000 are expected to have meters installed by the end of 2002.

The rate of 150 bursts per 100km and 25 bursts per 1,000 properties is high and indicative of an aging reticulation system. However, round-the-clock repair teams ensure that service is restored within two hours. Minimum water pressure is 24 metres. Encrustations in cast iron pipes, that restrict water flows, often lead to complaints about water pressure.

Unaccounted-for-water is around 15 per cent and these losses are probably linked to the aging infrastructure. Regular surveys identify leaks in the network, but would be assisted by the introduction of SCADA and GIS technology to enable early detection of problems. The municipality is implementing an integrated water management information system that includes an asset register and a management module.

Wastewater treatment and recycling

About 86 per cent of properties are connected to the sewerage system, which is owned and managed by the Municipality of Port Elizabeth. Unconnected properties discharge to either septic tanks or conservancy tanks (one per cent) or use buckets (13 per cent), although it is not clear where bucket discharges go. All collected wastewater is treated by the activated sludge process, with 97 per cent of the biosolids produced (about 15 000 tonnes a year) used in brick making. The remainder goes to land-fill.

Approximately 5 per cent of the municipality's wastewater is reused by industry and for irrigation. This is expected to rise to 40 per cent by 2020. Recycled waters are not used for drinking purposes, but it is expected that 30 per cent of the city's potable water will come from treated wastewater by 2020.

RIO DE JANEIRO

Background

Rio de Janeiro has a population of about 10 million and it draws all its water from the Guandu River. While Brazil's water catchments hold 12 per cent of the world's fresh water its quality is being adversely affected by deforestation, lack of wastewater treatment, increasing industrial pollution and uncontrolled land uses in some areas.

Resource management and regulatory control

Recently, the National Agency of Water has been created to develop a national policy for water resources and establish basin committees to manage the water catchments. It is also anticipated that water agencies will be created to act as the executive arm of these committees.

A concessionary state agency is responsible for harvesting, treating and distributing water and for the sewerage network for Rio de Janeiro. The State Administrator of Rivers and Streams is responsible for maintaining the integrity of rivers and streams within the city, and the State Environment Protection Agency is responsible for water quality, including that at the city's beaches.

The ability of government agencies to discharge their responsibilities is suffering because of the State Government's failure to develop an independent organisation to implement strict objectives for water supply and wastewater treatment. The establishment of this organisation was agreed by all states in the Federal Republic of Brazil under a National Purification Plan.

Wastewater treatment

Approximately 33 per cent of Rio de Janerio's wastewater is collected for treatment. Private companies treat some industrial wastes, while the rest is dumped directly into water bodies or cesspools.

The situation of the sewerage network of the city is very serious and requires a significant investment for its upgrading and extension. However, the Federation and the State of Rio de Janeiro are experiencing significant economic and financial difficulties.

In the vacuum created by inefficient state management, the City of Rio de Janeiro has assumed responsibilities over which it has no legal jurisdiction. Within the municipal framework, the Municipal Secretariat for Public Works recently created the Rio Águas Foundation that is in charge of drainage and part of the sewerage system.

Plans for the future

The state and the City of Rio de Janeiro have agreed to invite international tenders for a service concession in the western area of the city that is continuing to expand. This concession will develop and operate a water supply system, and collect, treat and discharge wastewaters.

RIYADH

Background

Riyadh, a city of 3.8 million inhabitants, is located in the extremely arid centre of Saudi Arabia. With little rainfall, the main water sources are desalinated water from Jubail (65 per cent) and ground water (35 per cent). All properties are connected to the town water supply. In 1999 water consumption was 506,483 megalitres, mostly for domestic uses. Current water supply can meet only 80 per cent of the demand for drinking water. With an eight per cent annual growth rate, Riyadh's population is expected to reach 7.7 million in 2010 and 10.5 in 2020, with a commensurate increase in water demand.

Ownership and regulatory control

All water utilities and resources are owned by the government, which also operates and maintains them through the Riyadh Water Supply Authority (RWSA). A licence to extract water is required from the Water Resources Management Department (WRMD), in the Ministry of Agriculture.

The tariff structure is based on volumetric consumption using a sliding scale that penalises high consumption, but the water revenues do not cover production and distribution costs. There are no plans to change the pricing policy.

Resource management and water quality

Existing water resources are limited, necessitating the application of an aggressive demand management plan. Measures introduced by the RWSA to restrict water consumption include banning the use of drinking water for irrigation, restricting water flows to properties and intermittent interruptions to water supply, and a campaign to detect leaks in the network and on domestic properties. Riyadh relies on public education campaigns and water pricing as measures to limit consumption.

The RWSA is planning to upgrade the system by adding six desalination plants at Jubail, expanding the well fields and constructing city feeders and terminal reservoirs. In the mean time, for areas experiencing shortages, the RWSA is using contractors to supply water by tankers.

Groundwater is treated through cooling, filtration and reverse osmosis. Both desalinated and ground water are of potable quality. Regular cleaning of production, storage and distribution systems and ongoing monitoring ensure water quality. Under water quality criteria of the WRMD the RWSA annually conducts about 4,950 bacteriological tests and approximately 95 per cent of samples comply with the criteria. The test results are available to the public on request.

Infrastructure maintenance and replacement

Water is stored in enclosed, reinforced concrete tanks, which have the capacity to hold 3,000 megalitres. The transfer system for desalinated water from Jubail is 400km long, and about 60-90km long for ground water. The predominant materials used are ductile iron and steel. The total length of the distribution and reticulation networks is 9,406km.

A one bar minimum pressure is maintained through the division of Riyadh into several zones, each with its own distribution system.

Unaccounted-for-water is about 32 per cent, half of which is due to leakages in the system and the rest due to illegal unregistered connections. Distribution and

reticulation networks are inspected periodically to identify and repair leaks. Pipes with repeated leaks are replaced.

Wastewater treatment and recycling

Sewage treatment plants are owned and operated by the municipality. About 35 per cent of the population is connected to the sewer. The majority discharge to septic tanks or use special tankers that transfer wastes to treatment plants. All collected wastes undergo tertiary treatment.

Treated wastewater is not currently reused in the town water supply, but the Riyadh Metropolitan Development Strategy proposes to use up to 50 per cent of treated wastewater for potable purposes by 2021. About 32 per cent of treated wastewater is currently used for irrigation, and three per cent for cooling.

SEOUL

Background

Seoul is home to 10 million people, approximately one quarter of South Korea's population, who use over 1.6 million megalitres of water annually. Over the past decade Seoul's population and water consumption have not changed greatly, and it is expected that this trend will continue over the next decade. All of Seoul's tap water comes from surface sources, the Paldang Dam and the Jamshil reservoir that is fed by the Han River.

The Han River is very important to Seoul and neighbouring municipalities. To protect the river's environment the central government has restricted residential development and the construction of polluting industries.

Ownership and regulatory control

Water resources are owned by the state. The National Ministry of Construction and Transport, and the Ministry of Environment, are responsible for water management as well as for water quantity and quality measures. The Korean Water Resources Corporation develops and manages the water resources. Special licences to harvest water are required from either the Seoul Regional Construction Office or the Korea Electric Power Corporation. The Seoul Waterworks, owned by the City of Seoul, produce and supply water to the city's inhabitants. Collecting revenue, levies and fines is the responsibility of 11 private sector companies, which are also contracted to build new infrastructure.

Resource management and water quality

The Paldang catchment is used for farming and has urban areas within it, but the Jamshil catchment is a protected area. The city's water resources are capable of

meeting 100 per cent of current and future demand. Nevertheless, water utilities routinely advise customers to conserve water. However, the city's standard fixed price for water and sewage disposal does not encourage efficient water use.

Public health issues are addressed by legislation that ensures quality of drinking water and the management of wastewaters. The Ministry of Environment is responsible for developing the necessary regulatory controls, which are implemented by the city and the Seoul Waterworks.

Paldang and Han waters are treated chemically and undergo coagulation, sedimentation filtration and chlorination. The Seoul Waterworks collects close to 11,000 water samples annually for testing against standards in the *Drinking Water Quality Guidelines 1995.* The results are published. Although there have not been instances of illness due to poor water quality, 1350 complaints were recorded between January - December 1999. The city has conducted a number of studies to examine the operation of water treatment plants, and water quality trends in the Han gang River, other surface sources and in the water supply system. It has also set up a research institute at the cost of US$3.2 million to study water quality and to develop new technologies.

Infrastructure maintenance and replacement

Two water treatment plants meet the entire demand for water in Seoul. Water pressure is maintained at a minimum of 15 metres at customer's properties, or 25 metres in the case of direct water supply where there is no water tank. Water pressure is measured periodically, and 24-hour emergency services are in place to respond to failure within one hour.

Over 36 per cent of the bulk water supply is not accounted for. Strategies to reduce water loss include water leakage detection, measuring night water flows, maintaining water pressure and replacing water meters.

Challenges for the future

Having moved from quantity-oriented to quality based water policy, Seoul is now focusing on enhancing water quality and security of supply, and improving the management and operation of the supply system. It is planning to introduce new technologies and management styles that will result in increased productivity and quality, lower production costs and cheaper water. Presently, water revenues cover only 75 per cent of the cost of production. Seoul is planning to review its pricing policy to remove the need for subsidised water.

Other challenges include enhancing the water treatment system and improving the distribution network to reduce the level of unaccounted-for-water.

SYDNEY

Background

The Sydney Catchment Authority (SCA) supplies water to close to four million customers. All of Sydney's water comes from surface sources and it is stored in 16 medium to large reservoirs. Current maximum annual sustainable yield is 657,000 megalitres, sufficient to meet the entire demand during normal conditions. In 1999 the SCA supplied 599,692 megalitres of water.

Trends over a ten-year period indicate that water consumption fell by eight per cent, even though Sydney's population increased by nine per cent. This trend is projected to continue with a 13 per cent drop in consumption against a nine per cent increase in population by 2010, which will be achieved through demand management targets.

Ownership and regulatory control

Water is owned by the state and managed by the Department of Land and Water Conservation. The government-owned SCA extracts and delivers water to privately owned water filtration plants that are managed by the Sydney Water Corporation (SWC), a government-owned water distributor and retailer. Contractors are used for water filtration and in engineering and construction activities. Various state acts and regulations govern water supply management, public health, and water quality.

The tariff structure is based on a 'user pays' system, combining volumetric consumption and a system access charge. An independent state regulatory tribunal sets prices. Water revenues exceed operating cost.

Catchment management and water quality

The Warragamba catchment supplies 80 per cent of the city's water and it supports intensive agriculture, some industry and mining, as well as urban development. Some catchments are forested and very few entirely protected. All of Sydney's water is treated by filtration, while 80 per cent undergoes comprehensive treatment.

SWC and the SCA work together to implement a demand management program involving community education in efficient water use, leakage control, water recycling, as well as audits of industrial, hospital and residential properties. Depending on the severity of droughts, water restrictions are imposed when storage levels fall below 55-60 per cent of capacity.

Both SCA and SWC monitor water quality against national standards with compliance ensured by the state regulator. Water samples are tested regularly, monitoring for cryptosporidium and giardia, and in some instances water samples are taken daily. Test results are published.

Infrastructure maintenance and replacement

Water is transferred mostly in pipes, and only 20 per cent by channel, aqueduct and tunnels over distances between 27km and 64km. During drought, water from the Shoalhaven catchment travels approximately 150km via pipelines, pumping stations and open channels. Open channels are inspected daily, while pipes and other components in the network are inspected every four years. Water pressure is maintained at 15 metres.

In spite of regular preventative inspections and maintenance works unaccounted-for-water is about 15 per cent of the total supplied.

For the SCA, the key areas for improvement over the next 10 years are technical development in catchment protection, pollution abatement and reducing water consumption.

Wastewater treatment and recycling

Approximately 97 per cent of the 1.5 million properties in Sydney are connected to the sewerage system. The rest use septic tanks or pump-out systems. In dry weather, 99.5 per cent of the collected effluent is treated. Wastewater is treated in sewage treatment plants. Primary treatment is provided for 85 per cent of the collected wastewater prior to discharge to the ocean, while the wastewater going through secondary and/or tertiary treatment is discharged to inland surface waters.

Treatment plants are owned and managed by the state, except for one that is run by a local municipality. They produce approximately 40,000 tons of dried sludge, which under State Environment Protection Authority guidelines, are primarily used in agriculture, forestry, and mine remediation.

Although encouraging water reuse, Sydney does not provide financial incentives to reuse wastewater. Over the next 20 years Sydney plans to increase the use of treated wastewater for non-potable uses from the current 2.4 per cent. However, it has deferred an investigation of water reuse for potable supplies.

TORONTO

Background

Toronto's water is drawn from Lake Ontario, one of North America's five Great Lakes. The city's Water and Wastewater Services Division (WWSD) supplies potable water to residents in Toronto and the York Region, north of the city. The combined population of three million annually consumes an average of 525,000 megalitres of water, which is less than one tenth of one percent of the lake's total water volume.

Four strategically located filtration plants ensure uninterrupted water supply, even in the event of a treatment plant closure because of accidental discharges or chemical spills in the lake.

Ownership and regulatory control

Canada and the USA own the water resources. The City of Toronto owns and operates the water supply system. The federal government provides guidelines for drinking water quality, and the provincial (state) government establishes legislative and regulatory controls. A permit is required to extract water.

Following local government restructuring in 1998, the WWSD was created to integrate the functions of several municipalities into one public utility, responsible for all water and wastewater services in the city. The WWSD is self-sustaining and has a separate budget. Tariff structures are based on water consumption and a sewage service charge. Revenues cover all annual operating costs and provide reserves for capital expenditure.

Catchment management and water quality

Situated between the USA and Canada, Lake Ontario is navigated by large ships and its northern and southern

shores are highly urbanised. Because it is not a protected catchment all the waters undergo extensive treatment, including a special treatment to minimise the taste and odour from naturally occurring compounds during late summer.

The City of Toronto is responsible for ensuring that water quality complies with the Ontario Drinking Water Standards. These standards establish the parameters for water treatment, monitoring quality, and reporting on performance. The city annually conducts 55,000 bacteriological tests on 18,000 samples, taken randomly from the four filtration plants and the distribution system. Quarterly reports are published.

Efficient water use is achieved through public education campaigns, leak detection, installing water meters, water audits for residential and industrial/commercial properties, and a toilet replacement program.

Infrastructure maintenance and replacement

Treated water is stored in 14 enclosed concrete tanks that have a combined capacity of 1,750 megalitres. Water is transferred predominantly in steel pipes. Distance from the source is between 25km and 40km. Regular inspections and flushing programs ensure water quality. Water reservoirs are cleaned every two to five years. Trunk transmission mains are not cleaned.

Water pressure in the mains is maintained at a minimum of 27 metres during peak demand. Performance is monitored using a SCADA system.

Unaccounted-for-water is estimated at around 14 per cent. Strategies to reduce this include leak detection, calibrating and maintaining existing water meters, and installing metres in older parts of the city.

The main reasons for water pipes bursting are freezing and corrosion. The burst rate is 40 breaks per 100km in the reticulation system. All interruptions to service are repaired immediately. The target is to restore supply within four hours to 90 per cent of unplanned interruptions.

Wastewater treatment and recycling

The City of Toronto owns and manages the sewage treatment plants. Almost all properties are linked to the sewer system. All dry weather, and approximately 98 per cent wet weather, flows are treated in secondary treatment plants and given final disinfection before discharge. The treatment plants' effluent discharge criteria are more stringent than the prescribed state limits. Annual sludge production is around 63,000 metric tonnes. Sludge is stored in digesters for 13 days after which 43 per cent is used in agriculture and the remainder incinerated. Areas spread with sludge are registered and controlled for pathogens and heavy metals.

The unlimited availability of raw water mitigates against the introduction of water recycling.

WELLINGTON

Background

Wellington, the capital of New Zealand, has a population of 347,000. Rivers provide 61 per cent of the water supply to the metropolitan area, with a secure artesian aquifer providing the balance. Water is supplied to 128,000 properties. With an annual water consumption of 54,000 megalitres and a maximum sustainable annual water supply yield of 77,000 megalitres, Wellington has ample supplies of good quality water for its population which is not expected to grow much over the next 10-20 years.

Ownership and regulatory control

The national government is responsible for legislative and regulatory control. Water catchments and the water system are owned and managed by the Wellington Regional Council, which is a water wholesaler and sells water to the four cities in the area. Each city retails water to its customers and is responsible for its own water reticulation services. The cities have a natural monopoly as retailers within their city boundaries. The cities set their own retail charges.

Tariffs for water supply and sewerage services are based on a uniform annual charge as part of property (council) rates. Less than two per cent of domestic properties have water meters, but most commercial and industrial properties are metered.

Catchment management and water quality

Surface water catchments are fully protected and consist of three pristine forested areas. Water is fully treated to a very high standard. Wholesale water is supplied under the provisions of the *Drinking Water Standards New Zealand 1995.*

The wholesaler tests water in the supply system and the four councils test water in the reticulation network. In 1999 the wholesaler took 2,700 routine samples, and it is believed that the retailers took a similar number of samples. Both public and private laboratories carry out testing and the results are provided to the Public Health Services for assessment. Test results are published.

There is pressure to retain as much water in the rivers as possible for environmental and recreational reasons. The maximum amount of water that may be extracted for public water supply is regulated under the Regional Council's *Fresh Water Plan. Government* consent is required to extract water and applications must be accompanied by an environmental assessment of the likely effects of extracting water.

One of the risks to the water supply system in Wellington is a major earthquake that could cause considerable damage. The parts of the system that would be prone to damage have been identified and a detailed earthquake response plan has been adopted.

Infrastructure maintenance and replacement

Water is harvested into a series of concrete dams, up to 5m high, with various types of infiltration structures constructed across the rivers; and eight wells, 30m deep, to tap the aquifer. As well, two lakes are used to store raw surface water as a back up when there is inadequate water in one of the rivers to ensure environmental flows, or it is too expensive to treat the river water because of its condition.

Water is treated in three treatment plants before being transferred in concrete lined steel or ductile iron pipes to the distributors. Distance from source is approximately 40km. Because of the high quality of the treated water cleaning of pipes and reservoirs is seldom needed.

Reservoirs may be cleaned once every 10-20 years.

The integrated nature of the system means that any of the three treatment plants can deliver water to any point of supply, allowing sections of pipelines to be isolated with no or minimal interruption to users. The pipes and network fixtures are routinely inspected. The expected life of the pipes ranges from 75 to 100 years.

Unaccounted-for-water is about 20 per cent and four cities address this through a yearly leak detection program.

Wastewater treatment and recycling

Nearly all properties are connected to the town sewer, except a few in rural areas that rely on septic tanks. Wastes are treated in sewerage treatment plants before being discharged to ocean outfalls. Treatment plants are owned and operated by the four councils using contractors for some services.

Abundant raw water resources mitigate against the reuse of treated wastewaters.

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Peter Dillon and J.M. Anderson, CSIRO, Australia,. New Approaches to Water Reciclyng and Trading.

RÉSUMÉ

La version française de ce rapport est disponible sur le site web de Metropolis: **www. metropolis.org**

Quelques unes des métropoles disposent d'abondantes ressources en eau qui leur permettront de satisfaire la demande future, mais près de la moitié des métropoles participantes mettront en œuvre des plans dans les dix prochaines années pour assurer la sécurité de l'alimentation en eau potable à long terme. Quelques métropoles auront recours à des sources d'approvisionnement non conventionnelles telles que le recyclage d'eaux usées pour satisfaire la demande, d'autres notamment celles des pays industrialisés ou développés, veulent obtenir un meilleur rendement, être plus économes en eau, introduire des systèmes de gestion de la demande et étudient de nouvelles sources d'approvisionnement qui ne demanderaient pas de nouvelles infrastructures majeures (barrages).

De nombreuses métropoles signalent qu'elles ont réformé leurs services d'eau ces dix dernières années, les approches étaient variées. Cette étude démontre que les métropoles continuent à réformer les systèmes d'approvisionnement en eau. Il semble que les principaux objectifs de ces réformes sont d'encourager la participation du secteur privé pour réduire les coûts et améliorer la qualité. L'ouverture du secteur de l'eau à la concurrence facilite aussi le financement, l'introduction de nouvelles technologies et améliore la prestation de service. Les services d'eau privatisés vendent l'eau à bénéfice qui est dans certains cas réglementé. La privatisation n'est pas le seul moyen employé pour améliorer le rendement et la qualité. Quelques villes villes ont adopté d'autres approches: référenciation, délégation par contrat d'activités annexes et contrôles réglementaires.

La plupart des métropoles disposent de plusieurs sources d'approvisionnement, la majorité utilise les eaux provenant de fleuves, de barrages et de lacs. Pour ce qui est des systèmes de distribution, la plupart des agglomérations disposent de deux, ou de plus de deux sources qu'elles considèrent essentielles à la minimisation des interruptions de service et au maintien de l'approvisionnement en eau. Dix métropoles indiquent que les activités implantées dans les bassins versants sont: forêts, pâturages, industrie, agriculture et habitat. Ces activités sont significatives dans certains bassins. Quelques unes doivent acheminer l'eau sur de longues distances. Il n'est pas rare que les sources d'approvisionnement se trouvent à 150 km de l'agglomération.

Les mesures prises pour protéger l'approvisionnement en eau sont directement liées à la provenance de l'eau et à la façon dont elle est prélevée. La plupart des villes n'ont pas de périmètres de protection autour des points de captage, ni de bassin versant clôturé. Elles réglementent les rejets et les activités implantées dans le bassin versant pour protéger la ressource en eau. Certaines métropoles élaborent de nouvelles stratégies pour protéger leur bassin versant, d'autres ne semblent traiter leur eau brute que pour préserver la santé des habitants. Deux des métropoles participantes conseillent aux habitants de toujours faire bouillir l'eau avant de la consommer à cause de la défaillance des infrastructures et des services de distribution.

Toutes les métropoles surveillent la qualité de l'eau et l'administration locale est responsable ou est directement impliquée dans l'approvisionnement en eau. Toutes les métropoles sont propriétaires et gèrent les stations d'épuration. Plus de trois quart des villes mènent des campagnes de conservation de l'eau.

Toutes les métropoles perdent de l'eau et le volume d'eau non comptabilisée varie de façon considérable. La plupart estiment qu'elles perdent entre 15 et 30% de l'eau émise dans le réseau. Certaines ne peuvent justifier de 50% des pertes, celle qui en perd le moins estime qu'elle en perd 3%.

La majorité des métropoles participantes indiquent que le maintien des débits nécessaires au milieu n'est pas une priorité. Certaines d'entre elles disent ne pas pouvoir faire autrement. Les agglomérations des pays riches sont celles qui reconnaissent la nécessité de maintenir les débits nécessaires au milieu..

La tarification est en général du ressort du gouvernement. Les villes qui touchent d'importantes subventions semblent avoir des structures de prix plutôt arbitraires.

Dans de nombeux pays en développement les services d'assainissement sont presque inexistants et un certain nombre de villes ne sont pas dotées de réseau d'égout. L'insuffisance de la collecte et de l'épuration des eaux usées dans les pays en développement est la cause de la pollution du milieu, de l'absence d'hygiène et fait courir un risque sanitaire.

Il n'est pas non plus surprenant qu'il ressorte de cette étude que les villes des pays développés consomment plus d'eau par habitant, sont dotés d'infrastructures mieux entretenues et traitent les eaux usées avant leur rejet dans le milieu.

Les trente métropoles participantes représentent tous les continents, les pays développés et les pays en développement ce qui est un avantage pour cette étude, mais le questionnaire a été interprété différemment. Par conséquent les données recueillies sont parfois contradictoires. Certaines villes n'ont pas répondu à toutes les questions. Ces problèmes ont été pris en compte dans le cadre de la rédaction de ce rapport.

RESUMEN EJECUTIVO

La versión española de este informe está disponible en el sitio web de Metropolis: **www. metropolis.org**

Aunque algunas ciudades disponen de suficientes recursos hídricos para satisfacer las necesidades futuras, casi la mitad de las ciudades del estudio cuentan con planes que se aplicarán en los próximos diez años para garantizar suministros seguros de agua a largo plazo. En algunos casos, para satisfacer estas necesidades se usarán fuentes de suministro no tradicionales, como la reutilización de agua saneada o reciclada. En muchos otros, especialmente en los países industrializados y desarrollados, las ciudades buscan un uso más eficiente y más económico del agua potable, la introducción de sistemas de gestión de la demanda y la explotación de fuentes potenciales de suministro que no requieran nuevas grandes infraestructuras, como presas.

Muchas ciudades informaron de que habían reformado sus servicios hidrológicos en los últimos diez años, aunque los enfoques variaban. El estudio demuestra un esfuerzo continuado por reformar los sistemas de suministro de agua. Al parecer, el objetivo principal es crear las condiciones para una mayor implicación del sector privado en estrategias de reducción de costes y de mejora de la calidad. La implicación del sector privado también se está utilizando para facilitar la entrada de nuevas tecnologías y fuentes de financiación, así como para mejorar los servicios mediante la competencia. Por lo general, los clientes de ciudades con servicios privatizados de suministro de agua deben pagar un nivel de beneficio, aunque este aspecto puede estar regulado en la legislación. La privatización no ha sido el único método utilizado para mejorar el rendimiento y la calidad. En algunas ciudades se han utilizado sistemas alternativos, como el fomento de la competencia mediante cotas de referencia, la subcontratación de actividades periféricas y controles reguladores.

La mayoría de las ciudades indicaron que su suministro de agua bruta procedía de diversas fuentes, en su mayor parte ríos, embalses y lagos. En sus sistemas de distribución, casi todas las ciudades tienen dos o más fuentes de recursos, lo cual se considera esencial para minimizar las interrupciones y mantener el suministro. Diez de las ciudades indicaron que la explotación del suelo en sus captaciones de agua incluía una proporción variable de bosques y prados, industria, agricultura y desarrollo residencial. En algunos casos, estas actividades son significativas. Algunas ciudades necesitan transportar el agua a grandes distancias y es bastante frecuente que las fuentes de agua se encuentren a 150 km de la ciudad.

Las acciones encaminadas a proteger los suministros de agua están directamente relacionadas con saber cómo y dónde obtener agua. La mayoría de las ciudades no disponen de captaciones cercadas y protegidas, y casi todas ellas protegen sus recursos mediante la regulación de los vertidos y de las actividades en las zonas de captación del agua. Algunas ciudades están desarrollando nuevas estrategias para proteger sus captaciones de agua, mientras que otras parecen centrarse únicamente en tratar los suministros de agua bruta para velar por la salud de los ciudadanos. Dos ciudades participantes en el estudio recomiendan siempre a la población hervir el agua destinada al consumo, debido a la precariedad de la infraestructura y de los servicios de la red.

Todas las ciudades controlan la calidad de sus aguas y todos los gobiernos municipales participantes en el estudio son responsables del suministro de agua potable o están directamente implicados en él. La titularidad y la gestión de las plantas de tratamiento de aguas residuales de todas las ciudades es pública. Más de tres cuartos de las ciudades organizan regularmente campañas de conservación de los recursos hídricos.

Todas las metrópolis notificaron la existencia de pérdidas de agua en sus sistemas, aunque el porcentaje varía considerablemente. La mayoría experimentan pérdidas de entre el 15% y el 30%, mientras que hay algunos casos en los que inexplicablemente se pierde más de la mitad del agua. En la ciudad con el mejor resultado las pérdidas no superan el 3%.

De las respuestas proporcionadas por la mayoría de las ciudades del estudio se desprende que la necesidad de caudales medioambientales en los ríos para su salubridad y su ecología no se considera un uso prioritario del agua e incluso muchas parecen no tener en cuenta esta opción. El reconocimiento de la necesidad de caudales medioambientales se limita fundamentalmente a las ciudades de los países más ricos.

La tarificación del agua corre por lo general a cargo del gobierno. Las ciudades que dependen en buena parte de subsidios gubernamentales presentan estructuras de tarificación aparentemente bastante arbitrarias.

En muchos países en vías de desarrollo, el mantenimiento de los servicios de aguas residuales no es precisamente adecuado y, en diversas ciudades, las redes de alcantarillas son casi inexistentes. En estos países, la recogida y el tratamiento inadecuados de las aguas residuales son la causa de contaminación ambiental, bajos niveles de higiene e importantes riesgos para la salud.

Por otro lado, no resulta sorprendente un dato que se desprende del estudio: las ciudades de los países desarrollados presentan un mayor consumo de agua per cápita, una infraestructura en mejor estado, además de un tratamiento y una evacuación de las aguas residuales más seguros y completos.

Participaron en el estudio treinta ciudades, en representación de todos los grandes continentes, tanto del mundo desarrollado como del mundo en vías de desarrollo. A pesar de que esta diversidad resulta beneficiosa para el estudio, hubo diferencias significativas en el modo en que se interpretó y se respondió el cuestionario, lo cual ha provocado algunas incoherencias en los datos recopilados. Por otro lado, algunas ciudades no contestaron todas las preguntas. En la preparación de este informe, estos aspectos han sido tenidos en cuenta.

About Metropolis

METROPOLIS, the World Association of the Major Metropolises, established in 1985, is the leading world-wide association of large cities, and is recognised as a major player by international organisations, such as the UN-Habitat and the World Bank.
Metropolis provides a comprehensive forum for exploring issues and concerns common to major cities.

About Standing Commissions' reports

Metropolis' triennial congresses are designed to report the results of the Standing Commissions. Metropolis congresses have been held in Seoul, Barcelona, Tokyo, Montreal, Melbourne, Mexico and Paris. The following reports have been published for the Seoul Congress 2002.

The impact of major events on the development of large cities

The report collects the experience of cities, which had organised major sports and cultural events, measures the effects on their development on different territorial scales and outlines the lessons to be learned, notably in terms of identification of the success and risk factors. All in all the report has been drafted on the basis of the fourteen events studied, of which eight took place between 1988 and 2000, which provides an interesting degree of hindsight to measure the effects.

Urban poverty reduction strategies

At the dawn of the 21st century, poverty remains the most pressing problem. Cities have become the main foci of poverty due to the growing urbanisation witnessed throughout the 20th century, particularly in developing countries.
The commission, comprising representatives of 20 metropolises, has been working to better define the problem of urban poverty, to identify the best practices and intervention strategies and to make the appropriate recommendations for the benefit of decision-makers in major cities.

Enhancing and maintaining water quality for metropolises

This Metropolis study was undertaken to encourage authorities to identify the critical sustainability aspects of water supply in their cities; provide decision makers in developed and developing countries with some indicative benchmarking information; and to give water authorities information about the experiences of participating cities.
Thirty cities participated in the study, representing every major continent and the developed and developing worlds.

The information society and the city

This study has concentrated on describing the means that major cities have used to reinforce their presence in the Information Society. It focuses on the identification and analysis of e-government's good practices and provides recommendations to the Local Administration. Information used in the preparation of the report was obtained through questionnaires to cities and an analysis of a selection of metropolitan area websites from around the world.

These reports can be found in English, French and Spanish on the Metropolis Website: www.metropolis.org

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