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Water quality management in Singapore: the role of institutions, laws and regulations

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Abstract The paper analyses the legal and regulatory instruments for water quality management that have been set in place in Singapore for control of water pollution, and their evolution since the time of independence in 1965. The role of institutions in the strict implementation of the laws and regulations is also discussed, with special emphasis on the efficient inter-institutional coordination machinery that has made it possible. The analyses show that overall long-term planning and policy-making and a strong political will have been instrumental to give all aspects of water management high priority in the national agenda, thus directly supporting urban, industrial and commercial growth.

Key words Singapore; water quality; pollution control; institutions; legislation; regulations; security

Gestion de la qualité de l'eau à Singapour: le rôle des institutions, des lois et des règlements

Résumé L'article analyse les instruments juridiques et réglementaires en matière de gestion de la qualité de l'eau qui ont été mis en place à Singapour pour le contrôle de la pollution de l'eau, et leur évolution depuis l'indépendance en 1965. Le rôle des institutions dans la mise en œuvre stricte des lois et règlements est également discuté, avec un accent particulier sur le mécanisme de coordination inter-institutionnelle efficace qui a rendu cette mise en œuvre possible. Les analyses montrent que la planification globale à long terme, l'élaboration des politiques et une forte volonté politique ont joué un rôle pour donner à tous les aspects de la gestion de l'eau une priorité élevée dans la politique nationale, soutenant ainsi directement la croissance urbaine, industrielle et commerciale.

Mots clefs Singapour ; qualité ; de l'eau ; contrôle de la pollution ; institutions ; législation ; réglementation ; sécurité

1 INTRODUCTION

In recent decades, concern has grown regarding the increasing deterioration of water quality and the related social, economic and environmental impacts. South and Central Asian countries, for example, have witnessed serious impacts on the quality of life of their growing populations and on every productive sector due to the increasingly poor quality of their water resources. It is often claimed that the main constraint to controlling water pollution in developing countries is lack of investment funds. However, failed efforts to maintain water-bodies within acceptable quality limits point to the complexity of setting efficient institutional frameworks and implementing legislation as well as regulatory,

economic and information and participation-related policy instruments. The prevailing lack of coordination among the relevant institutions, missing political will and apathetic societies are also at the core of the problem. The extent of the problems is such that proactive policies and strategies are starting to emerge in some Asian countries to strengthen implementation of environmental laws and regulations. Combined with institutional innovation, they are expected to improve overall water quality conditions and also to create opportunities for alternative paths of development and urbanization that are less polluting (Evans *et al.* 2012).

The present paper discusses the legal and regulatory instruments for water quality management that

have been developed in Singapore at different times in history; how they have been modified taking into account the urban, commercial and industrial growth; and the role ministries and agencies, as well as their inter-coordination, have played in the effective implementation of laws and regulations. It shows how related policies, laws and regulations have had a decisive role in the overall conservation of the water resources and, consequently, on their more efficient and effective use by the different sectors. Finally, it submits that it has been the realization of the importance of water resources in the national development agenda that has made the city-state give special emphasis to improved water quality as part of an overall strategy for its long-term management and conservation.

2 POLLUTION CONTROL: SETTING THE RULES

Singapore is a nation with a very small area (715.8 km² in 2012) (see Department of Statistics, http://www.singstat.gov.sg/statistics/latest_data.html#12) and very high population density (7257 per km²). It is one of the largest oil refining centres, with the largest port and biggest bunkering services in the world. It is thus bound to be prone to pollution, especially when it is also a hub for chemical, pharmaceutical and electronics industries.

At the time of independence in 1965, the situation was very different. Singapore's economic and environmental future was uncertain given the declining export trade in staples, growing unemployment, limited manufacturing capacity, collapse of the Malay Federation and the planned withdrawal of a British military presence. An integrated Plan of Action for Environmental Protection was thus implemented by the Ministry of the Environment (MoE 1973). In the 1950s and 1960s, environmental laws were perceived as concerned with the protection of public health, and so the first phase of the Plan was the reorganization of the Environmental Health Division, which then was primarily responsible for street cleaning. With the establishment of a cohesive chain of command and clearly defined responsibilities, it was expected that more efficiency would be achieved.

The Environmental Public Health Act (EPHA) 1968, was implemented in February 1969 (Government of Singapore 1968). This was undertaken by the Public Health Authority under the Commissioner of Public Health and under the direction of the Minister of Health. Its objective was to integrate the environmental

health responsibilities of the Public Health Division and to create a standard code for health-related issues regarding public cleaning and hawking (food-related) services, markets, food establishments, general health, sanitation and hygiene. The Act covered almost all fields of environmental health except for air and water pollution.

In 1970, with the Environment Public Health (Amendment) Bill in Parliament, the Minister of Health proposed to strive for even higher cleaning standards. This amendment, *inter alia*, addressed the problem of dumping refuse and garbage into streams, rivers, canals and drains, as well as polluting reservoirs, lakes and catchment areas (Hansard 1970).

2.1 Water pollution control

Control of water pollution was institutionally very complex with laws and regulations that were both insufficient and ineffective. Multiple agencies used to manage water pollution related issues: the Public Utilities Board (PUB) (under the Ministry of Trade and Industry) was responsible for adequate and reliable supply of water to domestic and industrial users; and the Public Works Department (under the administrative control of the newly formed Ministry of National Development) was responsible for sewerage and drainage. Sanitation and cleansing services were the responsibility of the Health Ministry.

There were some regulations dealing with wastewater outlet connections, connection to sewers, adequate sanitary provision and wash areas, the enforcement of which depended on several authorities. For example, in some cases it was the Director of Public Works Department or the municipality who would serve notices in cases of contravention. This resulted in poor enforcement (MoE 1973). The question of authority was further complicated with the introduction of the Environmental Public Health Act 1968 (Government of Singapore 1968) that empowered the Commissioner of Public Health to serve notices to owners to provide adequate sanitary facilities.

In 1969, the then Prime Minister Lee Kuan Yew intervened in the matter of cleaning of highly polluted watercourses. He wanted the engineers to work out a strategy to prevent polluted water or sewage flowing into waterbodies and also to dredge the rivers to keep them clean (National Archives 1969a). The Prime Minister also instructed the Ministry of National Development to make a real effort to clean up the main waterbodies: Kallang Basin, Stamford Canal and Singapore River

(National Archives 1969b). As a result, regulations to control trade effluent discharge into sewers and watercourses were drafted under the Local Government (Disposal of Trade Effluents) Regulations 1970 (Tan *et al.* 2009). Provisions in the Natural Reserves Act 1970 were also applied. These prohibited the introduction of animals into the natural areas, as well as the destruction of or damage to any objects of zoological, botanical or other scientific or aesthetic interest in the reserves (Science Council of Singapore 1980).

Despite these efforts, the extent of water pollution in the watercourses was persistent. In 1971, about $455\text{--}500 \times 10^3 \text{ m}^3$ of water were consumed every day in Singapore and of this only $260 \times 10^3 \text{ m}^3 \text{ d}^{-1}$ were adequately treated, with the remaining $240 \times 10^3 \text{ m}^3 \text{ d}^{-1}$ contributing to water pollution. The origin of the discharges was divided between industries ($68 \times 10^3 \text{ m}^3 \text{ d}^{-1}$), hawkers (food sellers) and markets ($22.7 \times 10^3 \text{ m}^3 \text{ d}^{-1}$), washing of clothes ($27.3 \times 10^3 \text{ m}^3 \text{ d}^{-1}$), drainage from Kampongs or native villages ($54.5 \times 10^3 \text{ m}^3 \text{ d}^{-1}$); and government and other agencies ($45.5 \times 10^3 \text{ m}^3 \text{ d}^{-1}$) (MoE 1973).

In the opening session of the Second Parliament on 21 July 1971, the Presidential Address mentioned water pollution as one of the most serious problems and urged the Parliament to act upon it. Numerous new regulations and amendments to existing laws were passed. For example, in 1972, under Section 88 of the Public Utilities Ordinance 1963 (Government of Singapore 1963), Public Utilities Board (Catchment Area Parks) regulations made the PUB responsible for managing the catchments in the parks.¹ Under these regulations, bathing or washing of any animal, person or thing in the reservoir was prohibited to avoid polluting the reservoirs.

Introduced in 1971, the Environmental Public Health (Prohibition of Discharges of Trade Effluents into Water Courses) Regulations and Local Government (Disposal of Trade Effluents) Regulations 1970, specified standards for various types of chemicals and solid suspended material in trade effluent discharged into any watercourse. They also prescribed for installation of pre-treatment plants where required (Chia 1978). Unfortunately, the quality criteria for the trade effluents discharged provided under these regulations did not include a quality suitable for raw water supply and, therefore, for any re-use, this discharge had to undergo further treatment.

These regulations were the precursor of the subsequent Water Pollution Control and Drainage Act 1975 (WPCDA; Government of Singapore 1975). This Act consolidated the provisions of these regulations and paved the way for a more comprehensive water pollution control.

2.2 Creation of the Ministry of the Environment

Public campaigns and the Environmental Public Health Act 1968 helped in improving the quality of the urban environment and catalysed its transformation into what would be called 'a garden city' (MoE 1973). Almost at the same time, several countries around the world created ministries, departments or other bodies responsible for environment-related activities. The Environment Protection Agency was established in the USA in July 1970 and, by 1972, 14 countries (i.e. Australia, Canada, Chile, Finland, France, West Germany, Greece, Japan, Malta, New Zealand, Portugal, Senegal, Sweden and the UK) had also established such agencies. Following the trend, Singapore also established a Ministry of the Environment. The departments under the ministries of Health and National Development responsible for pollution control, sewerage, drainage and environmental health were brought under it.

After the formation of the Ministry of the Environment, the Sewerage Department was given the responsibility for water pollution control. In the 1970s, two types of preventive measures were used to protect the quality of water. The first was the control of polluting activities in and around the reservoirs under the responsibility of the PUB. The second was the control of effluents (both domestic and trade-related) into watercourses in unprotected catchment areas (catchments in densely populated areas) under the responsibility of the Ministry's Sewerage Department.

2.3 Wastewater management

The Sewerage Department launched a programme to provide a comprehensive sewerage system and keep pace with new industrial, housing and commercial developments. Started in 1972, this programme ensured discharge of all sewage into sewers and subsequently to sewage treatment works through a network of underground sewers and pumping

¹The locations designated in Catchment Area Parks were MacRitchie Reservoir and Park; Seletar Reservoir; Seletar Zoo; Pandan Reservoir; Kranji Reservoir; Pulau Tekong Reservoir and Upper Peirce Reservoir Park.

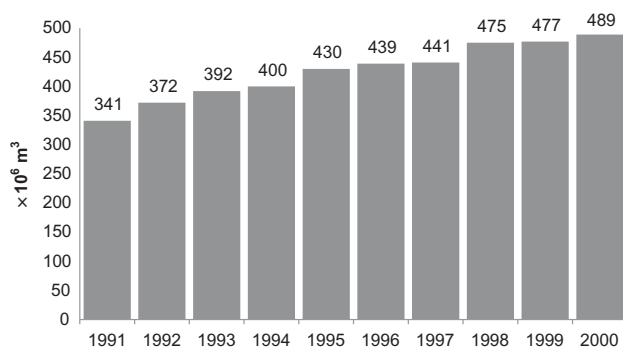


Fig. 1 Volume of wastewater treated, 1991–2000.

Source: Ministry of the Environment Annual Report 2000, Singapore.

stations. For industries unable to treat their effluents to required standards, the Trade Effluent Regulations were amended in 1977 to make provisions for measurement of biochemical oxygen demand (BOD), total suspended solids (TSS) and treatment of effluent for which they were charged. The charge was calculated on the basis of BOD and TSS concentrations and the volume of the discharge, and the levy was kept proportional to the pollution load. Tariffs were revised in 1983, 1992 and 1993 to reflect the market cost in treating wastewater (MoE 1993a).

By 1992, there was a network of 2300 km of sewer lines and six major wastewater treatment works which treated $372 \times 10^6 \text{ m}^3 \text{ d}^{-1}$ of wastewater. This volume increased and, in 2000, the volume treated of wastewater reached $489 \times 10^6 \text{ m}^3 \text{ d}^{-1}$ (MoE 2000; see Fig. 1).

Irrespective of the volume of the discharge, either to the sea or to the river estuaries, the treated effluent quality should meet the standards of 50 mg L^{-1} of biochemical oxygen (BO) and 50 mg L^{-1} of TSS (see NEA 2000).

Officers of the Sewerage Department made regular inspections of industrial and trade premises to ensure that preventive measures were taken to minimize the discharge of waterborne pollutants. Factories were encouraged to adopt good housekeeping procedures, less polluting processes and use recycled water in their premises to reduce the volume of effluent and also to save water. Factories that produced large quantities of acidic effluent were required to monitor pH in the discharges. These inspections and sample tests led to prosecution of industries found discharging acidic effluent into the sewers (Pollution Control Department 1993).

Regulatory measures to control pollution were well supported by the Government's investments in

environment infrastructure. For example, in the 1980s, Singapore invested annually around 1% of its GDP on environmental management. In the early 1990s, the Government was spending S\$609.3 million annually on the environment, including S\$246.12 million on environmental health, S\$86.45 million on sewerage, and S\$55 million on drainage programmes (EDB 1991). In 1990s, the exchange rate Singapore dollar to US dollar was an average of 1.6.

3 PLANNING FOR THE TRANSFORMATION OF THE CITY STATE

The 1972–1992 period was a time of transformation for Singapore. As the city-state embarked relentlessly on industrialization and urbanization, legislation played a key role along with the development of infrastructure and provision of services to reach air and water quality standards well within the acceptable levels prescribed by both the US Environment Protection Agency and the World Health Organization. Regarding inspections, the Pollution Control Department used to conduct regular trade effluent tests. Data available for the same period show that, on average, 2425 tests were conducted yearly and an annual average of 310 failures were detected. It was observed that the number of tests corresponded with the number of complaints; thus, for a higher number of queries, more inspections followed (Tortajada *et al.* 2013).

According to Tan *et al.* (2009), it was during this period that Singapore drafted its first Water Master Plan (1971) and Water Conservation plans (first in 1981); alleviated flood from urban areas; built incineration plants (Ulu Pandan 1979, Tuas 1986, Senoko 1992), estuarine reservoirs, water reclamation plants (Jurong 1974, 1981, Bedok 1979, Kranji 1980, Seletar 1981); eradicated malaria by 1982; successfully completed cleaning of its rivers (1987); and eradicated night soil buckets (1987). None of these would have been possible without effective legislation, regulations and working institutions. Inter-ministry and inter-agency coordination, although difficult, played a key role in policy-making, on the development of laws and regulations and on their effective implementation.

3.1 The Water Pollution Control and Drainage Act 1975

As mentioned in Section 2, the focus of the Environmental Public Health Act 1968 was on

environmental health and it was considered to be insufficient in terms of water pollution control. After the Prime Minister stressed the importance of taking urgent action to clean the watercourses, two other trade effluent related regulations were passed in 1970 and 1971. A growing need was felt for comprehensive legislation on water pollution control, which resulted in the Water Pollution Control and Drainage Act 1975.

When presenting the Bill in Parliament, the Minister for Law and Environment outlined the need to enact new laws in view of the changed circumstances and increasing environmental problems, due to the rapid growth in population, economy and industrial development. Provision of effective sewerage and control of water pollution were identified as a priority to ensure water supply. Stating that sewage management was the most effective method of water pollution control, the Minister emphasized the need to enact appropriate laws, as the old laws were insufficient and obsolete (Hansard 1975).

By this time, environmental pollution had become a cause of concern around the world. For example, USA data of 1964 show that, of the total wastewater from all manufacturing industries in the country, 27% was discharged to surface waters after treatment, 7.5% was discharged to public sewers, and about 1.5% was disposed of in deep wells, but most of the remainder was discharged to surface waters without treatment. As a result, the USA passed the Water Pollution Control Act 1972, which required industries to use the best technology for wastewater treatment by 1977, and to aim for zero discharge of waterborne wastes by 1985 (Pakiam and Mason 1978).

Within three years of its formation, the Singapore Environment Ministry adopted appropriate environmental practices and enacted the Water Pollution Control and Drainage Act 1975. This Act was primarily based on the principle that effluents, wherever possible, must be discharged into sewers and that regulation should focus on the quality of that effluent. It was made a punishable offence to discharge any toxic substance into any inland water causing environmental hazard. It is important to note that the regulation did not require proof of fault, i.e. it was an offence of strict liability. A maximum penalty of S\$5000 was prescribed in regulation 31(5) of Part V of the Water Pollution Control and Drainage Act 1975, against the violation of the law. Later on, in 1985, with respect to inland waters, the fine was increased to S\$10 000 or six months imprisonment. For subsequent offences, the fine prescribed

was a maximum S\$20 000 and imprisonment for between one and twelve months. A fiat by the Public Prosecutor was needed before prosecution. By the early 1990s, the number of prosecutions under this Act had been only a few and in most of the cases defendants pleaded guilty (Foo 1993).

The Water Pollution Control and Drainage Act 1975 empowered the Director, Water Pollution Control and Drainage of the Sewerage Department, to control the discharge of wastewater from all sources. The Act made it mandatory that no person was allowed to discharge any trade effluent into a watercourse without written approval of the Director.

The requirements of this Act were reiterated, modified and expanded in related legislation. These laws prohibited the discharge of trade effluent into watercourses or public sewers without the permission of the Director of Water Control and Drainage. They provided for conditional consent which depended on the submission of details of the proposed operation, water consumption and the nature of the effluent. The changes that would affect the effluent or nature of the effluent had to be notified within 14 days of such change. It was required that the trade effluents were treated prior to the discharge. The Trade Effluent Regulations 1976 referred in detail to the monitoring facilities, equipment and particulars of operational discharges (Government of Singapore 1976).

The laws also prohibited certain discharges and controlled downstream water quality by specifying concentration limits for a range of effluents which might be discharged into a watercourse. Different limits applied to controlled watercourses (controlled watercourses are those from which water is abstracted and treated for potable use), other watercourses and public sewers. The controlled watercourses were the most stringent because of their importance to drinking water supplies. For similar reasons, trade-effluent discharges were prohibited to reservoirs located in the Central Catchment Area. The laws made water pollution control and effluent management more effective by empowering the Director of Water Control and Drainage to revoke or suspend, if necessary, a permit already given for the discharge, and to change the permitted volume, quantity or discharge rate of the effluent.

The stringent standards set initially worried some industries, especially those using or by-producing concentrated organic waste that were not able to install expensive treatment plants. However, the industries received technical support from the government when and if needed.

4 EVOLVING INTO A GREEN CITY

In 1992, Singapore prepared the Green Plan for Environmental Protection and Improvement. The Green Plan was a holistic plan formulated with input from various government agencies, ministries, private sector groups and members of the public. It mapped the policies and strategies to transform the city-state into a model green city with a high standard of public health and environmental quality conducive to higher quality of life (see MoE 1993b, and MEWR 2012). The extensive public consultations for the plan encouraged policy-makers to emulate a similar type of engagement process for other campaigns as well. In fact, this was the beginning of 'public consultations' as an engagement tool in environmental issues.

The Plan was subsequently reviewed and updated in 2002 and 2005, to ensure that it remained relevant for the city-state. The Singapore Green Plan 2012 was published in 2006, setting out broad directions and strategies, the end objective of which was to achieve environmental sustainability (MEWR 2006).

During these years, the Government had become aware of the importance of further involvement of the public in the protection and conservation of the limited water resources available. Strategies that included massive awareness programmes and social campaigns, as had been done for decades, were reinforced by additional education campaigns with the objective to make the public more water-responsible (PUB 2004a, Tortajada and Joshi 2013).

4.1 Integration of the water administration

Water management in Singapore entered a new era characterized by a holistic approach in which institutions were further restructured, legislation continued being updated and the public was further engaged into water resources conservation activities.

Regarding the various water-related services, controls and administrations, coordination under one umbrella took place slowly. Water administration is centralized under the PUB. Since its inception in 1963 and until 1995, the agency was responsible for electricity, gas and water supply. In 1995, electricity and piped gas were corporatized as Singapore Power Limited. Water pollution control and sewerage and drainage functions continued under the Pollution Control Department and the Sewerage and Drainage Department, respectively, under the Environment Ministry (MoE 1994). It was only after acknowledging

that Singapore's water catchments and supply system, drainage systems, water reclamation plants and sewerage systems were parts of a comprehensive water cycle that the PUB was restructured to become the national water agency in 2001. The PUB kept its water supply functions and absorbed the sewerage and drainage departments from the Environment Ministry. The PUB itself was transferred from the Ministry of Trade and Industry to the Environment Ministry. The regulation of the electricity and gas industries was transferred to a new statutory board, the Energy Market Authority in April 2001 (Tan *et al.* 2009).

In 2002, the National Environment Agency (NEA) was established under the Environment Ministry after merging the Environment Public Health and the Environment Policy and Management divisions of the Ministry of Environment with the Meteorological Service Department of the Ministry of Transport. This statutory board status gave NEA greater administrative autonomy and flexibility to implement its responsibilities innovatively and quickly.

In 2004, the Environment Ministry was renamed the Ministry of the Environment and Water Resources (MEWR). With this, the broader focus on a more comprehensive administration of environment and water under one ministry was completed. Implementation of policies was left to the two statutory boards: PUB and NEA. This new structure had the objective to add an environmental dimension to water resources administration.

4.2 Water catchment policies

Land-use planning has played a very important role in protecting the water catchments. For instance, in order to control developments within the unprotected catchment areas, the Water Catchment Policy of 1983 established that a maximum 34.1% of land could be developed within water catchments, limiting population density to 198 dwelling units per hectare until 2005. Together with stern pollution control measures, this restriction ensured well-planned urban development and good water quality even from unprotected water catchments. In the 1990s, by adopting advanced water treatment technology to upgrade treatment plants, water catchment policy changed as PUB was able of using water from increasingly urbanized and unprotected catchments. This made it possible for the government to lift the urbanization cap and population density limit within the unprotected water catchments. Planners and various agencies could work in tandem to review and update policies

as technological and pollution management practices evolved (Tan *et al.* 2009).

4.3 Repeal of Water Pollution Control and Drainage Act

In 1999, the Water Pollution Control and Drainage Act 1975 (Government of Singapore 1975) was repealed, and the Sewerage and Drainage Act 1999 (Government of Singapore 1999a) and Environmental Pollution Control Act 1999 (Government of Singapore 1999b) were enacted, with stipulations on the control of discharges into public sewers and watercourses, respectively (Tan *et al.* 2009).

The Sewerage and Drainage Act 1999 governs the provision, operation and maintenance of the sewerage system. It states that all used water (wastewater) be discharged into public sewers, if they are available. It also regulates the treatment and discharge of industrial wastewater into public sewers. Penalties for breach of various provisions are also provided in this Act and in various regulations made under this Act. The Act, along with the Sewerage and Drainage (Trade Effluent) Regulations, was transferred to the PUB when the latter was reconstituted as the national water agency in 2001. The Sewerage and Drainage Act 1999 empowered the PUB to establish control on all types of sewage. The Act also empowered the agency to maintain and manage public sewerage systems, public sewers and storm water drainage systems, and drains and drainage reserves, in addition to its functions related to supply of water.

Fast-paced infrastructural developments, initiated by the Revised Concept Plan of 1991, created the need for maintaining the effectiveness of the entire sewerage system. In March 2000, the first edition of the Code of Practice on Sewerage and Sanitary Works 2000 was published by the Sewerage Department which later, on 1 October 2004, was reorganized as the PUB Water Reclamation (Network) Department. This Code replaced the Code of Practice of Sanitary Plumbing and Drainage System 1976, and Sewerage Procedures and Requirements 1968. The Code was issued under Section 33 of the Sewerage and Drainage Act 1999. It aimed to be a guide for qualified persons in planning and designing of the sanitary and sewage system. Not only the minimum and mandatory design requirements, but also some good engineering practices in the planning, design and

construction of the sanitary and sewerage system are provided in the Code (PUB 2004b).

In March 2000, the first edition of the Code of Practice on Surface Water Drainage was published by the Drainage Department. It specified the minimum engineering requirements for surface water drainage for new developments. The goal of the code was to provide an effective and adequate drainage system to prevent flood and public health risks (PUB 2006).

4.4 Restructuring the Public Utilities Board

In the process of transforming the PUB into the national water agency, the agency was reconstituted under Section 3 of the Public Utilities Act 2001 (Government of Singapore 2001). Some consequential amendments to it were made by Statutory Corporations (Capital Contribution) Act, 2002 (Government of Singapore 2002a). It made the PUB responsible for water reclamation and for the management and maintenance of the drainage system, in addition to ensuring the supply of piped water for human consumption. Part V of the Public Utilities Board Act 2001, which deals with the offences, imposes various responsibilities on both the PUB and the public. Section 45 of PUB 2001, makes staff responsible for the maintenance and safety of the water facilities.

4.5 The Environmental Pollution Control Act 1999

The Environmental Pollution Control Act (EPCA) 1999 came into existence after the consolidation of previous separate laws on air, water, noise pollution and hazardous substances control (Government of Singapore 1999b). It was expected that with continuous growth and expansion of the industrial sector, the amount of pollutants would increase, and therefore adequate and appropriate regulatory powers would be required to keep it under control. It was also expected that the new set of standards for pollutants emitted or discharged would instil discipline and self-regulation among industries and the public.

Part V of the Environmental Pollution Control Act 1999 deals with Water Pollution Control. Section 15 (s.15) of this Act authorizes the Director General of Environment Protection to issue licences for discharge of trade effluent, oil, chemical, sewage or other polluting matters. He is also empowered to grant licences for trade effluent treatment plants (s.16). The Act also provides penalties for

discharging toxic substances or hazardous substances into inland waters (s.17) and empowers the Director General to take measures to prevent water pollution (s.18). The Act was amended and renamed the Environmental Protection and Management Act, with effect from 1 January 2008. The change in name is not only symbolic but it reflects a broader scope to cover the protection and management of the environment and resource conservation (Tan *et al.* 2009).

The discharge of sewage into open drains, canals and rivers is regulated by the Environmental Protection and Management Act 2008 and the Environmental Protection and Management (Trade Effluent) Regulations. The Environmental Protection and Management Act 2008 and its Regulations are administered by the Pollution Control Department of Environmental Protection Division within NEA.

4.6 The Environmental Public Health Act (Chapter 95)

This Act came to its present form after several amendments of the original Environment Public Health Act 1987. It was amended in 1989, 1992 and 1996. More amendments were introduced in 1999 (during the enactment of the Environmental Pollution Control Act) and in 2002 (during enactment of the National Environment Agency Act) and also after the enactment of the Sale of Food (Amendment) Act, 2002 (Government of Singapore 2002b).

As what pollutes land ultimately pollutes water, the Environmental Public Health Act (Chapter 95) is very important for water pollution control. Part III of this Act deals with public cleansing and Part IV with food establishments, markets and hawkers. Part VI of this Act deals with insanitary premises, sanitary facilities, drains, sewers and wells. Section 78 (Part IX) prohibits sale or offer of polluted or unwholesome water. Section 80 makes the NEA responsible for developing regulations that prescribe standards related to the quality of water supplied in any area or premise.

Apart from the Environmental Public Health Act (Chapter 95), two other regulations administered and enforced by NEA are relevant in water administration. First, the Environmental Protection and Management (Trade Effluent) Regulations which empower NEA to regulate and set standards of trade effluent discharged into any watercourse, and the discharge of toxic or hazardous substances into inland waters. Second, the Environmental Public

Health (Quality of Piped Drinking Water) Regulations, which empower NEA to regulate and set standards for the quality of piped drinking water. These standards are primarily based on the WHO's *Guidelines for Drinking Water Quality* (WHO 2006). These regulations also require *inter alia* that the piped drinking water suppliers develop a water safety plan as well as a monitoring plan. This reflects the high importance attached to the quality of piped drinking water in Singapore by its legislatures, as it has established a separate and different agency to monitor potable water quality, owing to PUB's role as a water supplier.

The Environmental Public Health (Toxic Industrial Waste) Regulations have also been reviewed and were amended in 2009. The scope of waste covered under these regulations has been expanded in order to cope with new industries, emerging environmental issues and changing policies on the environment. Onerous legislative procedures that were no longer valid or relevant in today's context have been made simpler. To enhance enforcement, penalties for less severe offences were reduced to fines instead of prosecution in court (NEA 2009).

4.7 The Sewerage and Drainage Act (Chapter 294)

The Sewerage and Drainage Act (Chap 294) forms a comprehensive set of laws on sewerage (Part III); drainage (Part IV); protection of water resources (Part V); registration, codes of practice and certificates or approval for works (Part VI) and enforcement (Part VII) and other related issues (Government of Singapore 1999a). Under this Act, wastewater from all sources should be discharged into the public sewer. However, if this option is not available, after the approval of relevant authorities, wastewater may be discharged into watercourses such as canals and drains upon meeting much more stringent standards.

Section 16 (1) of the Sewerage and Drainage Act (Chap 294) prescribes a maximum penalty of S\$20 000 (US\$16 101 at the July 2014 exchange rate of S\$0.08 to US\$1.00) if trade effluents are discharged into public sewers without written approval of the Board. If any person is found guilty of discharging any effluent and/or substance into the public sewers, the person must stop the discharge and the activity producing the effluent. If the person fails to comply, then he/she may be fined up to S\$40 000 (US\$32 202 at the July 2014 exchange rate of S\$0.08 to US\$1.00) or be imprisoned

for up to three months, or both (s.17). Causing damage to public sewers or drains by any act is also punishable and the penalties are similar to the above (s.19 and 20). Similarly, the Act provides penalties for offences against drains and the drainage system; intercepting water from any place or the sea, within the territories of Singapore (s.31(5)); neglect by qualified persons (s.35(2)); carrying out any work without a clearance certificate if needed (s.34(1)), etc. The Act was revised in 2000 and then in 2001.

4.8 Recent trends in water pollution in Singapore

An analysis of the water pollution data for the period between 2002 and 2010 shows remarkable achievements in water pollution control. All the resulting data are within the standards established by the WHO.

4.8.1 Monitoring of inland waters The water quality of more than 34 streams and 14 ponds in the water catchment areas is monitored quarterly. Water quality of the reservoirs within the water catchment areas is jointly monitored by the Pollution Control Department and the PUB.

Table 1 shows water quality based on dissolved oxygen (DO), BOD and TSS between 2002 and 2010 (the data are shown as percentage of total samples checked that meet the quality standard). Table 1 also shows water quality in non-catchment areas. These data are collected quarterly from 20 rivers and streams in non-catchment areas. The data in Table 1 show that in both catchment and non-catchment streams, water quality has remained consistently good over these years, and also, that inland waters are conducive to aquatic life.

4.8.2 Resolution of complaints about water pollution control The Pollution Control Department has a robust system to follow up the complaints received. Table 2 presents the number of complaints related to water pollution under various categories, and the result of enquiries between 2002 and 2010 (data shown in brackets are the number of cases substantiated).

The data show that, although the number of complaints of all types of water pollution (except farm waste, the number of which is a negligible fraction of total complaints) has been increasing over the years, the actual number of incidents or substantiated complaints has decreased. The more numerous complaints are those related to cases of industrial wastewater

Table 1 Monitoring results for inland waters shown as percentage of total samples checked that meet the quality standard.

Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010
DO ($>2 \text{ mg L}^{-1}$)	100	100	98	100	100	100	100	100	100
Water catchment streams	91	95	97	95	94	96	92	96	100
Non water catchment rivers/streams	91	91	92	95	100	99	99	97	99
BOD ($<10 \text{ mg L}^{-1}$)	91	90	91	92	89	94	98	100	98
Water catchment streams	95	97	100	98	99	99	99	100	99
Non water catchment rivers/streams	100	96	99	100	100	100	99	100	100
TSS ($<200 \text{ mg L}^{-1}$)									
Water catchment streams									
Non water catchment rivers/streams									

Note: DO: dissolved oxygen; BOD: biochemical oxygen demand; TSS: total suspended solids. Data source: Annual reports, National Environment Agency (NEA), Singapore.

Table 2 Resolution of water pollution complaints.

Type of pollution	No. of complaints in respective years (and substantiated complaints or incidents)								
	2002	2003	2004	2005	2006	2007	2008	2009	2010
Chemical/oil	50 (19)	33 (4)	56 (17)	62 (12)	37 (5)	51 (3)	84 (6)	85 (3)	28 (2)
Industrial wastewater	3 (1)	12 (3)	30 (6)	54 (4)	52 (3)	105 (10)	170 (2)	173 (1)	323 (7)
Farm wastes	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	7 (2)	3 (5)	1 (3)	0 (0)
Domestic wastewater	22 (7)	16 (2)	2 (0)	8 (1)	20 (1)	14 (2)	25 (0)	29 (0)	8 (0)
Others	34 (7)	30 (11)	7 (3)	7 (0)	7 (0)	2 (1)	102 (3)	103 (2)	9 (0)
Total	111 (35)	91 (20)	95 (26)	131 (17)	116 (9)	179 (18)	384 (16)	391 (9)	368 (9)

Source: Annual reports, National Environment Agency (NEA), Singapore.

followed by oil and/or chemical pollution. However, an average of only 16.5 incidents of water pollution per year indicates an excellent enforcement record in a highly industrialized economy.

5 LESSONS LEARNT

The present analysis shows the relevance, appropriateness and impacts of the efforts to develop and also fine-tune laws and regulations, as well as setting, structuring and restructuring the several institutions to respond to the evolving economic, social and environmental needs in the city-state. In fact, policies, institutions and legislation have constituted the tripod of water pollution control and the backbone of Singapore's development.

From the early 1960s, and in spite of the urgent need for foreign investments to ensure industrial and commercial development, Singapore has ensured they do not compromise the quality of its water resources. Appropriate policies, enforcement of laws and regulations, transparent rules and infrastructural development have meant that in spite of the high requirements, no company has argued that the standards set were not achievable (Hansard 1999). Law enforcement has been ensured by regular inspection conducted to guarantee proper and efficient operations and maintenance of pollution control facilities, swift action on complaints, and a competent legal system. Additionally, regular monitoring of the waters has been done to supervise the adequacy and effectiveness of the control programmes (Tortajada 2006, Luan 2010).

The institutions involved in water management, including the PUB and the Pollution Control

Department, have been involved in formulating policy principles, regulations, amendments to existing regulations, penalties and standards to be applied. This has ensured that legislation remains relevant and effective in spite of the fast urban, industrial and commercial growth. The success is even more important because Singapore has been able to attract significant amounts of foreign investment despite its strict environmental requirements.

One less discussed aspect of the success of effective enforcement of pollution control legislation in Singapore has been the economic benefits gained by meeting, and sometimes exceeding, international standards for water supply, sanitation and wastewater treatment. It is now universally acknowledged that investments in water supply and wastewater treatment reduce health and social costs significantly. Equally, there are significant costs associated with inaction in these areas (OECD 2008). The city-state has understood that enforcement of legislation and provision of quality services are the result of long-term planning and policy-making, institutional development and capacity, and strong political will. Even in the late 1960s, the question of safe potable water supply and sanitation facilities was not about the technical knowledge and capability of treatment processes, but of the willingness on the part of the Government to plan and provide the services, and willingness of the people to not accept pollution as an inescapable consequence of urban and industrial development.

Involvement of the public in conservation of water resources, including in terms of good water quality, has been encouraged for decades mostly through consultative mechanisms and massive

information and awareness programmes and campaigns. Nonetheless, in order to achieve more effective involvement from the public, further interaction and communication is still necessary. In fact, the next challenge for Singapore regarding long-term planning and policy making will be to make the public realize that their sustained engagement is necessary to achieve sustainable use of water resources (Tortajada and Joshi 2013).

Singapore has become different from many other countries in three main respects. First, water trade effluent discharge standards adhere to strict standards that do not allow watercourses to remain 'moderately polluted', unlike many other countries. Secondly, in many countries, laws and regulations have remained virtually unchanged since their enactment; however, the city-state has kept its laws relevant to the changing needs by regularly amending them and enacting new ones. Thirdly, it has maintained stringent enforcement of its laws, with monitoring as an important tool. Clearly, long-term planning has been essential, as it has provided the framework for policies, regulations and institutions to operate and achieve steady improvements through the years. Efficient inter-agency coordination, even if not free of complexities and difficulties, has allowed the implementation of policies over the years.

The city-state has tried to follow a comprehensive approach of development and been willing to invest a great deal in terms of appropriate institutions, infrastructural development, laws and regulations, instruments for their stringent implementation, skilled personnel necessary for such an endeavour and infrastructural development, among others. Undoubtedly, whatever investments have been made have been worthwhile because they have brought numerous benefits to the city-state and its people. A willingness to face the challenges of a complex journey for development is the difference between success and failure. Although every process can be improved in many ways, Singapore decided a long time ago that it had the will to develop the means to embark on the journey to sustainable development in which availability of water in the appropriate quantity and quality has played an essential role.

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