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CLEANING THE LAND AND RIVERS

We can make Singapore cleaner by placing community before self. Showing concern for the well-being and cleanliness of the environment is the mark of a mature, refined society. In short, the environment is everybody's responsibility. Everyone has a stake in it. In a society like Switzerland, those who litter are deeply frowned upon. There is great social pressure to conform to good environmental habits. I think there should be more such peer pressure in Singapore. Many litterbugs still do not feel the shame for what they do.

Prime Minister Goh Chok Tong, at the Model Environmental Workers Award Ceremony, 9 November 1997

The warm and humid equatorial climate in Singapore is highly conducive to the rapid decomposition of refuse and the breeding of vectors or disease-bearing insects such as mosquitoes and flies. In the 1960s, against the backdrop of a high population density of more than 3,000 persons per sq. kilometre (rising to about 15,000 per sq. kilometre in the urban areas), improper disposal of refuse

and indiscriminate littering would inevitably create health hazards to the population, and could result in rapid infectious disease transmission.

Keeping Singapore clean was thus one of the foremost challenges that the government had to tackle after the island state gained independence in 1965. It was a challenge born out of necessity.¹ Moreover, during the early days of nationhood, a clean living environment was seen as a boost to the national morale and civic pride of a nascent state, helping to motivate the people to strive for higher standards of performance.

Removing litter is expensive as it involves the labour-intensive task of sweeping roads and drains, as well as subsequently collecting and disposing the litter. With the cost of litter removal many times that of domestic refuse removal, cost considerations alone would underscore the need to stop or minimize littering.

The government also recognized that improving public cleanliness was a crucial step towards achieving a good standard of public health, which in turn would contribute to a higher quality of life for Singaporeans. In addition to providing a more comfortable living environment for residents, a clean and litter-free Singapore also presents a significant competitive advantage in terms of attracting tourists to visit, foreign talents to work, and businessmen and industrialists to invest in Singapore.

CLEANING THE LAND

With these motivations, an ambitious plan of action was worked out to transform Singapore into one of the cleanest cities in the world. The formula that has proven to work for Singapore has four components — providing good and reliable public cleansing services and collecting refuse daily (elaborated on in Chapter 4); educating the public on the need to keep the environment clean; strict law enforcement; and investing in infrastructural improvements.

Providing Good and Reliable Public Cleansing Services

Since 1961, the Environmental Health Branch, which was then under the Ministry of Health, has been tasked with the responsibility of cleansing the streets. While it may sound straightforward, cleansing the streets was an enormous and highly laborious task in those days. The street cleaners had to make do with primitive and cumbersome methods and tools, pushing large and bulky wooden handcarts to bring their sweepings to the bin points. This was not helped by the prevalence of spitting, indiscriminate littering, and rampant illegal dumping. Although refuse bins were placed in designated open areas in the backlanes and vacant lands, these areas more often than not ended up as public dump sites due to the bad habits of the people. This made the cleansing work all the more difficult.²

The street cleaners, also referred to as the “broom brigade”, were daily-rated employees (DREs) and were paid a wage for each day of work performed. To this day, every DRE is assigned a “beat”, or a length of street that could range from two to five kilometres, and is responsible for ensuring that his assigned beat is free of public health nuisances. Thus, apart from sweeping the streets, he also goes into drains to clear chokages.

Wanting to put in place a reliable system with no lapses in cleansing work, the government amended the labour laws to allow cleaners who worked on a Sunday or public holiday to be given a day off on any other day, in lieu of additional pay. This paved the way for the introduction of a daily public cleansing regime by 1968. Henceforth, the streets were swept and refuse removed every day of the week including Sundays and public holidays. Following the formation of the Ministry of the Environment (ENV), the Environmental Health Branch was transferred to a newly created Environmental Public Health Division (EPHD) in the new Ministry.

Even after the daily cleansing regime was introduced, the government continued to pursue innovative ways to achieve greater operational efficiency. One measure was to decentralize the

management of public cleansing services to the district offices under the Environmental Health Department, through integrating the supervision of public cleansing work into the duties of the public health inspectors based in these offices. Because the inspectors were familiar with every nook and cranny of the areas under their charge, they were able to schedule the cleaning work to achieve a high level of performance.

Despite decentralizing the management of public cleansing services, a more fundamental problem remained – the difficulty in recruiting DREs as cleaners. The abundance of employment opportunities in the rapidly growing economy meant that many people shunned a cleaner's job, which was seen as a low-grade, menial occupation. As a result, it became necessary to turn to mechanical sweepers.

First brought into Singapore in 1972, mechanical sweepers quickly proved to be an effective substitute for manual labour. Each sweeper is able to take on the work ordinarily performed by thirty to forty workmen. As a result, more of such vehicles were progressively deployed to clean the roads, while ENV continued to source for other labour-saving tools that were lighter and better designed to perform specific tasks such as litter picking.

Although the introduction of mechanical sweepers went a long way towards easing the labour crunch, the ageing DRE workforce soon emerged as a new challenge. By the end of the 1990s, some of the longest serving DREs had worked for more than half a century. The prospect of finding younger workers to replace the retiring DREs was a daunting one. Certainly, judging from the retiring DREs who were still cleaning the same streets decades after their initial employment, the career prospects for their replacements were not rosy.

With this consideration, as well as with the aim of improving operational efficiency, ENV found that it was necessary to deploy mechanical road and pavement sweepers to carry out the cleansing work, as far as the physical conditions of the roads and pavements allowed these machines to be used. This reduced further the number

of workmen who had to be recruited. However, the route to mechanization was not plain sailing. Street fixtures such as lamp posts, signs, and benches obstructed the movement of the mechanical vehicles, particularly the pavement sweepers, such that these areas ended up having to be cleansed manually. To overcome this problem, the relevant government agencies were roped in to ensure that street fixtures and furniture were sited in a way that would minimize obstruction. This facilitated the wider deployment of pavement sweepers. An unexpected positive spin-off engendered by this exercise was that the pavements were also made more user-friendly for the elderly and handicapped on wheelchairs.

The government also decided to outsource the provision of public cleansing services to private contractors to allow private sector involvement and reap the efficiency gains from competition. Today, public cleansing services in two-thirds of the island are provided by private contractors, and there are plans to outsource progressively the remaining part over time.

Educating the Public on the Need to Keep the Environment Clean

In spite of the efficient public cleansing service that has been put in place over the last three decades, the government recognized from the early days that public cleansing alone would not be sufficient to keep the streets clean. While public cooperation and participation are critical to controlling the littering problem, these were also the most difficult to achieve as they required the public to develop a sense of civic consciousness, social responsibility, and discipline. Hence, a two-pronged approach was adopted to cultivate civic consciousness – national public education and law enforcement.³

The first national public education effort was a month-long “Keep Singapore Clean” campaign that was launched in October 1968. The campaign sought to educate each individual on the importance of not littering the streets, drains, and public places.

This campaign was planned and run by an intersectoral committee headed by the then Minister for Health. The committee comprised representatives from organizations with a broad mass base or those that provided specialized services. These included the chambers of commerce, employers' and trade unions, government ministries (Education, Interior and Defence, and Culture), the Police and the Public Works Department, as well as statutory boards such as the Housing and Development Board, the Public Utilities Board, the Tourist Promotion Board, and the Jurong Town Corporation. It was probably one of the earliest examples of inter-agency collaboration within the government.

The national campaign was a month-long intensive programme of activities, with sustained and extensive coverage by the mass media since this was the most effective channel in reaching out to individuals. Jingles, newsreels, documentaries, filmlets, and slides were broadcast daily over TV and radio, while a roving exhibition was held to reach out to the rural population. Social pressure was subtly used in the campaign, with "candid camera" style films and photographs of places and establishments found in a bad state of cleanliness, and errant members of the public caught littering the streets.

Children in schools were a key target audience. As they were at an impressionable age, it was hoped that they would internalize the message and form desired habits. Poster design and essay competitions exclusively for school children were organized. Special talks on cleanliness by health officers, inspectors of schools, and principals were made at least twice in each school during the campaign month. Teachers also gave daily reminders against littering and the importance of keeping the premises clean.

To promote mass participation, public and private entities were encouraged to organize their own Keep Singapore Clean activities over and above those at the national level. The most significant were competitions held to select the cleanest offices, shops, restaurants, markets, factories, government buildings, schools,

and public vehicles, in which the judges not only picked the ten cleanest premises, but also the ten dirtiest premises. The political leadership provided much support for the campaign. Members of Parliament, together with community leaders, organized activities at the constituency level to get as many of their constituents involved as possible.

While the national public education campaign received resounding responses from all sectors of society, its momentum would be lost unless it was followed up with some concrete action after the campaign. This follow-up action had to be the strict enforcement of the anti-litter laws. However, to provide time for the public to become accustomed to the enforcement, those who were caught littering and indiscriminately disposing refuse during the campaign month were not penalized, but were warned of the possible penalties. The intent was that when the enforcement kicked in after the campaign, there should be no complaints that no adequate warning had been given.

While the majority of the public became aware of the need not to litter and also supported enforcement against litterbugs, there was inevitably a minority who persisted in their bad habits, and on whom the law had to be brought to bear. The government took the unpopular decision to prosecute recalcitrant adult offenders strictly and even published their names in the media. School children offenders were reported to their school principals, who would then discipline them by making them sweep their classrooms or school compounds.

The national public education campaign successfully imprinted indiscriminate littering and dumping in the minds of the public as anti-social acts that would not be condoned.

Riding on this initial success, annual campaigns in the ensuing years were conducted along similar lines, with each focusing on a specific theme in addition to the underlying one of keeping Singapore clean. The theme in 1969, for instance, was "Keep Singapore Clean and Mosquito-Free" to generate public interest

and participation in the prevention and control of mosquito breeding so as to contain the mosquito population at a low level.

The “Keep Singapore Clean” campaign took on an additional dimension in 1971 with the launch of the “Tree Planting Day” by then Deputy Prime Minister Dr Goh Keng Swee on Sunday, 7 November at the summit of Mount Faber. It marked the beginning of a tradition that spanned the next two decades, during which Tree Planting Days were held on the first Sunday of each November. The Tree Planting Day was a hallmark event supporting the tropical garden city initiative, which aimed to transform Singapore into a clean as well as green city. In his book, *From Third World to First*, the first Prime Minister Lee Kuan Yew wrote about the drive to make Singapore a tropical garden city. He said that greenery not only raised morale and made people proud, but also demonstrated the efforts put into maintenance. The Tree Planting Day was deliberately set at the beginning of the rainy season in November to minimize watering.

The annual campaigns were significant in many ways. First and foremost, they made Singaporeans aware of the need to be socially responsible and disciplined, and provided an excellent platform to address a number of important public health issues, ranging from communicable diseases and poor food hygiene to mosquito control and pollution. Through the campaigns, the public was informed of public health issues to look out for and changes that were taking place, such as the commencement of daily refuse collection, and the availability of public cleansing services. The campaigns also created avenues of communication between the people and the authorities, and served as a gauge for the public’s response to new services and regulations that were introduced.

By the 1980s, the series of annual campaigns had enabled the government to make significant advances in several other aspects of environmental health such as managing the mosquito problem, raising standards of personal hygiene, and controlling air and water pollution. With increasing urbanization that also improved the

physical environment, the focus of the national public education campaign accordingly shifted from broad-based issues to more targeted ones, such as proper disposal of refuse in plastic bags, cleanliness of public toilets, and anti-spitting.

In 1990, the Ministry of the Environment launched the first Clean and Green Week (CGW) as a new approach to environmental education. The CGW incorporated the Tree Planting Day, with tree planting activities still held in every Clean and Green Week.

The CGW was a week-long campaign that occurred in November each year. Apart from continuing to promote an appreciation for a clean and green environment in Singapore, it also sought to increase community awareness for global environmental concerns, as well as encourage their participation in caring for the environment. Consequently, themes such as “Commitment and Responsibility”, “Awareness and Action”, and “A Better Living Environment” were adopted in different years to make Singaporeans realize that caring for the environment was one aspect of social responsibility.⁴

One particular CGW programme is the Cleanest Estate Competition, which ran from 1995 to 2002. The competition pitted HDB estates against one another in a race to clinch the title of the cleanest estate, thereby encouraging their residents to stop littering and do their part in keeping their surroundings clean. The assessment covered both the physical appearance of the estate, such as the presence of litter in common areas, as well as the social behaviour demonstrated by the residents. Points were deducted for irresponsible acts such as killer litter,⁵ vandalism to common property, and the illegal dumping of bulky refuse and other obstructions in common areas.

While the competition was largely successful in the beginning, it became increasingly seen as a battle between town councils managing the estates (including their cleaners) rather than as a healthy competition among the residents. Instead of encouraging the residents to take ownership of keeping their living environment clean, the competition led to town councils competing on the strength

of their cleaners. In 2007, the Islandwide Cleanest Estate Competition (ICEC) was introduced, with an emphasis on raising community awareness and promoting social responsibility in keeping the living environment clean, and promoting the residents' sense of ownership over the common areas in the estates. The judging criteria of the ICEC give greater weight to community efforts in promoting social responsibility among residents than to efforts by the cleaners.

Strict Law Enforcement

Although public education has played a significant part in helping Singapore achieve its reputation as a clean and green city, it would be too simplistic to conclude that education alone has had such a transforming effect. No matter how successful public education initiatives may be, there will invariably be a small group of individuals who remain recalcitrant.

Prior to 1968, health officials had been working with legislation that was formulated for a colonial era. However, this would not be adequate in addressing future public health problems since past legislation focused mainly on preventing the spread of infectious diseases and the control of epidemics, while other challenges such as the cleanliness of the environment were not sufficiently covered. Therefore, a thorough and complete revision of all principal and subsidiary legislation governing matters of public health was necessary.⁶

The revision took into account the prevailing political and social conditions as well as the behaviour and attitudes of the population. It also included a reappraisal of what constituted acceptable health standards or requirements. This culminated in the birth of a new piece of legislation in 1968 that equipped the then Ministry of Health to carry out its battle against litterbugs – the Environmental Public Health Act (EPHA). The EPHA replaced Part IV of the Local Government Integration Ordinance, 1963, which had previously governed the maintenance of public health.

The Act in its fourteen parts covers all fields of environmental health. In particular, Part III (Public Cleansing) deals with the cleansing of streets, the collection and removal of refuse, and the cleanliness of “public places”. Comprehensive provisions against littering and the disposal of refuse in public places were introduced. Under the Act, it is an offence to throw or leave behind bottles, paper, food containers, food, and cigarette butts. The spilling of noxious and offensive matter and the dropping or spilling of earth in public is also considered an offence.

The Act further requires the owners and/or developers of flats and industrial complexes to provide at their own expense proper facilities for refuse collection and disposal. Bin centres are now a requirement for building complexes as they provide a convenient point from which refuse can be removed by refuse collection vehicles. Compactors have also been introduced to maximize the storage space in bin centres, as well as improve on the efficiency of transporting the refuse to the incineration plants.

Among the new provisions introduced was a fairly controversial presumption clause, which provided that any litter or refuse found on the frontages of premises would be presumed to be deposited by the occupiers of the premises until proven otherwise. As the burden of proof is on the individuals committing the act, it provided a form of deterrence, and is likely to have also resulted in social pressure against littering.

Most of the offences under the Act carried a fine not exceeding S\$500 for the first conviction, and a fine not exceeding S\$2,000 for the second and subsequent convictions, which was a hefty sum in the 1960s and 1970s. A more severe penalty was imposed on builders, developers, and contractors who, during the course of their work, left building materials in public places, or failed to take reasonable precautions to prevent people in public places from being injured by falling dust or building fragments.

To achieve the desired outcome of improving public cleanliness, strict legislative provisions had to be accompanied by equally serious

enforcement. Much thought was put into how the legislation should be enforced. The first consideration was that the public should be provided with sufficient means and opportunity to comply with the law, without being overly inconvenienced in their daily routine. For instance, provisions were made for people to have adequate and conveniently sited bins that were emptied and cleaned regularly, to throw their litter.

Second, the new laws were publicized and explained to raise awareness and gain the public's acceptance of the changes in behaviour that were expected of them.

Third, great care was taken to ensure that the legislation was properly spelt out so that the implementation would be uniform and not subject to bargaining. Enforcement officers were expected to be firm, but fair, in enforcing the laws. For instance, if a person unconsciously drops litter and regrets his action, he would be given an opportunity to pick the litter up for proper disposal. However, if the act was deliberate, the person would be penalized. Also, while the maximum penalty or fine for each offence may seem harsh, they are only applied to recalcitrant offenders. For others, lighter penalties, such as the offer of composition, would apply.

Finally, swift action must be taken against recalcitrant offenders who fail to abide by the laws. This is important as environmental offences are often viewed as being negligible when compared with statutory offences. The offender is given an immediate punishment after committing the offence so the deterrent effects of punishment are not lost.

To this end, enforcement procedures for certain offences under the EPHA are designed to be dealt with expeditiously, with minimal paper work. Under this procedure, a littering offender is served a ticket on the spot requiring him to attend a designated Court on a prescribed day. The offender is dealt with summarily if he pleads guilty; the offence is compounded by levying a fine not exceeding S\$500. If the fine is paid, no further action will be taken. If the

offender claims trial, a date will be fixed for the hearing. Any offender who fails to turn up in court will be arrested on a warrant.

Over the years, the combination of anti-littering laws with fines as penalties and the series of annual "Keep Singapore Clean" campaigns, have helped reduce the littering problem to a large extent. Nonetheless, litter has never been totally eradicated due to the thoughtlessness of litterbugs, especially the "diehards". A Littering Behaviour Survey conducted by the National Environment Agency (NEA) in 2006 found that about 14 per cent of the people interviewed felt that it was acceptable to litter.

The Corrective Work Order (CWO) introduced in 1992, in place of a hefty fine, sets the offender to work in cleaning up the community for periods of up to three hours, subject to a total of twelve hours. This applies to those who are above sixteen years old, are repeat offenders, and/or have committed serious littering offences. The first CWO was performed in 1993 in public places such as parks and beaches, and was subsequently extended to housing estates. Other than being punitive, the CWO regime also had a reparative element as cleaning up housing estates was a means to increase the offenders' awareness of the impact of littering, and to experience the difficulties faced by the cleaners.

Not surprisingly, the CWO regime attracted its fair share of controversy, with many seeing it as a shaming tool. While the majority accepted the CWO as an additional punitive option, there were some who felt that the initiative was introduced ahead of its time, with the public in Singapore still relatively unreceptive to the idea of performing work in lieu of a financial penalty, unlike in developed countries where such punishment was more common. Notwithstanding this, the government stood its ground.

This was not an altogether easy decision. However, to realize the vision of a clean Singapore, the government was prepared to make the unpopular choice by adhering to strict enforcement against littering. This would be borne out in the longer term, when there are clean streets and public places for all to enjoy.

INVESTING IN INFRASTRUCTURAL IMPROVEMENTS — RE-SETTLING HAWKERS

Investing in infrastructural improvements has gone a long way in helping Singapore to address a major public health challenge — the unsanitary and hygiene problems posed by itinerant hawkers.

In the post-World War II period, unemployment was a widespread problem. Many unemployed people took to the streets, literally. Street hawking became a thriving trade because the entry barrier was low. The good income attracted many poorly educated individuals with little capital and skills.

The number of street hawkers soon grew, with many congregating in convenient open areas within housing estates, and along major traffic routes. Although they were unsightly, the government then adopted a liberal attitude towards street hawking as it not only encouraged entrepreneurship, but was also a means for the unemployed to earn an honest living.

By the late 1960s, rapid industrial and economic development followed Singapore's independence. The abundance of employment opportunities saw more family members going to work and taking their meals outside. The demand for cheap and convenient hawker food grew, and consequently, many more people were drawn to the lucrative hawking trade. It was estimated that at one stage, hawkers numbered close to 25,000, or nearly one in 100 of Singapore's population.

The rapid proliferation of street hawkers soon posed a major public health problem. Street hawkers lacked proper equipment and amenities (such as refrigeration and clean tap water) and many did not observe good personal and food hygiene. The food was mainly prepared in makeshift stalls, with no direct access to clean water for cooking and washing of utensils. Consuming hawker food was often associated with food-borne disease outbreaks such as cholera and typhoid. Those peddling perishable food items such as cut fruits, cold drinks, and ice-cream were particularly culpable, as they often used contaminated water and ice.

Without a refuse management system in place, food waste generated from street hawkers was indiscriminately dumped onto streets, or thrown into drains and waterways, giving rise to severe chokages and water pollution. The market produce hawkers were also a problem, as they left behind vegetable waste, poultry droppings, fish cuttings, and other litter on the roads. These invariably found their way into the waterways and streams.

The accumulation of waste gave rise to the proliferation of vectors such as rats, flies, and mosquitoes. Street cleansing works were practically impossible to carry out because roads and drains were obstructed by the makeshift structures of the vendors and their paraphernalia. The noise generated by hawkers hawking their fare was also a distraction to nearby schools and public institutions.

It did not take long before the appearance of the city deteriorated. The presence of hawkers in almost every street, footway, and backlane was a blight to the cityscape. The dilapidated makeshift structures put up by the hawkers caused many parts of the city to resemble slums. The negative externalities went beyond just public health, with many able-bodied adults preferring street hawking, which was perceived to be a lucrative trade, to joining the workforce to serve in more economically efficient sectors.

It soon became imperative that effective policies and measures be put in place to curb the uncontrolled proliferation of street hawking. As a step towards achieving this, an island-wide census of street hawkers was carried out between December 1968 and February 1969. The government then decided on two courses of action — a short-term and a long-term solution.

The short-term solution involved the licensing of street hawkers and relocating them to temporary sites. This effectively limited the number of street hawkers so that their activities could be properly circumscribed. As this move was not popular with street hawkers, the licensing exercise was carried out in close consultation with the Citizens Consultative Committee members. Because of the political

repercussions, a committee was set up to decide on the policies governing licences and to consider complaints and appeals.

A total of 24,000 hawkers were licensed in the exercise. Of these, 6,000 were operating in markets while the remaining 18,000 were operating on the streets. These hawkers were issued with temporary street-hawking licences and resited to side streets, back lanes, side lanes, and car parks, where washing areas connected to the sewers were provided wherever possible. New licences were issued only to those who were genuinely suffering financial hardship. The Environmental Public Health (Hawkers) Regulation and relevant sections of the Environmental Health Act regulating the activities of the hawkers were strictly enforced to ensure that stall sites and their surroundings were kept clean at all times.

The licensing exercise was to pave the way for identifying *bona fide* hawkers who would ultimately be relocated into permanent premises. This represented the long-term solution – to house all street hawkers in purpose-built buildings within five years. This was kickstarted with an initial provision of S\$5 million to the Housing and Development Board in 1971 for the construction of permanent hawker centres and markets, which served the dual objectives of resiting street hawkers and providing amenities for residents of new towns.

Each market cum hawker centre comprised a market section and a cooked food section. The centres were provided with essential amenities such as proper sewage connections, piped water and electricity, and bulk bin centres for the disposal of refuse. The cooked food stalls were also compartmentalized, and lined with glazed tiles. Fixed tables and stools for customers became a common feature in all hawker centres. Ceiling fans and toilet facilities were also available for the comfort and convenience of the patrons.

Riding on the initial success, the government embarked on a massive programme to build markets and hawker centres outside the new towns. To accelerate the pace of building such centres, a policy was introduced in which the permission for land

redevelopment use was granted to a developer, on the condition that a hawker centre was built to house the street hawkers affected by the redevelopment.

The resettlement of the street hawkers was not without its problems. First, all hawkers along the same street would need to be resettled *en masse* to a nearby location, while ensuring that no new unlicensed hawkers reoccupy the vacated street. This necessitated working closely with the Police. In spite of the better environment, many street hawkers were reluctant to move into the centres as business was deemed to be better on the main streets where there was more human traffic. To encourage street hawkers to relocate into the newly built centres, the rent for stalls was deliberately kept at the same level as that levied on street hawkers. At that time, the need to recover the costs of building and maintaining these hawker centres from the hawkers was the least of the government's considerations when deciding on the rental to be levied. The hawkers also had to be convinced of the benefits of operating in a hawker centre, such as the availability of utilities, and not being subjected to the vagaries of the weather.

To clear the entire nation of street hawkers, the government worked closely with Members of Parliament, grassroots leaders, and the hawkers themselves. In many cases, Members of Parliament themselves presided over the balloting of stalls, to ensure that this was perceived as a fair and transparent way of stall allocation. The entire resiting programme was successfully completed after about fifteen years in 1985. Today, there are 111 government markets cum hawker centres, housing about 15,000 stalls.

The earlier generations of markets and hawker centres were constructed with the main purpose of providing a permanent site for the resettlement of street hawkers. Practicality was the key consideration, with little attention paid to their façade. By the late 1990s, most of these centres were at least twenty years old. Many of them were in poor physical condition, which made maintenance a big challenge. Visually, these centres had also not kept up with the

rejuvenation that had been taking place in the housing estates where they were located.

In 2001, the Environment Ministry, therefore, decided to embark on the Hawker Centres Upgrading Programme (HUP), committing more than S\$420 million over ten years. The upgrading works range from complete demolition and rebuilding of the centre to retrofitting such as re-tiling, installation of new tables and stools, widening of passageways, replacement of utility infrastructure such as sewer pipes, rewiring, improvement to the ventilation, bin centres, and toilets, provision of improved lighting, and optimizing the space utilization with better layout.

The newly upgraded centres boast features such as better ventilation and lighting, open courtyards, and outdoor dining areas. They also have a more visually pleasant building façade and finishings, as well as flexible seating arrangements. The toilets have been refurbished, not only to improve them, but to make maintenance easier. The upgrading has not only benefited the stallholders, but the patrons as well, who now have a more pleasant and congenial ambience to enjoy their meals. As of 2008, 63 out of a total of 110 eligible centres have been upgraded under the programme.

Hawker centres may have been born out of necessity. But today, many say they provide the best eating experience in Singapore. In fact, dining in a hawker centre has achieved international acclaim, and was featured in Patricia Schultz's book in 2003 – *1,000 Places to See before You Die*.⁷

THE SINGAPORE RIVER AND KALLANG BASIN CLEAN-UP

Much of what pollutes the land will eventually pollute the rivers. Any rubbish on the road, if not cleared, will be washed by rain into the drains, and from there to the culverts, then on to the canals, and eventually into the rivers. The cleaning up of the Singapore River

and Kallang Basin serves to highlight the importance of keeping the land clean. By doing so, the high-quality living environment on land can extend to the waters as well.

The Singapore River, the disembarkation point for many early settlers and the birthplace of Singapore's commercial hub, has been associated with the traditional trading and business activities of Singapore for more than a century. Over the years, the Singapore River, together with the Kallang River, which are both waterways with urban catchments, became highly polluted due to population growth, urbanization, industrial expansion, and the uncontrolled discharge of all forms of waste and pollution.

From the early 1800s, as more and more settlers arrived on Singapore's shores, many of them found accommodation along the quays and riverbanks. Some of their activities, such as dumping garbage into the water and using the rivers for sewage disposal, probably marked the beginnings of a river that was soon to become extremely polluted. Early industries that were sited along the banks of the Singapore River, such as processing of gambier, sago, and seaweed, also contributed to the pollution.⁸

By the second half of the century, the importance of these industries had diminished, but the escalating problems of pollution did not end. Port-related activities along the Singapore and Kallang Rivers, including warehouses and bumboats that carried goods from the large ships in the harbour, flourished. Ship building and repairs were also carried out at the Kallang Basin. The by-products of these activities, namely oil, sullage water, and solid waste, were either disposed of directly into the rivers, or eventually found their way to the rivers via the drains.⁹

Markets sprang up in the riverside community, where perishables were sold. As they were adjacent to the river, any leftovers were conveniently discarded into the water. Street hawkers also set up shop right by the river, often dumping used water and food into the drains or even directly into the river. Squatters set up homes along the river without sewage facilities. Some had overhanging latrines that would discharge waste directly into

streams. Backyard trades and cottage industries in these unsewered premises aggravated the problem. Their trade effluent was also discharged into drains. Pig and duck farms proliferated, adding animal waste to the cocktail of pollution in the rivers.¹⁰

These rivers were essentially open sewers and became extremely polluted by the 1960s. With office towers and hotels being built along a newly created central business district, there was a pressing need to clean up the rivers.

At the same time, water reserves grew insufficient. The few reservoirs could not hold sufficient water to serve the needs of the expanding population which had reached one million by the 1950s. Water supply for the island had to be imported mainly from the Tebrau River in Johor, as local water sources were inadequate. A drought in 1963 demonstrated the severity of the situation, with local reservoirs drying up and the volume of water in the Tebrau River dropping dramatically. Water rationing had to be imposed on the people in Singapore. With high density housing projects springing up to accommodate an exploding population, efforts to ensure the provision of a good water supply and maintain cleanliness were strained to the limit. Hence, a programme to build more local reservoirs and maintain the cleanliness of the water supply at all costs became a matter of utmost importance for the future of Singapore.¹¹

It was apt that in declaring the Upper Peirce Reservoir open on 27 February 1977, then Prime Minister Lee Kuan Yew said, "It should be a way of life to keep the water clean, to keep every stream, every culvert, every rivulet free from unnecessary pollution. In ten years, let us have fishing in the Singapore River and fishing in the Kallang River. It can be done."¹²

What was involved was no less than unclogging the way Singapore worked. Engineering solutions to remove pollution could not adequately address the pollution. Rather, the very causes and sources of pollution needed to be tackled. The river was a workplace and a home for the many hawkers and squatters lining its banks. It was not enough simply to prevent them from dirtying

the river. They had to be given an alternative way of life where possible.¹³

Since livelihoods were at stake, cleaning up the river meant giving people a different lifeline to the future. Squatters and farmers had to be resettled. Backyard trades and industries had to be relocated. Street hawkers had to be resited. These meant building houses, industrial workshops, and food centres, in addition to developing proper sewage infrastructure. To free the river from pollution meant, in many ways, constructing a new Singapore through which a rescued river could flow. The physical task was gigantic, but it was only one aspect of a larger human drama.¹⁴

A Master Plan for the cleaning up of the Singapore River and Kallang Basin was drawn up for the purpose. The draft plan indicated that the Singapore River and Kallang Basin were the two most badly polluted catchments in the city. The Kallang Basin was drained by the Kallang River, Bukit Timah-Rochor Canal, Whampoa River, Geylang River and Pelton Canal. The plan also noted the scope of the challenge:

In general, the pollution problem is three-fold. In areas where pollution control facilities have been provided, we have to ensure that these facilities are used and efficiently operated. In some areas where such facilities have not been provided, but are possible with redevelopment, we need to know what plans there are for redevelopment and if need be, to spur them on and set targets. In the remaining areas where it is either impossible or economically not feasible to provide such facilities (e.g. for roadside hawkers, boat colonies, etc.), we need to have a plan of action to control, minimise or eliminate these sources. The main objective is to restore the Kallang Basin and Singapore River to the extent that marine life can thrive in the water. Organic and inorganic pollution in the form of solid and liquid waste should be prevented or minimised.¹⁵

As the catchments made up some 30 per cent of Singapore's area, it was a challenge for the planners, who had to piece together

an overview of the entire range of pollutive activities in the catchments. These included pig and duck farms, squatter huts, backyard industries, and hawkers, some of which were actually located quite a distance from the rivers.¹⁶

The draft plan revealed the enormity of the task, the undertaking of which would not be restricted to the departments under the Ministry of the Environment, such as environmental health, sewerage, drainage, and hawkers, but also involved departments and agencies under the Ministry of National Development (MND), Ministry of Trade and Industry (MTI), Ministry of Communications & Information (MICA) and Ministry of Law (MinLaw). These agencies included the Housing and Development Board (HDB), Urban Redevelopment Authority (URA), Jurong Town Corporation (JTC), Primary Production Department (PPD), Port of Singapore Authority (PSA), Public Works Department (PWD) and Parks and Recreation Department.¹⁷

Approximately 46,000 unsewered squatters were affected by the clean-up exercise. The Kallang Basin was very heavily squattered with about 42,000 squatters in its five catchments, while the Singapore River Catchment had about 4,000 squatters. This included about 26,000 residential families, 610 pig farmers, and 2,800 backyard trades and industries.¹⁸

The squatters were resettled under a Resettlement Policy, which was introduced in the 1960s. Under the policy, all persons and business establishments affected by resettlement were to be offered rehousing and compensation. However, the benefits only applied to Singaporeans. Some of the squatters were not Singaporeans and hence were not entitled to resettlement benefits. If they were forcibly evicted, they could become destitute vagabonds sleeping on the sidewalks. These were sensitive issues which had to be resolved in a way that would not make the government appear uncaring and callous. Whenever possible, non-Singaporean squatters were allowed to rent flats. Another problem arising from the resettlement process was the question of whether the squatters were on private

land or State Land. If they were on State Land, the government could readily resettle them and then spruce up the vacant land. However, if they were on private land, the government had to acquire it, which was not a popular move. The resettlement of squatters was thus a slow process.¹⁹

The 610 pig farms, as well as 500 duck farms located within the Kallang Basin, were initially relocated to Punggol. However, by the mid-1980s, to eradicate such pollutive and unhygienic activities, as well as conserve Singapore's limited land and water resources for housing and industry, the decision was made to phase these activities out completely.²⁰

In 1971, for reasons of hygiene, the hawker resettlement programme was introduced, in which street hawkers were moved to purpose-built hawker centres and markets. The river clean-up project accelerated the programme. Close to 5,000 street hawkers within the catchments were relocated to markets and hawker centres, such as those at Boat Quay, Empress Place, and Chinatown. So that the hawkers would not lose their clientele, the new food centres were built very near the streets where the hawkers were operating. Vegetable wholesalers who had been traditionally operating on the five-foot ways, streets, and vacant land without proper facilities were also relocated to the Pasir Panjang Wholesale Market.²¹

To prevent human waste, sullage water, and other forms of waste from being discharged into the rivers by bumboat operators and their families staying on board the vessels, cargo handling, storage, and mooring facilities were established at Pasir Panjang for the purpose of relocating the lighters there. By 1983, the lighters were completely relocated. The decision to do so was carefully weighed, given its potential impact on Singapore's entrepôt trade. The conclusion was that the phasing out of lighter transport was not undesirable as it would mean moving from a two-transfer system to a one-transfer system where vessels worked alongside wharves, simplifying the process. Initially, there were many complaints about the lighter anchorage at Pasir Panjang, with claims

that the waves were stronger there than in the sheltered water of the rivers, and that it was too far away, as most lighter operators lived in the Chinatown area. To make the move less painful, a breakwater was built to buffer the lighters from the waves, and a canteen set up to provide food. The canteen also served to reduce the practice of cooking on the boats and throwing the resulting waste into the water. Four years later, the lightermen were quite happy to be in Pasir Panjang despite their initial complaints.²²

There were also some sixty-six boatbuilders and repairers in the Kallang Basin catchment. To remove them in one fell swoop would have been too harsh. To let them vanish through attrition would have taken too long. Thus, a compromise was struck. The larger boatyards were required to upgrade their operations to comply with anti-pollution requirements. Where possible, neighbouring boatyards were also advised to join these larger yards so that pollution control facilities could be provided in a more economical and technically feasible manner. Small boatyards which were unable to upgrade their operations and comply with pollution control requirements but were otherwise viable, were offered alternative sites in Jurong.²³

Rubbish and flotsam that had accumulated in the rivers and along their banks were dredged and removed after these primary sources of pollution had been addressed. During the month-long removal operation, more than 260 tonnes of rubbish were collected and disposed of. In 1986, the PWD improved and tiled the riverside walkway along the Singapore River, while the Parks and Recreation Department carried out landscaping along the riverbanks. In the same year, the Environment Ministry commenced physical improvement works at the Kallang Basin. The river bed was dredged to remove the mud at the bottom and 1 metre of sand was put in. Certain sections of the Kallang Basin were also covered with sand to create aesthetically pleasing sandy banks.²⁴

The clean-up cost the government nearly S\$300 million, excluding resettlement compensation. In addition to addressing the sources

of pollution, engineering measures were also used to prevent the entry of further pollution into the river. For instance, drains in litter-prone areas were covered with slabs, vertical gratings were installed at selected outlet drains leading to main canals and rivers, and float booms were installed across rivers and canals to trap inorganic litter, such as plastic bags and bottles.²⁵

The entire nation rejoiced when the programme was completed in September 1987. The river could flow freely. Its banks, once cluttered with boatyards, backyard trades and squatters, were transformed, almost unbelievably, into attractive riverside walkways and landscaped parks. Fish and other forms of aquatic life returned to the river. So did the people, to relax along the shores or play in the waters of a riverine stretch that Singapore had reclaimed as its own.²⁶

The team behind the clean-up was led by the Permanent Secretary of Environment, Lee Ek Tieng, who would go on to become Head of the Civil Service. He and nine others were each awarded a gold medal by the Prime Minister for their efforts in cleaning up the Singapore River.²⁷

On completion of the clean-up in 1987, the Environment Ministry launched the Clean Rivers Education Programme to educate the public on the massive efforts taken to clean up Singapore's waterways, and urge them to act responsibly and do their part in contributing to this effort.²⁸

In a television interview shortly after the clean-up, then Prime Minister Lee Kuan Yew said:

In 20 years, it is possible that there could be breakthroughs in technology, both anti-pollution and filtration, and then we dam up or put a barrage at the mouth of the Marina – the neck that joins the sea – and we will have a huge freshwater lake. The advantages are obvious. One: a large strategic reserve of water – fresh water – for use in emergency: a drought, or some such period. Second, it will help flood control because at high tides – exceptional high tides – which happens about two periods a year, if they coincide with heavy rain, the three rivers and canals

will flood parts of the city. Now with the barrage, we can control the flooding. And with the barrage, the water level can be held steady. We need never [sic] have low tides. So the recreational use and scenic effect would be greatly improved. And it is possible in another 20 years, and therefore, we should keep on improving the quality of the water.²⁹

The clean-up of the Singapore River and the rivers in the Kallang Basin had become a model for other rivers and set in motion a process to realize the vision of creating a reservoir in the city. Today, that vision has become reality. With the construction of the Marina Barrage, Singapore will have a new source of freshwater, an ability to alleviate flooding in the city, as well as a new venue for recreation and revitalization. As it was said, "It can be done."

CONSERVING SINGAPORE'S NATURAL HERITAGE³⁰

Keeping the land and rivers clean not only has benefits for public health and results in a higher quality living environment, but also supports efforts to conserve Singapore's natural heritage through preventing its natural ecosystems from being polluted.

Singapore's conservation model is one that enables environmental sustainability in a small urban setting, balancing growth with conservation. Areas which are representative of key indigenous ecosystems are legally protected by the government as gazetted nature reserves. There are four nature reserves in Singapore, namely the Bukit Timah Nature Reserve and the Central Catchment Nature Reserve which is made up of primary and mature secondary forests and a fresh water swamp; the Sungei Buloh Wetland Reserve which conserves a mangrove forest and is also a bird sanctuary; and the Labrador Nature Reserve which comprises coastal secondary vegetation and a rocky shore. Together, these cover more than 3,000 hectares or about 4.5 per cent of Singapore's land area. Outside of the nature reserves, Singapore's network of green spaces, park connectors, and water bodies cover a further 4.5 per cent of its land area. Through careful management, these areas are also optimized

to enhance urban biodiversity. Even Singapore's offshore landfill, Pulau Semakau (see also Chapters 4 and 11), defying the common stereotype of a landfill as a dirty, unpleasant dump, is a green natural environment thriving with rich biodiversity. The island is home to over 13 hectares of mangroves, which shelter a thriving community of flora and fauna. A coral nursery has also been established off Semakau to maximize the survival of naturally occurring corals, in which coral fragments are grown for transplanting to existing coral reef habitats.

Through these conservation efforts, Singapore can count itself a city which is rich in biodiversity despite being a small, island city state. For instance, Singapore has some 360 species of birds, which is slightly more than 60 per cent of the 568 species in the United Kingdom. It has eleven out of twenty-three seagrass species found in the Indo-Pacific region. Singapore also has over 250 species of reef-forming hard corals that account for about 30 per cent of the world's hard coral species – there are more coral species per hectare of reef in Singapore waters than there are in the Great Barrier Reef.

VECTOR-BORNE DISEASES

The systems and processes that the government had put in place in cleaning up the land and waterways also greatly benefited Singapore's environmental public health, particularly in the control of infectious disease transmission. First, the resettlement of street hawkers into purpose-built food centres has minimized the likelihood of food being prepared in unsanitary conditions, thus contributing to a low incidence of food-borne diseases and food poisoning. Second, the rodent population has been kept under control with improvements in refuse management practices that deprived these vectors of food sources. This has helped to keep the incidence of rodent-borne diseases low all these years.

Perhaps the most significant impact that a high standard of public cleanliness has made is in helping Singapore tackle the threat of mosquito-borne diseases, since mosquito breeding is often closely associated with poor sanitary conditions. Malaria, in particular, was the most threatening vector-borne disease in Singapore before World War I, and again during and soon after World War II. Fortunately, the rapid urbanization that took place in the 1970s saw the progressive displacement of hilly and swampy areas that were once conducive to the breeding of the *Anopheles* mosquitoes, the vectors for malaria.

While this had, to a large extent, reduced the availability of breeding sources for the vector, it would not have been possible to bring the disease well under control if not for the intensified integrated disease control programme. This was backed by a well-established epidemiological surveillance regime that was capable of detecting and eliminating the focus of transmission quickly, thus preventing the re-establishment of endemicity. Through these relentless efforts, Singapore's malaria control programme finally achieved success on 22 November 1982, when the name of "Singapore" was entered in the World Health Organization (WHO) Official Register of areas where malaria has been eradicated.³¹

This "malaria-free" status has remained till this very day, even though Singapore is situated in a region that is still endemic for the disease. Today, although Singapore has continued to maintain a low incidence rate for malaria, with a majority of the cases imported, the government still maintains a close vigilance on the disease and the vectors that are present in some poorly-drained areas so as to ensure that the disease has no chance of staging a comeback.

The threats from mosquito-borne diseases were, however, far from over. After indigenous malaria was eradicated, Singapore was soon confronted by a different mosquito-borne disease – dengue, whose vectors, the *Aedes* mosquitoes, are highly adaptable and habituated to an urbanized, domestic environment. They commonly breed in stagnant water found in places such as roof

gutters, ornamental flower pot plates, and domestic water containers in houses. The close proximity of their breeding habitats to human hosts and the presence of the virus in the country and the region also means that people are always at risk of becoming infected. Since the *Aedes* mosquitoes breed in relatively clean water, dengue will continue to be around in the foreseeable future.

Being located in dengue-endemic Southeast Asia, Singapore is not spared from this public health threat. By the mid-1960s, dengue had replaced malaria as the most menacing mosquito-borne disease in Singapore. A Vector Control Unit (VCU) was set up in 1966 under the then Ministry of Health to develop a comprehensive system of dengue control, with source reduction as the mainstay of control. The government also realized that to maintain adequate control after the initial reduction, it was necessary to involve the people and this could only be achieved through public education supported by law enforcement.³²

Thus, in 1968, the DDBIA (Destruction of Disease Bearing Insects Act) was introduced to replace the outmoded Mosquito Ordinance that was enacted during the rule of the British colonial government. The DDBIA gave the government more teeth for tighter and more effective control over persons who intentionally or unintentionally propagated disease-bearing insects. Following its enactment, the DDBIA was enforced on a limited scale against persons who bred mosquitoes. In the following year, a countrywide, month-long “Keep Singapore Clean and Mosquito Free” Campaign was launched to educate the public and elicit the widest possible community participation in mosquito control. For the first time, the public was made aware of the seriousness of vector-borne diseases, and that they had a responsibility to act in order to curb its propagation. With the implementation of an integrated system of *Aedes* mosquito control encompassing public education, law enforcement, and source reduction, Singapore was able to achieve long-term suppression of the mosquito vector population, with a concomitant improvement in the disease situation from the mid-1970s.³³

In 1998, the DDBIA was replaced by the Control of Vectors and Pesticides Act, which strengthened the powers of the government in the destruction of vectors and the control of vector-borne diseases. The Act also provided for the control of the sale and use of pesticides and vector repellents, as well as the registration, licensing, and certification of persons engaged in vector control work, to raise the professional standards of these personnel.

Since the start of the 1990s, Singapore, like many countries worldwide, has been experiencing a resurgence of dengue. In the local context, the interplay of the following factors could have fuelled this trend. First, rapid urbanization taking place in the country and region has favoured the breeding and propagation of the mosquito vectors, contributing to a global resurgence of dengue. Next, increased global travel has greatly accelerated the rate of importation of dengue virus. Furthermore, while the decades of intensive vector control operations had successfully suppressed the mosquito population, it has paradoxically also resulted in a lower immunity among the local population. This means that the population has become more susceptible to infection, and transmission can be easily sustained, despite a relatively low *Aedes* mosquito population here. The problem is further compounded by the presence of four different dengue virus serotypes.

Although the odds were clearly stacked against Singapore, NEA pressed on relentlessly with the integrated approach to dengue control. Source reduction continued to be the primary focus of NEA's mosquito control strategy as it is only through removing the source of breeding in outbreaks and, more importantly, during the inter-epidemic months (through the intensive source reduction exercises) that there is a better chance of breaking and preventing disease transmission, given that a dengue vaccine was unlikely to be available any time soon.

Dengue surveillance in Singapore evolved into an integrated approach that includes both passive and active case surveillance

from the medical community, entomological surveillance in the field, and virological surveillance in the laboratory. First, accurate and timely “ground intelligence” is gathered. While some 500 field officers collect field entomological data, perform source reduction, and enforce against mosquito breeding in premises to reduce the incidence of *Aedes* breedings, the Environmental Health Institute (EHI) provides virological surveillance and identification of mosquito species collected. This information is fed into a Geographical Information System (GIS) that tracks the spatial and temporal distribution of reported dengue cases obtained from the Ministry of Health. The GIS promptly detects any unusual clustering of cases, which then triggers off epidemiological investigation to determine the source of infection, and concurrently, the ramping up of intensive search-and-destroy operations to eliminate these sources, thus abating disease transmission.

Second, proactive surveillance and source reduction is practised. Source reduction is no longer confined to just the locality or period with a clustering of reported cases. A pre-emptive approach is adopted instead, utilizing information about the spatial and temporal distribution of the mosquito population, the geographical distribution of the predominant dengue virus serotype that is circulating in the local population, as well as the ambient temperature and the susceptibility of the population in a particular locality. This allows for the stratification of different localities based on their potential for outbreak into focus areas thereby allowing prioritization in the deployment of manpower to carry out pre-emptive source reduction, according to the assessed risk level. Such proactive surveillance allows the problem to be nipped in the bud before it has a chance to escalate into an outbreak situation.

Third, NEA focuses on improving operational effectiveness. NEA’s environmental health officers, having operated on the ground for years, are highly attuned to seeking out mosquito breeding habitats. In fact, many of them have also acquired the knack for picking out unusual breeding habitats, and this has continuously

allowed transmission to be interrupted quickly in most clusters. Last, but not least, NEA adopts a system of continuous follow-up and assessment. Following the successful abatement of transmission in each cluster, NEA continues to survey the cluster area for mosquito activity for up to two weeks, to ensure that the sources of infection are completely eliminated and transmission has abated.

Recognizing that tackling the mosquito problem cannot be accomplished by the government alone, NEA has actively continued to encourage the participation of the community and other stakeholders through a combination of intensive public education and community outreach campaigns. Over the years, NEA has built a network of grassroots volunteers who help to disseminate dengue prevention messages to residents in the locality of an outbreak, so as to ensure that transmission is curbed in the shortest possible time. Through the Inter-Agency Dengue Taskforce, the other government land agencies come together to strengthen and intensify mosquito control efforts.

Despite being held up by WHO³⁴ as having one of the most successful dengue control programmes in the world, it is not possible to eradicate completely the mosquitoes that transmit dengue. Moreover, because Singapore has succeeded in keeping the mosquito vector population low, more intensive vector control efforts are likely to yield only marginal improvements in the disease situation. Consequently, new approaches that are based on scientific understanding of both the vectors and the viruses are needed to achieve a further breakthrough.

Leveraging Scientific Research to Control Diseases

The VCU that was set up in 1966 had functioned as an advisory and research body, providing laboratory support services for Singapore's vector control operations. The Unit was later renamed the Vector Control and Research Department (VCRD), and in

February 1992, took over vector control operations to streamline the coordination and lines of commands between planning, research, and operations. However, scientific research on vector-borne diseases was mostly carried out on an “*ad hoc* need-to” basis, with studies commissioned from research institutions, universities as well as hospital laboratories. Apart from these studies, some laboratory studies on vector biology and behaviour were conducted in an in-house laboratory under the VCRD. Other than this, research on vector-borne diseases in Singapore was relatively unstructured, as it was felt that outsourcing such research to the private sector was more cost-effective than building up in-house research capability.

The highly competitive biomedical research landscape meant that individual research institutions had their own research focuses and priorities. These were often not aligned with the research priorities of the government agencies concerned with public health. Yet, from the government’s perspective, building up capabilities in public health research was necessary to fulfil a national need. Having such capability would enable the government to be better prepared to react to and handle outbreaks as well as the emergence of new viruses, and more importantly, to detect the introduction of these diseases into Singapore, without relying on laboratories overseas.

The development of this capability was made possible with the establishment of the Environmental Health Institute (EHI) in April 2002 as a department under the Environmental Public Health Division of NEA. The mandate for EHI was clear – to support the division’s role as the national authority responsible for vector control, through carrying out research on vectors, vector-borne pathogens, and their control. The Institute carries the mission of ensuring that Singapore’s environmental public health standards are not compromised in the face of a growing population, increased urbanization, and emerging infectious diseases of environmental health concern.

The vision is for EHI to leverage scientific research and the latest biomedical technologies to understand better the vectors and

the diseases they transmit, with a special focus on the *Aedes* mosquitoes and dengue. The Institute also conducts risk assessments of the vulnerability of the local population to vector-borne diseases, and applied research to develop new, innovative, and cost-effective disease prevention strategies.

Attracting the right talent to join the Institute was an important first step. With the rapidly growing biomedical industry, there was no lack of employment opportunities for biomedical researchers. However, it was critical to attract talented individuals who were interested in carving out a career in public health research and prepared to cast their lot with a nascent set-up that had no track record, and hence no efforts were spared in recruitment. From a humble beginning of fewer than twenty employees, the Institute has grown to a staff strength of forty in 2008, with nine researchers holding postgraduate qualifications, and twenty-five with tertiary qualifications.

Over time, research at the Institute has also shifted from an initial focus on vector-borne diseases, centring on dengue fever and Japanese encephalitis, to becoming organized into five programmes, namely Surveillance, Vector Research, Epidemiology, Diagnostics, and Pathogenicity, as well as Indoor Air Quality, each staffed by specialists trained in the relevant disciplines. Far from being just a speciation of research programmes, this move signified the adoption of an integrated approach to environmental public health research that amalgamates clinical and laboratory surveillance with field vector control operation.

EHI and the SARS outbreak in 2003

Although the EHI was set up primarily to carry out research work on vector-borne diseases, it contributed its expertise readily during the SARS outbreak of 2003 by agreeing to cultivate the live SARS virus in its laboratory. The live virus was required for the study of the SARS coronavirus and the development of diagnostic kits.

Unfortunately, a student contracted SARS while working in the laboratory. The government took prompt remedial action. All activities within the Institute were suspended and a Review Panel, comprising international and local experts, was invited to audit the laboratory's biosafety procedures and recommend measures to strengthen the work processes at the Institute. Through interviews and laboratory investigations of samples from the laboratory, the panel found that the infection was caused by inappropriate laboratory practices and cross-contamination of West Nile Virus samples with the SARS coronavirus. The Biosafety Level 3 (BSL-3) laboratory was disinfected and downgraded to Biosafety Level 2 (BSL-2).

It was an eye-opening lesson for EHI and Singapore as it highlighted the need to manage inherent risks associated with the operation of a high-containment laboratory, and the need for a robust biosafety framework to govern the conduct of research activities. Since then, biosafety procedures have been put in place, and research staff given refresher training on biosafety.

In 2005, EHI began a new lease of life when it moved into a new facility at Biopolis, the hub of Life Sciences research in Singapore. Apart from the High Containment Laboratory at BSL-3, the facility is also equipped with an Arthropod Containment Laboratory (ACL) Level 3, that allowed the Institute to expand its scope of research to address more vector-borne diseases of public health importance. More importantly, the various biosafety procedures that the Institute has put in place allows it to comply with the requirements prescribed by the Biological Agents and Toxins Act, a legislation which was enacted in 2006 to, among other things, provide for safe practices in the handling of such biological agents and toxins at BSL-3.

The BSL-3 laboratory provides an appropriate setting for surveillance and research of high risk vector-borne viruses, including West Nile virus, Japanese encephalitis virus, Chikungunya virus, and Hanta viruses, while the ACL allows research on infected mosquitoes to be conducted. Until then, most of the research was

centred on the vectors that spread the disease. The complexity of vector-borne diseases due to the interplay of many factors, however, means that a holistic understanding of the role played by the viruses, host, and environmental factors in disease transmission is necessary. To this end, the Institute, with the availability of the new facilities, has become better positioned to study the viruses directly responsible for the diseases in order to obtain a fuller picture of the problems, as well as possible solutions.

Contributing to Dengue Prevention Efforts

EHI's capability was put to the test during the dengue resurgence in 2005. The Institute had at the time just completed the development of a PCR (polymerase chain reaction)-based diagnostic assay that could accurately detect the dengue virus and its serotype in an infected blood sample, as early as the first day of disease onset. The new capability shortened the diagnostic and serotyping time from weeks, using the current gold standard of virus isolation, to less than an hour.

Accurate and rapid diagnosis is essential in the fight against dengue. It is needed for patient management and directing vector control response to minimize further transmission and spread of the disease. In the dengue epidemic of 2005, the test contributed to an improvement in the rate of the clinicians' diagnosis. Riding on this success, the EHI went on to develop a test kit that is able to detect anti-dengue antibodies in the saliva. This non-invasive approach holds the potential for early post-infection detection of the disease and is currently undergoing field trial.

Apart from improving the diagnostic capability for dengue, the EHI has also enhanced its surveillance system for early detection of the emergence of any new predominant serotype circulating in the population. The system leverages a close network of medical practitioners who collect blood samples from patients displaying symptoms of dengue, and send them for laboratory diagnosis by

the Institute. The early detection of a switch from Dengue 1 to Dengue 2 in 2007 enabled the vector control response to be initiated more promptly to mitigate the effects of an ensuing outbreak. The detection of an emergence of the uncommon Dengue 3 serotype in 2005 and 2007 (in several areas in Tampines) also triggered an enhanced effort in these areas to prevent the spread of the serotype to other parts of Singapore. Since 2006, the Institute has further extended this surveillance system to include the Chikungunya virus, West Nile virus, and Hanta virus.

EHI's research has also contributed to a better understanding of mosquito vector biology. In a study of the dispersal range for dengue vector mosquitoes, *Aedes aegypti* and *Aedes albopictus*, the Institute has found that the mosquitoes could disperse easily and quickly throughout areas of radius 320 metres in search of egg-laying sites. This contrasts with the general belief that the *Aedes* mosquito seldom flies more than 50 metres in its lifetime. In the same study, it was also found that with releases on the twelfth storey of a twenty-one-storey apartment block, the mosquitoes showed a similarly easy and rapid dispersal to the top and bottom of the block. The work, published in an international journal in 2004, won the Royal Entomological Society Award for best publication in Medical and Veterinary Entomology during 2004–2005. These findings provided a firm scientific basis to refine existing vector control practices such as expanding the geographical range of source reduction to ensure better effectiveness.

The research at EHI has also shaped the way mosquito vectors are controlled. For instance, trials conducted by the Institute have found the use of *Bacillus thuringiensis* strain *israelensis* (*Bti*) to be effective in controlling mosquito breeding at construction sites. *Bti*, a biological vector control agent, eliminates mosquito larvae through degradation of their digestive tract, but is environmentally friendly since it is non-toxic to human and other animals, compared with chemical pesticides. The finding has led to the successful and widespread usage of *Bti* as a mosquito control method, particularly

in Singapore's many construction sites. The Institute also conducts other trials, including the use of residual spray, traditionally used for malaria control, for dengue control.

With EHI's research capability gaining better recognition, the Institute has gradually moved beyond the role of supporting the national vector-borne disease control programme, to collaborating with, and supporting other aspects of public health research in Singapore also. EHI's team of researchers has collaborated with various local and international academic bodies, research institutes, and organizations, constantly identifying working partners with relevant expertise for mutual exchange of knowledge and expertise. As a member of the Dengue Consortium and the Malaria Consortium, EHI has worked closely with other major research institutions in Singapore on projects, including the surveillance of rodent-borne diseases. EHI also supports local and overseas pharmaceutical companies in the development of anti-dengue drugs through the provision of supporting services such as viral testing for drug companies that are carrying out trials, as well as sharing of knowledge about the local vector-borne disease situation.

Even though EHI has developed considerable research capability, the Institute is acutely aware of the need to further its understanding of the disease so as to enhance Singapore's own vector-borne disease control efforts. The Institute has, therefore, been actively exchanging notes with other research institutes. In 2007, NEA entered into a Memorandum of Understanding with the Instituto de Medicina Tropical "Pedro Kouri", in Cuba, a country that is also well known for its dengue control programme, to collaborate on various projects in dengue surveillance, control, and research.

Diseases such as dengue or Chikungunya fever do not recognize geographical boundaries or socio-economic status. Singapore cannot fight the battle against dengue alone. To this end, EHI has started to assist in capacity building in less developed countries, through helping to strengthen their disease surveillance capability, and

thereby reducing their disease burden. As a way for Singapore to reciprocate the help that international organizations such as WHO rendered it during its early developing years, the Institute has contributed to the WHO WPRO's (Western Pacific Regional Office) efforts in developing research plans on communicable diseases, as well as the Asia-Pacific dengue control strategic plans.

Besides vector and vector-borne viruses research, the EHI's other focus is on gathering scientific evidence to support the formulation of environmental public health policies. This was particularly evident in the assessment of the indoor air quality in entertainment outlets in 2006 in preparation for the introduction of smoking prohibition in these places. Parameters, including the indoor and outdoor levels of respirable suspended particles and carbon monoxide, were measured in these outlets. A comparison of the air quality measurements taken one month before and after the introduction of the smoking prohibition showed a significant reduction in the levels of key indoor air pollutants, thus affirming the value of indoor smoking bans. The Institute has also undertaken surveys to assess the risk of *Legionella* infection in spa pool water as part of the evaluation of the need to regulate spa pool water quality to protect the health of spa users.

CONCLUSION

Singapore's experience in cleaning up the land and rivers is a unique one. It began with a clear vision by the government, who appreciated that economic development need not progress at the expense of the environment, and more importantly, a high standard of living for the people could not be achieved without a clean and healthy environment.

In translating this vision into reality, the government understood the need to adopt a long-term perspective in planning and executing the various programmes to support the realization of the vision. For example, to tackle the problem of illegal street hawking

permanently, the government was prepared to invest heavily in infrastructure, i.e. purpose-built food centres and markets.

Realizing the vision of a clean Singapore could not have been achieved within such a short span of time, if not for the practical and effective implementation of policies and programmes. In solving the pollution problem of the Singapore River, for instance, the government had decided that controlling the sources of pollution was the most practical and effective approach, rather than implementing direct engineering solutions to remove pollution from the river. Other than emphasizing practicality, continuous innovation has also been a hallmark of many environmental policies and programmes. The evolution of the “Keep Singapore Clean” campaign in the early years to the “Clean and Green Week” of the 1990s shows how the government explored new approaches of engaging the population to sustain a clean and healthy environment, in response to changing socio-economic trends as well as public expectations.

Today, Singapore can pride itself on being among the few cities in the world where residents can regard a clean environment as a matter of fact. Some may even take this quality living environment for granted, forgetting that not so long ago, the environment in Singapore left much to be desired. Indeed, in spite of the four decades of efforts spent exalting the benefits of a clean living environment, and encouraging all residents to play their part in keeping the country clean, the current state of cleanliness is still far from ideal, and to some extent, still very much dependent on the efforts of the cleaners.

The behaviour and psyche of persistent litterbugs are still poorly understood. This is an area where perhaps socio-psychology experts may provide some insights.

Beyond a better understanding of the motivations of the litterbugs, there is also a need to develop the cleaning industry through raising the professional standards of the workforce, as a skilled and well-trained workforce would be better equipped to

meet the rising expectations of the public, and at the same time, address the inferior image that has long been associated with the industry. Moving forward, the government should also be prepared to leverage technological advancements in materials research that could lead to the design of buildings and other structures that facilitate more efficient cleansing.

But most importantly, the people in Singapore must come to the realization that the cost of keeping the country clean would ultimately be borne by them, in one form or another. Apart from paying directly for the cost of cleaning up public places, the people must recognize that the indirect cost of an environment with poor sanitation would be many times more – the higher likelihood of infectious disease transmission, or tourists and investors staying away.

As the transformation of Singapore's living environment in the last four decades was an achievement made possible only through the dedicated efforts of both the government and the people, this partnership must continue. Sustaining the cleanliness of the land and waterways will need to be a perpetual commitment, one to be carried through to future generations.

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