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ORIGINAL ARTICLE

# Urban water-related environmental transitions in Southeast Asia

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**Abstract** This article reviews water-related urban environmental conditions in Southeast Asia. It argues that the development of urban environmental challenges in the region follows a unique pattern compared with those experienced in the now developed world. The new pattern is defined by the so called *time–space telescoping* of the development process. The process of *time–space telescoping* reduces the levels of income at which environmental challenges emerge and forces their appearance in a simultaneous fashion, as sets of problems. During previous eras, cities experienced sequential environmental transitions. Urban water-related environmental burdens emerged on local scales and expanded geographically and temporally in impact, with growing levels of affluence. Moreover, certain environmental challenges appeared later in economic growth because the technologies and practices that induced these problems emerged at higher levels of income. The article has two main findings. First, except for wealthy urban centers, for example Singapore, cities in the region are experiencing multi-scaled water burdens simultaneously. Second, low-income and middle-income cities are experiencing burdens at lower levels of income than did their contemporaries in the north.

**Keywords** Urban environmental transitions · Water-related environmental burdens · Scale · Time–space telescoping · Southeast Asia

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## Introduction

In his article ‘‘Ecology Matters: Sustainable Development in Southeast Asia’’ Savage (2006) critically examines very many processes and trends pertinent to urban development in Southeast Asia. Using population growth and distribution, the growth and form of capitalism in the region, ecological linkages between biophysical and socio-cultural spheres, and multi-faceted aspects that contribute to development, he explores growth within the region and sets up a discussion on how its cities can become sustainable. He finds the basis of current environmental conditions, and therefore the keys to solutions, in two dominant circuits of urban dwellers. The first is the lower circuit of ‘‘ecosystem people’’ who depend on the ecosystems and the services they provide within and surrounding slums and squatter dwellings. These citizens suffer from and contribute to traditional ‘‘brown issues’’, for example poor water supply, sanitation, and solid waste management, and indoor air pollution, resulting in morbidity and mortality from respiratory and infectious diseases. The second group inhabits the upper circuit of cities and are called ‘‘biosphere people.’’ This group lives in wealthy gated-communities and high-rise apartment buildings. While avoiding traditional environmental burdens they suffer from materialism and high consumption habits, which reduce ecosystem services in ‘‘distant elsewheres’’ (Rees 2002), produce emissions that generate global systemic environmental change, for example the greenhouse effect, and suffer personally from general loss of cultural values. Essentially, the article points not only to different sets of environmental burdens faced by those living in the same city, but also to the notion that different burdens have different scales of impact.

I believe this argument to be correct and would like to further expand on this line of thinking. This article also examines urban environmental conditions in Southeast Asia. It focuses on the emergence of different scales of urban water-related environmental burdens previously associated with different income levels of cities. The main premise is that the patterns of transitions among different sets of environmental conditions experienced by those living in cities in the region are unique, and different from those experienced historically by the now developed world. Specifically, within cities in Southeast Asia environmental challenges increasingly appear on all scales simultaneously. Compared with the chronological experiences of now developed cities, environmental burdens are also emerging at lower levels of income. The analysis suggests that even for low-income cities, urban managers are faced with a spectrum of issues.

The article is organized in three further sections. In the next section, I present a basis for understanding the environmental conditions occurring within cities of Southeast Asia. Using the concept of urban environmental transitions the article presents a variant of this theory that addresses how transitions are currently unfolding within the region. In the third section I present evidence in support of the claims. In the fourth section, I briefly discuss the implications of the findings and conclude the paper.

## A perspective on the unique environmental conditions in Southeast Asian cities

My main argument is that urbanites of cities of the Southeast Asian region are experiencing several layered environmental conditions and burdens associated with varied and complex development forces. Specifically, in comparison with the historical experiences of the now developed world, particularly Western Europe and North America, one finds in Southeast Asia a collapsing, compression, and telescoping of different development trends. The results include changes in the speed, timing, and emergence of transitions and the changes in the geographic concentration of different phenomena.

The processes that lead to these changes have been called *time–space telescoping* (Marcotullio 2005), which is composed of changing time-related and space-related effects. Time-related effects include increases in the speed and efficiency of human activities. Changes in the speed and intensity of different aspects of development have been associated with globalization, communications and transportation technology (Dicken 1998; Held et al. 1999). Space-related effects include processes that concentrate diverse physical, social, and economic activities in geographically uneven patterns and in increasingly concentrated areas. For example, the increasing concentration of different income classes (Massey 1996) and diversity of technology used by them, and the infrastructure available for urban citizens are a result of the space-effects. Recent work on globalization suggests space-related effects result from the concentration of certain types of infrastructure (communication, transportation, financial and business services, headquarters of transnational companies) in specific locations around the world (e.g. world cities) (Friedmann 1986; Friedmann and Wolff 1982; Lo and Yeung 1998; Sassen 1991). These concentrations have been facilitated by new transportation and communications technology which have transformed the ability of information, goods, and services to move across space (Dicken 1998).

Time–space effects change constraints placed upon human activities and, therefore, transform our ability to affect the environment. Janelle (1968, 1969), for example, identified the increasing speed at which people move across space and its affects on economic activity and social relations. His term ‘‘time–space convergence’’ defined the process of reducing the friction of distance between places and results in reducing average amounts of time needed to travel between them. Processes creating ‘‘time–space convergence’’ have not only made the world smaller, but have also increased our ability to affect a larger number of different environments around the world, and more intensely. Harvey (1989), focused on what he called ‘‘time–space compression’’ as underpinning the emergence of the post-modern condition. Time–space compression includes processes that revolutionize the objective qualities of space and time and alter, sometimes in quite radical ways, how we see the world. These notions demonstrate changes in the speed and location of activities with time, which have thus transformed human behavior and its environmental impact.

The argument raises issues about the meaningfulness of comparing development patterns across space and time. Is it fair to compare New York City at the turn of the twentieth century with 1980s Bangkok? How, more generally, can urban development patterns and environmental conditions be justifiably compared?

A current popular view is that the development of cities and nations can be compared on the basis of their GDP levels per capita, and the environmental conditions associated with different levels of income can be meaningfully interpreted. Those that subscribe to this perspective often use the Environmental Kuznets curve (EKC). The EKC compares countries and cities at similar levels of income and suggests that, irrespective of when or how they obtained similar levels, they will follow a similar pathway that is described by the "inverted-U" function of environmental degradation across income levels. Specifically, they suggest that all countries undergo environmental degradation to a threshold level, when processes reverse and environmental degradation decreases. According to this theory, all environmental conditions follow this pathway.

Two limitations of EKC analyses include the equation of development solely with economic growth and the notion that all environmental trends follow the "inverted-U" curve. First, to EKC advocates, development is equated with the increasing capacity of the national economy to generate increases in production. Using per capita indicators demonstrates that increases in economic growth are different from those of population growth. Typical EKC comparisons use purchasing power parity (PPP) per capita indicators, which enable income standardization across price differences in goods and services between countries. That is, a PPP value for income in one country will match the ability of citizens to purchase the same amount of an exact set of goods and services in another country and their own. Although using PPP per capita values is more appropriate than simply comparing GDP or GDP per capita figures, it still leaves much of what development encompasses out of the picture.

Economic growth does not necessitate changes in social or political structures, for example. Those attempting to address these problems often supplement economic data with social indicators including acquisition of material possessions, for example telephones, televisions, and radios, and the use of banks, schools, and cinemas, and provision of housing, medical, or educational services (see any *Human Development Report* of the United Nations Development Program).

Nor does a focus on economic growth always include emphasis on the reduction or elimination of poverty, inequality, and unemployment. Many argue, however, that development concerns equity and distributive justice on all scales. Economists have recently turned toward definitions that include improving the quality of life for citizens, broadly defined, and, especially, the poor (World Bank 1991).

These different critiques of using economic growth as an indicator of development suggest the process is more than increasing wealth. "Development must therefore be conceived a multidimensional process involving major changes in social structure, popular attitudes and national institutions, as well as the acceleration of economic growth, the reduction of inequality and the eradication of poverty" (Todaro 1997, p. 16).

The second critique of the EKC analysis suggests that different environmental effects have different relationships with development (World Bank 1992). EKC studies have been performed on several different water and air pollutants, for example, with expectations that trends of these environmental burdens will follow the "inverted-U" shape with increasing income (Grossman and Krueger 1995). More recent studies, however, have found that different environmental burdens follow different patterns with increasing wealth (Yandle et al. 2004).

One response to the limitations of EKC notion has been the development of urban environmental transition theory. Urban environmental transition theory suggests that wealth, among other factors, accounts for a variety of changes in environmental conditions within cities (McGranahan et al. 2001; McGranahan and Songsore 1994). As cities increase in wealth, urban environmental challenges shift in type, scale, and timing of impact. The theory defines three different sets of relationships between increasing wealth and environmental burdens. Traditional urban environmental challenges are the first to emerge. These include those in the brown agenda. Brown agenda issues are most clearly seen at the household and neighborhood level. The key effects of these issues are on human health; the timing of the effect is immediate and those most affected are those within lower-income cities (McGranahan and Satterthwaite 2000).

Environmental challenges that emerge during rapid development are at the scale of the entire metropolitan region. These issues have been associated with the gray environmental agenda (Marcotullio and Lee 2003). The key effects of these issues are both human health and the natural and man-made environments. The timing of the effects can range from immediate to delayed (for some pollution, years can pass before effects are noted). Those worst affected are populations living in the city and, particularly, those in poor neighborhoods.

The environmental burdens associated with wealthy cities are typically categorized as part of the green environmental agenda. The key effects of these conditions and trends are on ecosystem health. The timing of the effects are delayed and the worst affected are future generations (McGranahan and Satterthwaite 2000). These issues can be observed on internationally regional or global scales.

The theory also focuses on more than economic growth as the driving force in environmental change.

Wealth can be used as a central axis to demonstrate shifts in the type and scale of impact, but the theory is valid for other factors complementary to economic growth as driving forces of change. Indeed, according to the theory, economic growth is not the only, or even the major, force driving environmental change. For example, recent studies in urban environmental transition theory suggest that agenda setting, environmental crises, risk transfer, and the social construction of environmental burdens are some of the numerous factors affecting urban environmental transitions (Marcotullio and McGranahan 2007). These notions do not, however, negate the value of environmental transition theory but rather help to further refine the approach.

Previous studies of urban environmental conditions within East and Southeast Asia have, however, been a variant of urban environmental transition theory and EKC studies. They suggest, for example, that cities experience different environmental burdens with economic growth. For example, Webster (1995) was the first to use urban environmental transition theory to describe urban conditions in Southeast Asia. He divides cities in the region into three categories. Category 1 cities are poor and afflicted with largely brown issues. Hanoi, Ho Chi Minh, and Phnom Penh and Vientiane belong to this category. Category 2 cities are middle-income cities with air pollution and congestion problems as the dominant concerns. These include Bangkok and Kuala Lumpur. Category 3 cities are high-income cities that are battling hazardous wastes and degradation of urban amenities. This category includes Singapore and Hong Kong. Bai and Imura (2000) also examine the environmental conditions in different cities in East Asia and largely follow Webster's scheme. In their analysis they suggest that cities undergo staged evolution. According to their scheme, cities in the region are differentiated into three types. Type I are cities with poverty-related environmental problems. Type II cities are those confronted with rapid growth-related environmental issues. Type III includes those in which the residents are primarily concerned with wealthy lifestyle-related complications. The model also postulates that cities experience three distinct sets of environmental problems sequentially. That is, cities "evolve" through "stages" one after another. Curiously, however, the authors also suggest that cities can jump between types, although the process by which this is possible is not elaborated.

The patterns outlined by these previous studies follow those outlined for the now developed world. In his study of the history of urban sanitary services, Melosi (2000) notes that chronologically, US cities developed infrastructure, scientific theories, and new cultural adaptations to meet existing problems as they grew during the nineteenth and twentieth centuries. He notes that the first challenges were all localized. Subsequent problems progressively grew in geographic scale because often the solutions to problems simply displaced the environmental burden. Indeed solutions for a previous pollution problem often generated new challenges later, although these challenges took some time to emerge and they often did so in different locations and in different environmental media (Tarr 1996). Hence, at any one period of time, cities in the now developed world addressed environmental burdens on mostly one scale, be they local, regional, or global.

The environmental transitions between sets of different scaled burdens were not only related to the solutions of problems but to the limitations of the standard ways of operating in previous eras. Barriers, however, only became apparent with new urban growth, new technology, and new demands by citizens. As a new urban order developed, it disrupted and even destroyed the former, as a response to its limitations (Peterson 1982). These changes occurred over long periods of time. Sometimes the shifts took 50–70 years to occur (Kondratieff 1979). For example, Newman and Kenworthy (1999) have identified specific urban forms associated with different type of transport as they evolved in the developed world. Given the shift in environmental challenges over long periods of time and the distinctness of the urban orders that emerged, it is easy to see why the environmental histories of now developed cities are written as stages related to the dominant environmental challenges of the period (Berry 1990; Melosi 2000; Yeates 1998).

The notion of *time–space telescoping* challenges the underlying understanding of development portrayed by the EKC, and versions of environmental transition history, that have been applied previously to cities in Southeast Asia. Rather than following sequential patterns, contemporary time-related and space-related effects associated with the current development context are strong enough to produce a new and unique pattern for newly developing cities. Some of the basic differences between the forces that created previous histories and those creating the emerging patterns found in Asia include:

- Processes that unfolded over long periods of time in developed world history are now revealed rapidly in the contemporary developing world context;
- Conditions that were once seen over large areas during any given historical period in developed

world history are now seen within increasingly concentrated spaces and particularly within cities in the developing world;

- Patterns of social, economic, environmental, and institutional development, that were once regarded as sequential and which previously occurred in stages in developed world cities are now occurring simultaneously in developing world cities;
- Technology, information, goods, services, etc., that were historically associated with wealthy societies and associated with environmental problems in those cities, are now increasingly found in cities at all levels of income;
- Urban forms that once defined different economic and social activities of cities at different stages of development are now enmeshed and evolving together in developing world cities.

These processes hypothetically force environmental conditions of rapidly developing cities to:

1. appear sooner (at lower levels of income);
2. rise faster (over time); and
3. emerge in a more simultaneous fashion than they did in previous urban history.

It would be difficult to demonstrate all these trends in a study that focuses only on cities in the rapidly developing world. It is possible, however, to show through a cross-sectional examination of urban environmental burdens of cities in the region that environmental effects on different scales are now important to most cities, irrespective of their income level. Demonstrating multi-scaled environmental concerns in cities at low or medium levels of income is arguably direct evidence of the telescoping notion. The task of this article is to show that there are numerous water-related burdens within all cities of the region and that these burdens appear on different scales within individual cities, even those of low-income and middle-income.

## Cities awash in water-related burdens

Water-related urban environmental challenges can be divided into categories on the basis of their scale of impact (Table 1). This section provides evidence that urban water decision-makers in the region are increasingly forced to address similar sets of water-related challenges, on all scales and at lower levels of income than experienced during previous times. It does so by presenting data for both the state of the environment within cities of the region as well as status of the driving forces affecting the environmental conditions.

**Table 1** Different scales of urban water-related challenges

| Water-related challenge | Scale of impact |
|---|---|
| Brown issues | |
| Access to water supply | Household |
| Access to sanitation | Household |
| Adequate drainage | Neighborhood |
| Gray issues | |
| River pollution | Metropolitan region to regional |
| Overdrawn groundwater supplies | Neighborhood to metropolitan region |
| Ground subsidence | Neighborhood to metropolitan region |
| Coastal area degradation | Metropolitan region to regional |
| Flooding | Neighborhood to metropolitan region |
| Green issues | |
| Increasing water consumption per capita | Metropolitan region to regional |
| Water scarcity | Metropolitan region to regional |
| Increased vulnerability because of climate change/variability | Regional |

### Local water issues

Local water-related environmental issues include access to safe drinking water and sanitation and appropriate drainage. These are associated with local environmental health, which in turn are associated with urban poverty (Hardoy et al. 2001).

Although economic growth in Asia has led to reductions in both relative inequality and absolute poverty (Fields 1995), levels of poverty in the ASEAN region remains high in some countries (Table 2). In Cambodia, Lao PDR, and Vietnam poverty levels are between 35 and 40%. For other countries, for example Indonesia, Myanmar, and the Philippines, the situation is slightly better with poverty at levels between 17 and 28%. There are also other counties with lower but significant levels of poverty, for example Thailand and Malaysia with 10 and 8%, respectively. Brunei Darussalam and Singapore, on the other hand, can boast of small populations living in poverty.

Until recently, the problem of poverty throughout Asia was regarded as predominately rural (Quibria 1993). With increasing urbanization, poverty has urbanized (see, for example, UN-HABITAT 2003a). Indeed, in a review of urban poverty in Asia, Mills and Pernia (1994, p. 2) predict that "because of continuing

**Table 2** Percent of total population living in poverty

| Country | Poverty (%) |
|---|---|
| Brunei Darussalam | 0 |
| Cambodia | 36 |
| Indonesia | 17 |
| Lao PDR | 39 |
| Malaysia | 8 |
| Myanmar | 23 |
| Philippines | 28 |
| Singapore | 0 |
| Thailand | 10 |
| Vietnam | 37 |

*Source*: ASEAN Statistical Yearbook 2004

**Table 3** Households below poverty in selected Southeast Asian cities

| City | Country | Households below poverty (%) |
|---|---|---|
| Phnom Penh | Cambodia | 16.4 |
| Bandung | Indonesia | 2.0 |
| Jakarta | Indonesia | 6.6 |
| Semarang | Indonesia | 24.8 |
| Surabaya | Indonesia | 0.9 |
| Vientiane | Lao PDR | 19.0 |
| Penang | Malaysia | 6.1 |
| Yangon | Myanmar | – |
| Cebu | Philippines | – |
| Bangkok | Thailand | 15.9 |
| Chiang Mai | Thailand | 9.7 |
| Hanoi | Vietnam | 2.1 |
| Ho Chi Minh | Vietnam | 10.6 |

UN-HABITAT (2003a)

urbanization and urban population growth, poverty will increasingly become an urban phenomenon and, regardless of economic growth performance in the short to medium term, will remain a formidable problem in many countries for years to come.''

In the urban setting, the poor typically live in slums or squatter developments. Globally, there are approximately 900 million people living in slums, including 43% of the urban population in developing regions (Garau et al. 2005). As there is no simple measure of slums, this figure probably underestimates the extent of urban poverty (Satterthwaite 2005).

Conservative estimates of households in poverty in the region's cities are listed in Table 3.[1] Even these data suggest that the percentage of households living in poverty is high in some of the region's cities. Detailed case studies suggest that poverty figures alone are not sufficient to identify slums. Research demonstrates that Bangkok still has 866 slum areas typically located along canals or in concentrated nodes, which hold 16% of the city's population. In Jakarta, estimates suggest that 20–25% of the city's population lives in *Kampungs*, with another 4–5% squatting illegally. In Manila 526 slum communities house 2.5 million people. Although these communities are fairly discrete, urban poverty in Metro Manila can be found wherever there is space and opportunity (UN-HABITAT 2003a). In the relatively high-income Klang Valley, Malaysia, the location of Kuala Lumpur, approximately 9.2% of dwellings are squatter housing (Bunnell et al. 2002).

Poverty and slums are typically known for local environmental issues associated with ill-health. Two important indicators of poverty, slums and the brown agenda, for example, are the numbers of people without access to water and sanitation (UN-HABITAT 2003a). Globally, the number of urban dwellers who have inadequate access to water and sanitation is underestimated and reaches into the hundreds of millions.

International efforts to measure local access to water and sanitation can be confusing. One set of indicators suggests there are those who have access to ''improved'' water and sanitation. For example, 93% of the urban population in Asia have ''improved'' water and 78% have ''improved'' sanitation (Table 4). Many of those populations classified as having ''improved provision'' may, however, be sharing facilities with hundreds of people (Garau et al. 2005), so although provision may be ''improved'' it may not be ''safe'' and ''adequate'' (UN-HABITAT 2003b).

Another important limitation of urban data is the misleading quality of aggregated statistics, which hide the scale or depth of deprivation among poor urban populations. That is, concentrations of middle and upper-income populations within cities, which have good access to services, can bring up averages (Garau et al. 2005). For example, in a review of demographic change in developing country cities Montgomery et al. (2003), documented differences between urban poor and non-poor child health (in terms of height and weight) and household access to public services (water supply, sanitation, electricity). The distinctions between the urban poor and urban non-poor were similar among a number of variables. Access for the urban poor to services is sharply worse than that of the urban non-poor and childhood health of the urban poor is worse than that of the urban non-poor. These authors conclude that it is likely that poverty-related differences in children's health are partly because of different access to environmental and other services.

[1] Estimates of the number of people living in slums in Southeast Asia are as high as 56.7 million or 28% of the total urban population in the region (UN-HABITAT 2003a).

**Table 4** Estimates of the number of urban dwellers lacking provision for water and sanitation in 2000 based on who has "improved" provision and who has "adequate" provision

| Region | Number and proportion of urban dwellers without "improved" provision for: | | Indicative estimates for the number and proportion of urban dwellers without "adequate" provision for: | |
|---|---|---|---|---|
| | Water | Sanitation | Water | Sanitation |
| Africa | 44 million<br>15% | 46 million<br>16% | 100–150 million<br>35–50% | 150–180 million<br>50–60% |
| Asia | 98 million<br>7% | 297 million<br>22% | 500–700 million<br>35–50% | 600–800 million<br>45–60% |
| Latin America and the Caribbean | 29 million<br>7% | 51 million<br>13% | 80–120 million<br>20–30% | 100–150 million<br>25–40% |

*Source*: UN-HABITAT (2003b)

These differences are hidden by averages for entire cities.

In addition to confusing nomenclature and the misleading quality of aggregated information, urban data for water issues are hard to obtain. More often than not the data are not standardized across cities and can be used in comparative studies only with care. Numbers change without adequate explanation or data cited are old and may be out-of-date. Given this state of confusion it is not surprising that some have called for a region-wide assessment of urban conditions so that policies can be adequately elaborated (Savage 2006; Sonnenfeld and Mol 2006).

Given these caveats, one approach to using data is to present a number of different datasets for analysis. Information complied at the regional or national level may be conservative, but these data can be supplemented by figures from more detailed studies of individual Southeast Asian cities. Together this information provides a fairly accurate picture of what is happening in the region.

As shown in Table 4, the numbers that do not have access to safe water and sanitation in Asia are in the hundreds of millions—up to 700 million without access to safe drinking water and up to 800 million without access to sanitation. Data at the national level for Southeast Asian access to water supply reveal improvement over the last decade (Table 5). The recognized improvements are probably because of a number of recent reforms to local environmental governance including increased decentralization, community participation, and privatization of water facilities (Memon et al. 2006). Despite the improvements, however, in countries such as Cambodia, Lao PDR, Indonesia, and Myanmar more than 69 percent or more of the urban population still have no household connection to drinking water. Almost half of the urban population of Vietnam are without safe access, 40% do not have safe access in the Philippines, and 20% do not have safe access in Thailand. Table 5 also illustrates the difference between those with "improved" provision of water supply and those with household connections (which might be the basis for a definition of

**Table 5** Progress in safe drinking water coverage, national and urban populations (%)

| Country | Improved drinking water coverage | | | |
|---|---|---|---|---|
| | Total population | | Urban population | |
| | Total improved | With household connections | Total improved | With household connections |
| Brunei Darussalam | | | | |
| 1990 | | – | 97 | 100 |
| 2002 | 99 | 100 | 98 | 100 |
| Cambodia | | | | |
| 1990 | – | – | – | – |
| 2002 | 34 | 6 | 58 | 31 |
| Indonesia | | | | |
| 1990 | 71 | 10 | 92 | 26 |
| 2002 | 78 | 17 | 89 | 31 |
| Lao PDR | | | | |
| 1990 | – | – | – | – |
| 2002 | 43 | 8 | 66 | 25 |
| Malaysia | | | | |
| 1990 | – | – | 96 | – |
| 2002 | 95 | – | 96 | – |
| Philippines | | | | |
| 1990 | 48 | 3 | 73 | 11 |
| 2002 | 80 | 8 | 95 | 23 |
| Thailand | | | | |
| 1990 | 87 | 21 | 93 | 37 |
| 2002 | 85 | 44 | 90 | 60 |
| Singapore | | | | |
| 1990 | – | – | 100 | 100 |
| 2002 | – | – | 100 | 100 |
| Thailand | | | | |
| 1990 | 81 | 28 | 87 | 69 |
| 2002 | 85 | 34 | 95 | 80 |
| Vietnam | | | | |
| 1990 | 72 | 11 | 93 | 51 |
| 2002 | 73 | 14 | 93 | 51 |

*Source*: UNEP RRCAP (2004), ASEAN (2005)

**Table 6** Provision of water supplies in selected Southeast Asian cities, mid-1990s

| City | Population with house taps (%) | Population served by public taps (%) | Persons per public tap | Notes |
|---|---|---|---|---|
| Phnom Penh | 83.1 | 0 | | 17% without piped water; rely on wells and ponds |
| Bandung | 31.4 | 10.4 | 100 | 58% without piped water: relying mostly on tube wells and dug wells |
| Jakarta | 20.5 | 6.7 | 300 | 73% without piped water relying on tube wells, dug wells, and rain collectors |
| Medan | 57.1 | 5.7 | 60 | 37% without piped water; most use tube wells and shallow wells |
| Vientiane | 54.2 | 0.1 | 16.25 | Utility claims 8% without piped water relying on wells, rivers, and rainfall |
| Johor Bahru | 99.9 | 0 | | |
| Kuala Lumpur | 45.9 | 0 | | Utility claims 100% coverage |
| Penang | 100 | 0.1 | 50 | |
| Mandalay | 36.6 | 0.4 | 50 | Utility claims 20% without piped water relying on tube wells or rivers |
| Yangon | 56.4 | 11.8 | 180 | 40% without piped water relying on tube wells, ponds, and rain collectors |
| Cebu | 20.9 | 1.6 | 128 | 77% without piped water; 47% relying on wells, rest from vendors |
| Davao | 52 | 0 | | 48% without piped water relying on tube wells and rain collectors |
| Manila | 38 | 5.7 | 357 | 33% without piped water; most depend on wells |
| Singapore | 100 | | | |
| Bangkok | 62.8 | 0 | | Utility claims 18% without piped water relying on wells, ponds, and rain water |
| Chiang Mai | 64.8 | 0 | | 35% without piped water relying on wells and rain water |
| Chonburi | 79.8 | 0 | | Utility claims 11% not covered relying on tube wells and rain water |
| Hanoi | 70.8 | 4.9 | 116 | 24% without piped water relying on wells, ponds and rain water |
| Ho Chi Minh City | 50 | 0.1 | 1,270 | 48% without piped water relying on tube wells |

*Source*: UN-HABITAT (2003b)

''adequate''). In Indonesia in 2002, for example, although 78% of the total population had ''improved'' access to water supply, only 17% had household connections.

Data from studies of individual cities within the region tell a more detailed story (Table 6). Not only does a large proportion of the population with ''improved'' services, lack safe, convenient, and adequate services, but current percentages of those with safe and adequate services may have been overestimated. Within the major metropolitan centers in the higher-income countries (except Singapore) there are large differences between statistics for numbers of people without access to water. UN-HABITAT (2003b), for example, reports that although official statistics for Kuala Lumpur suggest 100% of the population have access to water, only 46% have access to outlets in their homes. The same publication suggests that despite a claim that 82% of the population of Bangkok have access to water only 63% have taps in their homes. In Manila, only 38% have taps in their homes and up to 33% do not have any access to piped water.

For many cities in the region water consumption per person is, moreover, very low. In Phnom Penh average water consumption is 32 liters per person per day. In Hanoi average water consumption is 45 liters per day and in Yangon water consumption is 67 liters per day. Given that these are averages for whole city populations, they probably hide significant proportions of each city's population that use less than 20 liters per person per day (UN-HABITAT 2003b).[2] The low levels of water provision do not necessarily mean that citizens in these cities are more conserving of the resource than others, or that water is scarce. It is more likely fresh water is not being provided in sufficient quantities. These statistics emphasize the serious problems of potable water in many of the region's cities (Laquian 2005).

Another side of water supply is sanitation and waste water removal. This aspect of water management is crucial, because obnoxious, if not unhealthy, conditions can result if it is done poorly. Table 7 suggests there have also been significant increases in access to improved sanitation services throughout the region during the 1990s. Thailand has achieved almost complete coverage. Myanmar's improvement jumped from 45 to 64% access during the decade (UNEP Regional Resource Center for Asia and the Pacific 2004). Improvements at the urban level have been even more impressive. Improved sanitation reached 71, 84, and 96% of the urban populations of Indonesia, Vietnam, and Myanmar. Again, these figures may not tell the

[2] Twenty liters per day per person is regarded as essential and between 50 and 60 liters per person per day is needed for such domestic needs as washing, food preparation, cooking, cleaning laundry and personal hygiene (more would be needed if flush toilets were being used) (UN-HABITAT 2003b). According to the World Commission on Dams (2000), in 1990, over a billion people had access to less than 50 liters of water a day.

**Table 7** Progress in safe sanitation coverage, national and urban populations (%)

| Country | Improved sanitation coverage | |
|---|---|---|
| | Total | Urban |
| Brunei Darussalam | | |
| 1990 | – | – |
| 2000 | 100 | – |
| Cambodia | | |
| 1995 | 14 | – |
| 2000 | 18 | 53 |
| Indonesia | | |
| 1990 | 54 | 66 |
| 2000 | 55 | 71 |
| Lao PDR | | |
| 1990 | 19 | – |
| 2000 | 30 | 61 |
| Malaysia | | |
| 1990 | 94 | 94 |
| 2000 | 100 | – |
| Myanmar | | |
| 1990 | 45 | 39 |
| 2000 | 64 | 96 |
| Philippines | | |
| 1990 | 74 | 63 |
| 2000 | 83 | 81 |
| Singapore | | |
| 1990 | 100 | 100 |
| 2000 | 100 | 100 |
| Thailand | | |
| 1990 | 79 | 95 |
| 2000 | 98 | 97 |
| Vietnam | | |
| 1990 | 29 | 46 |
| 2000 | 47 | 84 |

*Source*: UNEP RRCAP (2004); ASEAN (2005)

Note: For urban coverage all starting dates are 1990 and the latest date is 2002

entire story. They are records of "improved" sanitation, not access to safe (i.e. in-household) sanitation.

Within many cities in the region water-supply systems are not well integrated with sewerage, drainage, storm water, and flood-control systems. The Asian Development Bank (2004) has recently reviewed the performance of utilities in selected cities in Asia. Some of the findings are presented in Table 8. It is apparent none of the urban centers of the Lao PDR are serviced with a sewerage system (UNEP Regional Resource Center for Asia and the Pacific 2001a). Vientiane's small-bore sewage system is not working properly. In Phnom Penh, only 41% of the city is covered by the city's sewerage program. Approximately 12% of households have no toilet facilities. Ho Chi Minh has even lower levels of sewerage coverage (approx. 12%).

In Metro Manila, 7% of the population served by the Metropolitan Waterworks and Sewerage Service have sewerage connections (Memon 2003).

In Jakarta, there is no comprehensive water sewer system. Only 2% of the city is currently served with sewerage. Approximately, 73% of households have private lavatories in their homes,[3] and 16% had shared private toilets and 12% used public toilets. Of 851 household toilets observed, more than half have no hand-washing basin in the vicinity. One-third of respondents report that some people in their neighborhood, mostly children, defecate outside, most commonly in drains and gutters (UN-HABITAT 2003b).

Trends are similar in other cities in the region. In Cebu, the Philippines, approximately 45% of households have access to water-sealed toilets (sharing of which is common), with 18% relying on pit latrines and 36% having no toilets. For this last group the convenient recourse is defecation in the open (UN-HABITAT 2003b). Even in higher-income Bangkok and Kuala Lumpur there is not yet full sanitation coverage. Only 2% of Bangkok's households are connected to the city's sewerage system, 25% rely on septic tanks, and the rest use pit latrines and other means of disposing of human waste and gray water (Laquian 2005). In Kuala Lumpur approximately 80% of the city's population has access to sewerage; the remainder use septic tanks.

Many cities in Southeast Asia do not have formal drainage systems but merge combined sewer overflow systems with a series of canals, called *klongs* in Thailand or *esteros* in the Philippines. There are approximately 1,145 *klongs* left in Bangkok. These waterways are remnants of previously extensive systems that ran throughout the city intimately weaving water into the urban form. Indeed, Bangkok started as a city of floating houses, as is still found in some parts of the region. Only the Grand Palace and the temples were initially on firm ground. The city initially grew in a ribbon pattern of settlement which clung to the banks of the Chao Phraya River. By 1864, there were a few inland roads. One observer at that time wrote "Bangkok is the Venice of the East and whether bent on business of pleasure you must go by water" (quoted in Smithies 1986, p. 38).

As Bangkok and other cities close to waterways grew, however, particularly after the 1950s, they changed in nature and in regard to these transport and drainage systems. Inland roads were developed and canals were filled in as people and activities moved on

[3] Cybriwsky and Ford (2001) estimate that approximately half of Jakarta's residencies lack toilet facilities. Hadiwinoto and Lietmann (1994) suggest that among the lowest-income quintile of the city only 6% have piped-in water and 64% share toilets.

**Table 8** Sewerage access in selected Southeast Asian cities

| City | Coverage (%) | Notes |
|---|---|---|
| Vientiane | 0 | No piped sewerage system in this or any city of the country. The small-bore sewer system currently installed in limited areas of the municipality is not working because of blockages. In areas with on-site sanitation, septic tank effluents discharge into storm drains and into watercourses |
| Phnom Penh | 41 | 37% of households use septic tanks and 12% have no toilet facilities |
| Ho Chi Minh | 12 | The sewerage system is combined with the storm drainage system. Coverage is low in new urban (1%) and rural districts (0.3%). Approximately 79% of households have septic tanks |
| Manila | 7 | Existing system is old without improvement over the last 10 years. Many households rely on individual septic tanks with effluent that discharges into storm drains |
| Jakarta | 2 | Sewerage is restricted to high-rise buildings and a small number of households. Approximately 39% of households use septic tanks and 20% use pit latrines |
| Kuala Lumpur | 80 | Septic tanks are still in use in the city. All new housing subdivisions are required to provide adequate hook-ups to the central sewerage system |

*Source*: Asian Development Bank (2004)

to higher ground. The canals that remain, in cities as economically diverse as Bangkok, Ho Chi Minh City, and Jakarta, are now primarily used for drainage. In Jakarta, this has left entire sections of the city without formal drainage (Cybriwsky and Ford 2001) and much of what acts as a drainage system is made up of former canals and local rivers (Laquian 2005).

In other cities, there is even less adequate drainage. In Lao PDR, for example, storm-water drainage in most urban areas consists of roadside ditches leading, ultimately, to natural streams or rivers. Drains are not adequately interconnected and do not form networks. Storm-water drainage is a serious issues in Vientiane (UNEP Regional Resource Center for Asia and the Pacific 2001a). Invariably, in all these cities, the canals, roadside drains, and small streams are contaminated with fecal matter from latrines and septic tank effluent and become clogged and overflow during floods, creating health problems.

In all but the wealthiest cities in the region, for example Singapore, local brown-water-related challenges continue to be important. The effects of these conditions are significant. When provision for water and sanitation is poor, diarrheal diseases and other diseases linked to contaminated water or contaminated food are among the most serious health problems within urban populations (Hardoy et al. 2001; UN-HABITAT 2003b; UNESCO 2003).[4] In the Asia Pacific Region in 1999, diarrhea-related diseased killed more than one million people and accounted for nearly 50% of global reported deaths from diarrhea. Contaminated water and poor sanitation were the main causes of the disease (UNEP Regional Resource Center for Asia and the Pacific 2004). In Bangkok, for example, cases of acute diarrhea have varied between 877 and 677 per 100,000 a year for the last 10 years. The highest-risk groups were those under 4 years of age and those between 5 and 9 years of age (Panich 2003).

## City-wide water issues

Southeast Asia receives abundant rainfall and has abundant water resources. Annual renewable water resources per unit of land area range from 2,200 to 14,000 $m^3$ $ha^{-1}$ throughout most of Southeast Asia. There are several important river systems in the region including 200 in Indonesia and 20 in Thailand. The international Mekong River is approximately 4,600 km in length and drains approximately 800,000 $km^2$ of land. Among the largest lakes in the region are the Tonle Sap (Cambodia), Lake Toba (Indonesia), Laguna de Bay (Philippines), and Lake Songkhla (Thailand) (UN ESCAP 2000).

Despite the abundance of water, concerns over the sustainability of water supply and protection of water quality have become important issues (UNEP 2002). Threats to water resources come from many sources, but one of the most important is pollution. Much of the region's river pollution is, moreover, associated with urbanization. Urbanization and surface water pollution problems become worse because they are associated with over-extraction of groundwater and subsequent ground subsidence. Many cities in the region are also causing degradation of coastal zones. Finally, almost all cities in the region are subject to seasonal flooding. These are the city-wide water-related challenges faced by most cities at all income levels within the region.

For most Asian countries results from a surface-water-quality monitoring program under United Nations Global Environmental Monitoring System

[4] Diarrheal diseases are still a primary cause of infant and child death for large sections of the world's urban population.

(GEMS/Water) are available.[5] The GEMS/Water Program provides scientifically-sound data and information on the state and trends of inland water quality. GEMS/Water is a UNEP program which, since 1978, has been hosted at Environment Canada's National Water Research Institute. More than 100 countries currently participate in the program and data for river quality start from 1977 to continue to the present. These data are important sources of information, because national level data are sometimes difficult to obtain. This report uses GEMS/Water data to examine several water pollutants including pathogens, suspended solids, and heavy metals. Regional and global environmental assessments and individual city case studies supplement this information.

Urban related river pollution results from discharge of untreated solid and liquid waste into rivers (from both domestic and industrial sources), the increase in silt loads, because of expansion of urban land use into peri-urban areas, and overflows of wastewater plants because of high surface runoff associated with increased impermeable areas.

In cities on or close to the coast, untreated sewage and industrial effluents often flow into the sea with little or no provision to pipe them far enough out to sea to protect the beaches and inshore waters, thereby posing a major health risk to bathers (Savage 2006). Besides damaging the tourist industry, however, pollution from cities can also negatively effect coastal fisheries and, therefore, livelihoods and sources of protein, create serious health problems in downstream settlements, and reduce the usability of water for agriculture. Table 9 presents data on the amount of urban sewage treated by cities in the region before it is returned to water bodies. These data reveal that within developing countries of the Asia Pacific only 10% of urban wastewater undergoes any form of treatment (UN ESCAP 2000).

Pathogenic bacteria and viruses are found in untreated sewage and effluents from animal husbandry, storm water run-off, and leachate from open waste dumps. Increases in the number of pathogens in water bodies are directly proportional to population density, so numbers of pathogens in streams and lakes are related to populations of cities. This is particularly true when waste water is not treated.

Numbers of pathogens are measured by a variant of either oxygen demand (OD), biological oxygen demand (BOD), and/or chemical oxygen demand (COD). BOD measures the load of biodegradable organic substances and COD measures the chemical degradability of nearly all water-soluble organics. The higher the BOD or COD, the larger the amount of oxygen needed to break down material in the water and so the greater the organic pollution. In a sample with a fixed supply of oxygen, it is possible to measure the amount of oxygen consumed over a period of time (usually 5 days) (Dunne and Leopold 1978).

**Table 9** Amount of wastewater treated in selected Southeast Asian cities

| City | Country | Waste water treated (%) |
|---|---|---|
| Phnom Penh | Cambodia | 0.0 |
| Bandung | Indonesia | 23.4 |
| Jakarta | Indonesia | 15.7 |
| Semarang | Indonesia | 0.0 |
| Surabaya | Indonesia | 0.0 |
| Vientiane | Lao PDR | 20.0 |
| Penang | Malaysia | 20.0 |
| Yangon | Myanmar | 0.0 |
| Cebu | Philippines | – |
| Singapore | Singapore | 100.0 |
| Bangkok | Thailand | – |
| Chiang Mai | Thailand | 70.0 |
| Hanoi | Vietnam | – |
| Ho Chi Minh | Vietnam | – |

UN-HABITAT (2003b)

BOD of Asian rivers are 1.4 times the world average. Although values declined in the early 1980s, they increased in the 1990s because of increased organic waste loading (Asian Development Bank 1997). Asia's rivers contain three times as many bacteria from human waste (fecal coliforms) as the world average, ten times higher than Organization of Economic Co-operation and Development (OECD) guidelines; the median fecal coliform count in Asia's rivers is fifty times higher than World Health Organization (WHO) guidelines (Asian Development Bank 1997). BOD and fecal coliform counts in Southeast Asia are therefore rated very severe (UN ESCAP 2000). In Vietnam's urban areas, surface water COD and BOD are typically 2–5 times higher than acceptable limits set for surface water. In some streams and rivers they are 10–20 times higher than national standards (UNEP Regional Resource Center for Asia and the Pacific 2001b). In Jakarta, all rivers crossing the city are heavily polluted from household gray water (Hadiwinoto and Leitmann 1994). Approximately 7% of total nitrogen inflows into Bangkok from food, fertilizer, animal feed, atmospheric deposition, and waste water are retained, and 97% of the remaining nutrients are passed into the Chao Phraya River and result in elevated nitrogen levels (Faerge et al. 2001). For food alone, nitrogen volumes are approximately 19,400 tons per year.

[5] See http://www.gemstat.org/queryrgn.asp.

**Table 10** Selected biological water-quality indicators and measures for rivers in Southeast Asia, annual averages for the last year on record

| River | Nearest major metropolitan center | Year | Organic matter | | Microbiology | Physical characteristics | |
|---|---|---|---|---|---|---|---|
| | | | COD (mg $L^{-1}$ $O_2$) | BOD (mg $L^{-1}$ $O_2$) | Fecal coliform bacteria (no/100 mL) | Suspended solids 105°C (mg $L^{-1}$) | Temperature (°C) |
| Klang river | Kuala Lumpur | 1992 | 42.56 | – | 606,750 | 311.3 | 27.00 |
| Mekong | Vientiane | 1995 | 1.52 | – | – | 930.0 | 29.28 |
| Pampanga river | Metro Manila | 1984 | – | 4.36 | 2,026 | – | 29.29 |
| Laguna lake | Metro Manila | 1990 | – | – | – | – | 27.98 |
| Chao Phrya | Bangkok | 1993 | – | 5.13 | 278,000 | – | 30.63 |
| Ciliwing | Jakarta | 1981 | 18.24 | – | 99,999 | 399.4 | 29.20 |
| Banjir canal | | 1995 | – | 8.90 | 999,999 | 94.5 | 27.56 |
| Mekong | Phnom Penh | 1994 | 3.73 | – | – | 87.3 | 29.12 |

*Source*: UNEP GEMS-water

Table 10 presents GEMS/Water data for water courses near large cities in the region. The measures presented are for indicators of nutrients, organic matter, microbiology, and physical characteristics of the cities. Average BOD levels of 2 mg $L^{-1}$ are indicative of limited organic pollution. Much higher values are found in North American rivers, for example. Average levels of 5 mg $L^{-1}$ are indicative of pollution and values over 10 mg $L^{-1}$ are indicative of serious pollution. COD values are typically higher. Average COD levels in the Klang River are indicative of extreme pollution. Indeed, the BOD of the Banjir Kanal, in Jakarta, and the COD of the Klang River, in Malaysia, suggest these water bodies are devoid of oxygen.[6]

Bacterial contamination counts are expressed as number per 100 mL. They vary over several orders of magnitude at a given point, because they are the most variable of water-quality measurements. Typically, in rivers that receive untreated sewage coliform counts can well exceed 100,000 colonies per liter. Examples include the Klang River, the Chao Phrya, the Ciliwing, and Banjir Canal. WHO drinking-water standards suggest the objective of zero *E. coli* per 100 mL of water as the objective for all water supplies (WHO 2004).

Water quality tests performed near Hanoi show that concentrations of ammonia and nitrites exceed country standards by a factor of 1.5–2. The BOD of the Saigon River exceeds Vietnamese standards by a factor of four and coliform levels are 50–100 times higher than acceptable (UNEP Regional Resource Center for Asia and the Pacific, 2001b).

Since the late 1990s there have been improvements in some of the region's waters. Although specific GEMS/Water data are not available for all rivers, there are enough research studies to suggest general improvements in the region. Sonnenfeld and Mol (2006), for example, report that river BOD values improved dramatically from 1980 to 2000 in Indonesia (16% decrease in BOD per day per worker) and Malaysia (27% decrease per day per worker). River water pollution, particularly biological and nutrient levels, however, remains an important environmental concern (UNEP Regional Resource Center for Asia and the Pacific 2004).

Another urban-related water-polluting activity that creates river pollution is land clearing for urban land use construction. This facilitates soil erosion and enhances natural siltation processes, particularly in tropical climates with heavy rainfall (Douglas, 1968). Siltation is affected by deforestation and urban activity. Indeed, urban development can generate up to 100 times more soil erosion than natural systems (Douglas, 1986). Although it is difficult to determine the exact proportion of the region's river sediment which arises from urban activity, urban development is not an insignificant factor in changes in the amounts of suspended solids in rivers.

Amounts of suspended solids in Asia's rivers have almost quadrupled since the late 1970s (Asian Development Bank 1997) and rivers typically contain four times the world average and 20 times OECD levels. This amount of sediment causes critical problems for most coastal zones and large water bodies (UNEP 2002). Examples of water bodies affected by high siltation in Southeast Asia include Lake Tonle Sap, Cambodia. Sediment deposits are reducing the lake's depth and affecting the yield of the lake's fisheries. In Malaysia the Dungun River in Kuala Terrengganu has

[6] For further information see the GEMS/Water Digital Atlas of Water Quality at http://www.gemswater.org/atlas-gwq/intro-e.htm.

also been polluted by sandy sediment exacerbated by dredging activity along the river (UN ESCAP 2000).

The indicator total suspended solids (TSS) includes both organic and mineral particles transported in surface water. TSS is closely linked to land erosion and to erosion of river channels. According to GEMS/Water suspended solids are frequently poorly measured. Values higher than 1,000 mg $L^{-1}$ affect water use by limiting light penetration and can limit reservoir life. In 1995, in the Mekong near Vientiane levels approached this value.[7]

In addition to human and animal waste and sediments, urban-related water pollution also occurs when industrial effluent is not treated before release into waterways. Many rivers and lakes in Southeast Asia are severely polluted by industry. Asia's surface water contains 20 times more lead, mainly from industrial effluents, than surface waters in OECD countries. The worst examples are heavy metal and toxic chemical pollution in the water bodies of Southeast Asia (Asian Development Bank 1997; UN ESCAP 2000; UNEP 2002). A survey of river water quality in Thailand revealed heavy lead contamination (in several major rivers including the Pattani and Colok in the south, the Moon river in the Northeast, the Pa Sak river in the north, and the Mae Klong in the central region), mercury contamination (in the lower central region's Pranburi River, the Mae Long, Chao Phraya and Petchburi rivers of the central region and the Wang River in the Northern region), and high levels of arsenic poisoning in the Tambon Ron Phibun (UN ESCAP 2000). Urban industrial pollution in Indonesia is also significant. Of Jakarta's 30,000 factories, for example, only 10% have wastewater treatment (Tibbetts 2002).

Levels of heavy metals in selected rivers and the WHO (2004) guideline values are listed in Table 11. Sources of heavy metals are numerous but many are related to industrial and urban activity (Table 12). For the rivers examined, concentrations of heavy metals reach or exceed those recommended by the WHO. For example, in some cases concentrations of Arsenic (As), Cadmium (Cd) and lead (Pb) in the rivers examined exceed WHO guidelines. For the Klang River, levels of chromium (Cr) and Manganese (Mn) also exceed WHO guidelines. Concentrations of iron above 0.3 mg $L^{-1}$ are likely to give rise to consumer complaints (disagreeable tastes and odors and staining of laundry and sanitary ware). Zinc (Zn) is not usually a health concern but may affect water acceptability.

Global attention has recently turned to monitoring persistent organic pollutants (POPs) in air, land, and water. POPs encompass many different groups of anthropogenic chemicals. The United Nations Environment Program (UNEP) has listed POPs such as organochlorine compounds as being of particular concern. Specifically, the twelve high-priority organochlorine compounds (known as the ''dirty dozen'') are from four groups:

1. dioxins and furans, which are produced as products of municipal and medical waste incinerators, open burning, landfill fires, and during the production of polyvinyl chloride (PVC) products;
2. polychlorinated biphenyls (PCBs) (industrial chemicals that have been banned but are still released to the environment from old sources and as unintentional byproducts of combustion and processes involving the manufacture, use, and disposal of organochlorine compounds);
3. hexachlorobenzene (HCB), which is used as a pesticide and in the manufacture of pesticides and produced as an unwanted by-product of a variety of industrial processes involving organochlorine compounds; and
4. organochlorine pesticides, including DDT, chlordane, toxaphene, dieldrin, aldrin, endrin, heptachlor and mirex.

POPs have been identified in Southeast Asian waters. For example, large amounts of chlordane are present in the rivers of Southeast Asia and PCBs can be found in rivers throughout the region (Allsopp and Johnston 2000).

Data on organochlorine compounds in selected water bodies in Southeast Asia are presented in Table 13. These data reveal the amounts of pesticides found in rivers of the region, particularly those in Selangor, Malaysia. Comparative work in the region suggests that POPs are being used increasingly in the tropical developing areas of Asia rather than in the

[7] Paradoxically, although human activities increase sediment flows in rivers by approximately 20%, reservoirs and water diversion projects prevent approximately 30% of sediments from reaching the oceans, resulting in a total net reduction of sediment delivery to coasts of approximately 10% (Agardy et al. 2005; Vorosmarty et al. 2003). In Southeast Asia, dam building began in the 1950s. In 2000, Thailand had the most dams (204) followed by Indonesia (96), Malaysia (59), the Philippines (15), Myanmar (5), Vietnam (3), Singapore (3), Brunei (2) and Cambodia (2) (World Commission on Dams, 2000). Recent evidence suggests that globally both water and energy demand may require more dams and hence dam building may increase from 2000 to 2050 (ICOLD-CICB 2006). Several nations in Southeast Asia are considering building new large dams, including some on the Mekong River (Dore and Yu 2004) (see below). Projected increases in dam building in the region may ultimately reduce the amount of sediment reaching the oceans.

**Table 11** Selected heavy metal water-quality indicators and measures for rivers in Southeast Asia, annual averages for all years on record

| River | Nearest major metropolitan center | Years | Total arsenic (mg $L^{-1}$) | Total cadmium (mg $L^{-1}$) | Total chromium (mg $L^{-1}$) | Total copper (mg $L^{-1}$) | Total iron (mg $L^{-1}$) | Total lead (mg $L^{-1}$) | Total manganese (mg $L^{-1}$) | Total mercury (µg $L^{-1}$) | Total nickel (mg $L^{-1}$) | Total zinc (mg $L^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Klang river | Kuala Lumpur | 1979–1992 | 0.07402 | 0.0040 | 0.0609 | 0.0200 | 3.1400 | 0.0388 | 0.4794 | 0.0024 | – | 0.0683 |
| Chao Phrya | Bangkok | 1991–1993 | – | 0.0036 | 0.0377 | 0.0231 | 0.8265 | 0.0526 | 0.2204 | 0.4163 | – | 0.1735 |
| Banjir Canal | Jakarta | 1985–1994 | 0.0030 | 0.0074 | 0.0221 | 0.0270 | 3.5915 | 0.0957 | 0.3000 | 0.2000 | 0.0137 | 0.1247 |
| WHO 2004 guidelines | | | 0.0100 | 0.0030 | 0.0500 | 2.0000 | NA | 0.0100 | 0.4000 | | 0.0200 | |

*Source:* UNEP GEMS-Water (WHO 2004)

developed parts (Iwata et al. 1994) and that there is increasingly a shift in the airborne and water distribution of POPs from Northern to Southern air and water systems (Iwata et al. 1993). Concentrations and prevalence of POPs in water around Singapore are most likely because of the increasing presence and importance of the petroleum industry in the city (Basheer et al. 2003).

The results of these pollution levels are evident in the quality of the rivers that run through the region's cities. High levels of pollution from Phnom Penh Cambodia are contaminating wetlands nearby. Contamination is from industry, and the result is high levels of heavy metals. Farmers in the region make a living by growing vegetables and selling these in local markets. These vegetable then pose serious health hazards to consumers in the city (Muong 2004). Water-quality tests performed near Hanoi and testing of the Saigon River have detected heavy metals, for example lead, mercury, chromium, and cadmium (UNEP Regional Resource Center for Asia and the Pacific 2001b). The Pasig River in the center of Metro Manila is effectively dead (UN ESCAP 2000). Studies of Thailand's Chao Phraya River suggest this river is also heavily polluted. The Chao Phraya River contains serious organic and bacterial pollution that is a threat to many species of aquatic life. Acute diarrhea and food poisoning are still increasing, whereas between 1983 and 2001 the incidence of enteric fever, dysentery, and helminths decreased. Also alarming is the increasing number of diseases caused by chemical and toxic substances contaminating water resources. These contaminants are of domestic, industrial, and agricultural origin (UNESCO 2003). In Malaysia, of the 110 rivers monitored for pollution, 16 were found to be seriously polluted and 71 slightly polluted (Savage 2006). As the figures for the Klang River (Tables 10, 11) demonstrate, both fecal contamination and chemical pollution are high. This river is the most polluted in the country and, like the Pasig, has been characterized as "dead" or no longer suitable for drinking or habitation by aquatic species (Hussain and Hassan 2003). The Malaysian example is interesting, because the country has a relatively high level of income. Notwithstanding its economic development, however, it still faces several different environmental challenges that are reflected by the quality of its rivers. For example, while, obviously, there is a need to address wastewater treatment, the rivers, and general environmental quality, are threatened by several activities, including palm oil plantations, logging, housing construction, agriculture, and industrial activity (including metal finishing, rubber-based production facilities, food and beverage

**Table 12** Potential sources of heavy metals

| Element | Source |
|---|---|
| Arsenic | Pesticides, fertilizers, plant desiccants, animal feed additives, copper smelting, sewage sludge, coal combustion, incineration and incineration ash, detergents, petroleum combustion, treated wood, mine tailings, parent rock material |
| Cadmium | Phosphate fertilizers, farmyard manure, industrial processes (electroplating, non-ferrous metal, iron and steel production), fossil fuel combustion, incineration, sewage sludge, lead and zinc smelting, mine tailings, pigments for plastics and paint residues, plastic stabilizers, batteries, parent rock material |
| Chromium | Fertilizers, metallurgy, electric arc furnaces, ferrochrome production, refractory brick production, iron and steel production, cement, sewage sludge, incineration and incineration ash, chrome-plated products, pigments, leather tanning, parent rock material |
| Nickel | Fertilizers, fuel and residual oil combustion, alloy manufacture, nickel mining and smelting, sewage sludge, incineration and incineration ash, electroplating, batteries, parent rock material |
| Copper | Fertilizers, fungicides, farmyard manures, sewage sludge, industrial processes, copper dust, incineration ash, mine tailings, parent rock material |
| Lead | Mining, smelting activities, farmyard manures, sewage sludge, fossil fuel combustion, pesticides, batteries, paint pigment, solder in water-pipes, steel mill residues |
| Manganese | Fertilizers, parent rock material |
| Mercury | Fertilizers, pesticides, lime, manures, sewage sludge, catalysts for synthetic polymers, metallurgy, thermometers, coal combustion, parent rock material |
| Zinc | Fertilizers, pesticides, coal and fossil fuel combustion, non-ferrous metal smelting, galvanized iron and steel, alloys, brass, rubber manufacture, oil tires, sewage sludge, batteries, brass, rubber production, parent rock material |

Sources: O'Neill (1995), Alloway (1995), McGrath (1995), Baker and Senft (1995), Davies (1995), Smith and Paterson (1995), Steinnes (1995), Kiekens (1995), Brady and Weil (2002)

**Table 13** Persistent organic pollutants (organochlorine pesticides) in local water environments in Southeast Asia

| Location | BHC (ng $L^{-1}$) | Aldrin (ng $L^{-1}$) | Dieldrin (ng $L^{-1}$) | Endrin (ng $L^{-1}$) | a-Endosulfan (ng $L^{-1}$) | b-Endosulfan (ng $L^{-1}$) | Heptachlor (ng $L^{-1}$) | Lindane (ng $L^{-1}$) | p,p′-DDT (ng $L^{-1}$) | p,p′-DDE (ng $L^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Selangor river | | 884 | 850 | 10,970 | 8.9 | 12,270 | 13,710 | 40,950 | 44,770 | 2,310 |
| Surabaya river | | | | | | | | | 50 | |
| Philippine coast | 21 | 7 | | | | | | | | |
| Dampha and Balat estuaries | | | | | | | | | 30 | |
| Singapore | 7 | | 18 | 2 | | 2 | | | 1 | 1 |

*Source*: Basheer et al. (2003)

producers, and paper factories). The industries in Kuala Lumpur, are typically small to medium and operate without proper wastewater-treatment facilities (Shapiee 2003). Thus, in this upper-middle income country, both brown issues and gray issues are important to urban water-quality managers.

The cost of environmental remediation (COR) for the region's rivers varies. The COR is calculated as the cost to reduce the pollutant load within rivers by 90% in ten years. Calculated costs are presented in Table 14. Results suggest that the cost of cleaning the region's rivers within ten years varies from between US$ 260,000 for Lao PDR and US$ 100 million for Indonesia (Jalal and Rodgers 2002). Despite the lower cost for some countries these amounts are still a significant part of the annual GDP. This suggests that remediation for some countries may necessarily only be plausible over a longer period of time.

Poor quality river water and low access to piped water promote the use of groundwater in cities. According to UNESCO (2003), almost 1.2 billion urban dwellers rely on groundwater globally. Groundwater resource availability in the region is typically in the range of 10–20% of the magnitude of internal surface water resources (ASEAN 2005). Extensive groundwater extraction has, however, resulted in serious problems of subsidence in, for example, Bangkok, Jakarta, and Metro Manila (Das Gupta and Babel 2005; Hadiwinoto and Leitmann 1994; Laquian 2005).

Bangkok is an example of how groundwater extraction can have city-wide effects. Unplanned groundwater extraction in the city has had three major results:

1. depletion of near surface levels of aquifer water;
2. land subsidence; and
3. deterioration of water quality as a result of saltwater encroachment.

Associated problems, for example flooding, loss of property, deterioration of infrastructure facilities,

**Table 14** Cost of river water pollution remediation in Southeast Asia

| Country | Annual cost of remediation (1990 millions US$) | Percentage of GDP |
|---|---|---|
| Singapore | 24.42 | 0.24 |
| Thailand | 67.00 | 0.83 |
| Myanmar | 3.56 | 1.23 |
| Malaysia | 43.15 | 1.32 |
| Philippines | 39.59 | 1.40 |
| Indonesia | 100.10 | 1.43 |
| Cambodia | 0.31 | 5.62 |
| Vietnam | 12.97 | 7.30 |
| Lao PDR | 0.26 | 7.43 |

*Source*: Jalal and Rodgers (2002)

groundwater pollution, and health hazards have also been attributed to the effects of groundwater withdrawal (Das Gupta and Babel 2005).

Large groundwater usage for the public water supply in Bangkok began in 1954. At the time water extraction amounted to approximately 8,000 $m^3$ per day. Daily withdrawals increased over the years. In areas were public water was not available private wells appeared. By 1982, total groundwater withdrawals from Bangkok and its adjacent areas reached 1.4 million $m^3$ per day. The city implemented control measures in 1983 and the pumping rate decreased from 1985 to 1990. Groundwater abstraction started increasing again after 1991, however. By 2003, groundwater wells withdrew over 1.7 million $m^3$ per day (Das Gupta and Babel 2005).

Initially groundwater levels in the Bangkok area were very close to the ground surface and some areas had abundant free-flowing artesian wells. Over the decades the water table has fallen, at a maximum rate of 2–3 meters per year. The lowest levels have been recorded in Samut Sakhon area in the range of 65–70 m below ground. Lowering the water table to these levels makes it more difficult and expensive to gain access to the water (Das Gupta and Babel 2005).

The second result has been massive land subsidence over large parts of the city. Between 1940 and 1980 some parts of the city subsided by 1.14 m. Between 1978 and 1980 the maximum land subsidence was 54 cm. After measures controlling groundwater pumping were introduced in 1983, the rate of pumping declined in the central Bangkok area. Pumping started increasing in the suburban areas of the city, however, and the pumping zone expanded. By 1997, the rate of subsidence in downtown areas was 1–2 cm per year and in the suburbs of Samut Prakan, Lat Krabang, and Samut Sakhon, subsidence increased to 3.0–3.5 cm per year compared with 2.0–3.0 cm per year observed in 1989–1990 in the eastern suburbs (Das Gupta and Babel 2005).

The third major city-wide environmental consequence of lowered water tables is contamination of aquifers because of saltwater encroachment. In Jakarta and Bangkok the pumping out of groundwater causes intrusion of saltwater into the aquifer.

Bangkok has also experienced a substantial increase in the hardness and iron and manganese content of the water (Das Gupta and Babel 2005). Metro Manila has also experienced seawater intrusion into aquifers and in the major river basin and coastal plain of Vietnam the average salinity of groundwater is approximately 3,000–4,000 ppm, making it unsuitable for drinking (UN ESCAP 2000).

Water pollution also affects coastal ecosystems, were freshwater and saltwater mix. These ecosystems are the most productive and also among the most highly threatened ecosystems in the world. Examples of the global effects of these pressures include loss of 35% of mangrove areas, destruction of 20% of the world's coral reefs, loss of 20% of coastal wetlands, and increases in harmful algal blooms and other pathogens which affect both humans and marine organisms (Agardy et al. 2005).

The deterioration of coastal ecosystems is because of a complex association of activities including urbanization (i.e. port development, dredging, recreation development, pollution from industry, and domestic waste). Although agriculture is the largest cause of increased nitrogen levels in coastal marine systems, wastewater from urban centers is also a significant component of change, contributing 12% of the nitrogen pollution in rivers of the USA, 25% in Europe, and 33% in China (Howarth 2004). Every year sewage-treatment facilities discharge 5.9 trillion gallons of sewage into coastal waters, and an estimated 160,000 factories dump between 41,000 and 57,000 tons of toxic organic chemicals and 68,000 tons of toxic metals into coastal waters (UNEP and UN-HABITAT 2005). The World Resources Institute (2002) identified several indicators of coastal degradation including the development of coastal areas, marine-based pollution, sedimentation pollution, overfishing, and destructive fishing. Urban activity, including land consumption and waste emissions, dominates inputs to some coastal ecosystems (Howarth 2004).

The degradation of coastal zones by urban centers should not be a surprise. Historic urban development patterns demonstrate that people have always agglomerated near ecologically important areas. Hence, 58% of the world's major reefs occur within 50 km of major urban centers of 100,000 people or more, and 64% of all mangrove forest and 62% of all major estuaries occur near such centers (Agardy et al. 2005). This trend is increasing as, in many parts of the world, giant densely populated coastal cities continue to grow (Small and Nicholls 2003; Tibbetts 2002). Coastal populations on every continent have grown with global trade. Most trade is shipped by boat and this encourages the growth of international ports, which create jobs and economic growth. Hence, urbanization and all that it entails is an important force driving coastal zone change.

Significant environmental challenges have emerged in coastal and near marine environments in and around cities in Southeast Asia (Lebel 2002). Degradation can be seen in indicators of marine pollution, loss of mangrove forest, and the degraded condition of coral reefs. Within the Asia Pacific region coastal and marine pollution has increased, mainly because of discharges of domestic and industrial effluent, atmospheric deposition, oil spills, other wastes and contaminants from shipping, and land development, dredging, and upstream river modifications (UN ESCAP 2000; UNEP 2002). Urban and agricultural areas both produce substantial quantities of organic waste in such concentrations that the nutrient filtering mechanisms of the coastal zone are unable to neutralize their effects. Thailand and Cambodia contribute approximately 30% of the BOD entering the South China Sea (Table 15). Of all the nitrogen entering these coastal waters, Thailand and Cambodia contribute 20%. Vietnam contributes approximately another 21% (UN ESCAP 2000). Sewage effluent from urban and tourist areas makes substantial and increasing contributions to pollutant loads in the upper Gulf of Thailand (Lebel 2002). Metro Manila's sewerage system pumps effluents into Manila Bay with only rudimentary treatment, and as a result serious cases of ''red tide'' disease outbreaks occur each summer. As a result the Philippines Health Department has banned the consumption of oysters, clams, mussels, and other shellfish from the bay (Laquian 2005).

More than 40% of the world's estimated 18 million hectares of mangrove forest occur in South and Southeast Asia (UN ESCAP 2000). Unfortunately, large areas of mangrove have been removed for industrial, residential, and leisure developments, and in particular for establishment of ponds for aquaculture of fish and prawns. Within Southeast Asia the loss of original mangrove areas is high; less than 20% in Brunei, more than 30% in Malaysia, more than 40% in Indonesia, more than 55% in Myanmar, more than 60% in Vietnam, more than 70% in Singapore, and more than 80% in Thailand (UN ESCAP 2000). In the Philippines, 210,500 ha of mangrove (approximately 40% of the country's mangrove cover) were lost to aquaculture from 1918 to 1988. By 1993, only 123,000 ha of mangroves were left, equivalent to a loss of 70% by that time (Agardy et al. 2005; Nickerson 1999; Primavera 2000).

Another measure of coastal zone degradation is the condition of coral reefs. Southeast Asia is endowed with over 85,000 km$^2$ of coral reefs (approximately 29% of the world's total). These reefs have some of the highest biodiversity in the world, especially coral-reef fish, mollusks, and crustaceans (World Resources Institute 2002). The reefs of Indonesia and the Philippines are noted for their extraordinarily high diversity—each contains at least 2,500 species of fish. Currently, however, only 30% of these reefs are in good or excellent condition (UN ESCAP 2000). In Indonesia, moreover, approximately 47% of the reefs highly threatened (Table 16). In the Philippines 70% of the coral reefs are highly threatened and in Vietnam over 73% of the reefs are highly threatened. In the entire region approximately 46,000 km$^2$ (54%) are under high risk of degradation (World Resources Institute 2002).

The climate in Southeast Asia, which is predominantly wet equatorial, is characterized by substantial rainfall of approximately 3,800 km$^3$ annually, of which approximately two-thirds falls on Indonesia (UNEP

**Table 15** Pollutant fluxes from rivers in Cambodia and Thailand to the South China Sea

| Country/river | Annual discharge (km$^3$) | BOD (tons/year) | Total nitrogen (tons/year) | Total phosphorus (tons/year) | Total suspended solids (tons/year) |
|---|---|---|---|---|---|
| Cambodia | | | | | |
| Tonle Sap lake-river system | 36.46 | 6,022 | 1,084 | 303 | 13,250 |
| Mekong River, Cambodia section | 128.38 | 4,964 | 894 | 255 | 10,950 |
| Thailand | | | | | |
| Center, Eastern Southern Rivers | 144.2 | 299,224 | 130,044 | 7,137 | 12,587 |
| Total South China Sea for Continental Countries | | 1,015,936 | 636,840 | 58,202 | 58,642,827 |

*Source*: UN ESCAP (2000)

**Table 16** Coral reefs at risk, by country and risk level

| Country | Total coral reef area (km²) | Share of regional total (%) | Risk level | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Low | | Medium | | High | | Very high | | High and very high |
| | | | (km²) | (%) | (km²) | (%) | (km²) | (%) | (km²) | (%) | (%) |
| Indonesia | 50,875 | 59.4 | 6,930 | 13.6 | 19,809 | 38.9 | 23,403 | 46.0 | 733 | 1.4 | 47.4 |
| Philippines | 25,819 | 30.2 | 559 | 2.2 | 7,099 | 27.5 | 16,311 | 63.2 | 1,850 | 7.2 | 70.3 |
| Malaysia | 4,006 | 4.7 | 533 | 13.3 | 1,771 | 44.2 | 1,541 | 38.5 | 161 | 4.0 | 42.5 |
| Thailand | 1,787 | 2.1 | 419 | 23.4 | 427 | 23.9 | 917 | 51.3 | 24 | 1.3 | 52.7 |
| Myanmar | 1,686 | 2.0 | 742 | 44.0 | 604 | 35.8 | 336 | 19.9 | 4 | 0.2 | 20.2 |
| Vietnam | 1,122 | 1.3 | 43 | 3.8 | 252 | 22.5 | 551 | 49.1 | 276 | 24.6 | 73.7 |
| Brunei | 187 | 0.2 | 147 | 78.6 | 30 | 16.0 | 10 | 5.3 | 0 | 0.0 | 5.3 |
| Singapore | 54 | 0.1 | 0 | 0.0 | 0 | 0.0 | 54 | 100.0 | 0 | 0.0 | 100.0 |
| Cambodia | 42 | 0.0 | 0 | 0.0 | 0 | 0.0 | 38 | 90.5 | 4 | 9.5 | 100.0 |
| Regional totals | 85,578 | 100 | 9,373 | 11.0 | 29,992 | 35.0 | 43,161 | 50.4 | 3,052 | 3.6 | 54.0 |

*Source*: World Resources Institute, WRI (2002)

Regional Resource Center for Asia and the Pacific 2000). Given climatic conditions that produce monsoon rains, flooding is common. In ASEAN, tropical wet/dry season cycle flooding is exacerbated by the short, steep nature of many rivers which results in characteristic short, sharp peaks in stream flows. The seasonal climate exacerbates water challenges for cities.

Globally, floods affected the lives of, on average, 65 million people annually between 1972 and 1996, more than any other type of disaster, including war, drought, and famine (World Commission on Dams 2000). In 2005 alone, floods around the world claimed the lives of 6,135 people.[8] Floods affect a large number of people throughout Southeast Asia. Between 1990 and 2006 there were approximately 208 flood events, which affected approximately 58 million people and killed 9,912 people.[9]

Flooding continues to be a challenge for most cities in the region. Some of the flooding challenges for selected cities in the region are listed in Table 17. Floods are annual occurrences in Vientiane. When the Sap River, a tributary of the Mekong River, floods during the rainy season the river reverses course and sewage discharges from Phnom Penh flow upstream to the water supply intake (Dany et al. 2000). In Jakarta, habitual flooding of the northern third of the city occurs as a result of heavy seasonal rains combined with high tides in Jakarta Bay (Hadiwinoto and Leitmann 1994). Parts of Kuala Lumpur are flooded for short periods of time. Flooding occurs in Bangkok during the monsoon season when run-off exceeds the Chao Phraya River's drainage capacity. This problem is exacerbated by infilling of *klongs*, deforestation upstream, and loss of marshes and empty areas that previously acted as retention ponds (ASEAN 2005; Panich 2003; UNEP 2002).

This analysis suggests that all cities in the region, across the income scale spectrum, are affected by city-wide water challenges. These water-related burdens include water pollution (biological, nutrients, suspended particles, heavy metals and POPs), over extraction of groundwater, subsequent ground subsidence, salt water intrusion, coastal zone degradation (large nutrient and pollution loading, loss of mangroves and natural habitat, and declining quality of coral reefs) and flooding. A recent study has also suggested that these issues will only increase in importance. UN ESCAP (2005) suggests that high levels of industrial growth, expanding tourism and related infrastructure, particularly in coastal areas, are environmental driving forces that will continue into the future. Because the costs of remediation of these water challenges is relatively high, it may take more than local and national efforts to bring rivers and coastal systems back to national standards.

## Regional and global water issues

Much of the growth and development of the region has been centered on the major metropolitan centers (Lo and Yeung 1996). The region's water supplies are managed to provide the necessary requirements for this growth and development. Both economic growth and previous management schemes have also brought further water-related environmental effects including increasing water consumption (both direct and indirect), water shortages (including seasonal physical

[8] See EM-DAT: The OFDA/CRED International Disaster Database, http://www.em-dat.net - Université catholique de Louvain - Brussels, Belgium.

[9] Ibid.

**Table 17** Flooding in some Southeast Asian cities

| City | Notes |
|---|---|
| Vientiane | Long history of inundation problems caused by overflowing of the Mekong River. Drainage is inadequate to carry storm water runoff and the situation is deteriorating. The districts of Sikhottabong, Sisattanak, and Hatxaiphong are flooded at least once a year |
| Phnom Penh | The city is susceptible to flooding from surrounding river and water back up during peak flood events. Controls include outer and inner dikes in rings, ten drainage pumping stations, drainage channels and a small sewer network. Dikes are eroded and drainage channels clogged |
| Ho Chi Minh | Parts of Ho Chi Minh City suffer from floods several times each year during the rainy season (June–November) and during the high tide season (October–January) |
| Manila | Recurrent flooding is related to water flows from Pasig-Marikina River and Laguna Lake basin combined with high tides and inadequate drainage |
| Jakarta | Approximately 50% of the city is prone to flooding when several or all of the 13 rivers in the city overflow. Approximately 40% of the city is below sea level during high tide. Only a quarter of this area is protected by dikes leaving the remaining areas subject to floods |
| Kuala Lumpur | Low lying areas of the city are susceptible to flooding during heavy downpours. Flood waters typically subside within 5–6 h |

*Source*: Asian Development Bank (2004)

water scarcity and economic scarcity) and rising tensions created by use of international waters. Because of global emissions of greenhouse gases and subsequent climate variability, some cities within the region have also become vulnerable to extreme water-related events (including flooding, droughts, and sea level rise). These are among the green issues that are typically on the global environmental agenda.

People need water for a variety of reasons including drinking, personal hygiene, cooling, lawn watering, urban agricultural and gardening, household and street cleaning, fire fighting, recreation, industry, etc. The result is that the largest flow of material into any city is water (Decker et al. 2000). In high-income cities, where there is more or less universal provision of services and high consumption of water, the average city of one million people use approximately 625,000 ton of water a day (Haughton and Hunter 1994; Wolman 1965).

Per capita water consumption within cities of the region is not yet a regional issue. Bangkok, for example has some of the highest water consumption figures for urban inhabitants within Southeast Asia (352 liters per capita per day), but consumption is still 43% lower than current per capita water use in Denver (670 liters per capita per day) 40% lower than Boston (643 liters per capita per day) and 25% lower than New York City (515 liters per capita per day) (Roberts 2006). Despite this, daily water consumption in Bangkok is more twice as great as that of Singapore (167 liters per capita per day) (UN-HABITAT 2003b).

Despite Singapore's higher income, the city-state has promoted successful water quality and conservation policies and as a result water consumption remains relatively low. Singapore's policies are in response to its prevailing natural situation—as a small island it suffers from water scarcity.

Singapore's history is an example of efficient water-supply development. Until 1986 the main thrust of the country's water supply management program was building of reservoirs. By that time approximately 50% of the island was designated as catchments. Little land was left for this purpose. Thereafter the City-State refocused efforts on three fronts: optimizing water yield from their natural catchments; conservation, including retarding water demand and reducing wastage; and creating access to alterative supplies by diplomacy and by exploiting modern technology (Long 2001). These strategies produced some of the most advanced water management schemes in the world including, *inter alia*:

1. building the Newater facility, a sewage-to-potable water recycling plant;
2. reducing system leakage to an internationally recognized minimum;
3. manipulating water prices to prevent waste; and
4. instituting efficient rain-harvesting infrastructure.

The country is now seriously considering building desalination plants that will further reduce its dependence on non-domestic water and hence the footprint of the city (Savage 2006). Although reducing the water footprint of the city is laudable, creating potable water from desalinization plants is expensive (approximately US$ 1–1.6 $m^{-3}$) and the processes used to make this water are highly energy intensive, although new, lower-cost technology is becoming available (Postel 1997). Although Singapore's programs have been, and continue to be, successful, they may not be transferable to other locations. For example, not every country in the region can afford such sharp trade-offs between increases in energy use and increased water consumption that would be demanded by building desalination plants.

For other cities in the region the condition of ample water resources is rapidly changing. Importantly, consumption within the region continues to rise as urban lifestyles lead to greater demand for water. For example, between 1995 and 2000 demand for refrigeration increased twenty-twofold in both Thailand and Vietnam (UN ESCAP 2005). Future growth in wealth will bring increases in water consumption for cooling, industrial, and domestic household uses.[10] Also, as nations within the region grow in wealth they will continue to urbanize, adding more and more people to each city. Given expectations for increases in urbanization in the region, ASEAN (2005) predicts that overall demand for water will increase by approximately one-third over the next 20 years.

At least three important constraints face cities in the region as they battle with increasing water consumption. First, as was mentioned in detail in the previous section, many of the region's rivers and water bodies are contaminated, limiting their use as potable supplies. Pollution alone has reduced the annual per capita availability of fresh water in developing countries of the region from 10,000 $m^3$ in 1950 to approximately 4,200 $m^3$ by the early 1990s (UNEP 2002).

But not all the water taken by cities makes it way to consumers. The second constraint on meeting increasing demand in cities of Southeast Asia is the old, poorly maintained water systems and poorly managed watersheds. The Bangkok waterworks, for example, was initially constructed in 1914 (Smithies 1986). The water-supply system in Phnom Penh was originally constructed in 1895 (Dany et al. 2000). Manila's waterworks system was built in 1878 by Spanish colonialist and designed for a city of 300,000 (Laquian 2005). Jakarta's basic water-supply system was built by the Dutch between 1900 and 1940 (Argo 1999). It is not unusually for half the water within these systems to be lost during distribution. Data on water loss in selected cities in the region are presented in Table 18. In most cities it is over 40%. In addition, given the inadequate infrastructure, poor levels of maintenance, and a large informal sector that taps into the system, twenty-four-hour service is not always possible. Together these effects create local and short term or seasonal water shortages.

Water shortages also occur for a number of other reasons, related to large-scale anthropogenic activity within watersheds. For example, in January 2004, Metro Manila reduced water supply from the Metropolitan Waterworks and Sewerage System (MWSS) by 5% (increased to 20% in April). This reduction was caused by a drop in the water level in the Angat reservoir, the main reservoir for the city. Dangerously low water levels were caused, in part, by logging in the Marikina watershed reservation, and hence rapid runoff (Laquian 2005). Development in Peninsular Malaysia also resulted in water shortage problems in urbanized areas of Selangor (Jahi et al. 2003).

The third constraint on meeting water demand is economic water scarcity. Absolute water scarcity, such as that faced by Singapore, occurs when a country does not have sufficient annual water resources to meet reasonable per capita water needs (Seckler et al. 1999).[11] Economic water scarcity is the condition were there is sufficient potential water resources to meet projected 2025 requirements but expensive water development projects are needed to develop these resources.[12]

In a global assessment of physical and economic water scarcity, several countries in the region were categorized as falling into the latter group including Cambodia, Indonesia, Malaysia, and Myanmar which will need to increase water development by between 25 and 100%. Also suffering from economic water scarcity are Philippines, Vietnam, and Thailand, although these three countries have only modest (less than 25%) requirements for additional water development (Seckler et al. 1999).

The capital investment requirements for advanced infrastructure to meet water supply access and sanitation and provision for industry, agriculture, energy, and leisure has major ramifications for ASEAN member

[10] Haughton and Hunter (1994) write that in the UK one toilet flush is 10 L, a shower is 30 L, a bath 80 L, one dishwasher cycle 50 L and one cycle in a clothes washing machine can be 100 L. Simply leaving the tap running while teeth brushing wastes between 25 and 45 L.

[11] Another term is physical water scarcity when the primary water supply of a country exceeds 60% of its potentially utilizable water resources (ASEAN 2005). In physical terms, Singapore suffers from water scarcity.

[12] It should be noted that water scarcity has little to do with access to water. As pointed out by UN-HABITAT (2003b) many countries that have a water scarcity have high percentage access and those that are located in water-rich areas have low access. Hence, although many cities in the region have a significant population without access and water within many cities is provided for a limited number of hours a day, availability of water for drinking is not physically scarce. This global or ''green'' issue should not be confused with the local or brown issue. Importantly, increasing access to water for the poor bears little relationship to creating water scarcity.

**Table 18** Water availability and cost in selected cities of Southeast Asia, mid-1990s

| City | Water availability (hours a day) | Average tariff (US$ per m$^3$) | Unaccounted for water (%) |
|---|---|---|---|
| Phnom Penh | 12 | 0.15 | 61 |
| Bandung | 6 | 0.369 | 43 |
| Jakarta | 18 | 0.611 | 53 |
| Medan | 24 | 0.266 | 27 |
| Vientiane | 24 | 0.081 | 33 |
| Johor Bahru | 24 | 0.186 | 21 |
| Kuala Lumpur | 24 | 0.131 | 36 |
| Penang | 24 | 0.208 | 20 |
| Mandalay | 24 | 1.201 | 60 |
| Yangon | 12 | 0.456 | 60 |
| Cebu | 18 | 0.663 | 38 |
| Davao | 24 | 0.271 | 31 |
| Manila | 17 | 0.232 | 44 |
| Singapore | 24 | 0.553 | 6 |
| Bangkok | 24 | 0.313 | 38 |
| Chiang Mai | 20 | 0.299 | 35 |
| Chonburi | 16 | 0.461 | 37 |
| Hanoi | 18 | 0.113 | 63 |
| Ho Chi Minh City | 24 | 0.131 | 34 |

*Source*: UN-HABITAT (2003b)

countries. Financing these projects will be a major challenge in the future (ASEAN 2005). In Phnom Penh, for example, increased demand by 2025, cannot be met financially by the government alone (Dany et al. 2000).

One way to circumvent water scarcity is to indirectly import water by purchase, use, and consumption of goods and services produced elsewhere that implicate water use and consumption. ''Virtual water'', as it is called, is the amount of water needed to produce a commodity or service. Trade in primary commodities and some goods implies flow of this water from one location to another, sometimes over great distances.

The amount of water needed to produce different commodities varies. The amount of water needed to produce 1 kg rice is approximately 3,000 L. The amount of water required to produce 1 kg beef is 16,000 L. Between 1997 and 2001 the global use of water amounted to 7,450 Gm$^3$ per year of which 1,625 Gm$^3$ per year was in international virtual water trade. Approximately 80% of the total ''virtual water'' trade is because of trade in agricultural goods (Chapagain and Hoekstra 2004).[13]

For the eight countries examined within Southeast Asia the total external flows were 71.3 Gm$^3$ per year (Table 19). This is only 1% of the region's water resources, leaving seemingly little to worry about. Regional averages can hide local differences, however. Water consumption patterns vary by country, with some countries, for example Malaysia, meeting significant levels of water needs (28% in this case) by use of non-domestic resources whereas Indonesia, a water rich country, is already one of the world's largest net importers of water (Hoekstra and Hung 2005).

As cities and nations grow in wealth we can expect to see changes in water trade budgets. Dependence on non-domestic water resources may continue to rise. Although trade economists may not see this as a problem, considering that global estimates suggest that by 2025, absolute water scarcity will affect 1.8 billion people (Seckler et al. 1999), questions arise about where water to grow food and help make goods will come from. Within the next 20 years more than a quarter of the global population will be living in countries were water extraction is higher than total supply by domestic sources. As clean water grows scarce the prices of goods made with it will rise. The outcome of these dynamics remains unpredictable, but has potentially adverse consequences for developing nations that depend on virtual water.

As water sources will be increasingly sought after, the management of larger bodies will also increase in importance. Today, around 3,800 km$^3$ of fresh water is withdrawn annually from the world's lakes, rivers, and aquifers. This is twice the volume extracted 50 years ago. Given increasing extraction, countries have turned to creating artificial water bodies by dam building. Over 45,000 dams have been built in over 150 countries (World Commission on Dams 2000). In the future, dam building is expected to continue and most of it will occur in developing countries. During the 1990s, for example, an estimated US$ 32–46 billion was spent annually on large dams, four-fifths of which were located in developing countries (World Commission on Dams 2000).

Dams provide for a variety of water management needs. Approximately half the world's large dams are primarily for providing irrigation water. Globally, approximately 12% of large dams are to supply water for drinking and those are related directly to urbanization. Hydropower dams currently provide 19% of the world's electricity. Approximately 24% of countries developing hydropower depend on it for 90% of their energy (World Commission on Dams 2000). The trend is that cities need increasingly more water and energy and this demand translates into demand for dams.

Dams on rivers that traverse several countries can cause international tension. In the Mekong River Basin dramatic changes are occurring and tension in the region is forecast to increase (World Commission on

[13] See also http://www.waterfootprint.org.

**Table 19** Water footprint of selected Southeast Asian nations

| Country | Total renewable water resources ($Gm^3$/year) | Internal water footprint ($Gm^3$/year) | External water footprint ($Gm^3$/year) | Total water footprint ($Gm^3$/year) | Water scarcity (%) | Water self-sufficiency (%) | Water import dependency (%) |
|---|---|---|---|---|---|---|---|
| Cambodia | 476.11 | 20.45 | 0.54 | 20.99 | 4 | 97 | 3 |
| Indonesia | 2838.00 | 242.30 | 27.66 | 269.96 | 10 | 90 | 10 |
| Laos | 333.55 | 7.44 | 0.21 | 7.64 | 2 | 97 | 3 |
| Malaysia | 580.00 | 38.87 | 15.01 | 53.89 | 9 | 72 | 28 |
| Myanmar | 1045.60 | 74.38 | 1.11 | 75.49 | 7 | 99 | 1 |
| Philippines | 479.00 | 104.40 | 12.45 | 116.85 | 24 | 89 | 11 |
| Thailand | 409.94 | 123.24 | 11.22 | 134.46 | 33 | 92 | 8 |
| Viet Nam | 891.21 | 100.21 | 3.12 | 103.33 | 12 | 97 | 3 |

*Source*: Chapagain and Hoekstra (2004)

Water scarcity: The ratio of the total water footprint of a country or region to the total renewable water resources. National water scarcity percentages can be more than 100% if a nation consumes more water than is domestically available

Water self-sufficiency: The ratio of the internal water footprint to the total water footprint of a country or region. Self-sufficiency approaches 100% when national water demand is taken from within domestic boundaries

Water import dependency: The ratio of the external water footprint of the country or region to its total water footprint. The dependency ratio increases as countries import more of the water demanded by domestic activities

Dams 2000). The Mekong is of great interest to five nations in Southeast Asia—Cambodia, Lao PDR, Myanmar, Thailand and Vietnam. The Lower Mekong Basin supports 60 million people. The Mekong River is an important river for transport, food, water, tourism, recreation, water management, irrigation, energy, industry, and biodiversity. The different countries in the region have different end uses planned for Mekong River water. Laos wants to use dams to generate electricity for export, Cambodia wants to secure sustainable fishery resources, Vietnam seeks to ensure the flow of water for its rice crops without salinity rising to dangerous levels, and Thailand wants to ensure consumption for its cities. International management of this water resource is therefore important for all these countries. Unfortunately, however, management of this common resource has been difficult. Importantly, China, from whose boundaries flow up to 20% of the Mekong's discharge (Mekong River Commission 2005), has put in place an aggressive dam program to meet its water and hydro-electric power needs (Dore and Yu 2004; Liebman 2005).

Current development trends in China have created a demand for the water. Some of the most fertile areas of China now face chronic water shortages. The Chinese government's decision to build three massive canals connecting the water-abundant south to the drier north is indicative of their concern. There are several signs that water use in China is not sustainable, including the long period of time the Yellow River runs dry, the abandonment of old wells, the drilling of 300,000 new deeper wells per year, the sinking water table, the return to less efficient rain-based agriculture, and the decreasing quality of water available to farmers (Liebman 2005).

China has, moreover, an increasing demand for energy, particularly modern energy (electricity). Currently, the country still relies heavily on fossil fuels for its energy supply, with 70% coming from coal. In 1993, China became a net importer of oil, importing approximately 100 million tons of crude oil a year, second only to the US (Liebman 2005). In this context, the Mekong's resources are immensely valuable to the country.

There are currently plans to build eight dams on the river by 2019 (Dore and Yu 2004), helping to fill the growing gap between electricity demand and supply through hydropower. Two dams (at Manwan and Dachaoshan) have already been built; two more (Xiaowan and Jinghong) have begun construction and are expected to be complete by 2010; and four more have been designed. These are large dams and the major component in the country's drive to double the amount of hydro-energy production by 2010 (Dore and Yu 2004).

The implications of damming the river are economically high, because 50% of Vietnamese rice production is located in the Mekong delta and 50% of the protein Cambodians eat (and a large source of employment) comes from their domestically caught fish supply. If the Mekong were to fail to reach the sea for half the year, as the Yellow River currently does, this would not only impose huge opportunity costs for lost hydro-power and trade, but immediate economic losses and dislocations in the riparian states would be severe (Dore and Yu 2004). Indeed, some argue that the current damming of the river has already had an effect (Dore and Yu 2004; Liebman 2005; Lu and Siew 2005). For example, some have claimed that during the first quarter of 2004, the Mekong reached record low flows in the downstream riparian states (Liebman 2005). These claims, however, may be linked to the previous years' higher than average low-flows, because there is no long-term evidence of systematic change in low-flow hydrology of the river (Mekong River Commission 2005). Whether Mekong River flows are affected by water infrastructure will continue to be debated as each country attempts to use the water in the river for its own purposes.

Finally, all low-lying cities in the region are facing the consequences of climate change and its potential impacts on water. Globally, anthropogenic activities are changing climates (including temperature increases, changes in precipitation, and sea level rise), both regionally and globally, and this, in turn, is affecting several physical and biological systems. Examples include shrinkage of glaciers, thawing of permafrost, later freezing and earlier break-up of ice on rivers and lakes, lengthening of mid to high-latitude growing seasons, poleward and altitudinal shifts of plant and animal ranges, declines of some plant and animal populations, and earlier flowering of trees and emergence of insects and egg-laying in birds (Watson et al. 2001).

Some areas of Earth have been affected by increases in floods and droughts, making them more vulnerable to extreme events. Projected changes in climate extremes are also dramatic and could have major consequences. While there are uncertainties attached to predictions and trends, estimates suggest that the frequency and or severity of extreme events is likely to increase in some regions (Watson et al. 2001). Importantly, coastal areas are increasingly physically vulnerable and many are already experiencing increased flooding, accelerated erosion, and seawater intrusion into fresh water (Agardy et al. 2005).

In Southeast Asia many cities are barely a meter above sea level and floods and droughts in the region are increasing. In 2001 the Intergovernmental Panel on Climate Change (IPCC) estimated that sea-levels will rise between 0.09 and 0.88 m by 2100, with regional variations. This places the delta regions of Myanmar, Vietnam, and Thailand and the low-lying areas of Indonesia, the Philippines, and Malaysia at risk (Nicholls et al. 1999). Specific areas identified as vulnerable to the effects of extreme events include the Tonle Sap lake and southern region of Cambodia and the coastal Koh Kong town, Bangkok, East Bangkok, Pattaya, Cha-Am, and Hua Hin and those areas in the sandy coastal plans including Rayong in the eastern region, the coast north of Songkhla, between Hua Hin and Cha-am, and the bays on the east coast, for example Rayong Bay in Thailand, many of the cities in Metro Manila, and entire provinces in the Philippines (in the Philippines alone almost 2 million people live in low-lying areas), Ca Mau province, Ho Chi Minh City, Vung Tau, and Xuan Thuy sea areas and large parts of South Vietnam, areas in the Red River delta, and much of Singapore (ASEAN 2005).[14]

Many cities in the region are facing green agenda, global water issues. While those on the upper end of the scale are experiencing higher levels of water consumption, physical or absolute water scarcity remains unimportant to all cities but Singapore. Many cities, however, are experiencing economic water scarcity and many others are also vulnerable to changes within international waterways and to the effects of climate change. Singapore's most dominant water concerns are in this category, but other cities, particularly low-lying coastal cities on the Mekong are also facing such issues.

## Discussion and conclusion

This survey has attempted to point out several water-related issues that cities across the region are currently experiencing. All cities have multi-scale water challenges ranging from water supply and sanitation access to water pollution and threats of future vulnerability from climate change. Table 20 summarizes the different water-related environmental burdens that each set of cities (based on level of income) currently faces. Although individual cities may have slightly different concerns, as a group each faces similar problems and challenges.

Although these issues have been reported before, what is new in this analysis is a holistic look and comparison with the experiences of cities in the now developed world. Doing so brings a new perspective to urban environmental history and an understanding of the relationship between development and the urban environment. For example, as mentioned, Melosi (2000) chronicled changes in water supply, sanitation, and solid-waste management in US cities. His history is a story of sequential policies that addressed environmental challenges of the period. The solutions to challenges at any given time lead to, in part, subsequent burdens in later periods. For example, comprehensive sewerage systems weren't even considered

[14] Lebel (2002) points out that a 1-m rise in sea level could lead to loss of 34,000 km$^2$ of land in Indonesia, 7,000 km$^2$ in Malaysia, and 5,000 km$^2$ in Vietnam (in the Red River Delta), and 15,000–20,000 km$^2$ of land could be threatened in the Mekong Delta.

**Table 20** Summary of different water related-challenges for cities in different income categories in Southeast Asia by scale of impact

| Local | City-wide | Regional and global |
|---|---|---|
| Low-income cities | | |
| Low water-supply coverage | River and coastal water pollution | Economic water scarcity |
| Low sanitation coverage | Overdrawn groundwater | Vulnerability because of climate change |
| Poor drainage | Subsidence | |
| | Coastal area degradation | |
| | Flooding | |
| Middle-income cities | | |
| Low water-supply coverage | River and coastal water pollution | Economic water scarcity |
| Low sanitation coverage | Overdrawn groundwater | Vulnerability because of climate change |
| Poor drainage | Subsidence | |
| | Coastal area degradation | |
| | Flooding | |
| Upper-middle income cities | | |
| Low to incomplete sanitation coverage | River and coastal water pollution | Increasing water consumption per capita |
| Water supply coverage not complete | Overdrawn groundwater | Vulnerability because of climate change |
| Poor to inadequate drainage | Subsidence | |
| | Coastal area degradation | |
| | Flooding | |
| High income cities | | |
| | River and coastal water pollution | Physical water scarcity |
| | Coastal area degradation | Increasing water consumption per capita |
| | | Vulnerability because of climate change |

Cities in the low-income category include Vientiane, Phnom Phen, Hanoi, and Ho Chi Minh. Cities in the middle-income category include Manila and Jakarta. Cities in the upper-middle income category include Bangkok and Kuala Lumpur. Cities in the high-income category include Singapore

until water-supply systems brought tremendous amounts of water into the city. When the water was there, engineers, city planners, and decision-makers identified the need to remove the wastewater. Hence, most sewerage systems were built after water-supply systems were developed (Tarr 1999).

As opposed to this sequential or staged scenario, many cities in the Southeast Asian region have had to address all these issues simultaneously. This makes identification of environmental transitions difficult. They must also do so with much lower tax revenues than were available to developed world cities. For example, as already explained, cities such as Hanoi, Ho Chi Minh, and Phnom Penh are suffering from the entire gamut of challenges. When cities in Europe and North America were at similar levels of income they had yet to experience all these challenges. National levels of income in 2000 of some developing countries, at PPP, are comparable with those in the USA in during the 1800s (Maddison 2001). This period in US history was before the implementation of city water-supply systems (New York City's first comprehensive supply system was developed in 1850s and the sewerage system in the 1870s). It was only during the early 1900s that New York was able to finance most of its current water-supply system (Galusha 1999).

Given the challenges they face, it is indeed wondrous the cities of the Asia Pacific operate as well as they do. Yet they are in need of new policies and modes of planning and management to address their challenges. That is, they must address different water-related challenges simultaneously and on a range of different scales. Given this enormous dissimilarity with the developed world experience, the effectiveness of policy transfer from North to South is questionable. Indeed, rather than looking for policies from the North, some of the most unique and effective policies to address environmental conditions are now coming from developing countries (i.e., Singapore's water and transportation policies).

The insights provided through *time–space telescoping* force us to re-think traditional development trajectories and, therefore, ways of addressing environmental challenges. This perspective identifies a set of patterns unique to cities within the region. It also suggests that despite the seemingly chaotic environmental situation in many cities in the region, there are, nevertheless, structural reasons for the patterns. That is, because the drivers of the new patterns of sooner occurrence and more simultaneous emergence of environmental burdens and the changes in spatial distribution of phenomena are indirect (i.e. acting on large geographical and temporal scales), the changes are structural (i.e. they will also not change easily or quickly). The structural patterns seen across countries and cultures suggest that not all conditions within cities can be reduced to special location geomorphology and cultural and individualistic characteristics. That is not to say that these other more proximate effects are not important, but it does suggest that both the indirect and proximate forces are working together. Not all urban challenges can be reduced to local determinants. The policy implication is that cities alone cannot be asked to resolve these problems, but rather governance at all levels is needed to address them successfully.

The theory also suggests that urban decision-makers in rapidly developing countries face a more complex set of environmental tasks, with less money than their developed country counterparts had previously. If, moreover, trends are changing faster (an issue not addressed in this article), the window of opportunity to set cities on a sustainable trajectory is narrower than in the past.

Despite these constraints, however, cities in region continue to show signs of viability and growth potential (Laquian 2005). There are, moreover, examples of how they have grown with lower levels of environmental burdens, compared to the now developed world. As mentioned briefly in this article, this can be seen in terms of water consumption per capita. Singapore's GDP per capita (PPP) is similar to that of the USA (World Bank 1999), yet water consumption per capita there is at least 50% lower than in most US cities. Studies have also shown that per capita amounts of $CO_2$ emitted from their road transport are lower than for comparable income levels in the USA (Marcotullio et al. 2005). Also, all countries in the region use less energy per capita at similar levels of GDP (PPP) compared with the USA (Marcotullio and Schulz 2007). What this suggests is that despite the seemingly daunting challenges of sooner, faster, and more simultaneous emergence of environmental problems, other aspects of contemporary development are promoting more environmentally efficient growth. Rapidly developing cities have arguably taken advantage of new technologies, information, and knowledge and have used these tools to their benefit (Angel and Rock 2000). A hypothesis for further study is that the *time–space telescoping* of development not only creates new challenges but also fertile grounds for the development, diffusion, adaptation, and adoption of new and more promising technology (both hard and soft) and methods for addressing urban environmental burdens.

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