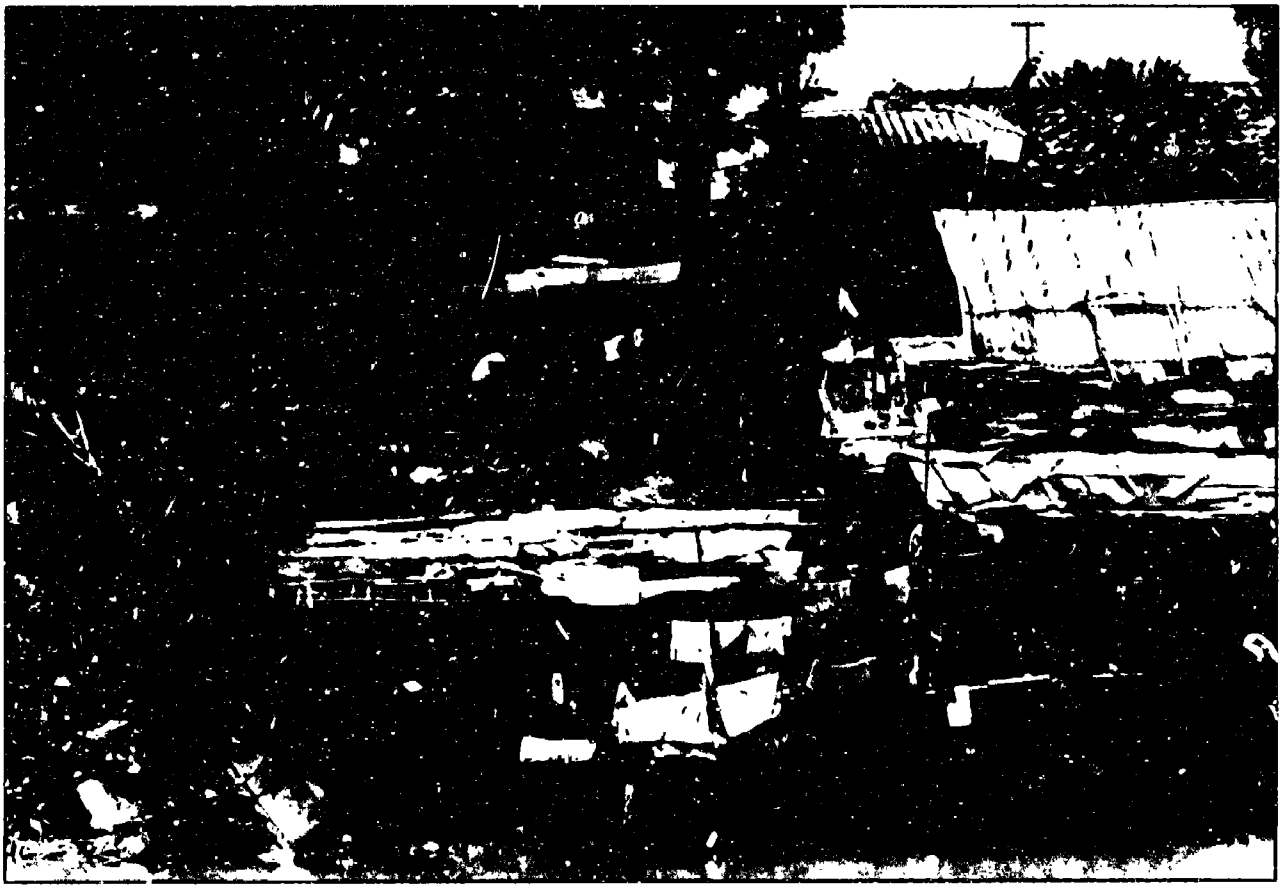
TROPICAL CITIES: MANAGING THEIR WATER

SOMETIMES TOO MUCH. SOMETIMES TOO LITTLE. OFTEN POLLUTED

". . . by the Year 2000 almost one-third
of the world's people will be living in the humid tropics."



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INTRODUCTION: what a city needs

Five requirements for the satisfactory growth of a city have been postulated by Ariel Lugo (1991). They are:

- *The maintenance of a healthy and productive internal environment;*
- *The handling in an environmentally acceptable manner of the required natural resources and waste products produced by the urban activities;*
- *The capacity of the institutions within and without the cities to manage the effects of natural hazards;*
- *The tolerance of the people to the situations within the cities; and*
- *The maintenance of the regional and national infrastructures such that they are able to supply the cities' needs from the outside.*

Failure to meet these requirements can place a city on a downhill path that can lead to economic stagnation, physical decay, social dysfunction and eventual consignment to the "dustbin" of history.

Many of the world's tropical cities appear to be taking this downward path. They are not providing clean water for large numbers of their residents. Nor sufficient waste collection, treatment and disposal facilities. Nor adequate protection from storms and their runoff. Nor freedom from the diseases that accompany polluted water. Nor much hope that things will get better in the near future!

More gloom than hope

There are some brighter spots, to be sure—Singapore is one example. But most of the urban concentrations located on the Earth's steamy belt have prospects that are far from lustrous. Their problems are many with most of these difficulties being related to water in some way.

Violent storms often batter and sometimes submerge their buildings and homes. Runoff from these storms contaminates their streams and aquifers. Extended droughts can deprive them of water for drinking, for industrial use or for waste carriage. Many of the water bodies that serve them as drinking water sources also furnish them with disease-producing organisms and chemicals that are toxic.

Over-withdrawals from some urban aquifers also are causing the ground to sink under their buildings, cracking pipelines and foundations in the process. This pumping is allowing brackish or saline water to enter the aquifers.

Their human, commercial and industrial wastes keep on accumulating. Their squatter settlements are a far cry from minimally decent

housing. And above all, their population pressures keep on building.

As might be expected from these various problems, the mortality rates in these cities are among the world's highest. Then to make things worse, the responsibilities of their different levels of government that should be solving these difficulties are tangled. There are few clear plans or marshalling of forces to attack the problems in a comprehensive way. One of the major problems is the failure to manage these urban areas in an integrated manner, especially the total water management aspects. Finally, the overall economic activity level of these tropical cities often is not high enough to pay for the needed facilities, especially if the cities insist on high standards.

Some corrective efforts have been made

There have been many projects initiated and completed in attempts to correct these water-related situations. Wells have been drilled, dams and canals constructed and waste treatment plants constructed. Still, most urban centers in the developing world lack adequate facilities for supplying clean water and for the proper collection, treatment and disposal of their domestic and industrial wastes. Also, as noted in 1988 by the World Health Organization (WHO), the mere existence of a sewerage system in a city does not ensure that proper treatment of the wastes takes place. The systems are often inoperative or inefficient. Nor do these cities generally consider the crisis prevention steps required to cope with the extremes of natural events to which most of the tropics are subject.

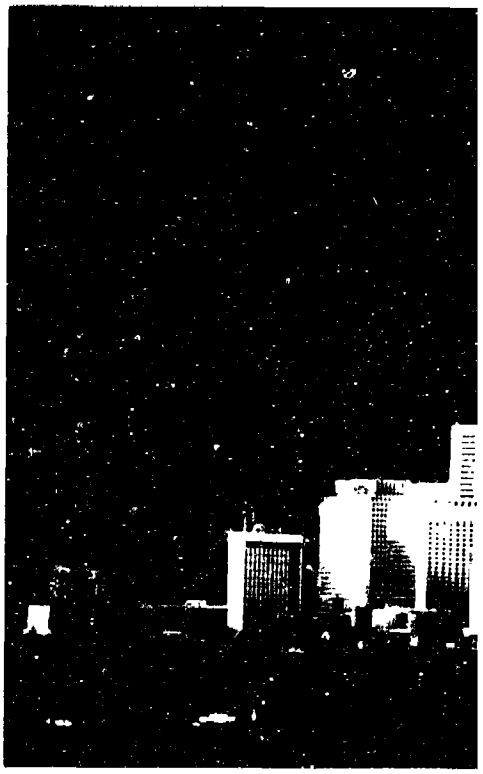
This recital of the difficulties faced by large centers of population in the tropical regions does not mean that their counterparts in the more temperate climate zones are totally free of some of the same problems. The recent racial unrest in Los Angeles, California ,USA, is but one example of social dysfunction brought about by overpopulation and the lack of equal economic opportunities. However, those problems that are water-related seem to be more acute in the equatorial regions lying between the Tropics of Cancer and Capricorn.

The philosophy of integrated water management—looking at the urban water situation as a whole—needs to be better understood, particularly by the tropical cities. Piecemeal planning often only transfers the locale of the problem, rather than providing a true solution.

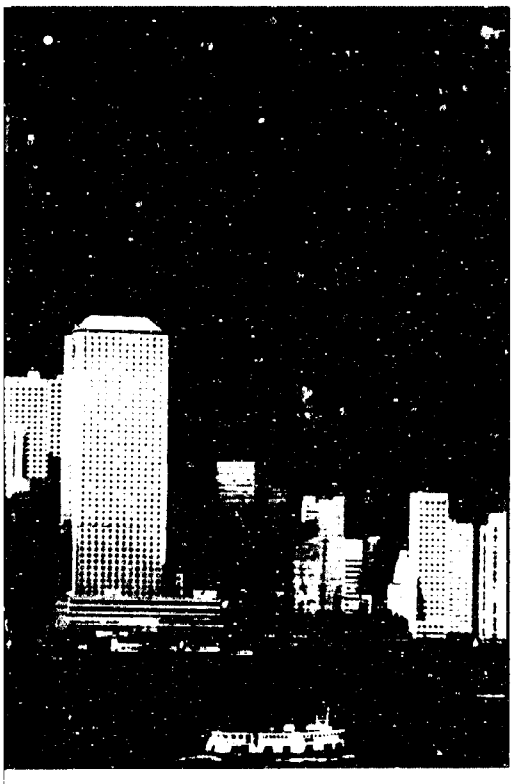
Population growth greatest in the cities

The accelerating population growth in these hotter regions is a major factor in this situation. Twenty years ago, most urban dwellers were living in the developed countries. This situation did not last long. The developing world's metropolitan areas—most of which are located in the tropics—soon surged ahead, seemingly to stay. It has been estimated that at least one-third of the world's total population will be living in the humid tropics by the year 2000, most of them in urban locations. That proportion is expected to continue to increase in the Twenty-First Century.

Taking the ASEAN countries as an example, six nations located there (Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore and Thailand) had an estimated population of 290 million in 1985. It has been forecast that by the end of this century, they will



Some cities in the tropics, such as Hong Kong above, may appear to be basking in progress whether or not they have their water quality problems under control. Others, such as the example shown below, definitely seem to be caught in a tightening circle of rapid population growth, with more economic development thus needed, but with more pollution resulting from the growth.

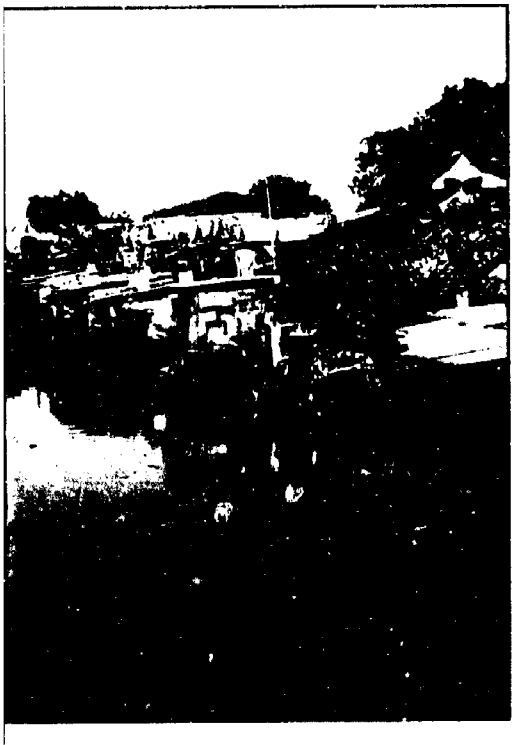


total some 385 million persons. Between 1980 and 1990, their rates of national population growth varied from 1.09% in Singapore to a high of 2.25% in the Philippines. The average global growth rate was 1.8% and 0.6 to 0.7% in the developed countries during the same decade (Maione, 1988). However,no one has suggested there is a correlation between the tropical weather and population numbers.

All tropical climates are not the same

Weather scientists argue over just what constitutes the tropics. However, the region between the Tropics of Cancer (23-1/2°N) and Capricorn (23-1/2°S) usually is considered to be The Tropics. However, there is nothing magical about those particular parallels of latitude. Tropical-type weather often migrates both north and south of those dotted lines on world maps. But if a city is located between those two parallels, or near to them, warm temperatures and heavy seasonal rains are usually part of the climatic picture. If the precipitation is accompanied by violent winds of cyclonic origin, floods and landslides also may be forthcoming. To take South -East Asia as an example, when masses of air from continental Asia and the Indian Ocean pass over the South China Sea, they gain in moisture content and wind strength. They then deposit heavy rain as they move over the land. Thus the east coasts of Peninsular Malaysia, Sabah and Sarawak and the eastern regions of Thailand and Kalimantan can become quite wet, with flooding common in the low-lying areas.

Although not as well-known, the other side of the coin can come up as well. Long dry spells do happen. Many areas within the region just referred to can receive little rain for four to five months out of a year. Kuala Lumpur, situated on the west coast of Malaysia, has a monthly rainfall of less than 150 mm about half of the year. The same is true in the Philippines and Indonesia. Central and northern Thailand can be even drier. Agricultural crops and other vegetation in these areas can be stressed unless they are irrigated from natural or artificial reservoirs of water.



These dry, then wet, periods exacerbate the water-related problems of the tropical cities as they intensify their pollutional loadings as well as diminish their potable water supplies. Severe health, environmental and aesthetic discomforts can result. In many tropical cities, sewage treatment systems are nearly non-existent, with human wastes being deposited directly into surface canals, ditches and drainageways. In some cases, the very same drainage is used by people for bathing and washing their clothes. The question then is, why is this situation tolerated?

The economics vs. pollution dilemma

The quick answer is that there is often little choice. The people who live in the slum and squatter areas of the urbanized regions are the most economically disadvantaged. They stay in these areas because they are accessible and the least sought-after lands. The rivers and drainage canals there provide convenient, if not acceptable, means of disposing of sewage and garbage.

A city's residents cannot be blamed for the sewage floating in their rivers if they are not provided with proper sanitation facilities. Nor are the cities' sanitary engineers or public works authorities at fault when they have to operate under inadequate budgets and/or technical constraints.

The essence of the problem is financial. As long as these cities

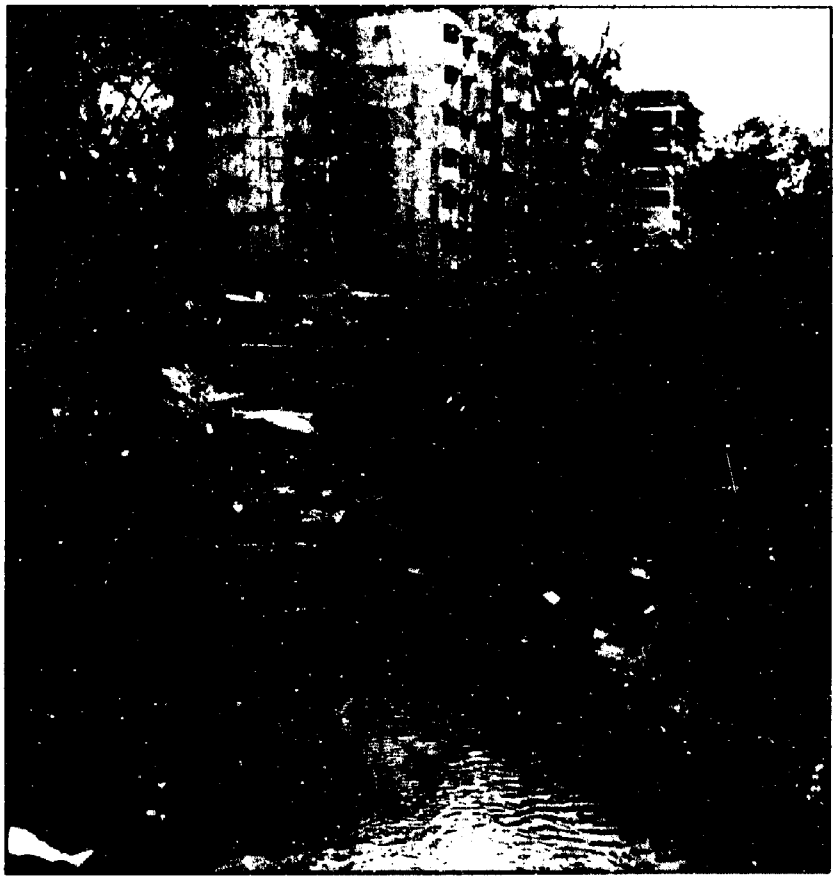
cannot afford to provide proper sanitation for their residents, the waste-related problems of water pollution cannot be expected to cease.

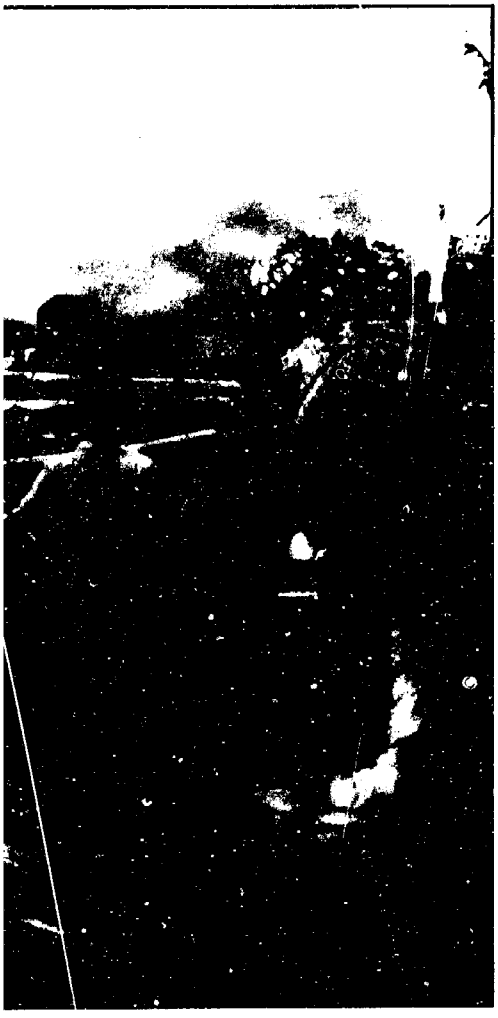
Unfortunately, there often are two very contradictory forces operating in the developing countries. The first is the developing of a country's resources, the second is the by-products of that development. A nation's leaders are often caught in the difficult situation of trying to increase the industrial output of their country in order to improve its economic well-being, when the very industrialization they are encouraging ends up impairing the quality of their waters and the health of their citizens.

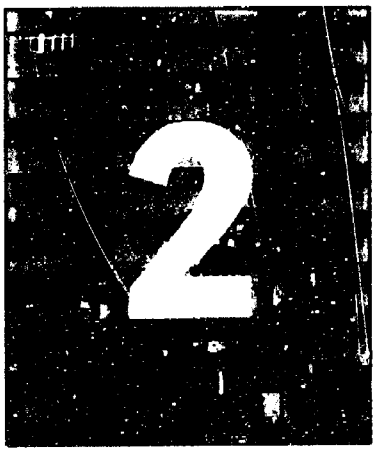
The following sections of this publication will review in more detail the myths and realities of the tropical cities' climates, their urban population situation and their present water quality. The special problems of tropical coastal cities, the overall water supply difficulties and the technical and non-technical solutions which have been proposed will also be examined.

Sometimes rivers are friendly, such as furnishing this water-based market. Other times, they can be deadly foes.

Development sited too near a stream or coast can impair the quality of the watercourse as well as place the development at risk from flooding or seepage, and, sometimes, land subsidence.







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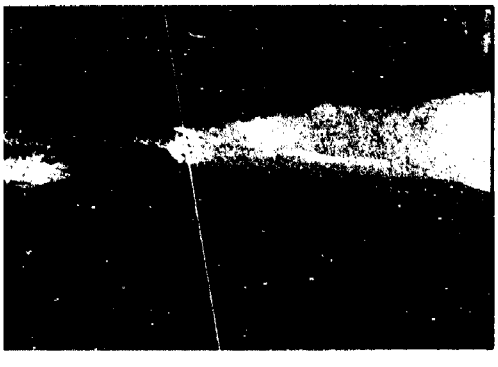
TROPICAL WEATHER: myths and realities

A number of misconceptions have been generated about the weather of the world's tropical region. It is generally thought that this part of the globe receives a greater proportion of rainfall and solar energy than the temperate and arid zones and thus must be a very damp and hot place. It is true that if one prefers a relatively dry climate with low humidity that furnishes pleasant evaporative effects, a tropical city is not the place to be. Should you be located as close to the equator as 10° North and South, you can expect to be dowsed with substantial amounts of warm rain at least four and a half months out of the year. Cities of South-East Asia situated in this latitudinal belt include Kuala Lumpur, Jakarta and Singapore. More than 600 millimeters of water have been recorded to have fallen on these urban centres within a 24-hour period.

Eastward across the Pacific Ocean, Panama, Caracas, Manaus and Belem all lie in this often soggy region. Further east on the African continent, Abidjan, Accra, Brazzaville and Kinshasa are in the same latitudinal belt. Local topography and/or nearby ocean currents may modify their precipitation regime slightly.

Cities established still farther north and south on the Earth's equatorial bulge do not escape seasonal deluges. Some may even experience higher and more intense rain. For example, toward the end of the year, very large masses of unstable, near-saturated air may start swirling over the South China Sea. As these masses pass over the sea, they intensify in strength and moisture. When they hit a coastline, such as Peninsular Malaysia, Sabah and Sarawak—as well as the eastern parts of Thailand and Kalimantan—heavy precipitation and flooding often ensue.

Wet air masses undergoing orographic uplift from tropical mountain ranges can lose additional amountrs of their moisture as precipitation.



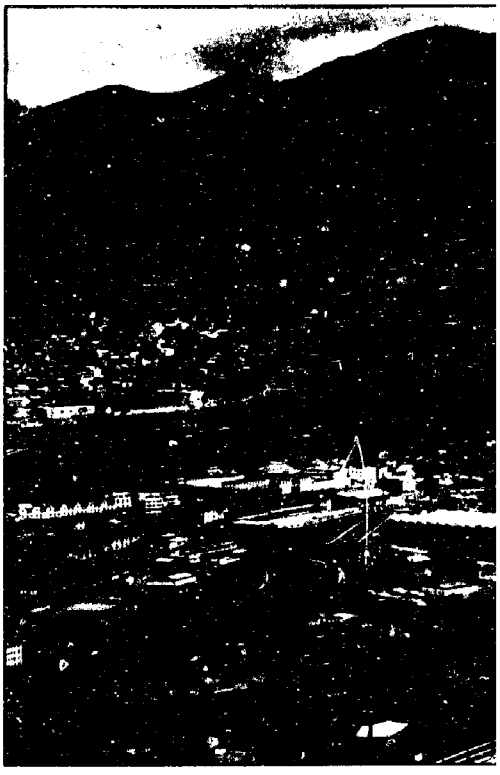
Lots of rain, fast and for a long time

To appreciate these downpours, consider that the intensity of a tropical rain that falls for fifteen minutes can be two and a half to four times higher than a rain of similar duration in western Europe. Should such a rain continue for sixty minutes, the tropical storm can be three to six times as intense.

These heavy rains, when coupled with the cyclonic-inspired winds, can be unpleasant under the best of conditions. But when these tropical moisture-monsters—called cyclones, hurricanes, or typhoons—hit a coastline, their wet winds can exceed 120 kilometers per hour. Such velocities can cause extensive property damage as well as contribute to the loss of life.

Another negative factor of these rainstorms can be their duration

"In São Paulo, two-thirds of the slum population lives in areas prone to flooding and landslides, 66% of the houses have no lighting, 98% have no access to sewers or septic tanks and about 80% have no drinking water." (World Health Organization, 1988)



Steep hillsides, as at Quito in the Ecuadorian Andes, can foster rapid runoff, accelerated erosion and landslides.

Low flows from occasional droughts are more common in the tropical regions than commonly thought. Such low water levels can make eutrophication and other water quality problems more severe.

and/or their strength. Some have a short life but others (the monsoonal storms) persist. Fortunately, the latter generally are lower in intensity. In both instances, however, the precipitation can exceed the infiltration rate of the soils, particularly those which have been disturbed in the development of the urbanized areas. Soil erosion thus will be accentuated. Furthermore, the topography of many tropical regions is steep and the soil often is highly weathered. Thus under the humid tropical conditions, large amounts of sediment can be delivered into a river system.

It is well-accepted that forests and other upland vegetation are significant guardians of the quality of the water headed downstream toward the urban centres. The humid tropical forests are generally species-diverse, multi-storeyed and broad-leaved with thick canopies. Some of these forests are earmarked or "gazetted" as national parks and protected forests, watersheds and for timber production. Nevertheless, due to population pressures, such forested areas are in short supply in many tropical areas.

The erosion of soil after deforestation in the uplands can be very severe due to the high erosivity of the humid tropical rainstorms. Thus, when an upland area is cleared of its vegetation, excessive amounts of soil can be eroded. Muddy rivers are a common sight in the densely populated regions of tropical countries.

Floods—and related deaths—have increased

As a result of land-use conversions upstream (deforestation followed by agricultural use of the land), the canalization of streams and the encroachment of buildings onto the flood plains, high water levels also have increased over the past few years in many instances. It has been reported that in Venezuela, for example, many towns have grown rapidly, occupying in the process most of the space in the narrow mountain valleys. The streets, acting as major drains, thus concentrate the flood waters rapidly on the lower ground, much of which has been occupied by highways, buildings and other types of development. Such encroachments into the natural stream courses and plains have resulted in deaths and major property damage.

From downpours to droughts

However, despite the fact that these tropical rainfall volumes are large and often quite intense, there are periods in which little or no rain falls. Prolonged droughts are known to occur regularly and can be more severe during the well-publicized El-Niño/Southern Oscillation (ENSO) events. When such phenomena take place, as in 1983 in South-East Asia, the droughts create other secondary problems. Forest fires increase and the incidence of cholera and typhoid grows among those riverine communities that are dependent on river water for drinking and washing.

Because of this variability in precipitation, tropical streams and canals can experience large ratios of high to low flows. When these low flows continue for long periods, the capacity of the streams to naturally dilute biodegradable wastes is lessened.

Although floods can be instantly recognized as a dangerous hazard, the droughts are more insidious. Since they increase imperceptibly over a period of time, awareness of their occurrence is low. By the time the water shortages are felt, the damage done may have already been severe enough to affect all sectors of a tropical city's economy.

Floods in the tropical regions often cause much more distress than a mere wading through a shallow overflow.

CITIES: where the growth is

In 1800, only one per cent of the world population lived in cities. By 1970, however, 37 per cent were in urban enclaves. This trend is continuing. More and more people are leaving the rural countryside. By the year 2000, just over half—51 per cent—of the Earth's humans will be awakening to the sounds of a city, not to the trills of woodland birds nor to the crows of farm cocks. Between 1970 and the year 2000, the urban population is expected to have increased almost two and a half times.

This urban population growth is not expected to take place uniformly all over the world. The total number of people living in the cities of the developed countries is expected to increase from 717 million in 1970 to 1,174 million by the year 2000. However, their urban counterparts in the less developed areas of the world are forecasted to grow in numbers from 635 million in 1970 to 2,155 million by the year 2000.

Since the end of World War II, a high rate of human reproduction has been a characteristic of the developing countries. Tropical cities also have grown in population through the movement of rural residents to the metropolitan areas. These people migrated for a better life, a job, or perhaps for the supposed excitement of a city. Unfortunately, the only goal that was achieved too often was the latter, which usually turned out to be just the glitter of nighttime neon.

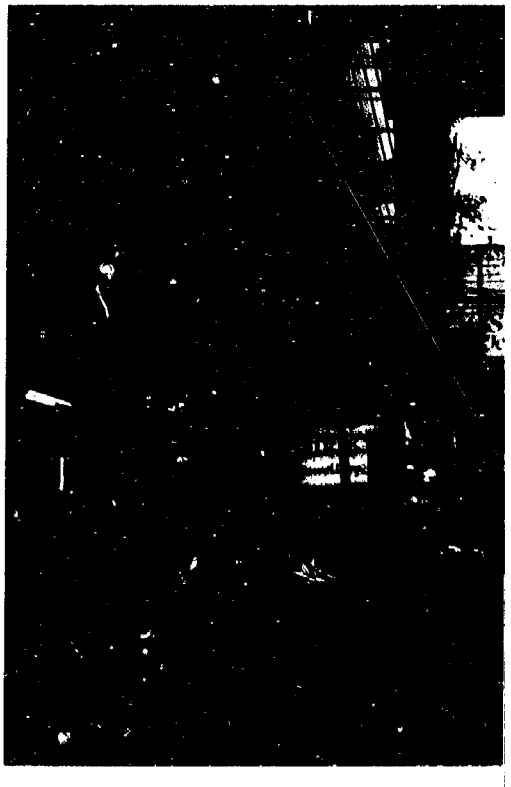
One example of this fast growth in city numbers is the population explosion in South-East Asia. Urban growth rates in the countries of this region are very high due to immigration and rural-urban movements brought on by the economic boom that has been going on since the early 1960s in many tropical cities. This growth has been based on both resource use and industrialization on a large scale. The result has been some staggering growth in the size of some metropolises of South-East Asia. In 1950, only Jakarta and Manila had populations of more than one million. Thirty years later, there were more than seven such mega-cities.

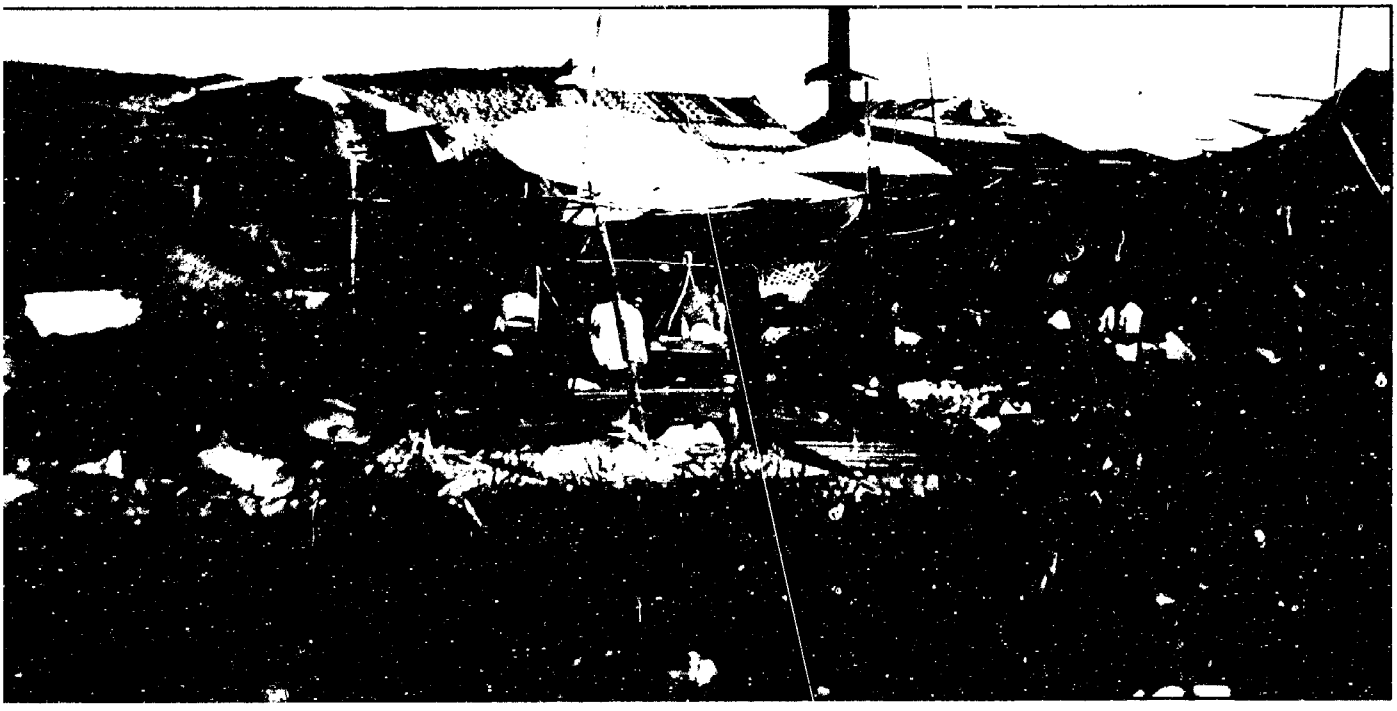
The growth is continuing

The "worst" may be still to come. It is estimated that by the year 2000, there will be at least eight cities (in what are generally considered to be tropical regions) of over ten million people each. Leading this list are São Paulo, Calcutta, Bombay, and Jakarta. In total, thus will be many, many people to house, feed and provide with waste disposal facilities.

The very long-range picture is not entirely black, however. There

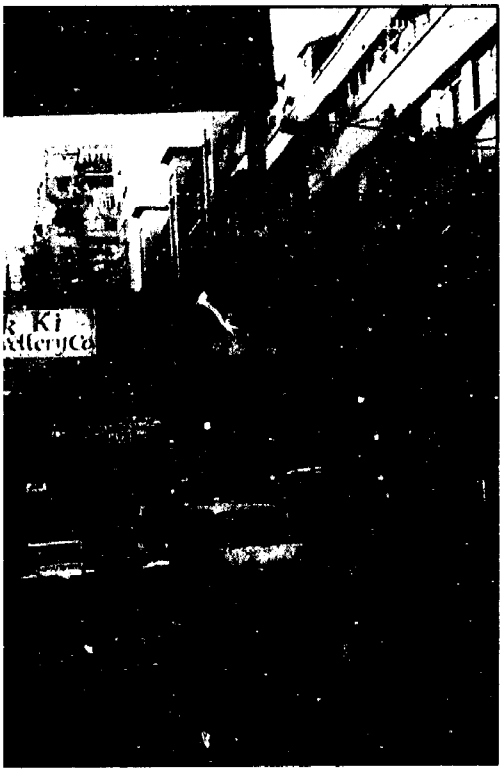
Massive housing developments as below have relieved the housing situation in some tropical cities—for some people. Others still are still stuck in slum squatter settlements such as at the right.





The migration of rural residents to the metropolitan centers continues despite the abysmal living conditions found in many of these cities.

Shopping bargains have attracted inumerable tourists to the large tropical cities, adding to the crush of in-country migrants drawn by the possiblity of employment.



have been significant cuts in infant mortality in the developing countries, the average life expectancy of their citizens has risen and their average incomes have doubled. With regard to the latter improvement, however, most incomes were very low to begin with.

An August 1991 report does offer hope for what has been the most intractable problem, population growth. A study performed for the Agency for International Development (AID) concluded that fertility had declined "sharply and unexpectedly" over the past two decades in **some developing countries** (emphasis added).It is also anticipated that as more children survive into adulthood, birth rates will decline.

But over the next few decades, the total number of people residing in the tropical cities will continue to rise. It has been pointed out that because of the large number of persons of child-bearing age now alive, the absolute number of people on Planet Earth will double over the next thirty years.

It must be acknowledged that the developed countries have contributed to this overall growth in world numbers and that their per capita impact on the Earth's resources and environment is considerably higher. People of both the developed and developing countries should consider that "production" of near-mirror images of oneself is individually understandable, but repeatedly doing so on a planet of finite space and resources can only add up to a collective disaster.

THEIR WATER QUALITY: good to very bad

Below, a water-borne waste disposal system can work but overflows in times of heavy precipitation can result in hazardous wastes being spread on the streets and canal banks.

For the cities of the tropics and their residents, the population increases just discussed cannot be good news as far as their water-related problems are concerned. The World Health Organization (WHO) recently estimated that 23 per cent of the Third World's urban population were not "served with water". Equally bad, 40 per cent did not have access to an "appropriate form of sanitation" . Things are even worse in some regions. In South-East Asia, 58 per cent of the urban population do not have an adequate water supply. In Africa, 38 per cent do not have access to water that is reasonably adequate and could be considered safe, according to the international health agency.

Rural water diseases moving to the cities

Especially in the densely populated areas where the facilities for disposal of household and industrial wastes are inadequate (or non-existent), the bacterial contamination of water by these wastes is a major problem. The importance of water to the transmission of diseases also can be seen in many developing countries where what were basically rural diseases are now becoming endemic in the cities. Malaria, yellow fever, dengue and schistosomiasis are among these water-related diseases. A relationship between the transmission of the latter disease and the migration of individuals from rural areas has been demonstrated in São Paulo and other Brazilian cities.

There is no doubt that polluted water is one of the chief causes of those diseases which are preventable. The provision of clean water for all has been a goal of many governments and international organizations for decades. Unfortunately, that goal is still out of reach—especially for the developing countries.

Flowing water carries trash—and disease

If there is any flowing water in the shanty towns, it soon becomes an open sewer. Cholera, hepatitis, typhoid, diarrhea—these are some of the water-related diseases just waiting for residents of these urban slums. Poor personal hygiene, failure to boil water before drinking it and the throwing of waste water into yards facilitate the transmission of such diseases. Cultural habits also may worsen this situation.

WHO adds that it is "hardly equitable to expect people in lower income groups to take responsibility for their own garbage and waste water disposal while those in the middle and upper income groups are provided with sewers and services for the regular collection of their household wastes."

Above, sometimes one must do the washing where one can.

Sources of contamination

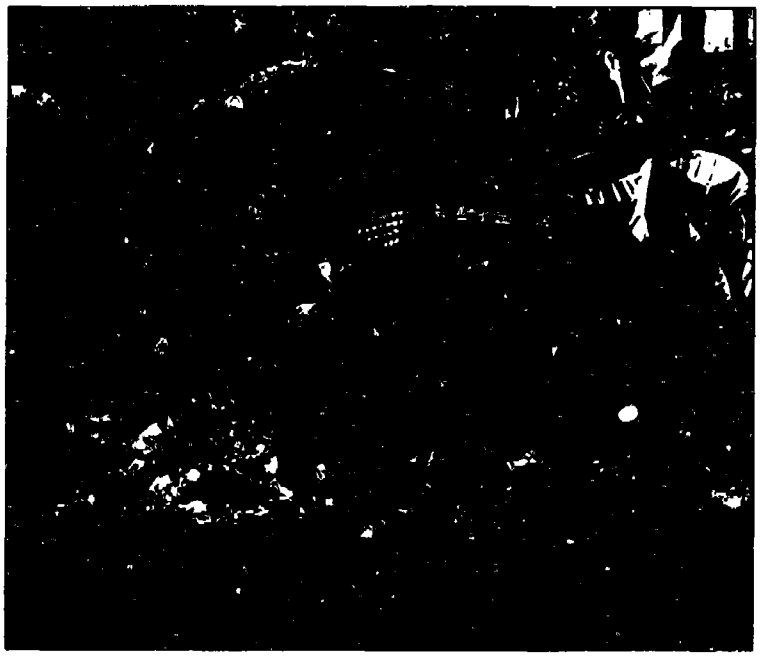
There are four major sources of water pollution in the tropics: sewage effluent and untreated faecal matter, domestic and industrial solid wastes, sullage and industrial waste water and sediment from soil erosion.

Sewage effluent and faeces: Although sewage, if adequately treated and disposed of, poses minimal pollution or health problems, its treatment can require heavy financial investment. Many tropical cities would rather spend their limited funds on something yielding more immediate benefit. Thus, in the urban areas of Malaysia, nine per cent of the population have no sewer facilities at all. Most of these people use pit privies or latrines directly constructed over rivers. Residents of Jakarta have it worse. It was estimated that less than seventy-five per cent of the population of the Indonesian capital city were being served by some form of sanitation facility. However, waste collection with sewers does not mean the waste will receive proper treatment. Maintenance of waste treatment facilities has always been a major problem.

Domestic and industrial solid wastes: Large amounts of garbage floating in rivers are a common sight in the humid tropics. This trash, in addition to polluting the water, constricts the flow of the watercourses. Localized flooding thus can be the result, even for very small rainfall events.

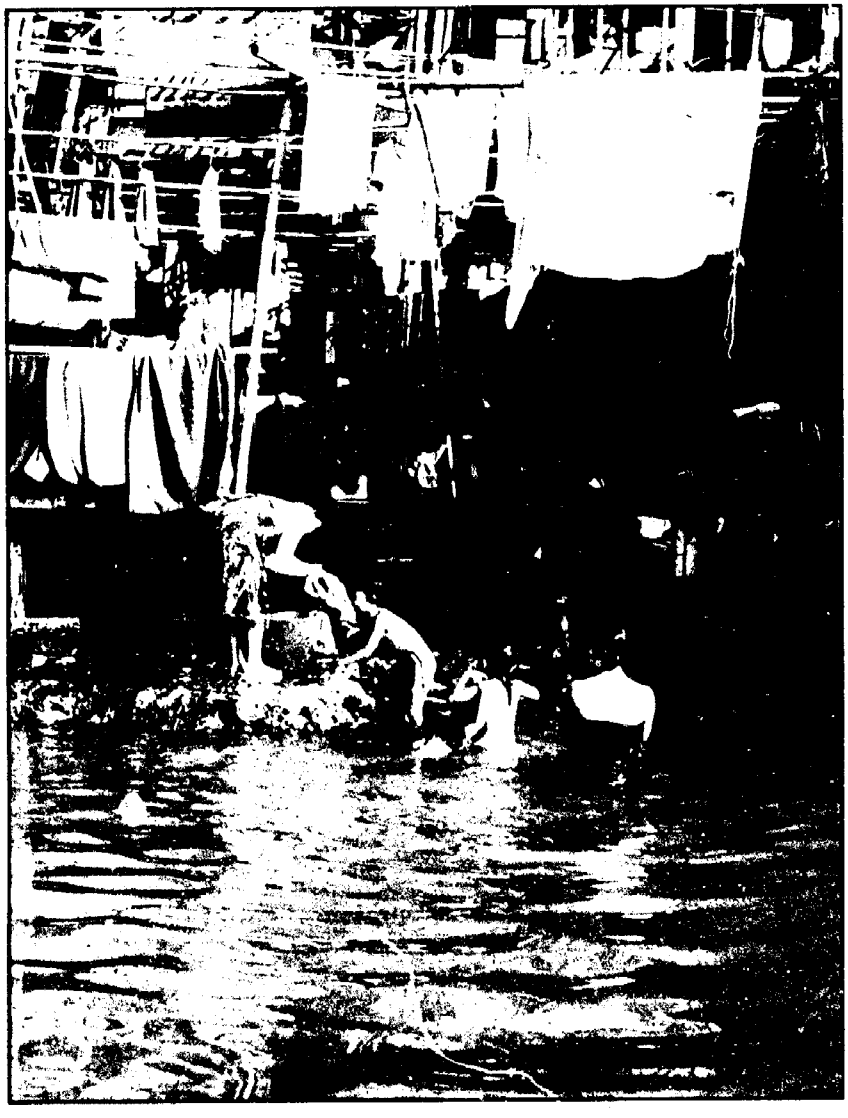
It is known that the solution is the proper disposal of such wastes. However, the sheer volume of the materials hinders such disposal. Metro Manila, for example, recently produced 3,500 tons of trash daily. While most of these wastes were disposed of at a large dump site, some 400 tons were estimated to be ending up in the Pasig, San Juan and Paranaque Rivers. These streams flow through the most densely populated areas of Manila. Complicating the problem is the fact that acquiring land for use as dump sites is expensive. Then, too, leachate from the dump sites that can pollute the ground water is another facet of the problem.

Low flows during droughts can also cause problems as the water velocities will be too slow to transport the wastes.

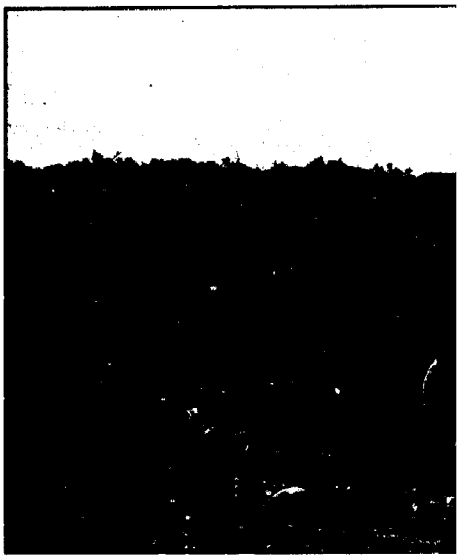


"In the survey of . . . the 'pirate' subdivisions . . . it was found that more than half of them lacked sewers, more than a third of them lacked water and electricity and a fifth of them were without water, sewers, electricity, streets, or pavements."
(World Health Organization, 1988)

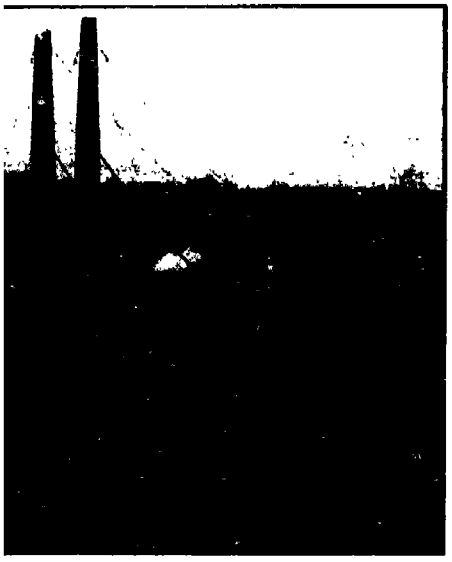
Sullage and industrial waste water: The waste water from household kitchens and laundries (sullage) often contains significant amounts of phosphates and oils, making it a significant source of water pollution. Many industries are also polluting the very rivers from which they abstract water for their own use. In Malaysia, for example, even though legislation existed that required industries to treat their wastes, the regulations were never complied with in the early 1970s when industrialization was gathering momentum. It was only in early 1980s, when the Malaysian government imposed stringent rules and severe penalties, that the factories started treating their wastes. In another example from South-East Asia, Malaban, north of Manila in the Philippines, once was a small, quiet city. But after the end of World War II, it was hit by an influx of industries, ranging from beer and soy sauce plants to paper product factories. These industries began discharging effluents into the clear-running Tenejeros River. Unfortunately, these wastes devastated the fishing industries along the river which had been in continuous productive operation for at least 200 years. Bitter complaints, feuds and legal actions between the fishermen, govern-



Water pollution can result from human contact, industrial effluents and contaminants, and sediment loosened by construction activities.



"In West Africa there is, in general, no sewage treatment, with raw sewage often being discharged directly into estuaries and lagoons very close to cities. As a result, the discharge of municipal sewage constitutes the main pollution load in all countries of the region. As a consequence, human health is threatened." (Linden, 1990a)



mental agencies and factory owners were the result.

The disposal of toxic wastes from industries has contributed to high levels of heavy metals, such as mercury, in some tropical river systems and in the bays where the rivers meet the sea. More information on the unique problems of tropical cities located along coastlines is given later.

The rubber and oil palm industries, common to many tropical countries, can be simultaneous major money earners and significant polluters of streams. In 1990, palm oil mills in Malaysia produced a total of 42,000 tonnes (metric tons) of palm oil mill effluent per day. A substantial amount of that effluent was discharged into Malaysian rivers.

Thailand also is plagued with the same kind of problem. In Bangkok and the adjacent province of Santprakarn, the amount of oxygen in tributaries of the Chao Phraya River is too low for healthy aquatic life. Factories located upstream and downstream from Bangkok are considered to be responsible for more than forty per cent of the wastes discharged into the Chao Phraya.

Large industrial complexes—which often use large volumes of water in their processes—may utilize lagoons and oxidation ponds to handle and concentrate their plant effluents. However, these lagoons and ponds can have considerable impact on the quality of the local ground water, especially in relation to nitrogen and organic compounds. If these ponds are not effectively sealed, they can contaminate the aquifers. But if properly maintained, they are effective and are commonly used.

Atmospheric deposition (falling dust) can be another source of solid wastes in urban areas. Dust coming from factories, construction projects, excavation sites, nearby agricuitural operations and from vehicles can add up to a sizable quantity. The cars and trucks also produce leaked fuels, lubricants and coolants; particulate exhaust emissions; dirt, rust and decomposed paint and vehicle components broken by vibration or impact. Such material can contribute substantially to the presence of hydrocarbons and toxic metals in tropical water supplies

Sediment and other upstream-downstream problems: It is well-known that locating a water intake below a source of pollution—such as disturbed forests and/or agricultural land, or municipal/industrial waste discharge pipes—is not a good way of doing things. However, many tropical cities have little choice in the matter. In many river basins, the urban enclaves receive the brunt of the water quality problems because of their downstream locations. Agricultural enterprises and industrial plants located upstream or over an aquifer tapped by the city can supply loosened soil, chemicals, pesticides and heavy metals. Various problems of water quality have arisen in Jakarta, Indonesia, for example, where the raw water intake structure is located downstream from domestic, agricultural and industrial waste water discharge pipes. These waste waters are harming the potability of Jakarta's water.

A major issue in tropical cities is the slow rate at which most are developing their water resources. The sheer size of most of these urban giants has a lot to do with this tardiness. For example, Bogota, Colombia, which is reported to spread over 300 square kilometers, has a chronic problem of water shortages during the dry season. This shortfall is caused not so much by a lack of rain but by very high

water losses induced by the distribution of water over such a wide area. Leakages and illegal connections have led to the losses.

Unauthorized tapping of water and leakage in the urban centres are also rampant elsewhere. In Jakarta, the "losses" in 1983 were over half of the total water produced. Across the Indian Ocean, in Dar es Salaam, Tanzania, there reportedly is considerable wastage of water in the city's distribution system due to failed valves and broken pipes. However, it is difficult to precisely estimate the water loss. It is thought to be more than a third of the amount originally produced. The lack of metering and low pricing also may be encouraging some people to consume excessive amounts of the city's water supply.

High-priced and questionable in quality

Many inhabitants of tropical cities have to rely on vendors who sell water of often doubtful quality at prices that can exceed by ten times or more the amounts paid by higher income groups in the same cities for piped water.

The rate of water resources development in the humid tropics also is very slow compared to the developed countries. While technological know-how is not a constraint at present, investment in tropical urban water supply projects is relatively low. In many of the equatorial belt countries, such investments hardly constitute 5 to 10% of their gross national expenditures. The expenditures for maintenance of their completed supply facilities are equally minimal.

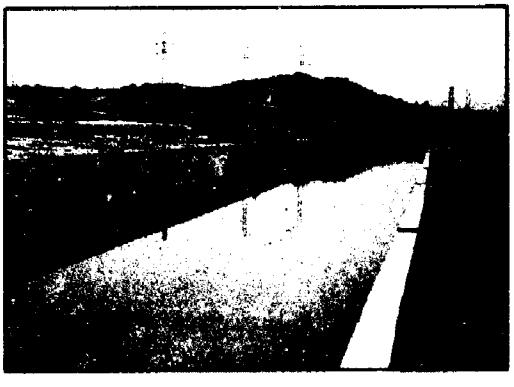
In addition, any planning that is done is often *ad hoc* in nature. As long as there is no long-term planning, their supply will not catch up with their demands. A rough estimate shows that the present population of the developing countries barely receives 150 liters per person per day compared to 250 to 300 liters in the developed countries.

This disparity appears to be widening. In Bombay, for example, it was estimated that in 1986, each person received 129 liters. That amount has since shrunk. The phenomenal growth of Bombay's population is the reason.

There are some residents of the Indian city who fare even worse. These are the squatters who share a common standpipe. Many of these people receive around 50 liters each daily. Some have water available for less than three hours each day. Projects to increase Bombay's water supply include the impoundment of the upper Vaitarna River while other less conventional methods, such as desalination and recycling of waste waters are also being planned.

Water from vendors can often be polluted with disease-causing organisms as well as be costlier than municipally-delivered water

Above, an ineffective effort at controlling riverbank erosion through the placement of logs.



At right, a large drainage canal constructed to alleviate storm-caused flooding in Malaysia.

5

COASTAL CITIES: their special problems

The water-related problems of a tropical city may be magnified if it has been built on a river's flood plain that is near a coastline. Sedimentation from the higher lands, subsidence from aquifer pumping and severe weather may combine to make life there often unpleasant and sometimes, very hazardous. Many of the cities of the tropics already are located on such unfriendly ground, with this demographic trend expected to continue. One forecast has three-quarters of the world's population living on a sixty kilometer-wide strip along the shores of the continents by the year 2000. Sixty-five per cent of the cities of South-East Asia are already located on coastal flood plains.

Flood plains popular but dangerous

It has been estimated that at least seventy-five per cent of the flood plains of the tropical region have been settled upon. Farms, towns, suburbs and cities occupy this flatter ground, thus increasing the damage from floods or sedimentation. If this trend continues, there will be more buildings to be damaged and more lives to be lost. The devastation of the April 1991 monsoonal storms over Bangladesh should serve as a tragic, long-term reminder of what can happen when people occupy low-lying flood plains. Unfortunately, in many cases, people have no options to resettle elsewhere. Moreover, the flood plains are fertile, allowing a livelihood to be made from the land.

The possibility of a rise in sea-level accompanying a projected global warming requires reconsideration of the land-use policies of coastal cities. Enormous costs will have to be incurred, either by the losses from increased flood damage or through the construction of expensive protective structures, should the sea-level rise take place as predicted.

With the exception of Singapore, all urban centres in the flood plains of the humid areas of South-East Asia are beset with water-related pollution problems. Bangkok, situated at the head of the Gulf of Thailand, seems to have more than its share with potable water shortages, land subsidence from overpumping and aquifer contamination from pollution. Its water supply problem is compounded by the fact that the city is located at the downstream end of the Chao Phraya River but its water intake is upstream in the headwater region where high variability in rainfall is experienced.

Moreover, much of the Chao Phraya's water is diverted above Bangkok for irrigation, with the return flow being highly contaminated

". . . it has been estimated that about one million tons per year of untreated sewage and industrial effluents are released into the Indian Ocean each year from these three cities alone." [Bombay, Madras,and Calcutta] (Linden, 1990a)

by pesticide and fertilizer residue. It cannot be used for drinking purposes unless it is heavily treated. As a result, up to thirty per cent of Bangkok's daily water demands are being met by ground-water withdrawals.

This pumping has caused considerable portions of the city to sink. With many areas being only a metre and a half above mean sea-level, they are very susceptible to flooding. Another associated problem with which the Bangkok authorities must wrestle is the intrusion of saline water from the nearby Gulf into the aquifers. Because of this intrusion, wells are being drilled deeper and deeper into the fresh water aquifers. This pumping allows the saline water to intrude farther and farther. However, pumping has been restricted, reducing the rate of subsidence. In the last decade, the Asian city also has resorted to an inter-basin transfer of water from the hilly Kanchanaburi Province, west of Bangkok.

Public health hazards

The discharge of untreated or inadequately processed wastes along coastlines has caused eutrophication of the water, with consequent oxygen depletion, algal blooms, "red tides" and outbreaks of stinging jelly-fish. Microbial pollution, related to the release of sewage, also is regarded as a public health threat along most tropical coasts. Since significant upwelling of nutrient-rich currents—as takes place off the northwestern coast of South America—is rather uncommon in tropical areas of the world's oceans, this magnifies the importance of their coasts. The mangrove forests, seagrass beds, coral reefs, estuaries and coastal lagoons to be found in these shallow coastal regions are noted for their marine productivity, including fish production. It should be noted that with the high human population levels along the coasts, urban dependence upon the protein provided through fisheries is usually high.

As one example, some coastal bays of the Philippines have been suffering from an uncontrolled growth of phytoplankton from the abundant organic wastes. The entire 90,000 hectares of Manila Bay—formerly rich fishing grounds—have been affected. Authorities have prohibited the eating of shellfish and other marine products harvested from the area during the "red tide" phenomena. This prohibition has caused considerable hardship to many fishermen

Rivers, while serving admirably as transportation arteries, also can devastate riverbank communities when heavy rains upstream raise the water level above the low banks.

Ocean and estuary fishing operations, the source of large amounts of protein for tropical residents, can be seriously hurt by sewage discharges from coastal city outfalls. Some aquaculture operations, such as shown here, also can be pollution sources.

"The bays of Havana and Cienfuegos in Cuba receive huge quantities of mainly untreated industrial effluents . . .These cause anoxic conditions, particularly during the summer." (Linden, 1990b)

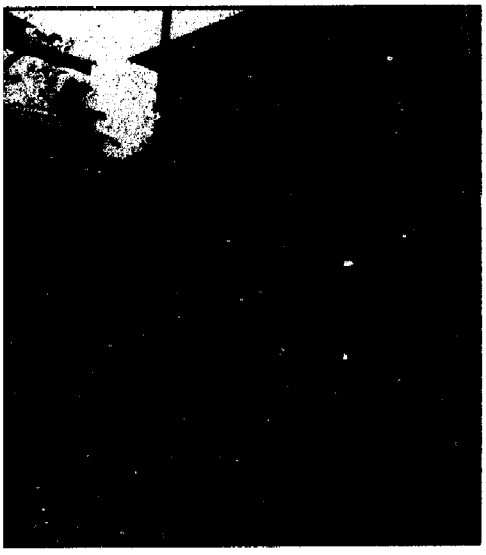
while removing an important source of cheap protein from the diets of many Manila residents.

However, the shallow coastal bays of the tropics often attract development because they offer protected ship anchorages and the adjacent land is often flat and easy to build on. As a result, many such bays are heavily polluted by industrial wastes. In addition, the coastal lagoons and shores inland from the barrier beaches are often the sites of cities, with their sewage often being discharged into the lagoons. The outfalls are more easily constructed in the relatively calm and shallow waters.

High numbers of faecal coliforms have been detected in the African coastal waters off Dakar and in the Volta River estuary. As a consequence, infectious hepatitis, dysentery, polio, typhoid and cholera are common in those areas. Westward across the Atlantic Ocean, the bays of Havana and Cienfuegos, located on Cuba's northern and southern coasts, respectively, receive huge quantities of mostly untreated effluents from many industries. These discharges cause anoxic conditions, particularly during the summer. Colombia's Bay of Cartagena is polluted with effluents from a refinery and petrochemical, fertilizer, food processing and chlor-alkali industries. The presence of heavy metals, such as mercury, in the waters of the Bay is especially worrisome. It has been reported that contamination with petroleum hydrocarbons is typical of many areas in the Caribbean.

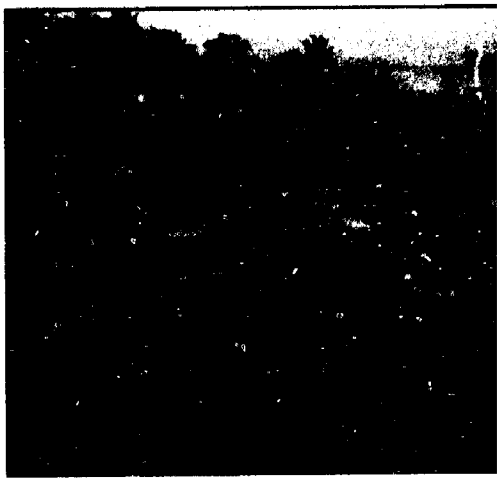
Pollution from urban sewage also has become noticeable over large areas of the coastal waters of the Indo-Pakistani subcontinent, with the main pollution coming from Bombay, Madras and Calcutta. These three metropolitan areas in India are estimated to be releasing about one million tons per year of untreated sewage and industrial effluents into the Indian Ocean. Oxygen concentrations in the nearshore areas off Bombay are around zero, with similar conditions prevailing in the lower Ganges estuary as a result of the release of waste water from Calcutta. It has been further calculated that the Gulf of Thailand receives over 300 tons of Biological Oxygen Demand (BOD) per day from the sewage flowing from the greater Bangkok area.

Most water-based economies and cultures find it difficult not to use the same medium for waste disposal.



Many tropical residents have become ill from fish and shellfish poisoning and while there may be as yet no direct proof of the relationship, the problems are of recent origin, which coincide with the pollutant discharges. Also, when one considers that over half of the people in the developing countries may be obtaining a very high percentage of their animal protein from their surrounding seas, it is obvious that losing these food sources to pollution would be an economic and human catastrophe. One observer has estimated that the loss of marine productivity in tropical and subtropical oceans could mean the difference between life and death for hundreds of millions of people (Linden, 1990b).

SOLUTIONS: technical and non-technical



Most national and local authorities in the tropical countries have not kept pace with the demands imposed by their cities' rapid growth. Their administrative arrangements have not been integrated into efficient and cohesive water and waste management system. Their policies, plans and projects are usually dictated by several agencies largely independent of each other. The primary agency responsible for water resources management often is constrained by its financial and manpower resources, with these amounts very often being determined by other central agencies. Thus, the vital multi-agency support needed to obtain the necessary funds for effective water resources project implementation can be missing.

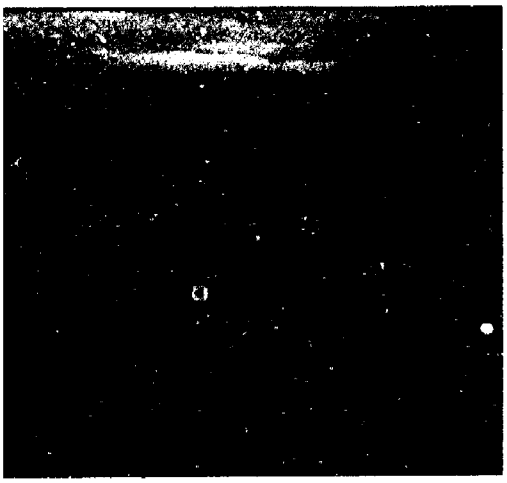
Technical solutions which have been proposed

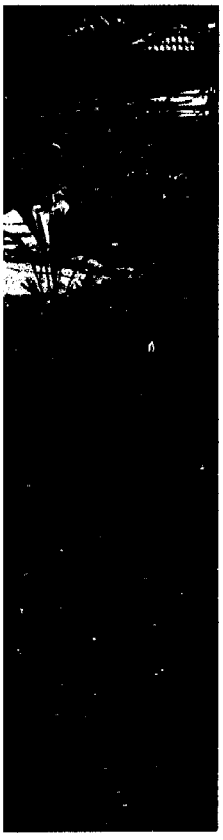
There is no shortage of remedies which have been proposed for solving or ameliorating many of these tropical water-related problems: more and deeper wells, piped distribution systems, garbage collection service, sewers, more treatment plants, desalination, waste water re-use, aquifer recharge, importation, etc. Many of these techniques have been used elsewhere, especially in the developed countries.

However, while the developing countries of the humid tropics might wish to aim for the standards they have seen in the highly-industrialized countries, those expectations are more often than not counteracted by the reality of the former's limited funds. As a result, many cities have taken no steps at all toward improving their sanitation. Nevertheless, their number one priority, from an overall health standpoint, should be effective excreta disposal programmes. That objective, depending upon the situation, can be achieved by sanitation technologies that can be considerably less costly than the developed world's water-borne sewage method. These systems are used throughout the world. However, the use of water-borne sewage systems is often the goal of most large cities of the tropics. Thus without the funds to implement the more expensive systems, the provision of a sewage treatment system lags considerably behind the growth of the population.

Biological processes suitable for tropics

However, the climatic conditions of the tropics are favorable for the full use of less expensive biological processes such as photosynthetic oxygenation, biochemical flocculation of polyaromatic compounds and biofiltration by zooplankton or zoobenthos.





Numerous solutions have been proposed for tropical water-related problems, including higher river levees and flood warning systems, along with improved public latrines and laundry facilities. Implementation of these and other solutions are hindered by a lack of funds and a failure to pursue them in an integrated manner.

Stabilization ponds are normally considered to be the most economic method for purification of tropical waste waters. In the case of concentrated industrial wastes, a combination of anaerobic reactors or high-rate biofiltration with stabilization ponds as the intermediate or final stages should be considered.

Flood and drainage alleviation

There are many technical options that can be exercised to alleviate a tropical city's flood and drainage problems. They include upstream storage reservoirs, flood plain clearance, river modifications and levees, retention basins, diversion channels, conversion of low-lying urban areas into polders, flood pumping stations, storm drains/sewers, and even the construction of streets to serve as drainageways. The option which is the most appropriate to the local economic and physical situation should be chosen.

Desbordes & Servat (1988) have suggested that good solutions must not induce strong constraints for the users, they must be easily and quickly constructed so that they may be quickly adapted to a changing socio-economic environment, they must not induce new problems and/or nuisances, especially in the sanitary domain , and they must not require the importation of costly materials or equipment, but rather they should lead to local economic development if possible.

In the case of flood protection, the building of dams in the upper reaches of a river, accompanied by levees along the river's banks in the vicinity of the urban area, is an option. This is the structural approach which has been followed throughout most of history. This method, however, can be very expensive. Dams and levees are proving to be more and more out of the financial reach of all but the most wealthy of nations.

Dams and levees not infallible

Furthermore, the structural approach can never guarantee the complete elimination of floods, as many communities have learned to their great sorrow when these protective works have failed. The design of these structures is, after all, based upon hydrologic data that in almost no case is to the total satisfaction of the design engineer. The design also may be dominated by the local economics. What level of protection can the city or region afford to buy is always the "bottom line" question.

Another option, which falls somewhere between the structural and non-structural, calls for keeping the flood-prone area free of all buildings and turning them into "greenbelts." The latter can form excellent recreational areas and when connected, a network of open space is maintained through which the flood waters can pass with a minimum of damage to the urbanized area.

Deciding which option to choose is not altogether straightforward from a "cost" point of view. One must be able to put a value on such aspects as reduced inconvenience, improved aesthetics and an increased sense of security.

Closely allied with the thinking that led to the "greenbelt approach" to flood damage control is the call for the utilization of other non-technical remedies. Better management, training, planning, public education, more political support and debt amelioration for the developing countries are among the newer approaches.

An integrated approach to urban management

A water policy for urban water management should not try to isolate the water sector from other urban sectors. Integrated water man-

agernent policies are required. In that respect, the need for reliable information on the various related aspects are required. But it also requires solid hydrologic data. The development of a water supply, for example, must consider total waste disposal (present practice and otherwise), surface drainage as well as other issues of an environmental nature. It is critical that the right sort of information be obtained when planning for water projects begins.

Management carried out with little or no information

In all too many urbanized areas of the humid tropics, however, management of the water and sanitation systems is now being carried out with little and/or poor (sometimes even no) information. This is particularly the case in those areas where ground water so often forms a major part of the useable resource.

Water management strategies will require structural changes in water pricing among other things, to relect more the private market mechanism. Unless this is done the chances are slim for a major change, at least from a financial point of view.

Whether or not the urban water problems will be solved, then, depends as much upon the existing social and economic situations (the willingness to do something about the condition) as they do upon the availability of affordable technical means. Lack of skilled or dedicated experts is not always the problem; but it does depend upon personnel that are able to look at the problems and offer solutions within a social and environmental context.

As pointed out by Nickum & Easter (1989), the perceived cost of enforcement of environmental regulations may also often exceed the apparent benefits to be received. Thus, in the case of industrial facilities, at least, there may be little incentive to enforce the rules. They note that different "tools" can provide different levels of compliance. Whereas an outright ban, with severe penalties, may act as a forceful deterrent to the pollution situation, it may also be a deterrent to the sharing of information by those who might violate the rules. On the other hand, standards without significant penalties will encourage the sharing of information, but will not be particularly effective in ensuring compliance. The different policy options have varying strengths and weaknesses, and the option chosen may very well depend upon the transaction costs involved in enforcement, obtaining the desired information and monitoring the situations.

Escalation of water-related problems probable

The financial gains from development are often too attractive to be superseded by anti-pollution legislation. The social and environmental problems are made even more difficult to control as a result of generally low literacy levels, lack of media coverage and a general lack of community participation in discussions of possible solutions. It is, therefore, an unfortunate conclusion that, given the rapid pace of urbanization, and the industrial and economic development being urged in these countries, with all too rare exceptions, the urban water problems will probably escalate rather than attenuate in the near future.

Communal standpipes are preferable to river and canal banks but still present the possibility of being disease-spreading points.

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The International Hydrological Programme

The developing nations of the humid tropics of the world will represent about one-third of the Earth's population by the end of the present decade. In the Twenty-first Century, these nations will pass the developed countries in numbers of people. Such a population shift will alter existing international economic and geopolitical relationships.

With this major change looming on the horizon, coupled with the need to treat the tropical resources wisely, the United Nations Educational, Scientific and Cultural Organization, (UNESCO) and the United Nations Environment Programme (UNEP) joined with 22 other organizations in July 1989 to hold the International Colloquium on the Development of Hydrologic and Water Management Strategies in the Humid Tropics. The International Hydrological Programme of UNESCO was the lead organization.

The Colloquium developed strong evidence that the present situation, including the question of tropical forest depletion, was not only in need of serious consideration, but that the potential for vastly increased negative human impacts will be quite significant if they are not adequately considered now. It was noted that although the general characteristic of the humid tropics is an overabundance of water, this very abundance and the variability of its distribution is one of the leading contributors to the difficulties.

This volume on the water-related problems of tropical cities is one of several publications having their origin in the Colloquium. An executive summary of the Colloquium, *Water-Related Issues and Problems of the Humid Tropics and Other Warm Humid Regions*, was released shortly after the Colloquium was held at James Cook University. *The Disappearing Tropical Forests* was made available for distribution in May 1991. Similiar volumes on tropical islands and water and health were issued in 1992. A major scientific text embodying many of the topics raised at the Colloquium also is being prepared

Further information on these publications can be obtained from the International Hydrological Programme, Water Sciences Division, UNESCO, 1 rue Miollis, 75732 Paris Cedex, France.

"And, sure, the reverent eye
must see
A Purpose in Liquidity ."
Rupert Brooke

MAB programme activities in the humid tropics

Improving the scientific understanding of natural and social processes relating to human interactions with the environment, providing information useful to decision-making on resource use, promoting the conservation of genetic diversity as an integral part of land management, enlisting and co-ordinating the efforts of scientists, policy-makers and local people on problem-solving ventures, mobilizing resources for field activities and strengthening of regional cooperative frameworks. These are some of the generic characteristics of the

"The philosophy of integrated water management—looking at the urban water situation as a whole—needs to be better understood"

Man and the Biosphere Programme—one of the sister environmental programmes of IHP within UNESCO.

MAB, launched in the early 1970s, is a nationally-based, international programme of research, training, demonstration and information diffusion. The overall aim is to contribute to providing the scientific basis and trained personnel needed to deal with problems of rational utilization and conservation of resources and resource systems, along with the problems of human settlements.

MAB activities are undertaken in cooperation with a range of other international programmes and organizations. IHP-MAB linkages include joint sponsorship of collaborative field research and training initiatives, such as the role of land-inland water ecotones and their role in landscape management and restoration. Associative links between IHP and MAB are also reflected in synthesis reviews and publications such as this one within the IHP Humid Tropics Programme Series. Other collaborative initiatives between MAB and IHP concern work on eutrophication and its practical control in lakes and reservoirs, the special water problems of the cities, water awareness in planning and decision-making, and water and nutrient balances of tropical rain forest ecosystems subject to disturbance.

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