CHAPTER 17

Urban and industrial watersheds and ecological sanitation: two sustainable strategies for on-site urban water management

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ABSTRACT: Many of the water crises in urban areas are based not so much on the availability of water but rather on our failure to manage how water is used. This is due to the failure to recognize stormwater as a water source and using water to transport unwanted wastes. Wastewater recycling is an important part of an integrated water strategy – but not the final answer. That integrated strategy includes stormwater collection, source separation, wastewater and graywater recycling for potable and non-potable use, and advanced conservation.

Keywords: *Integrated water planning strategy, stormwater, ecological sanitation, wastewater, watershed, recycling, reuse, conservation*

1 INTRODUCTION

> "Problems cannot be solved at the same level of awareness that created them".
> (Albert Einstein)

1.1 *The urban dilemma*

As the world's population increases, migrates to coastal areas and builds new cities, urban planners are confronted with insufficient supplies of fresh water to meet the increasing demands. As a consequence, supply augmentation, water demand management practices, and water recycling are expected to supplement the gap between available supply and new demand. The problem is not limited to arid zones. It is a function of population explosions and the inability to manage demand. "Even in water-rich countries such as Canada, lack of quality control for drinking water has led to death and illness in several communities, and some provinces suffer chronic shortages of water for agriculture; and almost everywhere capital costs for infrastructures to supply and remove water are growing" (Brooks, 2003).

Much of the water crises in urban areas are based not so much on the availability of water but rather on our failure to manage how it is used. Both the failure of urban planners to recognize stormwater as a resource and the continued use of water to transport unwanted wastes are at the root of the problem.

1.2 *Problems with the current approach*

Addressing urban water supplies is quickly becoming a high-priority challenge. The United Nations Population Fund estimates that by 2025, 61% of the world's population of 8000 million will live in cities (United Nations, 2004), creating population densities throughout the world heretofore unseen.

The problem is exacerbated as urban development follows the western model of big pipes bringing fresh water from long distances and then treating influent wastewater and discharging into receiving waters. Or, it flows to sophisticated expensive recycling treatment plants and then distributed through more big pipes to where the water was wasted in the first place.

Continuing this model, urban planners will have to seek:

– New supplies from other aquifers and surface waters (yet these resources are already overtaxed in many areas and may rob water from outlying areas and agriculture).
– Desalinization (very energy intensive).
– Wastewater recycling (energy and infrastructure intensive).

It is clear that wastewater recycling will be a necessary strategy in the years ahead. However, it is only one component of an ecological and integrated strategy that makes best use of local sites as well as local sources of water and local effluents that can be reused.

Continuing to combine wastes, including excreta, toxics, and heavy metals, in wastewater flows, then turning to advanced ultra-filtration at the end of the pipe will not be feasible for many cities, especially those in developing countries.

To identify water recycling as the best solution to the world's water supply challenges is to use the same mentality that created today's many water problems.

The practice of centrally collecting combined effluents from a wide variety of sources containing many constituents, and then treating it with end-of-pipe solutions has evolved in an effort to avoid the complexity of using many smaller, more local and effluent-specific strategies. Yet nature's model shows us that complexity is the best way to manage resources.

For this reason, urban wastewater recycling can only be viewed as an important part of a much larger picture of integrated water planning. Such a strategy, which decentralizes water collection, use and treatment, nevertheless still benefits from central management. Also, in contrast to the *big pipe* approach, this strategy requires us to heed the tenet *start at the source*. By first seeking more local opportunities – both on the site of the water use and wastewater discharge and according to what exactly is discharged – we may find ecological and low-entropy possibilities for reducing water demand and treating effluents in more ecologically effective ways. We will call this integrated source- and site-based water planning.

1.2.1 *Untapped water sources*

One aspect of integrated source – and site-based water planning is identifying all of the water sources available to a particular site of water use.

Consider the following example: on average, New York City receives about 937 Mm^3/yr (246,500 million gal/yr) of stormwater, or 2.57 Mm^3 (675 million gal) per averaged day (New York City has 836.1 km^2 of land area and receives 122.6 mm/yr of total precipitation). While some is lost through evaporation, most is piped away into the adjacent rivers and out to sea.

New York City uses about 4.16 Mm^3/d (1100 million gal/d). According to the New York City Water Department, the city saved 1.5 Mm^3 (400 million gal) of water by replacing 1.3

million old water-wasting toilets, installing locks on fire hydrants in neighborhoods throughout the five boroughs, and implementing a leak detection program to inspect underground water mains for leaks.

Therefore, if the stormwater had been collected, it would have satisfied 61.4% of the current demand. Using the current price: US$ 1.39 per m^3 (3.94 per 100 ft^3) (New York City Water Department) for water service, the value of the stormwater is US$ 3.56 million per day or US$ 1300 million per year.

Stormwater could satisfy 100% of the demand if: (1) demand is reduced by an additional 22% by continued conservation; and (2) recycled wastewater supplied 20% of the demand.

Yet the city draws its water from various watersheds in distant mountains, requiring miles of pipes and straining the communities along the watershed. New York City might instead look to capturing this stormwater, using some of the thousands of millions of dollars spent for collection and distribution pipe to fund cisterns, rooftop collection, and simple rainwater treatment to augment water supply.

1.3 *Recycled wastewater*

While recycling wastewater is an important step in the conservation of fresh water, it is technologically complex, expensive, and unacceptable to many communities, such as San Diego, California, according to the USA-based WateReuse Association (Web Page). In addition, there is a growing concern for the impacts of recycled water on valuable aquifers due to contamination by constituents that are currently not monitored by groundwater discharge permits. According to the California Department of Health Services (Web Page), these aquifer anti-degradation concerns are reported as action levels. Action levels are health-based advisory levels for chemicals in drinking water that lack maximum contaminant levels (MCLs).

1.4 *The QWERTY syndrome*

We humans have a curious tendency to continue old practices into the future long after the need for such practices has passed. Take the example of typing keyboards. The upper left row of letters begins with the letters *QWERTY*. This arrangement was developed in 1872 to slow down typists; otherwise the keys would jam on the early mechanical typewriters. We no longer have mechanical typewriters, yet we continue to use the old keyboard configurations to this day. It may be that this *QWERTY syndrome* is the root cause of some of today's most fundamental water management problems.

There are two *QWERTY*-related water issues that will be the focus of this paper:

– *Urban and industrial stormwater management attitudes*: we must reverse the attitude that stormwater in an urban and industrial setting is not a resource, but rather a problem due to flooding and so we must quickly pipe it away.
– *Historical linkage of water and sanitation*: one of the main impediments to sustainable water management is the historic linkage of water and sanitation. We must uncouple water from sanitation as much as possible or forever be trapped in flushing away unwanted residuals, valuable nutrients (found in urine), and pathogens with large volumes of water. An example is New York City's expensive flush. As of the 2000 census, the population of New York City was 8.1 million. Assuming that the average person flushes a toilet 5.1 times per day (Vickers, 2001) and that the average water use per flush is 11.36 L (3 gal), then New York

City flushes about 0.47 Mm^3 (123.75 million gal) worth US$ 0.65 million of drinking water into the sewers every day.

1.4.1 *The fundamental problem*

Essentially, we are using a valuable resource – drinking water treated and delivered at significant expense – to dilute and dispose of another potentially valuable resource, human excreta. To this we add industrial and household chemicals and stormwater drainage. Then we pay a very high cost to transport this combined effluent to a facility which attempts to separate all of those constituents, clean them to a degree mandated by national law, and discharge the remaining water back into the environment – usually rivers, oceans, and the ground. In most cases, the same nutrients and toxic chemicals that went into the wastewater mix are still present in what leaves the treatment plant. Growing realization of the effects of this is prompting regulators to mandate further treatment – and that is making this *combine-dilute-treat-and-dispose* approach very expensive.

However, even with ever-tightening requirements for advanced wastewater treatment, many of the world's waterways do not meet the goals of swimmable and fishable quality set by the USA 1972 *Clean Water Act* nor the United Nation's *Agenda 21* (Brooks, 2003). And, while much progress has been made over the last 32 years, there are many who ask if there might not be a better way.

Every year we are learning more about the longer-term effects of partial treatment and disposal, our present approach to cleaning wastewater. In USA, the 1972 *Clean Water Act* only required the reduction of suspended solids, biological oxygen demand and fecal coliform bacteria to protect lakes and rivers. But now, responsible regulators worldwide are mandating the removal of nutrients, toxic chemicals, parasites, viruses, radioactive wastes and other constituents. At the same time, planners are asking: in a world where drinking water is increasingly expensive and scarce, can we use this valuable resource for flushing toilets?

It is clear that better ways are needed; the good news is that many are here and more are emerging. However, the answer is not merely a matter of more clean-up at the end of the sewage pipe. A larger, more strategic solution is called for based on a broad approach:

- Advanced water conservation.
- Collect and store stormwater.
- On-site wastewater treatment.
- Recycling.

2 BETTER WAYS EMERGING: FROM DISPOSAL TO UTILIZATION

More regulations requiring better treatment, and increasing costs for water and wastewater treatment are prompting a reframing of the wastewater issue. In the current system, we create *wastes* that we want *disposed of*. A better strategy is to put these outputs to use, just as they are in nature's model. In balanced ecosystems there is no waste: the outputs of one organism are the inputs of another.

The solution to both of these problems is the development of a new ecological paradigm for integrated water management. To accomplish this integration we must investigate the new initiatives that address these issues. Key initiatives can be summarized as urban and industrial watersheds and ecological sanitation.

2.1 *Urban and industrial watersheds*

The ecological engineering approach for water management presented in this report will not only demonstrate environmental sustainability for the 21st century, but will also be testaments to these visions. The principles of industrial ecological and sustainable development do not preclude economic development or manufacturing efficiency. Rather, recycling, reuse and conservation result in reduced dependence on scarce resources, higher efficiency in manufacturing processes, and long-term cost savings.

Terrestrial life efficiently self-organizes around water and the mineral-rich landforms through which water flows. The ecosystem that best describes life and all related activities within the water and landform context is a *watershed*. A natural watershed synthesizes inputs of rainwater, solar energy and minerals from within its physical, chemical, and biotic communities to produce an array of nutrients, raw materials and products that sustains a certain quality of life for all its inhabitants. Concerning society's welfare, almost all essential landscape functions (i.e. fertile soil regeneration, climate stabilization, etc.) for are connected to water ecology. In the same way, the industrial watershed is defined by its rainwater, wastewater and process water flows and its interaction with the surrounding watershed.

2.1.1 *Ford Motor Company Rouge Facility as an Industrial Watershed (Del Porto & The Ecological Engineering Group, 2001)*

According to *Environment Canada* (Web Page), "an automobile coming off the assembly line, for example, will have used at least 80,000–120,000 L (21,000–32,000 gal) of water to produce its ton of steel and 40,000 L (10,600 gal) more for the actual fabrication process. Many thousands more liters of water are involved in the manufacture of its plastic, glass, fabric components".

The Ford Rouge Plant in Dearborn, Michigan – with its 243 ha (600 acres) of natural and constructed landforms, inputs of water, energy, minerals, capital, information, and nutrients from its 30,000 employees, and outputs of products that sustain the Dearborn community – is in fact a constructed ecosystem that we will call an *Industrial Watershed*.

2.1.2 *A water economic example*

With increasing prices and competition, water may arise as an important cost factor within the production process. Therefore, new water management strategies, not only in conservation but also in terms of reuse, are needed. Following figures show what the gain of water from the industrial watershed could mean to the production of automobiles.

2.1.3 *Source: stormwater*

About 2 Mm^3/yr (530 million gal/yr) of water falls on the 243 ha (600 acres) Rouge Plant site and discharges to the Rouge River. Average precipitation is 825.5 mm/yr (32.5 inches/yr) based on 30-year average (NRCS/US Department of Agriculture weather data). Increasingly this water is coming under state and federal jurisdiction as stormwater discharge controls are implemented to protect the Rouge River. The federal government, in order to limit pollutants in stormwater discharges from industrial facilities, implemented the National Pollutant Discharge Elimination System (NPDES), Phase I Storm Water Program, which includes an industrial stormwater permitting component. The requirement for a NPDES industrial stormwater permit has added an additional financial component to the Ford water management costs. While the

Michigan counterpart is voluntary, one can predict mandatory compliance will be coming in the near future.

2.1.4 *Application: process water*

General Motors de Mexico (Ramos Arizpe Complex) recently received the *Stockholm Industry Water Award* for demonstrating sustainable water and wastewater treatment and recycling techniques. Using a variety of physical, chemical and biological wastewater treatment processes, the facility was able to recover and reuse 70% of its industrial wastewater. The facility also increased its production seven-fold, while reducing the average amount of well water needed to produce a vehicle from 32 m^3 (8,452 gal) to 2.2 m^3 (581 gal).

The success of General Motors may serve as an incentive and model for other industrial operations that seek to minimize environmental impact while maximizing production and quality of life.

If Ford, using General Motors water usage, would collect 90% of the stormwater that would provide 1.8 Mm^3 (477 million gal) which could be used to make 820,998 vehicles ($477 \times 10^6/581$) without taking any from the Dearborn Water Company. Because the same water can be treated (in respect to its constituents) and reused with about 90% recovery efficiency, another 738,898 automobiles could be made ($429.3 \times 10^6/581$) after treatment. The remaining treated water could be sold back to Ford Steel or the Dearborn Water Department for a profit or used to grow some of the raw materials. Therefore, 1,559,896 vehicles per year could be made with only one recycle pass and still have recycled water to use for other profitable purposes!

2.1.5 *Source: waste water*

In 2001, the price of water service from the Dearborn Water Department via the Detroit Water and Sewer Department was comprised of the cost to treat and deliver potable water from Lake Huron and the Detroit River, as well as the cost of collecting and treating it as wastewater once it has been used (see Detroit News Online, Web Page). According to Dearborn, Michigan's 1999 annual report, the city spent US$ 25.3 million on the city's water distribution and sewage collection systems. Of the total bill, wastewater management is more than 66% of the total. Upgrading the aged infrastructure will cost US$ 5,300 million, which in the short-term will increase the sewage portion of the total bill by 13.7%.

The 2001 unit cost for water of US$ 0.87 per m^3 (US$ 3.30 per 1,000 gal) does not reflect the cost of infrastructure upgrade. Therefore, the unit cost does not reflect all the new marginal costs and will certainly escalate dramatically in the future.

2.2 *Water-wise design through ecological engineering*

The management of the *industrial watershed* to sustain the highest quality of life for the lowest cost of living involves adopting an engineering model that is founded on the ecological paradigm. The transformation of an industrial site into a highly efficient and therefore profitable industrial watershed will require the ecological engineering of all aspects of the facility.

Ecological engineering is predicated on the knowledge that the self-organizing order found in stable ecosystems is so universal that it can be applied as an engineering discipline to solve the pressing problems of global pollution, goods and services production, and efficient resource-utilization, while providing a high quality of life.

When possible, we must recycle, reuse or utilize effluents. Using them strategically, such as for landscape irrigation, flushing toilets, and evaporative cooling, helps save both water supply and wastewater treatment costs – and prevents effluents from becoming pollution.

Just as *reduce, reuse and recycle* has become the *credo* of responsible solid waste management, this five-pronged strategy will become more obvious and important to the world's population than presently can be imagined.

Increasing costs of water and wastewater treatment infrastructure are driving the interest for integrated water management, by viewing urban, domestic, commercial, industrial and agricultural landscapes and hardscapes as watersheds that collect water, use water, and dispose of stormwater and wastewater within larger regional watersheds.

2.3 *Ecological sanitation*

According to the *Deutsche Gesellschaft für Technische Zusammenarbeit* (GTZ, Web Page), "Conventional forms of centralized sanitation are coming under increasing criticism. Especially because of the enormous investment involved, the huge operating and maintenance costs, high water consumption and other drawbacks, they are not suitable as a blanket solution for developing countries, particularly in arid climate zones. Even conventional individual disposal systems, such as latrines and cesspits, make poor alternatives – especially in view of increasing population densities and the substantial groundwater pollution they cause. Moreover, all conventional types of wastewater and sewage disposal systems usually deprive agriculture, and consequently food production, of the valuable nutrients contained in human excrement. A more holistic approach towards sustainable sanitation is offered by the concepts referred to as *ecological sanitation.* The key objective of this approach is not to promote a certain technology, but rather a new philosophy of dealing with what has been regarded as wastewater in the past. The systems of this approach are based on the systematic implementation of a material-flow-oriented recycling process as a holistic alternative to conventional solutions. Ideally, ecological sanitation systems enable the complete recovery of all nutrients from faeces, urine and greywater to the benefit of agriculture, and the minimization of water pollution, while at the same time ensuring that water is used economically and is reused to the greatest possible extent, particularly for irrigation purposes".

2.4 *On-site and waterless sanitation: a component of ecological sanitation*

On-site options include composting toilets and constructed ecosystems for graywater that use up the effluent on site. In a Canadian office building and in a Swedish apartment building, waterless composting system process toilet wastes, while graywater is filtered and used to irrigate the landscapes around the buildings. In homes with on-site *waterless toilet systems* (WTS) in Toronto, Canada and in Massachusetts, graywater is utilized by water-loving plants in planter beds and greenhouses, which are integrated into the homes.

The United States Environmental Protection Agency has found that decentralized waste treatment systems are a viable alternative to centralized systems when analyzing their effectiveness and economics.

WTS (also known as dry, composting and biological toilets and non-liquid saturated systems) are gaining popularity because, among wastewater treatment technologies, they are one of the most direct ways to avoid pollution and conserve water and resources. Most users who install WTS do so simply because they need to have a toilet system where a conventional water-borne system is unavailable or cannot be installed due to environmental constraints.

Long used by developing countries, parks, subsistence homeowners, and vacation cottage owners around the world, WTS are now making their way into mainstream year-round homes in North America, for many reasons:

– Micro-flush (one pint or less) toilets are increasingly used with WTS, making these systems more socially acceptable.
– Graywater (wash water) systems are increasingly permitted by public health officials.
– Service contracts are available for maintaining WTSs.
– Water shortages threaten at least one-third of the world. Some estimates place it at one-half.
– Many states are tightening on-site wastewater system standards, so that many of the USA's millions of septic systems are now considered inadequate, and therefore in noncompliance. As a result, many property owners are seeking ways to supplement their septic systems, so they can avoid installing new ones. Diverting excrement and flush water from the flow removes more than 90% of the pollution, leaving only graywater to manage.
– Population densities are increasing in cities and coastal areas, intensifying the challenge of managing human waste.
– Owners are converting vacation homes into year-round residences. These homes are often in remote and environmentally sensitive natural areas, such as seacoasts, lakes and mountains, with limited capacity for wastewater disposal.
– Individuals and institutions are increasingly interested in sustainable technologies, as the public's awareness of sustainability issues grows.

2.4.1 *Sewer-less society*

According to the *United States Environmental Protection Agency* (USEPA), and the United States Census Bureau, on-site systems are increasingly chosen over central sewer systems by property owners and municipalities because they cost less than a central sewer system (USEPA, 1997).

Public health specialists at development agencies worldwide are promoting effective and ecological on-site waste treatment systems that save water and help prevent the spread of fecal-oral disease.

At the same time, the acceptance of WTS as a technology has grown tremendously. They are far more efficient, refined and proven. Every year, more states change laws and regulations to permit them. Even researchers at Harvard University have decided that this is the technology of the future, and have developed a high-tech prototype *smart* WTS with solid-state sensors and microchips that control the process.

Thanks to these developments, WTS – long considered appropriate only for remote applications – may soon be widely viewed as a conventional wastewater treatment technology with obvious advantages for the present and the future (Del Porto & Steinfeld, 1999).

2.5 *Innovative financing and management*

The United States Environmental Protection Agency and regulators worldwide are recommending the formation of on-site management districts in response to poorly maintained or inadequate conventional on-site systems. These would involve a central organization that manages a district's on-site systems, so no matter what system a property owner used, an agency would be accountable for its performance.

The formation of these districts would allow on-site systems to receive the federal funds for design, construction and maintenance that were once provided only for central wastewater treatment plants.

Recently New York City instituted a financial incentive for individual property owners to recycle wastewater and stormwater (New York City Department of Environmental Protection, Web Page). The program, called the Comprehensive Water Reuse Program (CWRP), provides a 25% reduction in water rates and a reduced sewer bill to property owners who install wastewater-recycling equipment (for onsite non-potable reuse) and rainwater collection equipment as well as take other water-saving measures.

2.6 *Comparing two water management scenarios (Steinfeld, 2004)*

2.6.1 *A hypothetical big pipe water recycling scenario*

An urban neighborhood in New York City comprises industrial, residential, and commercial buildings. The water supply transferred from a far distant watershed basin, is now completely recycled water from one of the city's treatment plants. Miles of pipes and pumping stations carry away the wastewater to a treatment facility converted to a full recycle facility three (and far more) miles away (1 mile = 1,609 m). Stormwater is piped to rivers and out to sea. To supply recycled wastewater back to this block, pipes and pumping stations have to be dug and installed, with great disruption to the city, to pipe water via the existing supply lines or new ones. Cost of the ultra-filtration and distribution is considerable.

Compare and contract the former to the following:

2.6.2 *Hypothetical integrated source – and on site – water scenario*

The same urban neighborhood is offered incentives to conserve and recycle water. Several buildings are retrofitted with low-flush dual-flush urine-diverting toilets flushed with treated graywater collected from sinks and showers. The flushed urine – which accounts for most of the nitrogen in wastewater – is used to fertilize and irrigate surrounding landscaping, green strips, parks, and green corridors via a hidden subsurface piping system. Excess nutrient-rich urine is piped to greenhouses on industrial roof tops and brownfields to grow food or oils used as a substitute for imported petroleum. Stormwater is collected from roofs, streets and parking lots and treated and disinfected to be used for process water for flushing toilets and urinals, evaporative air conditioning, boiler feed stocks, etc.

Graywater and combined wastewater is treated on site with a polyculture of treatment systems, including planted systems such as *Solar Aquatics/Living Machines* and constructed ecosystems (a category that includes planted evapotranspiration systems and constructed wetlands) that double as landscaping, recreation area, gardens, bird habitat, orchards, and public art. These systems create an incentive for planners to create green spaces, such as terraces and public gardens. The beauty of these ecological designs increase land values and foot traffic in the neighborhoods.

Toilets and kitchens effluents drain to treatment tanks for these appliances only. Septage is taken to a septage composting facility. Recipients of this composted septage (sludge) are relieved to know that no industrial chemicals, toxics or heavy metals are in this material, unlike today's composted sewer sludge. Or, dry or micro-flush toilets drain to aerobic composters which are periodically removed to a central processing facility.

Industrial flows with toxics and heavy metals are treated separately by systems designed for their specific constituents (because the solution to pollution is not dilution). Cooling water and condensate is recovered and recycled.

To minimize combined sewer overflows, the rooftops are retrofitted with green eco-roofs to absorb stormwater and slow-release it for evaporation. Some of this water can be drained to cisterns. This also reduces heat islands in the city, insulates buildings, and extends the life of roofing. Raingardens, pervious paving, and other *lower-impact development* (LID) techniques are used to infiltrate stormwater, reducing flows to the wastewater treatment plant (see Low Impact Development Center, Web Page). Brownfields are used to infiltrate effluents and stormwater. Unused buildings may house cisterns and treatment works. Marginal buildings may be dismantled to make way for collection, treatment, and planted treatment systems.

Some uses are seasonal. Rainwater may be used during wet months and treated graywater used during dry months.

A city management team periodically checks on the systems. This staff formerly worked in the central plant or is funded with avoided central treatment costs.

The result: much-reduced flow to the wastewater treatment plant and reduced demand for water. Also, this scenario embeds incentives for building users to reduce toxics and perhaps water usage. This also makes for a more secure water system, as water supply and treatment is no longer entirely centralized, so that disease outbreak, terrorist action, or treatment plant failure do not affect users as much.

A decentralized approach may also offer a solution to one of the hurdles to implementing full water recycling:

- Security against terrorist attacks on central systems.
- Liability is dispersed, so that any disease outbreak can be more isolated.
- Users of these water sources, now more aware of and invested in their sources, are far more confident in using recycled water and more likely to safeguard it.

It is clear that combining excreta, toxics, heavy metals, and many other constituents in a water-carriage wastewater infrastructure and then attempting remove it all with advanced filtration may be unfeasible for many developing countries and perhaps the first world too. The advantages of an integrated site- and source-based approach are too great to ignore.

2.6.3 *Costs for an integrated urban water management plan*

A typical Los Angeles single-family household pays only US$ 63 per month for combined water, stormwater and wastewater services. It is estimated to cost an additional US$ 45 per month to implement an integrated water management plan (City of Los Angeles, Web Page).

3 CONCLUSION

Many of the water crises in urban areas are based not so much on the availability of water but rather on our failure to manage how water is used. Specifically, the failure to recognize stormwater as a resource and the practice of using water to transport unwanted wastes.

Wastewater recycling will be a necessary strategy in the years ahead. However, it is only one component that should be part of an integrated strategy that makes best use of local sites, as well as local sources of water and local effluents that can be used.

Continuing to combine wastes – including excreta, toxics, and heavy metals – in wastewater flows, then using advanced ultra-filtration at the end of the pipe to treat them will not be feasible for many cities, especially those in developing countries.

To identify wastewater recycling as the best solution to the world's water supply challenges is to use the same mentality that created today's many water problems.

The common urban approach of centrally collecting combined effluents from a wide variety of sources, then treating this soup with end-of-pipe solutions, has evolved in an effort to avoid complexity. Yet nature's model shows us that complexity is the best way to manage resources.

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