SICK WATER?

THE CENTRAL ROLE OF WASTEWATER MANAGEMENT IN SUSTAINABLE DEVELOPMENT

A RAPID RESPONSE ASSESSMENT

UNEP

UN-HABITAT

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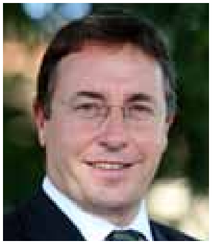
JOINT STATEMENT



The statistics are stark: Globally, two million tons of sewage, industrial and agricultural waste is discharged into the world's waterways and at least 1.8 million children under five years-old die every year from water related disease, or one every 20 seconds.

Over half of the world's hospitals beds are occupied with people suffering from illnesses linked with contaminated water and more people die as a result of polluted water than are killed by all forms of violence including wars.

The impact on the wider environment is no less striking. An estimated 90 per cent of all wastewater in developing countries is discharged untreated directly into rivers, lakes or the oceans. Such discharges are part of the reason why de-oxygenated dead zones are growing rapidly in the seas and oceans. Currently an estimated 245 000 km^2 of marine ecosystems are affected with impacts on fisheries, livelihoods and the food chain.

The climate is also being impacted: Wastewater-related emissions of methane, a powerful global warming gas, and another called nitrous oxide could rise by 50 per cent and 25 per cent respectively between 1990 and 2020.

Already, half of the world's population lives in cities, most of which have inadequate infrastructure and resources to address wastewater management in an efficient and sustainable way. Twenty-one of the world's 33 megacities are on the coast where fragile ecosystems are at risk. Without urgent action to better manage wastewater the situation is likely to get worse: By 2015, the coastal population is expected to reach approximately 1.6 billion people or over one fifth of the global total with close to five billion people becoming urban dwellers by 2030. By 2050 the global population will exceed nine billion.

Some of these trends are inevitable. However the world does have choices in terms of the quantity and the quality of discharges to rivers and seas if a sustainable link is made from farms, rural areas and cities to the ecosystems surrounding them.

In some cases, investments in improved sanitation and water treatment technologies can pay dividends. In other cases investments in the rehabilitation and restoration of nature's water purification systems—such as wetlands and mangroves—offer a cost effective path.

UNEP and UN-Habitat are increasing our cooperation across several fronts including meeting the wastewater challenge. This report is one fruit of that collaboration.

Investing in clean water will pay multiple dividends from overcoming poverty to assisting in meeting the Millennium Development Goals. It also makes economic sense. According to a recent report from the Green Economy Initiative, every dollar invested in safe water and sanitation has a pay back of US$3 to US$34 depending on the region and the technology deployed.

Meeting the wastewater challenge is thus not a luxury but a prudent, practical and transformative act, able to boost public health, secure the sustainability of natural resources and trigger employment in better, more intelligent water management.

Achim Steiner
Executive Director, UNEP

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Executive Director, UN-HABITAT

PREFACE

The wastewater challenge is not only a threat, but a challenge where we can find opportunities for green employment, social well-being and ecological health

The United Nations Secretary-General's Advisory Board on Water and Sanitation (UNSGAB) is committed to accelerating progress on the Millennium Development Goal targets for water and sanitation.

UNSGAB collaborates with others to galvanize action and foster new initiatives. One of our initiatives for improving basic sanitation coverage was the UN-backed International Year on Sanitation (IYS) in 2008. By all accounts, the IYS was a success. It triggered an honest, concrete and productive public discussion about expanding access to sanitary toilets and improving hygiene while fostering political commitments to act.

UNSGAB now is working to ensuring that these IYS commitments are fulfilled. We also are building on this positive momentum to widen the discussion to include the collection, treatment and reuse of human, household, agricultural, storm and industrial wastewater and run-off. More than 80 percent of wastewater is discharged untreated into water bodies. This untreated wastewater is the missing link to meeting the sanitation challenge. It has a material impact on human health, social and economic development and ecosystem sustainability.

The 2009 Istanbul Ministerial Statement embodies a global commitment to "further develop and implement wastewater collection, treatment and reuse." This report aims to place wastewater on the international and national agenda by pointing out that wastewater management provides opportunities not only challenges. Now, more than ever, we must promote strategic financial planning at the country level to maximize efficiency to improve coverage in the water and sanitation sectors.

UNSGAB has gained valuable experience and understanding that we will now bring to bear on improving wastewater management. Meeting this challenge will require new alliances and we are happy to have collaborated with UNEP, UN-HABITAT and UN Water in the development of this report. We are ready to work with the global community to promote a new wastewater paradigm encompassing modular design, appropriate technology, and sustainable financing. For as the report "Sick water? The central role of wastewater management in sustainable development" points out, the wastewater challenge is not only a threat, but is a challenge where we can find opportunities for green employment, social well-being and ecological health.

HRH, Prince Willem-Alexander of the Netherlands
Chair, UN Secretary-General's Advisory Board on Water and Sanitation

EXECUTIVE SUMMARY

The world is facing a global water quality crisis. Continuing population growth and urbanisation, rapid industralisation, and expanding and intensifying food production are all putting pressure on water resources and increasing the unregulated or illegal discharge of contaminated water within and beyond national borders. This presents a global threat to human health and wellbeing, with both immediate and long term consequences for efforts to reduce poverty whilst sustaining the integrity of some of our most productive ecosystems.

There are many causes driving this crisis, but it is clear that freshwater and coastal ecosystems across the globe, upon which humanity has depended for millennia, are increasingly threatened. It is equally clear that future demands for water cannot be met unless wastewater management is revolutionized.

Global populations are expected to exceed nine billion by 2050. Urban populations may rise nearly twice as fast, projected to nearly double from current 3.4 billion to 6.4 billion by 2050, with numbers of people living in slums rising even faster, from one to 1.4 billion in just a decade. Over a fifth of the global total, 1.6 billion people are expected to live by the coast by 2015. Inadequate infrastructure and management systems for the increasing volume of wastewater that we produce are at the heart of the wastewater crisis.

The way we produce our food uses 70–90 per cent of the available fresh water, returning much of this water to the system with additional nutrients and contaminants. It is a domino effect as downstream agricultural pollution is joined by human and industrial waste. This wastewater contaminates freshwater and coastal ecosystems, threatening food security, access to safe drinking and bathing water and providing a major health and environmental management challenge. Up to 90 per cent of wastewater flows untreated into the densely populated coastal zone contributing to growing marine dead zones, which already cover an area of 245 000 km^2, approximately the same area as all the world's coral reefs.

Contaminated water from inadequate wastewater management provides one the greatest health challenges restricting development and increasing poverty through costs to health care and lost labour productivity. Worldwide, almost 900 million people still do not have access to safe water and some 2.6 billion, al-

most half the population of the developing world do not have access to adequate sanitation. At least 1.8 million children under five years old die every year due to water related disease, accounting for around 17 per cent of deaths in this age group. Worldwide some 2.2 million people die each year from diarrhoeal disease. Poor hygiene and unsafe water is responsible for around 88 per cent of all diarrhoeal incidents.

Under-dimensioned and aged wastewater infrastructure is already overwhelmed, and with predicted population increases and changes in the climate the situation is only going to get worse. Without better infrastructure and management, many millions of people will continue to die each year and there will be further losses in biodiversity and ecosystem resilience, undermining prosperity and efforts towards a more sustainable future. A healthier future needs urgent global action for smart, sustained investment to improve wastewater management.

Change is both essential and possible. As a part of the shift to a green economy, the public sector including national, provincial and local governments must be more proactive in funding wastewater management, central to which will be issues of equity and social justice. To find solutions we will need to draw on a cocktail of existing and new policy approaches and funding mechanisms, from better water quality legislation and voluntary agreements, to market-based instruments and partnership-based financing and management models bringing together the public and private sectors, not forgetting the vital role of education.

Wise investments in wastewater management will generate significant returns, as addressing wastewater is a key step in reducing poverty and sustaining ecosystem services. Instead of being a source of problems, well-managed wastewater will be a positive addition to the environment which in turn will lead to improved food security, health and therefore economy. One fifth of the world's population, or 1.2 billion people, live in areas of water scarcity, and this is projected to increase to 3 billion by 2025 as water stress and populations increase. There is no option but to consider wastewater as part of the solution. To be successful and sustainable, wastewater management must be an integral part of rural and urban development planning, across all sectors, and where feasible transcending political, administrative and jurisdictional borders. There are few, if any, areas where investments in integrated planning can sustainably provide greater returns across multiple sectors than the development of water infrastructure and the promotion of improved wastewater management.

The first part of this report addresses the critical challenges we face in managing wastewater and considers the implications for people and the environment across different sectors, and how these may be influenced by issues such as population growth, urbanization and climate change.

The second part looks at solutions and how these challenges can be turned around. Finding appropriate solutions will require innovation at both ends of the pipe. Innovation to reduce the volume and contamination of wastewater produced, how to treat or even reuse the waste, and how to do it in an affordable sustainable way. The report reviews how the production and treatment cycle can be better understood and managed so that through better investment and management major environmental, societal, and economic dividends can be achieved.

A healthier future needs urgent global action for smart, sustained investment to improve wastewater management

KEY MESSAGES:

1 Wastewater production is rising

The global population is expected to exceed nine billion people by 2050. Major growth will take place in developing countries, particularly in urban areas that already have inadequate wastewater infrastructure. The financial, environmental and social costs are projected to increase dramatically unless wastewater management receives urgent attention.

2 Wise and immediate investment will generate multiple future benefits

Immediate, targeted and sustained investments should take multiple forms. They should be designed to (i) reduce the volume and extent of water pollution through preventative practices; (ii) capture water once it has been polluted; (iii) treat polluted water using appropriate technologies and techniques for return to the environment; (iv) where feasible safely reuse and recycle wastewater thereby conserving water and nutrients; and (v) provide a platform for the development of new and innovative technologies and management practices. If investments such as these are scaled up appropriately they will generate social, economic and environmental dividends far exceeding original investments for years to come.

3 Improved sanitation and wastewater management are central to poverty reduction and improved human health

The poor are affected first and foremost by this global crisis. Over half of the world's hospital beds are occupied by people suffering from water related diseases. Diarrhoeal diseases make up over four per cent of the global disease burden, 90 percent of which is linked to environmental pollution, a lack of access to safe drinking water and sanitation. Comprehensive and sustained wastewater management in combination with sanitation and hygiene is central to good health, food security, economic development and jobs. In terms of public spending on health issues, investing in improved wastewater management and the supply of safe water provides particularly high returns.

4 Successful and sustained wastewater management will need an entirely new dimension of investments, to start now

Currently, most of the wastewater infrastructure in many of the fastest growing cities is lacking. It is outdated, not designed to meet local conditions, poorly maintained and entirely unable to keep pace with rising urban populations. Experiences have shown that appropriate investments done in the right manner can provide the required returns. However, it will require not only investments, but careful and comprehensive integrated water and wastewater planning and management at national and municipal levels. This must transcend the entire water supply and disposal chain involving ecosystem management (including coastal waters), agricultural efficiency and production and treatment of wastewater and a stronger focus on urban planning.

Wise investments in wastewater management will generate significant returns, as addressing wastewater is a key step in reducing poverty and sustaining ecosystem services

The policy recommendations presented in part III of this report propose a two-pronged, incremental approach to tackle immediate consequences whilst thinking to the long term:

A Tackle immediate consequences

1. Countries must adopt a multi-sectoral approach to wastewater management as a matter of urgency, incorporating principles of ecosystem-based management from the watersheds into the sea, connecting sectors that will reap immediate benefits from better wastewater management.

2. Successful and sustainable management of wastewater requires a cocktail of innovative approaches that engage the public and private sector at local, national and transboundary scales. Planning processes should provide an enabling environment for innovation, including at the community level but require government oversight and public management.

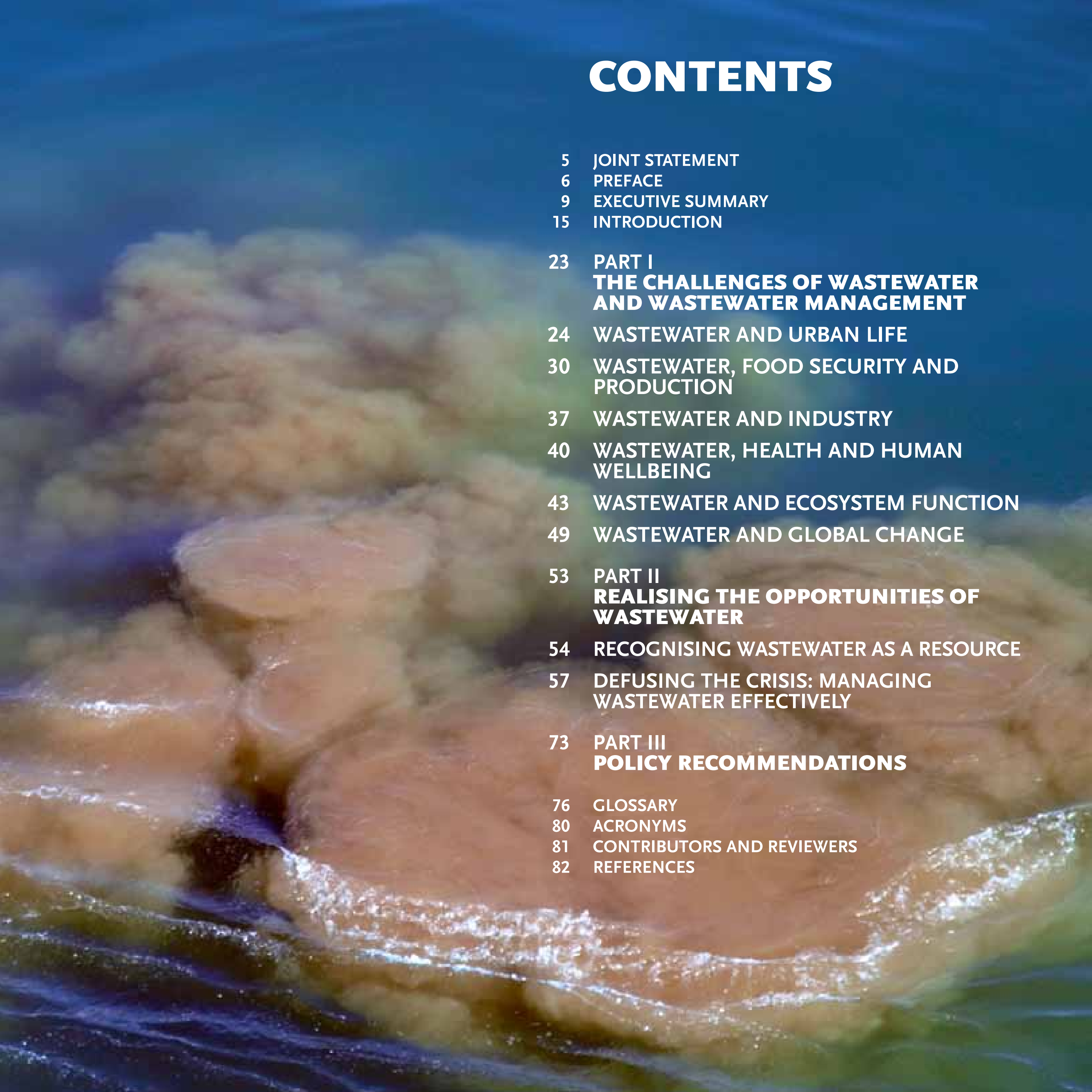
3. Innovative financing of appropriate wastewater infrastructure should incorporate design, construction, operation, maintenance, upgrading and/or decommissioning. Financing should take account of the fact that there are important livelihood opportunities in improving wastewater treatment processes, whilst the private sector can have an important role in operational efficiency under appropriate public guidance.

B Thinking to the long term

4. In light of rapid global change, communities should plan wastewater management against future scenarios, not current situations.

5. Solutions for smart wastewater management must be socially and culturally appropriate, as well as economically and environmentally viable into the future.

6. Education must play a central role in wastewater management and in reducing overall volumes and harmful content of wastewater produced, so that solutions are sustainable.



CONTENTS

INTRODUCTION

Water is crucial for all aspects of life, the defining feature of our planet. Ninety seven and a half per cent of all water is found in the oceans, of the remaining freshwater only one per cent is accessible for extraction and use. Functioning and healthy aquatic ecosystems provide us with a dazzling array of benefits – food, medicines, recreational amenity, shoreline protection, processing our waste, and sequestering carbon. At the beginning of the 21st century, the world faces a water crisis, both of quantity and quality, caused by continuous population growth, industrialization, food production practices, increased living standards and poor water use strategies. Wastewater management or the lack of, has a direct impact on the biological diversity of aquatic ecosystems, disrupting the fundamental integrity of our life support systems, on which a wide range of sectors from urban development to food production and industry depend. It is essential that wastewater management is considered as part of integrated, ecosystem-based management that operates across sectors and borders, freshwater and marine.

Fresh, accessible water is a scarce (figure 1) and unevenly distributed resource, not matching patterns of human development. Over half the world's population faces water scarcity. Because it plays a vital role in the sustenance of all life, water is a source of economic and political power (Narasimhan, 2008) with water scarcity a limiting factor in economic and social development.

International attention has to date, focused on water quantity, the supply of drinking water and increasing access to sanitation with commitment expressed through the World Summit of Sustainable Development and the Millennium Development Goal 7 for Environmental Sustainability, target 10 for safe drinking water and sanitation. 2005 – 2015 is the international decade for Action "Water for Life" (http://www.un.org/waterforlifedecade/), with a focus on the International year of Sanitation in 2008 (http://esa.un.org/iys/). Despite this high profile attention, these issues are proving difficult to resolve, requiring significant sums for investment, over long periods of time and with jurisdiction often spread across several government departments. Worldwide, nearly 900 million people still do not have access to safe water (UNDESA 2009), and some 2.6 billion, almost half the population of the developing world do not have access to adequate sanitation (WHO/UNICEF, 2010). Over 80 per cent of people with unimproved drinking water and 70 per cent of people without improved sanitation live in rural areas (DFID, 2008). This is also only part of the story.

What do we mean by wastewater?

Wastewater can mean different things to different people with a large number of definitions in use. However this report has taken a broad perspective, and defined wastewater as "a combination of one or more of: domestic effluent consisting of blackwater (excreta, urine and faecal sludge) and greywater (kitchen and bathing wastewater); water from commercial establishments and institutions, including hospitals; industrial effluent, stormwater and other urban run-off; agricultural, horticultural and aquaculture effluent, either dissolved or as suspended matter (adapted from Raschid-Sally and Jayakody, 2008).

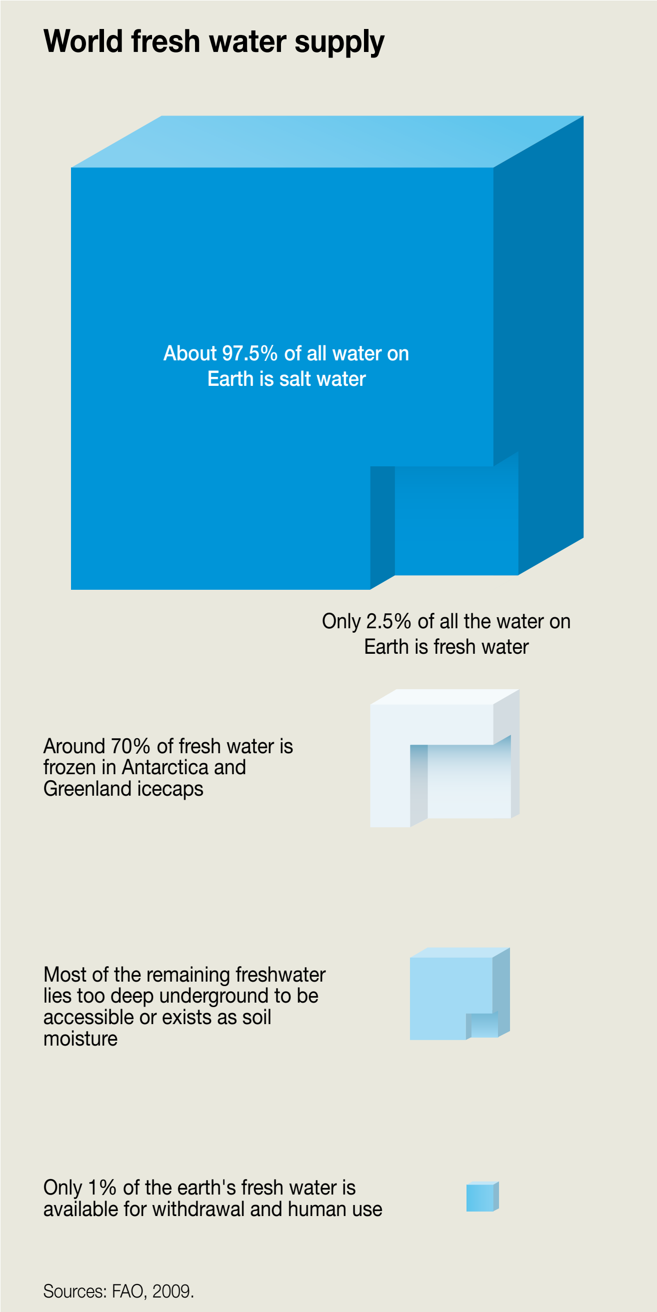


Figure 1: Water is the life force of our planet, but only 1 per cent of all the freshwater on Earth is available for human use.

Water is crucial for all aspects of life, the defining feature of our planet. Ninety seven and a half per cent of all water is found in the oceans, of the remaining freshwater only one per cent is accessible for extraction and use. Functioning and healthy aquatic ecosystems provide us with a dazzling array of services – food, medicines, recreational amenity, shoreline protection, processing our waste, and sequestering carbon. At the beginning of the 21st century, the world faces a water quality crisis, caused by continuous population growth, industrialization, food production practices, increased living standards and poor water use strategies. Wastewater management or the lack of, has a direct impact on the biological diversity of aquatic ecosystems, disrupting the fundamental integrity of our life support systems, on which a wide range of sectors from urban development to food production and industry depend. It is essential that wastewater management is considered as part of integrated, ecosystem-based management that operates across sectors and borders, freshwater and marine.

Access to safe water is a human right (UNDP, 2006). However, the right to pollute and discharge contaminated water back into

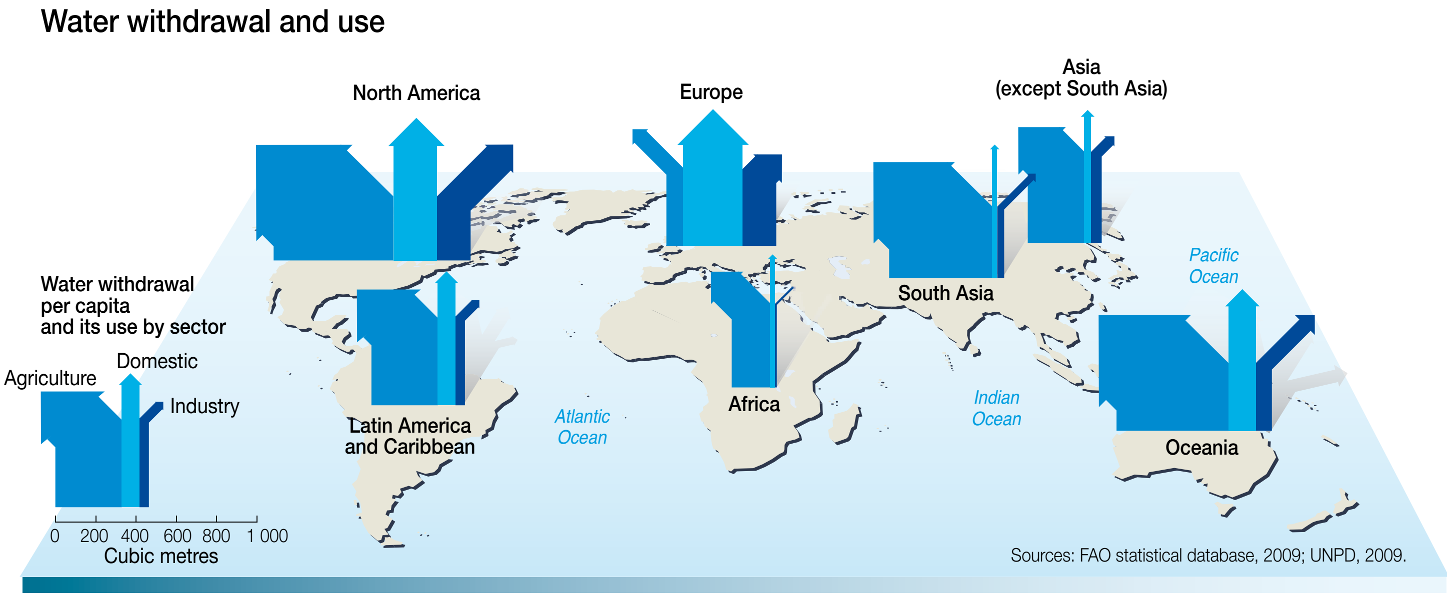
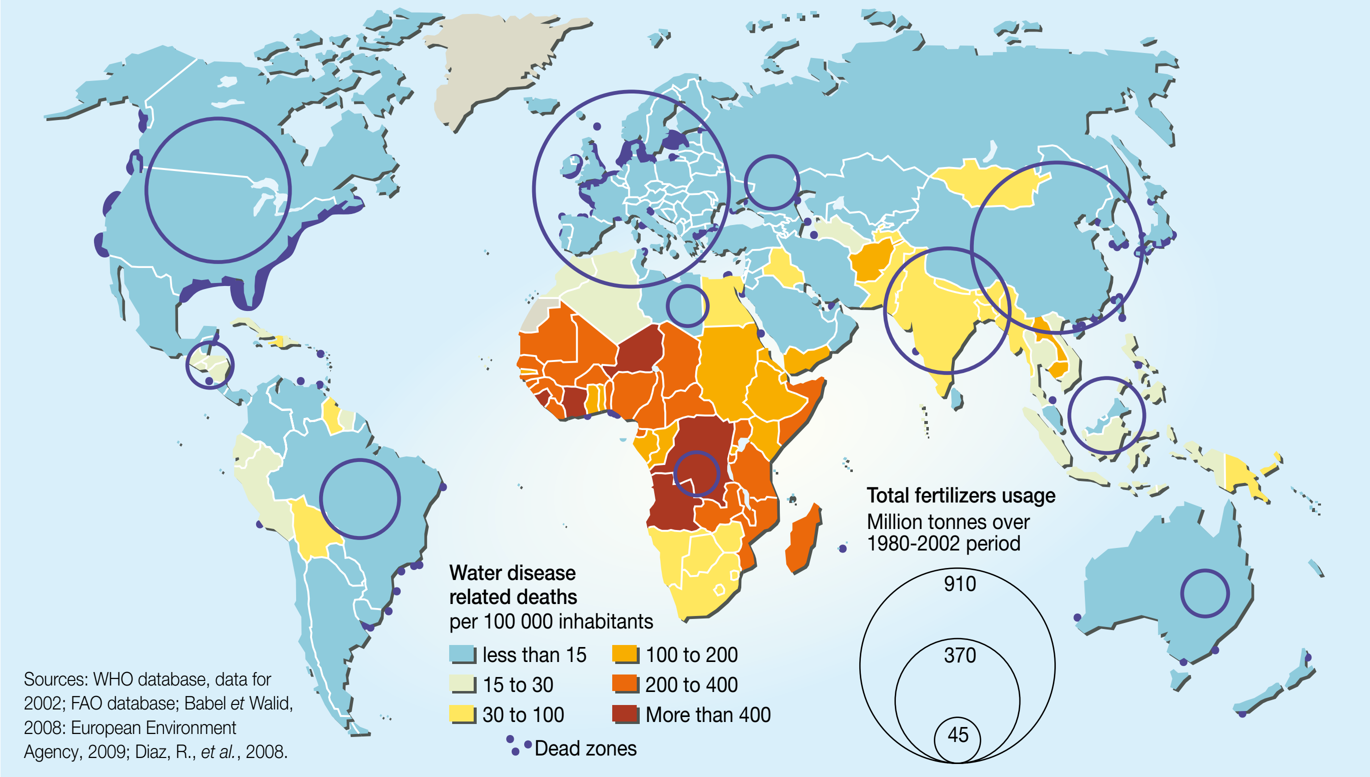
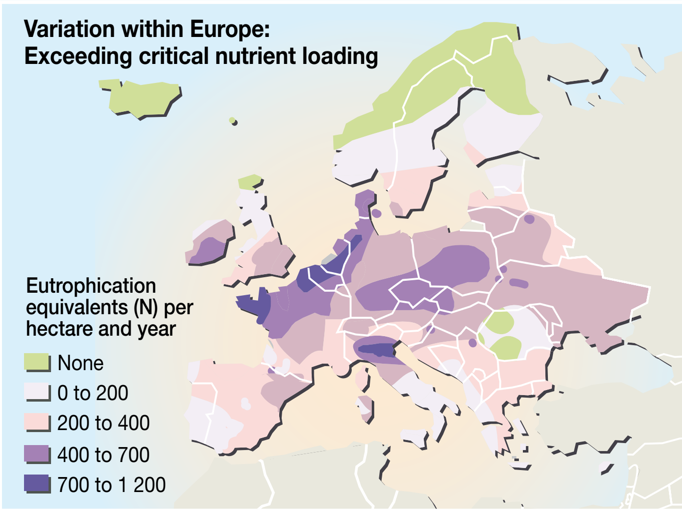
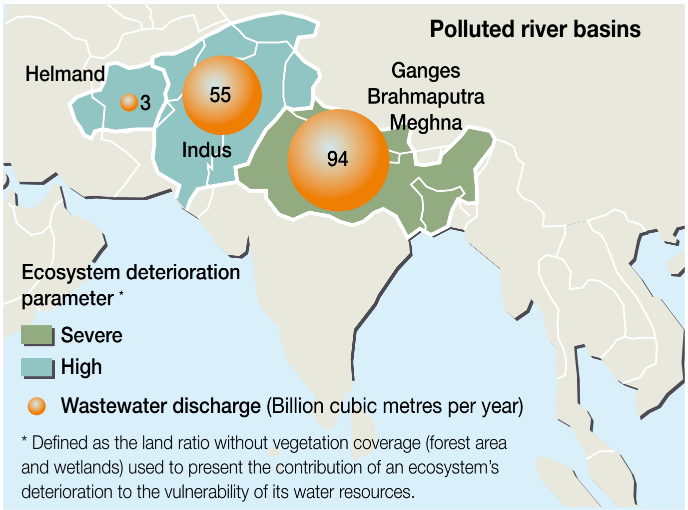


Figure 2: Regional variation in water withdrawal per capita and its use by sector.

Wastewater, a global problem with differing regional issues







the environment, polluting the water of downstream users, is not. As water travels through the hydrological system from the mountain summit to the sea, the activities of human society capture, divert and extract, treat and reuse water to sustain communities and economies throughout the watershed (agricultural, industrial and municipal) (figure 4). These activities, do not, however return the water they extract in the same condition. A staggering 80–90 per cent of all wastewater generated in developing countries is discharged directly into surface water bodies (UN Water, 2008).

Unmanaged wastewater can be a source of pollution, a hazard for the health of human populations and the environment alike. The Millennium Ecosystem Assessment (MA, 2005) reported that 60 per cent of global ecosystem services are being degraded or used unsustainably, and highlighted the inextricable links between ecosystem integrity and human health and wellbeing.

Wastewater can be contaminated with a myriad of different components (figure 5): pathogens, organic compounds, synthetic chemicals, nutrients, organic matter and heavy metals. They are either in solution or as particulate matter and are carried along in the water from different sources and affect water quality. These components can have (bio-) cumulative, persistent and synergistic characteristics affecting ecosystem health and function, food production, human health and wellbeing, and undermining human security. Over 70 percent of the water has been used in other productive activities before entering urban areas (Appelgren, 2004; Pimentel and Pimentel, 2008). Wastewater management must address not only the urban but also the rural context through sound and integrated ecosystem-based management including, for example fisheries, forestry and agriculture.

The quality of water is important for the well-being of the environment, society and the economy. There are however ways to become more efficient and reduce our water footprint. Improving water and sanitation services and managing water require

investment. It is not a question of the quantity of investment. There are numerous anecdotes pointing to a history of one-off, short-term, single-sector investments – capital treatment-plant developments which were unable to secure operation and management funding, built at the wrong scale or in the wrong location. Even without empirical data, it is clear that this approach is not generating results in either improved water quality or financial incentive.

A paradigm shift is required towards new approaches that include wise investments and technological innovation, not one size fits all, but now ensuring that investments are appropriate to the industries and communities they serve. Such investments can boost economies, increase labour productivity and reduce poverty. This report uses a number of case studies to illustrate the challenges of wastewater management, but also the opportunities for how wastewater management and reuse can safely meet the growing demands for water resources, without degrading the environment, and the ecosystem services on which we depend.

← **Figure 3:** The significance of wastewater and contents of wastewater vary greatly between and even within regions. In Africa for example, it is the impact on people's health that is the major factor, in Europe, the input of nutrients into the coastal waters reducing productivity and creating anoxic dead zones.

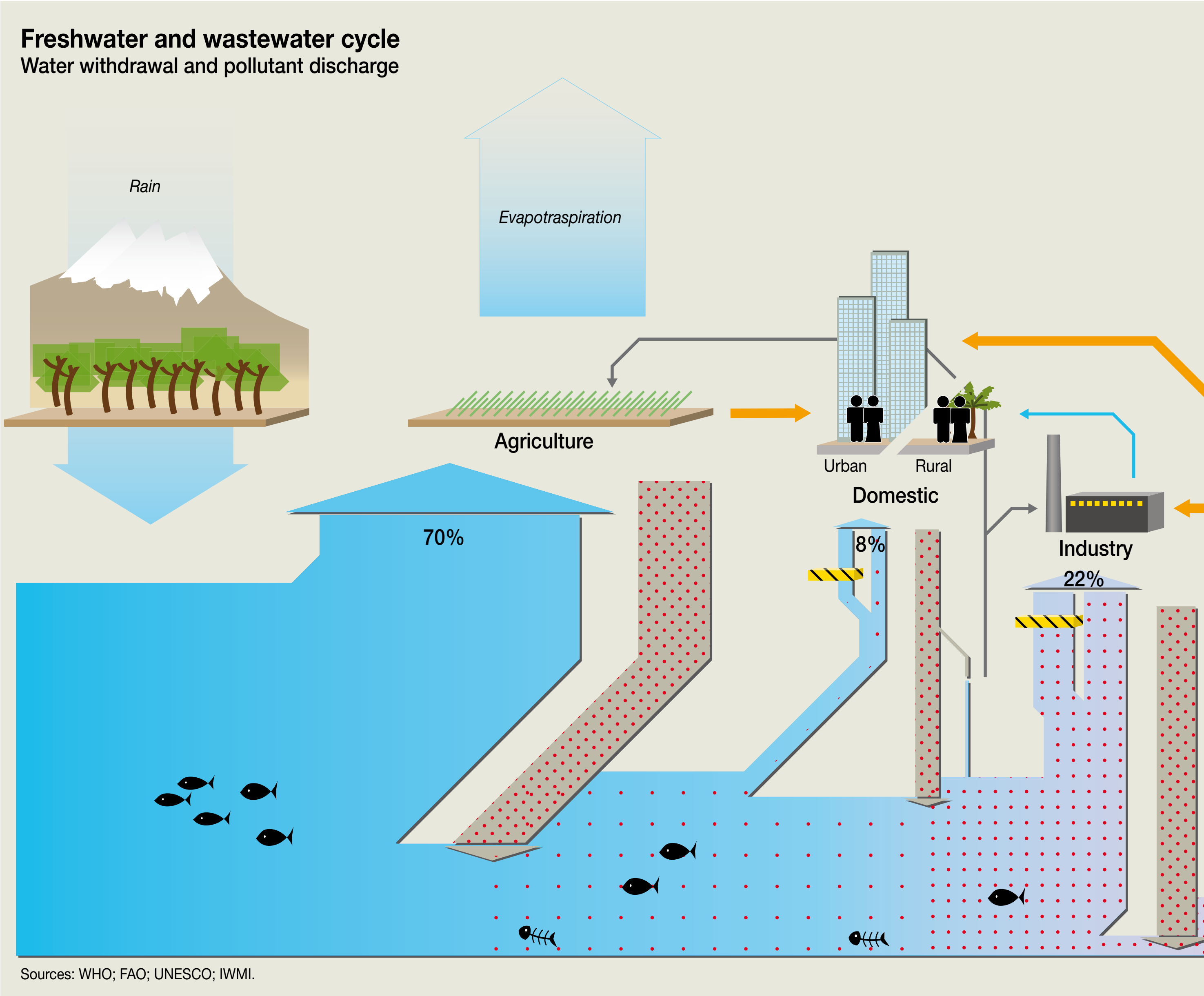
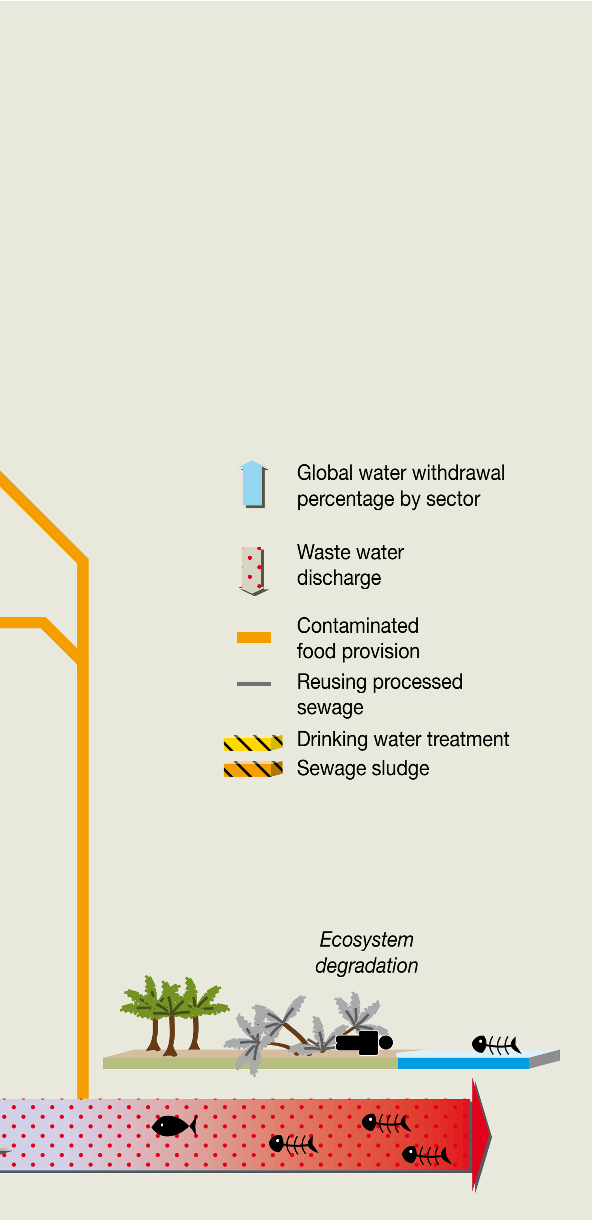
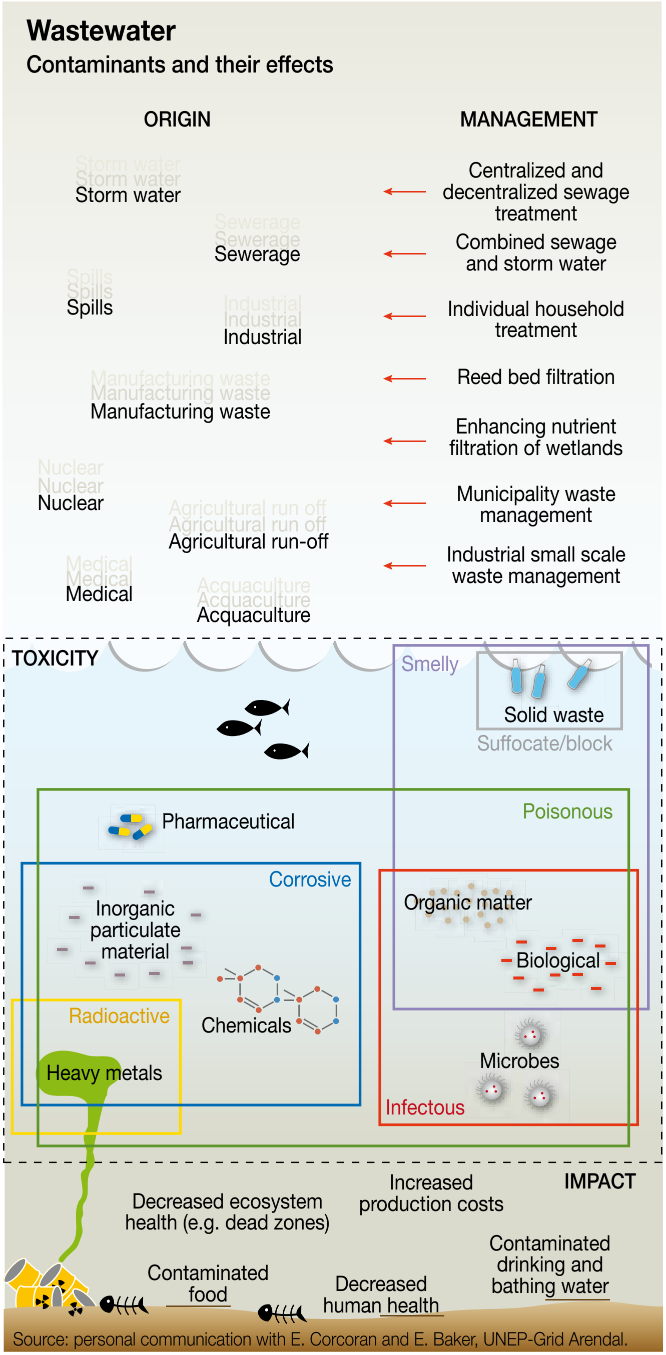


Figure 4: As water is extracted and used along the supply chain, both the quality and quantity of water is reduced.





➔ **Figure 5:** The contaminants in waste-water come from many different sources and can have cumulative and synergistic effects requiring a multi-pronged response.

PART I
THE CHALLENGES OF WASTE-WATER AND WASTEWATER MANAGEMENT

Wastewater – spent or used water from farms, communities, villages, homes, urban areas or industry may contain harmful dissolved or suspended matter. Unregulated discharge of wastewater undermines biological diversity, natural resilience and the capacity of the planet to provide fundamental ecosystem services, impacting both rural and urban populations and affecting sectors from health to industry, agriculture, fisheries and tourism. In all cases, it is the poorest that are the most severely affected.

These impacts continue to grow. Global populations are increasing rapidly and will reach between nine and 11 billion in 2050, and as population increases so does the production of wastewater and the number of people vulnerable to the impacts of severe wastewater pollution. Almost 900 million people currently lack access to safe drinking water, and an estimated 2.6 billion people lack access to basic sanitation (WHO/UNICEF, 2010).

Lack of capacity to manage wastewater not only compromises the natural capacity of marine and aquatic ecosystems to assimilate pollutants, but also causes the loss of a whole array of benefits provided by our waterways and coasts that we too often take for granted; safe water for drinking, washing and hygiene, water for irrigating our crops and producing our food and for sustaining ecosystems and the services they provide. The financial, environmental and societal costs in terms of human health, mortality and morbidity and decreased environmental health are projected to increase dramatically unless wastewater management is given very high priority and dealt with urgently.

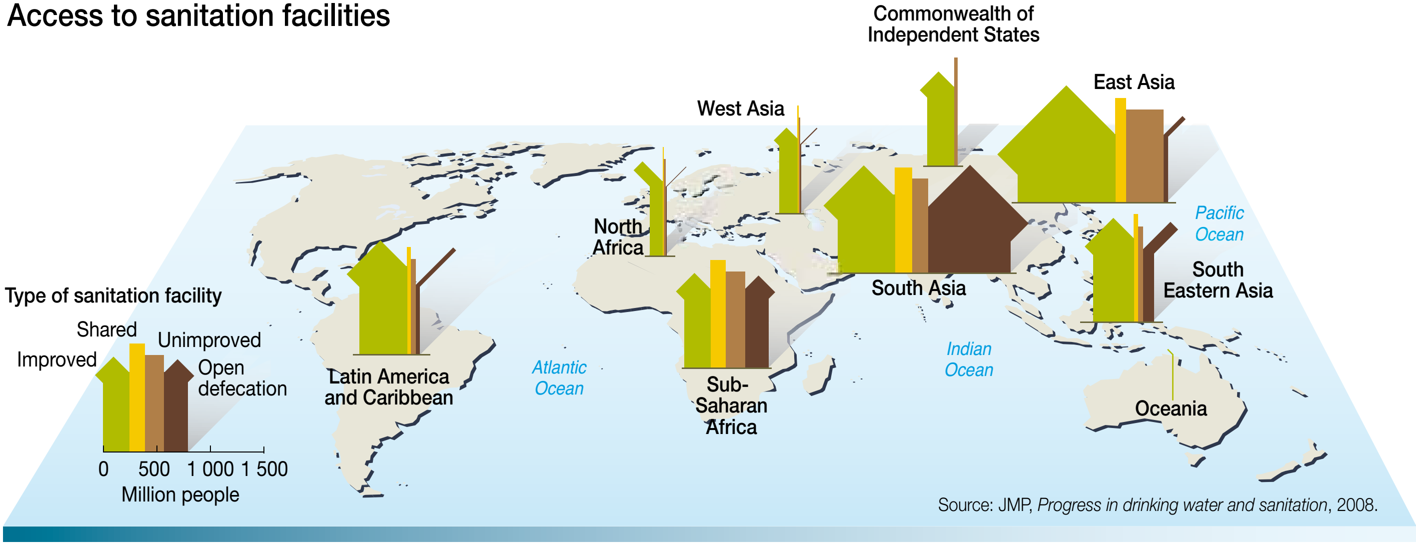
In this part of the report we will present some of the key challenges that the unregulated discharge of wastewater presents.

WASTEWATER AND URBAN LIFE

Global populations are growing rapidly, particularly so in urban areas where the rate of urbanization far outstrips planning and wastewater infrastructure development. Existing wastewater infrastructure of most cities is decaying or no longer appropriate and in slum areas there is no planning and few facilities. Management of wastewater in the urban context must be adapted according, not only to the size, but also to the economic development and governance capacity of the urban area. By working together, and cooperating across municipalities the challenges of addressing wastewater management can be met and potential benefits realized.

Urban areas are both consumers and producers of large amounts of wastewater. Providing good quality water and sanitation services to densely populated areas involves significant planning and infrastructure. Over the next 25 years the annual growth rate in urban areas is predicted to be twice as high as that projected for the total population (1.8 per cent versus almost 1 per cent). As soon as 2030, 4.9 billion people, roughly 60 per cent of the world's population, will be urban dwellers (UNDESA 2006).

Access to sanitation facilities



Improved: facilities that ensure hygienic separation of human excreta from human contact. Includes connection to a piped sewer system, septic tank, or pit latrines.

Shared: sanitation facilities of an otherwise acceptable type shared between two or more households.

Unimproved: facilities that do not ensure hygienic separation of human excreta from human contact

Open defecation: in fields, forests, bushes, bodies of water or other open spaces, or disposal of human faeces with solid waste.

Figure 6: Access to improved sanitation remains a pressing issue in many regions.

Most of the rapid expansion in urbanization is taking place not in megacities, but in small and medium sized cities with populations of less than 500 000 (UNFPA, 2007). Growth is often unplanned and attracting government and private investment to infrastructure development in areas that lack the economic clout of the megacities is difficult. In addition, an estimated one billion people currently live in urban slums without even the most basic services (UN-HABITAT, 2009). Because these informal settlements lack land tenure, providing water and sanitation services through investment in large infrastructure is extremely difficult.

Water and wastewater services are often controlled by multiple authorities operating at a local, regional or national level. The infrastructure may be state-owned or include private sector involvement. The reliance of traditional wastewater-treatment systems on large-scale infrastructure generally results in a natural monopoly and hence a lack of market competition.

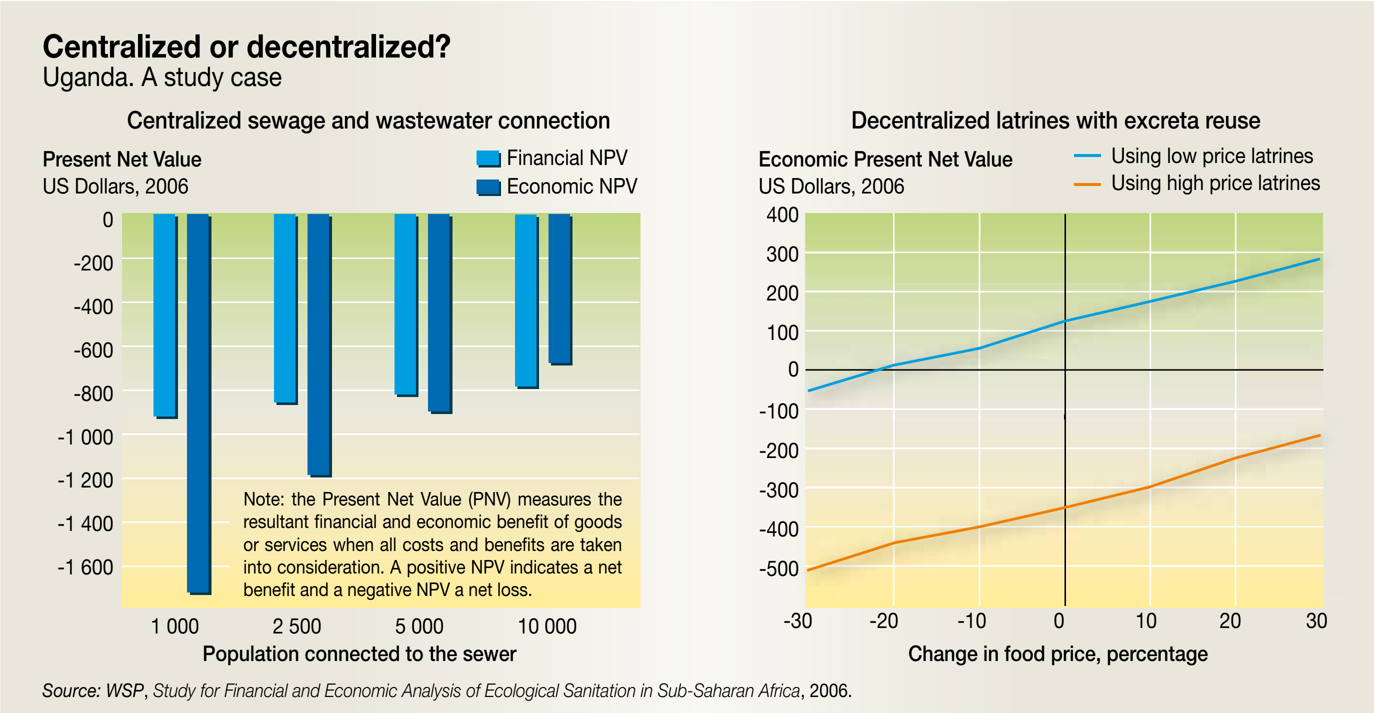


Figure 7: Looking at the costs and benefits, centralized systems may not be the answer in terms of best result for the investment. The chart on the left shows that the financial NPV does not change with increasing population size for centralized sewage and wastewater connection, however the economic NPV (which includes benefits to health and the environment) shows a positive trend with increasing populations. Centralized systems therefore generate a greater benefit as population increases, but show a significant loss with small community size. The chart on the right shows the situation where decentralized latrines have been installed, and where the excreta is reused for food production, and hence the overall benefits returned will depend on the current market price for food. With a good market, the reuse benefits of low-cost latrines can be realized by the households into a positive NPV, however those requiring greater investment, do not offer a return on the investment (WSP, 2006).

Sanitation in big cities

Big cities with little sanitation infrastructure can easily be swamped by human waste. In Jakarta, with a population of nine million people, less than three per cent of the 1.3 million cubic meters (enough to fill more than 500 Olympic swimming pools) of sewage generated each day reaches a treatment plant – there is only the capacity to process 15 swimming pools' worth. Compare this to a city like Sydney, with a population of four million, where 100 per cent of urban wastewater is treated to some degree. Sewage treatment plants process 1.2 million cubic metres per day (each person in Sydney produces nearly three times as much wastewater as a person in Jakarta).

In Jakarta there are more than one million septic tanks in the city, but these are poorly maintained and have contaminated the groundwater with faecal coliform bacteria. When tanks are emptied their contents are often illegally dumped untreated into waterways (Marshall, 2005). Jakarta has a network of canals, originally built to control flooding but these have been partially filled with silt and garbage. This coupled with severe subsidence due to groundwater water extraction (60 per cent of residents are not connected to the water grid so rely on wells), results in increasingly severe flooding. Flooding and stagnant stormwater create conditions for mosquitoes and the incidence of dengue fever and other water related diseases such as diarrhoea and leptospirosis is increasing.

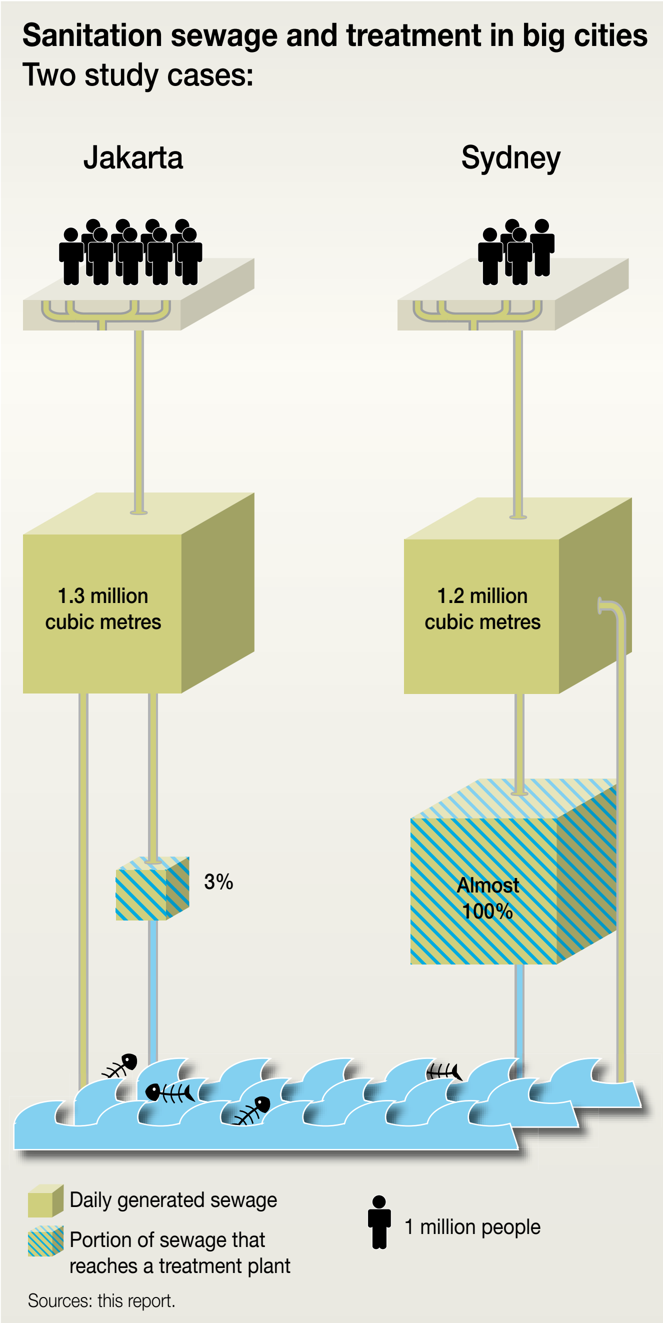


Figure 8: Case study to compare two urban centres.

Attracting funds to develop and maintain water and wastewater infrastructure requires a coherent governance structure and financial and technical feasibility.

The cost of investing in centralized wastewater-treatment systems can be high. Urban landscapes have large areas of impervious surfaces that increase surface run-off and reduce groundwater water recharge – utilities are often left to deal with extremely large volumes of water, especially during wet weather (Nyenje *et al*, 2010). In centralized systems, wastewater transport and treatment facilities must be engineered to cope with these irregular extreme flows. Investments for "modern" water and sewer systems have been estimated to be $30 billion per year, and by 2025 it may cost $75 billion per year, excluding costs for operation and maintenance (Esrey *et al*, 2001). Both the cost of building and maintaining these systems and the reliance on a regular supply of water means this may not be an appropriate economical or environmental solution particularly for smaller or secondary urban centres in developing countries. Instead urban planners are investigating decentralized systems where the wastewater is treated close to where it is generated. This may also be an appropriate option for urban areas prone to natural hazards. These systems can be designed to use no water or very little water and can be managed by households or communities. An example is the closed loop "ecological" toilet that separates urine and faeces so that they can be easily treated and then used safely in agriculture.

The increase in population and urbanization increases the demand for food. As discussed in the following section, urban wastewater is vital for agriculture in many areas. However while many urban centres in developing countries have household sewer connections, these often discharge, in combination with storm water, into open drains that flow untreated into local waterways. Local governments do not have the resources to build collection and treatment facilities so that untreated water is used in peri-urban agriculture.

Sanitation in urban slums

Slum dwellers frequently have to rely on unsewered communal public toilets or use open space. The lack of water, poor maintenance, plus the user-pays system in place for many communal toilets means that they are not widely used. A study in the slums of Delhi found that the average low-income family of five could spend 37 per cent of its income on communal toilet facilities (Sheikh, 08). Finding a suitable place to go to the toilet is especially problematic for women raising issues of personal security, embarrassment and hygiene.

There are approximately 600 000 residents living in the Kibera slums on the outskirts of Nairobi. The term "flying toilet" originated in Kibera. The flying toilet is a polythene bag that people used to dispose of faeces. These bags of waste are thrown onto roofs and into drains and pose a serious health hazard, especially during the wet season, when contaminated run-off pollutes water sources.

Integrated solid waste and wastewater management

It is not just wastewater that poses a major management challenge for the urban environment. Solid waste has been increasing with population growth and urbanization (Kan, 2009). Waste management planners must consider both solid waste and wastewater in order to appropriately allocate resources and successfully achieve MDGs. Solid Waste Management in the World Cities, is the third edition in UN-HABITAT's State of Water and Sanitation in the World Cities series published in March 2010. The report presents the state and trends for solid waste management, acknowledging the escalating challenges in solid waste management across the globe. The publication endeavours to help decision-makers, practitioners and ordinary citizens to understand how a solid waste management system works and to incite people everywhere to make their own decisions on the next steps in developing a solution appropriate to their own city's particular circumstances and needs.

Unregulated discharge of septic tanks to the coast, Lavender Hill, Accra, Ghana approximately two kilometres upstream from major tourist hotels

The city of Accra has sewer connections for only about seven per cent of its households, and the vast majority of those not living in slums have septic tanks. At peak hours there is a tanker car emptying every three minutes at this site, which is adjacent to homes and fishing grounds (Source and Photographs Robert Bos, World Health Organization, Geneva, 2006)

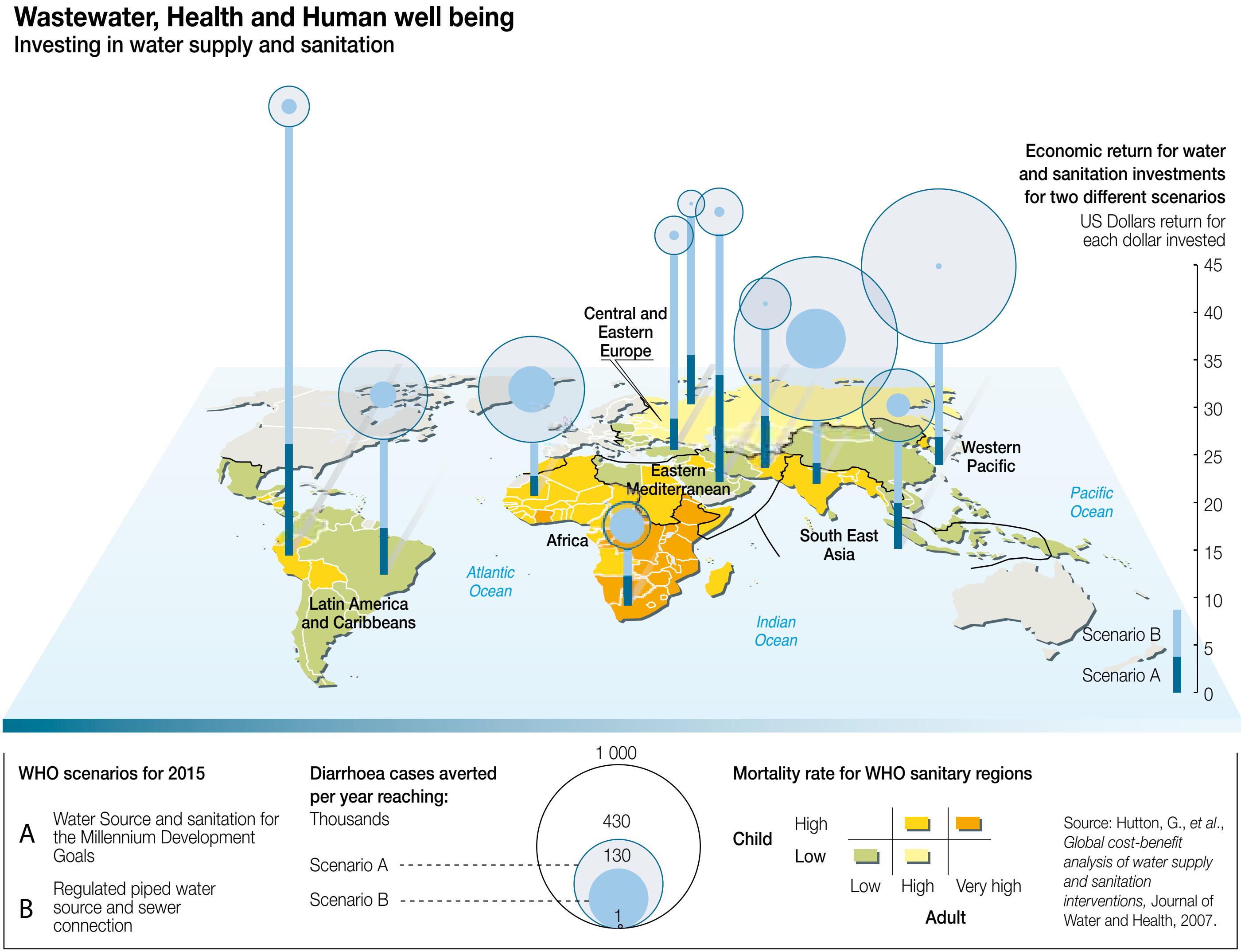


Figure 9: Investment to improve basic access to a safe water source and sanitation (WHO scenario A) can have a significant return with the largest impact on health in particular averting diarrhoea cases and time saved (increasing productivity). Urbanized areas provide a large proportion of GDP, therefore the future development of developing countries is dependent on the productivity of growing urban areas.

WASTEWATER, FOOD SECURITY AND PRODUCTION

Agriculture is the single largest user of water. This sector uses an estimated 70 per cent of total global fresh water (Appelgren, 2004; Pimentel and Pimentel, 2008), returning the majority of this water back to the system. Where agriculture takes place in upper catchments, it may be the first cause of contamination in the water basin. However, agriculture also takes place downstream, where the water may already be polluted by other human activities that result in domestic and industrial waste. Hence there is a complex relationship between water quality, agriculture and food quality, which is in turn linked to human and ecological health.

Impact of food production practices on water quality

Deterioration of water quality caused by agricultural practices can be addressed by optimizing water use, irrigation practices, crop selection and reducing evaporation, as well as cutting the application of nitrogen and phosphorus fertilizer, and pesticides. It is also necessary to consider the opportunities and threats posed by the reuse of wastewater in achieving these goals.

Irrigation has enabled crop yield to increase by up to 400 percent (FAO, 1996) and is one of the practices that has enabled production to keep up with the increased food demands of a growing population, increasing yield by 2.5 times (Kindall and Pimentel, 1994). The daily drinking water requirement per person is 2–4 litres, but it takes 2 000 to 5 000 litres of water to produce one person's daily food (FAO, 2007). Water requirements to produce different food stuffs vary hugely (Figure 10). Increased livestock production and associated meat processing consumes large quantities of water and produces significant amounts of contaminated wastewater. Hence, reducing meat production will also affect water availability in many regions.

Water originating from the snow and ice in the Kush Himalayas and Tibetan Plateau currently sustains over 55 percent

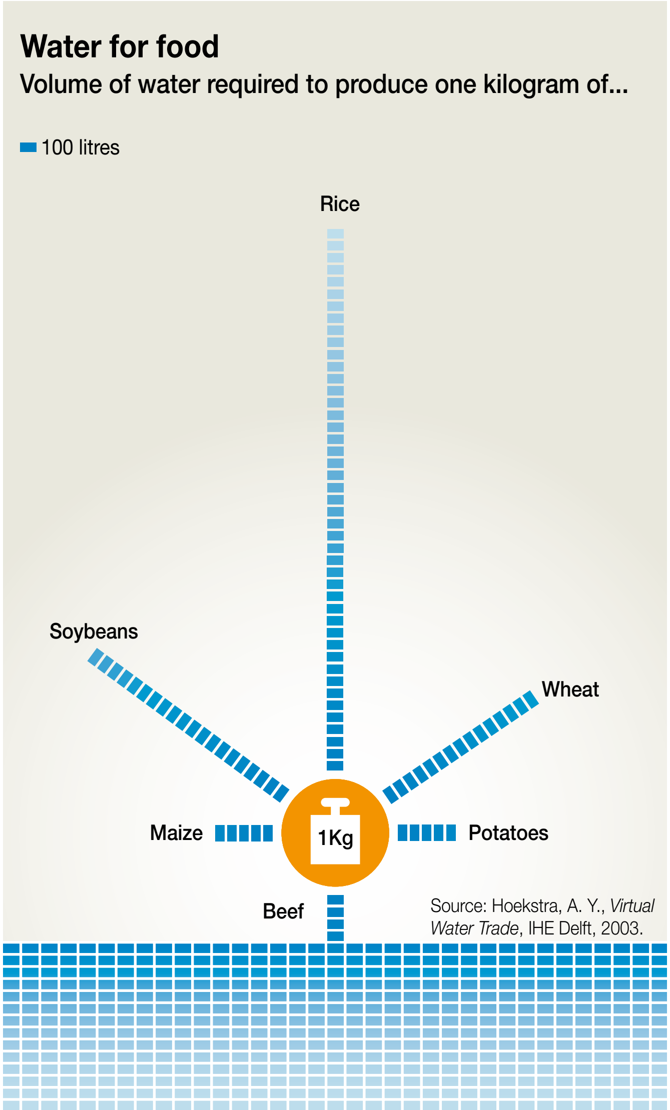


Figure 10: The volume of water required to produce different food products varies enourmously, as do the waste products.

of Asia's cereal production or approximately 25 percent of the world food production (Klatzel *et al*, 2009; UNEP, 2009). Investment in increased irrigation efficiency will not only have very substantial effects on overall water consumption and first-phase wastewater production, it will also significantly reduce food prices, increasing food production potential, and hence agricultural development and rural poverty reduction.

The wastewater produced from rural agriculture and livestock production, as well as inland urban areas, represents the first phase in wastewater production and pollution and constitutes a considerable challenge for downstream users. It is characterized by organic and inorganic contaminants; originating from dissolved contents of fertilizers, chemical runoff (such as pesticides), human waste, livestock manure and nutrients.

Agricultural practices, primarily the cultivation of nitrogen fixing crops and the manufacture of fertilizer convert about 120 million tonnes of nitrogen from the atmosphere per year into reactive nitrogen containing compounds (Rockström *et al*, 2009a). Up to two-thirds of this nitrogen makes its way into inland waterways and the coastal zone. This anthropogenic addition of nitrogen exceeds all natural inputs to the nitrogen cycle. The phosphorus story is similar – we mine approximately 20 million tonnes of phosphorus a year to be used mainly as fertilizer, but almost half of this finds its way back into the ocean (Rockström *et al*, 2009a). This is estimated to be approximately eight times the natural input. Together, the excess nitrogen and phosphorus drive algal booms, including toxic red tides and devastating hypoxic events that impact fish stocks or human health. (Tilman, 1998; Rockström *et al*, 2009b).

Impacts of water quality on food quality and health

Wastewater has long been used as a resource in agriculture. The use of contaminated water in agriculture, which may be intentional or accidental, can be managed through the implementation of various barriers which reduce the risk to both crop viability and human health. Today an estimated 20 million hectares (seven per cent) of land is irrigated using wastewater

Converting water into red meat

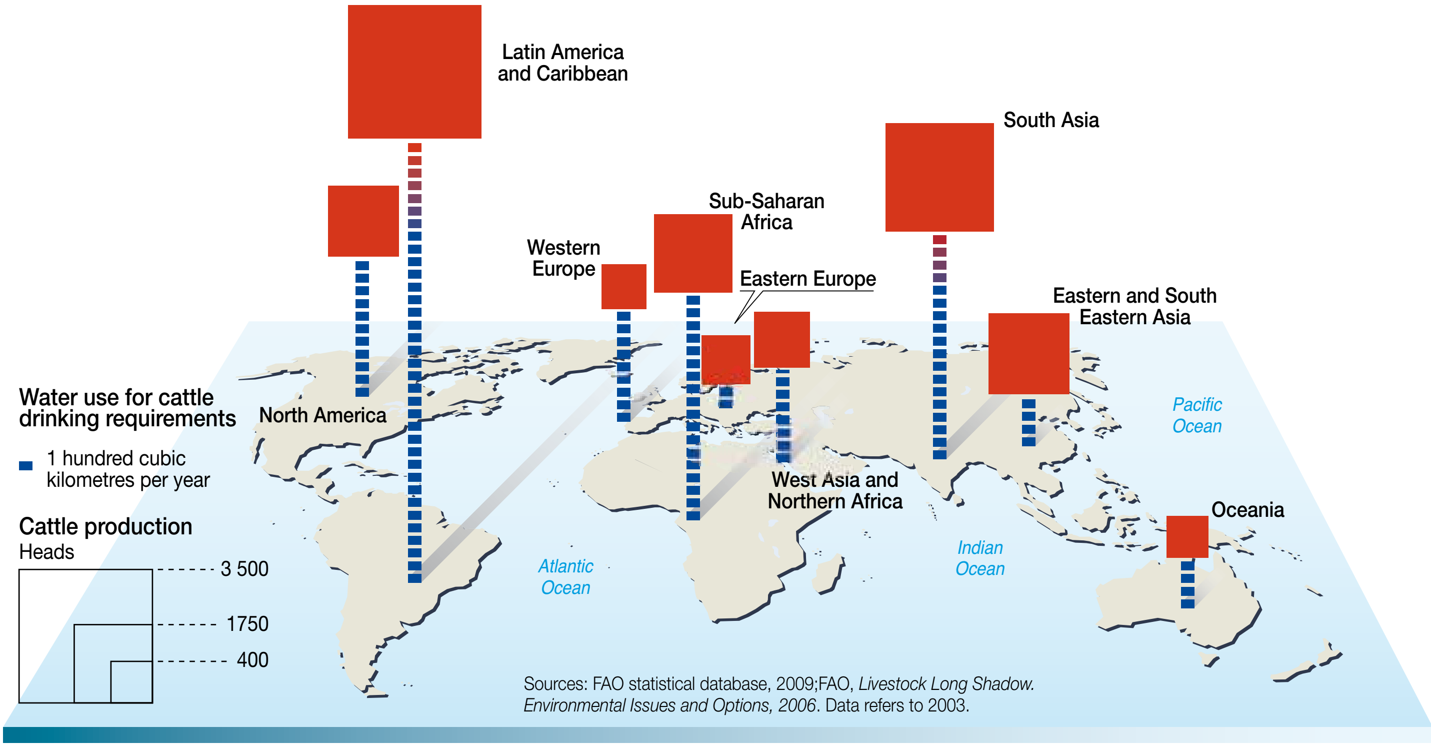


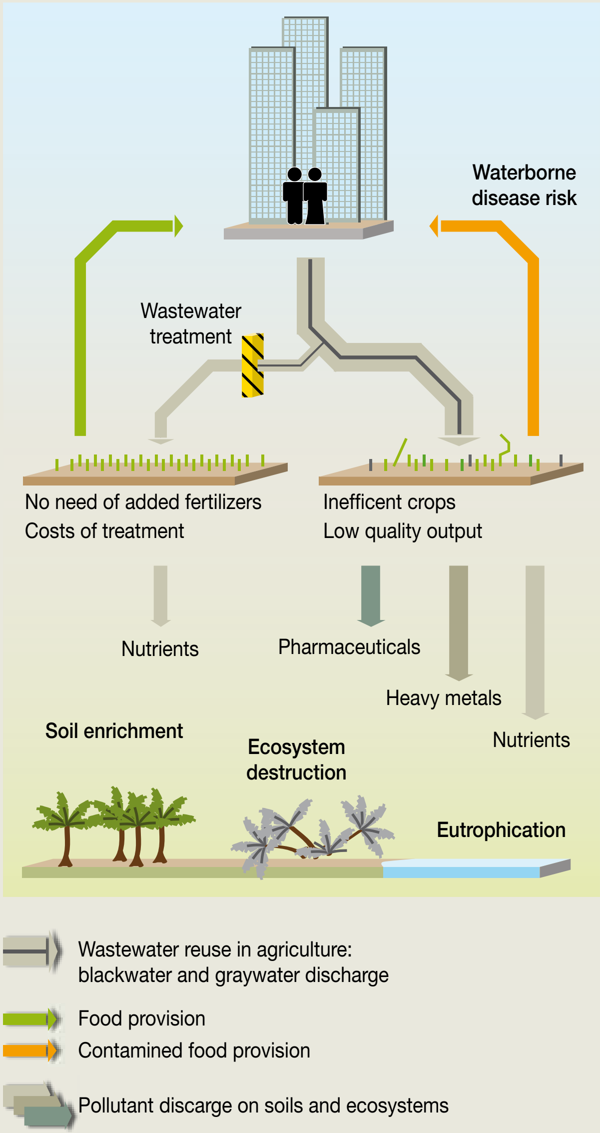
Figure 11: Production of red meat has a significant demand on water with impacts on quality.

worldwide (WHO-FAO, 2006), particularly in arid and semi-arid regions and urban areas where unpolluted water is a scarce resource and the water and nutrient values of wastewater represent important, drought-resistant resources for farmers. However, untreated wastewater may contain a range of pathogens including bacteria, parasites, viruses, toxic chemicals such as heavy metals and organic chemicals from agriculture, industry and domestic sources (Drechsel *et al*, 2010).

There are clear health advantages related to wastewater use in agriculture, stemming directly from the provision of food (mainly vegetables) to urban populations. It is estimated that 10 per cent of the worlds population relies on food grown with contaminated wastewater (WHO-FAO, 2006). In Pakistan, about 26 per cent of national vegetable production originates from urban and peri-urban agriculture irrigated with wastewater (Ensink *et al*, 2004). In Hanoi peri-urban agriculture, using diluted wastewater, provides 60–80 per cent of the perishable food for local markets (Lai, 2002, Van den Berg *et al*, 2003).

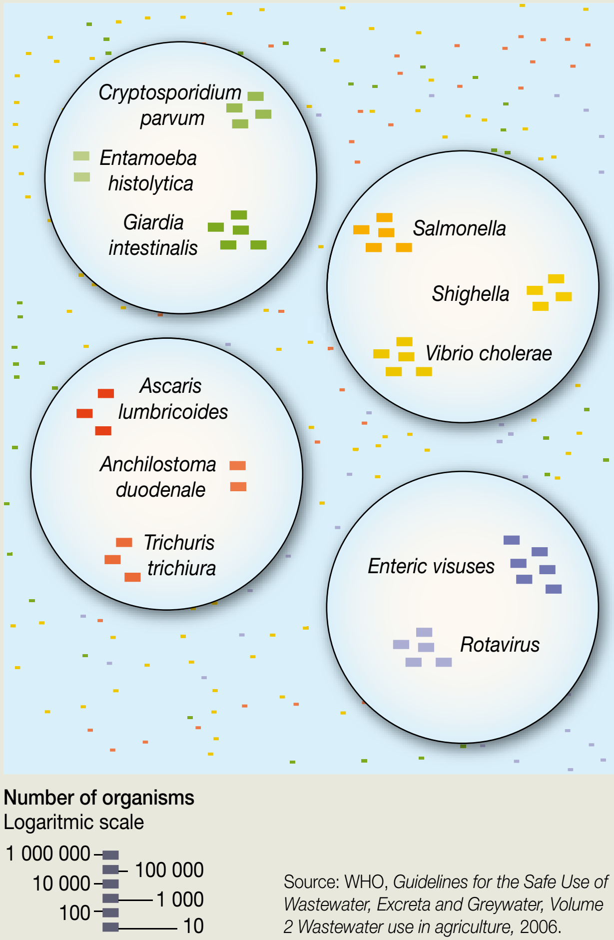
Whilst providing affordable food, the use of wastewater for food production without proper management can pose a serious risk. This risk can be to farmers and farm workers who come into direct contact with wastewater affected through faecal-oral transmission pathways or contact with disease vectors in the water, such as schistosomiasis. Consumers and

Wastewater in urban agriculture
Resource or threat?



Source: Drechser, P., *et al.Wastewater Irrigation and Health. Assessing and Mitigating Risk in Low-Income Countries,* IWMI-IDRC, 2009.

A look inside
Concentrations of micro-organisms excreted in one litre of wastewater



Source: WHO, *Guidelines for the Safe Use of Wastewater, Excreta and Greywater, Volume 2 Wastewater use in agriculture,* 2006.

Figure 12a: Is reuse of wastewater a benefit or a threat for agriculture? **Figure 12b** looks at what one litre of wastewater might contain in terms of pathogens.

marginalized communities living around agricultural and aquaculture regions where untreated wastewater is used are also exposed to risks. The impact on health varies depending of location and type of contaminant, however bacteria and intestinal worm infestations have been shown to pose the greatest risk (Drechsel *et al*, 2010).

In addition farmers often lack knowledge of water quality, including nutrient content, so they combine nutrient-rich irrigation water with chemical fertilizers. This makes agriculture a source of pollution rather than a step in environmental sanitation (Evers *et al*, 2008).

Whilst some countries have national guidelines for the acceptable use of wastewater for irrigation, many do not. The Guidelines on the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture (WHO/FAO, 2006a) provide a comprehensive framework for risk assessment and management that can be applied at different levels and in a range of socio-economic circumstances. The main characteristics of the approach proposed by the guidelines are:

- the establishment of health-based targets, which allow local authorities to set risk levels that can be handled under the local socio-economic conditions and with the capacities available in a country;
- the application of quantitative microbial risk assessment (for pathogenic viruses and bacteria) as a cost-effective way of assessing health risks;
- the identification of all risk points along the chain of events from the origin of the wastewater to the consumption of the produce (e.g. the farm-to-fork approach of the HAPPC method in food safety);
- the design of a combination of health risk management measures, to be applied along the same chain of events, with the aim of ensuring health protection as a result of incremental risk reduction. Such interventions can include partial wastewater treatment;
- monitoring at all stages to ensure measures are effective, applied correctly and lead to the desired impact on health.

In many countries the capacity to apply these guidelines and best practice recommendations is insufficient and needs substantial strengthening. Yet, this incremental approach to wastewater management is highly compatible with the concept of the sanitation ladder. Both improvements in sanitation and

improvements in wastewater use are mutually re-enforcing actions in support of optimizing wastewater management from the public health perspective (WHO/FAO, 2006).

Optimizing agricultural practices including irrigation techniques, fertilization practices, and reducing water evaporation and crop selection can save significant amounts of water with a subsequent reduction in wastewater production. In a similar way, opportunities for appropriate use of wastewater, as well as improvement in fertilization and animal production should continue to be explored. Development and modification of agricultural tools and practices should be promoted as one facet in addressing the management of wastewater.

Sectorally appropriate solutions may however not be beneficial across the board. Reuse of wastewater may, for example increase productivity and yield without the need for additional water sources and artificial fertilizers, but carry risks for consumer health – creating costs further down the chain. This again highlights the cross-cutting nature of wastewater management that requires collaboration and dialogue between partners who may not usually talk, for example farmers, public health officials, municipal and waste managers, planners and developers.

WASTEWATER AND INDUSTRY

Water is an important requirement in many industrial processes, for example, heating, cooling, production, cleaning and rinsing. Overall, some 5–20 per cent of total water usage goes to industry (WWAP, 2009), and industry generates a substantial proportion of total wastewater. If unregulated, industrial wastewater has the potential to be a highly toxic source of pollution. The vast array of complex organic compounds and heavy metals used in modern industrial processes, if released into the environment can cause both human health and environmental disasters. Industry has a corporate responsibility to take action to ensure discharged water is of an acceptable standard, and accept costs of any required clean up. The most cost-effective solutions usually focus on preventing contaminants from ever entering the wastewater stream or developing a closed system of water use. Industry can also benefit from access to cleaner water resources with fewer impurities, as impurities can add costs to the production processes.

In many developing countries more than 70 per cent of industrial wastes are dumped untreated into waters where they pollute the usable water supply (WWAP, 2009). Industrial discharge can contain a wide range of contaminants and originate from a myriad of sources. Some of the biggest generators of toxic industrial waste include mining, pulp mills, tanneries, sugar refineries, and pharmaceutical production.

In many instances wastewater from industry not only drains directly into rivers and lakes, it also seeps into the ground contaminating aquifers and wells. This pollutes water supplies and in developing countries often goes undetected, as monitoring is expensive. Even if it is detected, remediation often does not occur as the source of the pollution must be addressed and decontamination carried out at the same time, which can be extremely difficult.

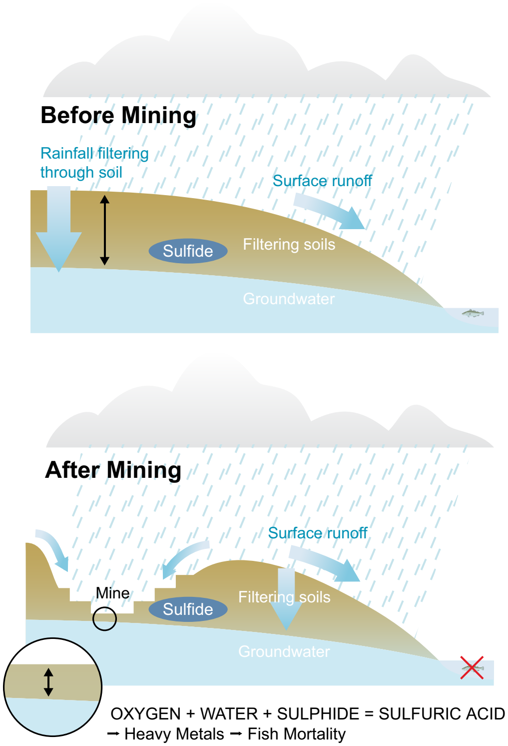
Mining has traditionally been a major source of unregulated wastewater discharge in developing countries. Tailings from mining operations can contain silt and rock particles and surfactants. Depending on the type of ore deposit being mined, tailings can also contain heavy metals like copper, lead, zinc, mercury and arsenic. The contaminants in mine waste may be carcinogenic or neurotoxic to people (e.g. lead and mercury) or extremely toxic to aquatic organisms (e.g. copper). There are many examples of persistent environmental damage caused by the discharge of toxic mine waste. In Papua New Guinea for example, companies discharge millions of tons of contaminated mine waste into rivers from the Ok Tedi, Porgera and Tolukuma mines (Christmann and Stolojan, 2001).

The food and agriculture processing industry can also be a major producer of wastewater particularly organic waste with high biochemical oxygen demand (BOD). BOD measures the amount of oxygen used by micro-organisms like bacteria in the oxidation of this material. Low oxygen levels or even anoxic conditions may result if large amounts of organic waste are discharged into waterways. Slaughterhouses may produce water polluted with biological material such as blood containing pathogens, hormones and antibiotics.

Cooling waters used in industrial processes like steel manufacture and coke production not only produce discharge with an elevated temperature which can have adverse effects on biota, but can also become contaminated with a wide range of toxic substances. This includes cyanide, ammonia, benzene, phe-

nols, cresols, naphthalene, anthracene and complex organic compounds such as polycyclic aromatic hydrocarbons (PAH). Water is also used as a lubricant in industrial machinery and can become contaminated with hydraulic oils, tallow, tin, chromium, ferrous sulphates and chlorides and various acids.

Industry has a primary responsibility to reduce the production of toxic waste. Many incentives are based on voluntary measures, but governments and the public sector must play a central role in monitoring, regulating and also implementing policy to reduce toxic waste. Industrialized nations have generally recognized that in theory it is simpler and more cost-effective to deploy cleaner production processes than to clean up large-scale industrial pollution. Pollution from wastewater depreciates land values, increases municipal costs and causes numerous adverse biological and human health effects, the cost of which are difficult to calculate.



Extraction decreases groundwater depth and natural filtration, and increases the groundwater contamination.

← **Figure 13:** Mining effects on rainfall drainage. Acid Mine Drainage (AMD) is the number one environmental problem facing the mining industry. AMD occurs when sulphide-bearing minerals in rock are exposed to air and water, changing the sulphide to sulphuric acid. AMD can devastate aquatic habitats, is difficult to treat with existing technology, and once started, can continue for centuries (Roman mine sites in Great Britain continue to generate acid drainage 2 000 years after mining ceased (Mining Watch Canada, 2006)).

How to get industry to clean up its act?

In many countries the responsibility for industrial wastewater treatment falls on ordinary taxpayers. In the absence of a user-pays system for pollution control, large volumes of contaminated industrial wastewater end up in municipal sewage treatment plants, which are expensive to construct, operate and maintain. The Netherlands introduced a series of incentives to polluters to reduce pollution at source, rather than opting for the more expensive end-of-pipe solution of public sewage treatment. This approach has been cost-effective in reaching water quality targets (the Urban Waste Water Treatment Directive). In contrast other European member states who have not introduced a polluter-pays system or have been slow to adopt one have consequently not reached targets (e.g. France) or have paid a high price to do so (e.g. Denmark) (EEA, 2005).

Bottled water

The problem of poor water quality in many urban centres has been one of the factors that have lead those who can afford it to turn to bottled water. Bottled water sales worldwide have increased rapidly with global consumption now at more than 200 000 million litres a year. While the USA is the biggest consumer of bottled water, China has shown the strongest growth, increasing consumption by more than 15 per cent since 2003 (Beverage Marketing Corporation). The cost of producing bottled water is a serious concern. In the United States it is estimated that the production of the bottles alone requires 17 million barrels of oil a year and it takes three litres of water to produce one litre of bottled water

(Source: Pacific Institute http://www.pacinst.org/topics/water_and_sustainability/bottled_water/bottled_water_and_energy.html)

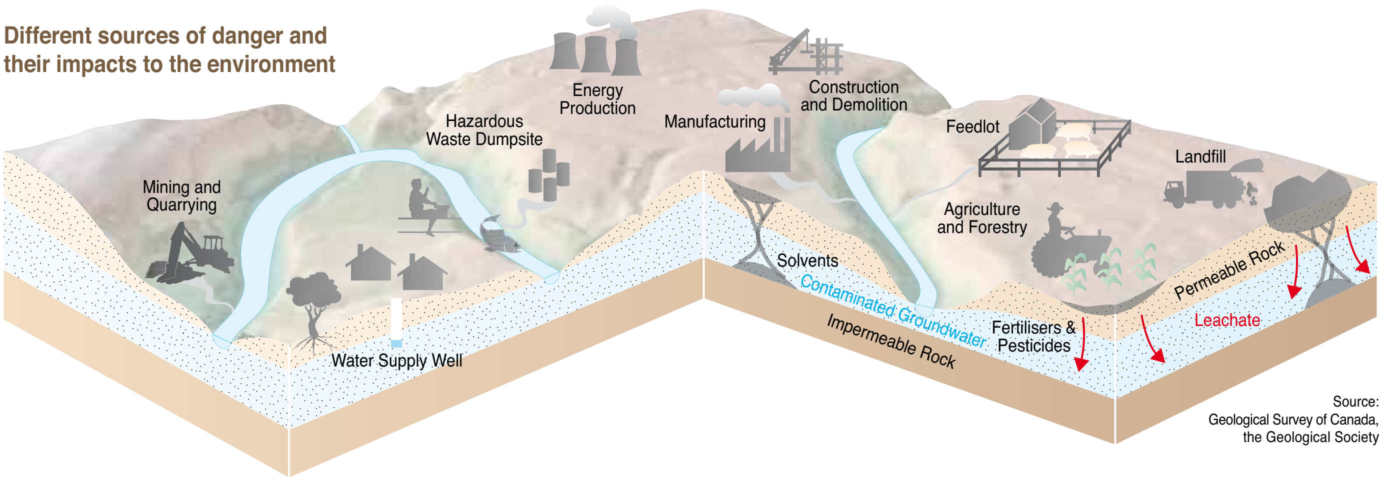


Figure 14: Sources of agricultural and industrial pollution and their impacts on the environment. Contaminated groundwater can adversely affect animals, plants and humans if it is removed from the ground by man-made or natural processes. Depending on the geology of the area, groundwater may rise to the surface through springs or seeps, flow laterally into nearby rivers, streams, or ponds, or sink deeper into the earth. In many parts of the world, groundwater is pumped out of the ground to be used for drinking, bathing, other household uses, agriculture, and industry.

WASTEWATER, HEALTH AND HUMAN WELLBEING

Securing safe water and reducing the unregulated discharge of wastewater are among the most important factors influencing world health. Unmanaged wastewater is a vector of disease, causing child mortality and reduced labour productivity, but receives a disproportionately low and often poorly targeted share of development aid and investment in developing countries. At least 1.8 million children under five years die every year due to water related disease, or one every 20 seconds (WHO, 2008).

THE BURDEN OF WATER ASSOCIATED DISEASE

Infectious disease

Estimates of the global burden of water-associated human diseases provide a simple index hiding a complex reality. WHO estimates that worldwide some 2.2 million people die each year from diarrhoeal disease, 3.7 per cent of all deaths and at any one time over half of the world's hospitals beds are filled with people suffering from water related diseases (UNDP 2006). Of the 10.4 million deaths of children under five, 17 per cent are attributed to diarrhoeal disease, i.e. an estimated 1.8 million under-fives die annually as a result of diarrhoeal diseases. For an estimated 88 per cent of diarrhoea cases the underlying cause is unsafe water, inadequate sanitation and poor hygiene. Moreover, it is estimated that 50 per cent of malnutrition is associated with repeated diarrhoea or intestinal worm infections. Childhood malnutrition is at the root of 35 per cent of all global child mortality (WHO, 2008).

The burden of disease is about more than just mortality; it also takes into account the proportion of healthy life years lost. The Disability-Adjusted Life Year (DALY) is a time-based measure of the burden on community health that combines years of life lost due to premature mortality and years of life lost due to periods of illness. Diarrhoeal diseases rank second in terms of global DALYs lost (see: Table 1).

It is difficult to tease out which fraction of the disease burden can be attributed to the poor management of wastewater. The role of wastewater in human ill-health can pass through one

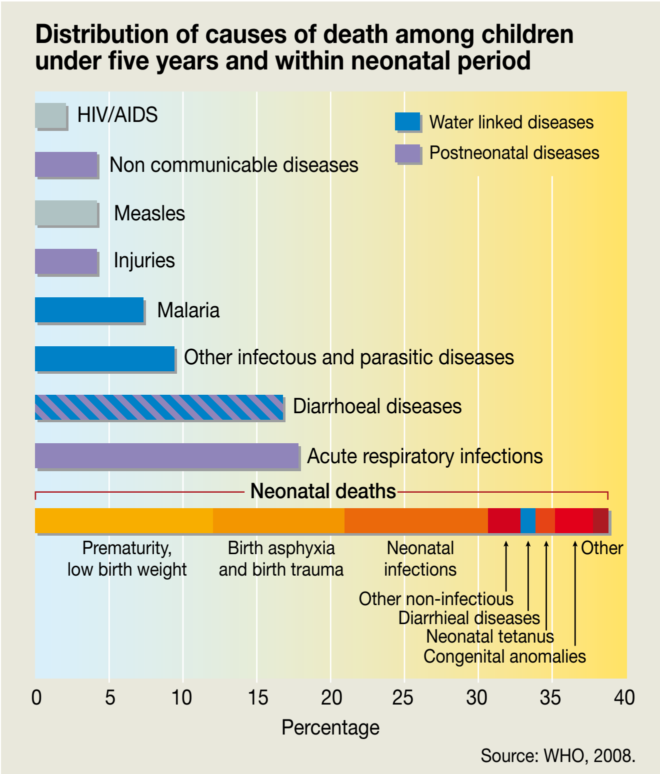


Figure 15: Distribution of causes of death among children under five years and within the neonatal period, 2004 (Figure from WHO, 2008).

Table 1: Global burden of disease and the relative disease burden caused by diarrhoeal diseases (measured in DALYs), 2004

	Disease or injury	Disability-adjusted life years, all age groups (millions)	Disability-adjusted life years, children 0–14 years (millions)	Percentage of total DALYs, all age groups
1	Lower respiratory infections	94.5	73.6	6.2
2	Diarrhoeal diseases	72.8	65.2	4.8
3	Unipolar depressive disorders	65.5	–	4.3
4	Ischaemic heart disease	62.6	–	4.1
5	HIV/AIDS	58.5	8.5	3.8
...				
11	Tuberculosis	34.2	3.4	2.2
12	Malaria	34.0	32.4	2.2

Source: WHO (2008)

of two transmission pathways; the faecal-oral pathway (i.e. disease-causing microbes originating from faecal contamination make their way when water is ingested); or the ecosystem, where wastewater collects providing an ecological niche for the propagation of certain human diseases vectors. The latter group includes lymphatic filariasis, and in some parts of the world, for some vector species, West Nile infection; it does not, however, include malaria, as the anopheline vectors of this disease generally do not breed in wastewater.

Non-communicable disease

Direct evidence of ill-health related to exposure to toxic compounds is harder to establish. This is because of complexities in the exposure pathways and the long-term effect of exposure to low doses over extended periods of time, during which other hazards and risks will complicate the picture. Pesticides and pesticide residues in agricultural run-off, heavy metals and toxic compounds in industrial waste, the group of persistent organic pollutants (which includes many first generation synthetic pesticides), endocrine disruptors and pharmaceutical and person care products all feature as confirmed, incriminated or suspect chemicals that pose health hazards.

ACCESS TO SANITATION

The connection between wastewater and human health is linked with access to sanitation and with human waste disposal. Adequate sanitation is expected to create a barrier between disposed human excreta and sources of drinking-water. Wastewater management is a key component of health risk management in this context.

Access to basic sanitation is part of the 2015 water and sanitation target under Millennium Development Goal 7: to halve, by 2015, the proportion of the population without sustainable access to safe drinking-water and basic sanitation. The WHO/UNICEF Joint Monitoring Programme (JMP) is the formal mechanism to keep track of progress towards achieving these targets. Information up to 2006 showed 2.5 billion people lacked access to basic sanitation (WHO/UNICEF, 2008). The 2010 JMP report (WHO/UNICEF, in print) will report that figure estimated to be 2.6 billion at the end of 2008. This means that, taking population growth into account the situation has remained stagnant and progress towards the sanitation target is off track.

Regionally, there are large variations in progress towards this MDG. For sanitation, the regions of Africa south of the Sahara and southern Asia show the greatest disparity, with 330 million and 221 million people without access to basic sanitation, respectively. Not surprisingly, the regional variations in lack of access are proportionally mirrored in the diarrhoeal disease data. Figure 16 presents the regional child mortality rates from diarrhoea for which lack of access to sanitation is the root-cause, modulated by regional differences in the capacity of health services.

THE SANITATION LADDER

In their efforts to monitor progress in achieving the MDG water and sanitation target, WHO and UNICEF designed the sanitation ladder. The sanitation ladder reflects incremental progress even in situations where it is not possible to achieve the full MDG target. Poverty is the overarching determinant, and the position of a community on the sanitation ladder therefore relates to that community's capacity to deal with wastewater management as well. Not only do higher rungs on the ladder reflect a better sanitation starting point for effective wastewater management, but the corresponding improved socio-economic status will also permit a greater capacity to manage wastewater and invest in the necessary infrastructure.

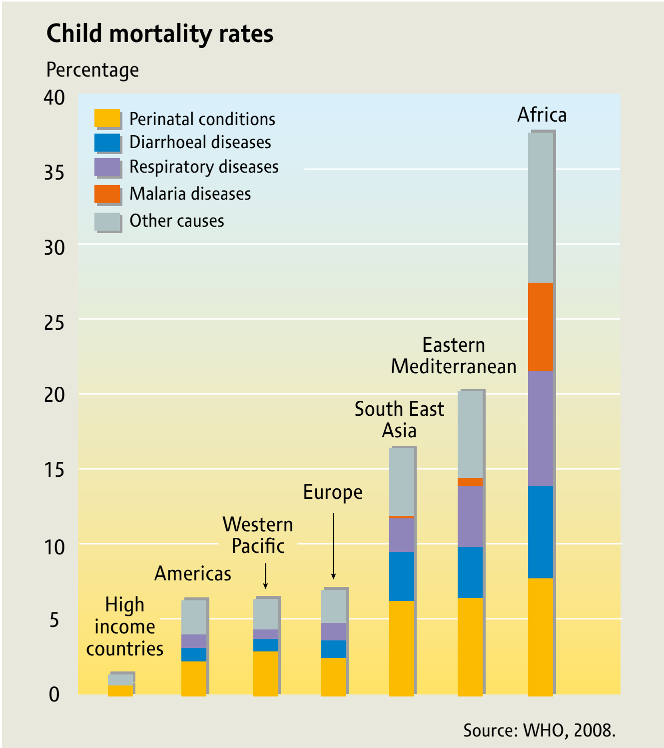


Figure 16: Child mortality rates by cause and region, 2004. Source: WHO, 2008.

WASTEWATER AND ECOSYSTEM FUNCTION

All waterways are connected. The unregulated discharge of wastewater therefore has far reaching implications for the health of all aquatic ecosystems, which threatens to undermine the resilience of biodiversity and the ecosystem services on which human wellbeing depends. One such impact, eutrophication is a major global concern affecting the functioning of marine and freshwater ecosystems. To address these challenges we must apply the principles of integrated ecosystem-based management so that the ecosystem services on which we depend can be sustained through the watershed and into the marine environment.

Water quality changes at the first point of extraction or use, whether this is the impact of livestock production, release of nutrients and sedimentation through deforestation, or the myriad of agricultural, industrial and urban activities taking place in the watershed all the way to the coastal zone and open ocean via rivers, ground water, aquifers and storm water run-off. These changes can impact aquatic environments in the following ways:

Mechanical impacts

The impact of water extraction can influence water quality through changes in sediment loading and thermal stress which can change the physical environment, increasing turbidity or scouring and in turn affect biodiversity. For example, changes in sediment loading of rivers can impact downstream habitats that provide ecosystem services of waste and nutrient assimilation. Many aquatic organisms and habitats such as bivalves, mangroves, salt marshes, fresh water marshes and sea grasses have a natural capacity to assimilate a certain amount of pollutants, such as nitrates and phosphates. Changes in sediment supplies can result in either smothering of sea grasses and coral reefs, or if restricted reduce the essential supply required for the accretion of coastal wetlands, resulting in the decline of these critically important and sensitive habitats.

Eutrophication

Eutrophication is one of the most prevalent global problems of our time. It is a process by which lakes, rivers, and coastal

waters become increasingly rich in plant biomass as a result of the enhanced input of plant nutrients mainly nitrogen and phosphorus in general originating from agricultural and urban areas, through the soil or directly into rivers and oceans (Gilbert, 2008, Nyenje *et al*, 2010). The impacts of eutrophication can result in profound environmental change and impact the ecological integrity of aquatic systems e.g. Agricul-

tural run-off exacerbating the spreading of dead zones (Diaz and Rosenberg, 2008): current agricultural practices, convert about 120 million tonnes of nitrogen from the atmosphere per year into reactive nitrogen containing compounds (Rockström *et al*, 2009). Up to two thirds of this nitrogen makes its way into inland waterways and the coastal zone, exceeding all natural inputs to the nitrogen cycle. Approximately 20 million tonnes of phosphorus are mined each year for fertilizers, almost half returns to the ocean – approximately eight times the natural input (Rockström *et al*, 2009a). Together, this excess nitrogen and phosphorus drive potentially toxic algal booms and changes in biodiversity which can in turn lead to devastating hypoxic events and enhancing dead zones (Tilman, 1998; Rockström *et al*, 2009b) resulting in huge economic losses across many sectors (Figueredo and Giani, 2001, Hernández-

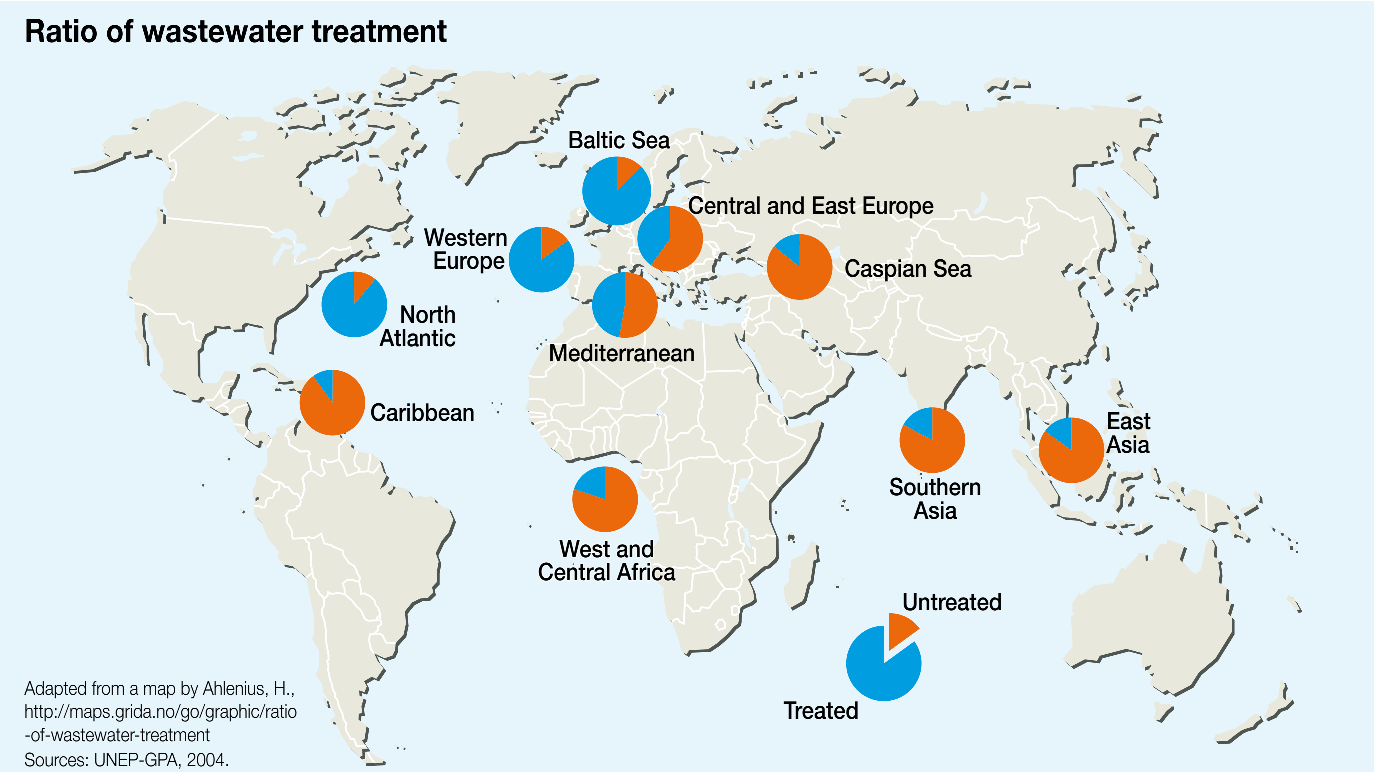
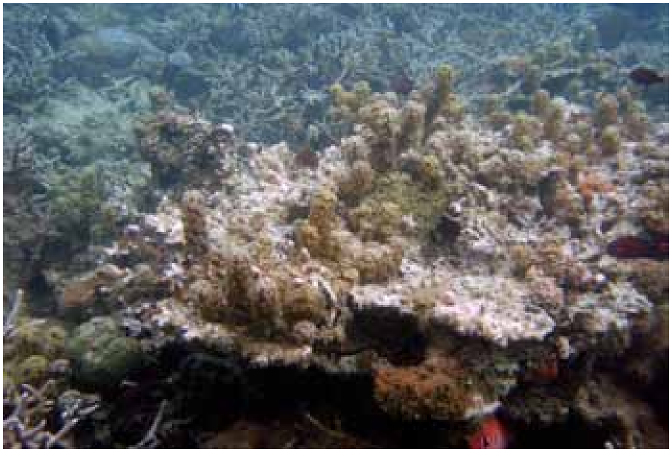


Figure 17: The ratio of treated to untreated wastewater reaching water bodies for 10 regions. An estimated 90 per cent of all wastewater in developing countries is discharged untreated directly into rivers, lakes or the oceans (UN Water, 2008).



Shancho *et al*, 2010). Dead zones are now thought to affect more than 245 000 km^2 of marine ecosystems, predominantly in the northern hemisphere (Diaz and Rosenberg, 2008), equivalent to the total global area of coral reefs.

Toxicity, saphrogens and mutagens

A wide range of toxic pollutants from land based sources are found in both fresh and marine waters ranging from agricultural and industrial chemicals such as organic compounds, heavy metals to personal-care products and pharmaceuticals. The impacts of these are wide-ranging. In the north east of Australia, run-off of agricultural herbicides caused the loss of 30 km^2 of mangrove between 1999 and 2002. In areas where mangroves were lost, the near shore zone suffered greater turbidity, nutrient loading and sediment loading as well as greater

exposure to the herbicide toxins which then had toxicological effects on other highly valued marine ecosystems such as the reefs and lagoons of the Great Barrier Reef (Duke *et al*, 2005). Another example of transfer of terrestrial pathogens to marine mammals concerns Toxoplasma gondii, a pathogen of marine mammals commonly found in domestic cats and terrestrial wild mammals. It is believed that the oocysts from cat faeces are washed into seawater where they remain a source of infection for up to two years, depending on the water temperature (Lindsay and Dubey, 2009)

Coastal regions and Small Island Developing States (SIDS) represent an area of particular concern as they contain some of the most productive ecosystems. It is here that human populations concentrate – they are the most densely populated on the planet, and yet the most productive. This zone where land and sea meet has historically been a strategic location for human communities, with good positioning for trade and security, productive land and water providing access to food and energy sources. Twenty-one of the world's 33 megacities are on the coast (Martínez *et al*, 2007). By 2015, the coastal population is expected to reach approximately 1.6 billion people, nearly 22.2% of the global total (Manson, 2005).

This increasing pressure from changing climate and growing populations threatens the continued provision of vital services, in particular where economies are highly dependent on coastal resources. In Zanzibar, a Tanzanian island off the east coast of Africa, for example, marine ecosystem services account for 30 per cent of GDP, 77 per cent of investment, and a large amount of foreign exchange and employment. The value of tourism alone in 2007 accounted for 25 per cent of GDP, five times greater than the combined value of all the other ecosystem values and dependent on a healthy marine environment. However uncontrolled release of wastewater from Zanzibar town into the coastal zone is a particular threat to water quality and ecosystem integrity impacting the two main economic activities – fisheries and tourism – a risk for the very assets that tourists pay to come and see (Lange and Jiddawi, 2009). In Caribbean SIDS, the economies of some states are almost entirely dependent on the health of their reefs for tourism, fisheries and shoreline protection. Degradation of the reefs could reduce these net benefits by an estimated US$350–870 million a year (Burke and Maidens, 2004).

Healthy, functioning ecosystems provide a wide array of valuable services to human security and wellbeing. Coastal ecosystems provide global services estimated at US$25 billion a year (Martínez *et al*, 2007) – contributing food security, shoreline protection, tourism, carbon sequestration through blue

Desalination and impacts on the marine and coastal environment

Desalination of sea water is often the only viable option for providing safe drinking water in many arid, coastal regions or isolated locations such as small islands, An established technology since the 1950s, by 2006 approximately 24.5 million m^3 of water were being produced per day for drinking water, tourism, industry and agriculture (58 per cent of all desalinated water produced) (UNEP, 2008; Lattemann, and Hoepner, 2008). Production is expected to increase to 98 million m^3 a day by 2015 (UNEP 2008). It is not however without consequences both in terms of high economic cost, energy requirements (Bleninger and Jirka, 2008; Lattemann, and Hoepner,2008; von Medeazza GLM 2005; Sadhwani *et al*, 2005; UNEP, 2008), environmental and social implications (Lattemann, and Hoepner,2008). There is scope to improve the sustainability of the desalination process.

The process results in the discharge of a concentrated brine into the receiving waters. Temperature and salinity are two factors that determine the composition and distribution of species in the marine environment affecting water density and causing stratification (Miri and Chouikhi ,2005;Lattemann and Hoepner,2008) changes to primary production and turbidity. Changes in these parameters over sustained periods could lead to local ecological changes, resulting in shifts in species diversity, opening the potential for the colonization of exotic and potentially invasive species, and changing ecosystem function. The process requires the use of descaling and antifouling products, which can contain heavy metals and toxic chemicals, although the impact of these can be managed with good practice and plant maintenance.

carbon sinks (Nelleman *et al*, 2009). However, loss of these ecosystems, or overburdening through poor management of water and wastewater compromises the integrity of these ecosystems and the services they provide. Resulting in, contamination of fish stocks, algae blooms, a rise in dead zones along the coasts, and subsequent loss of livelihoods and food security. The continued provision of these services requires management that will support healthy and functioning ecosystems, not just in the marine environment, but in the entire watershed.

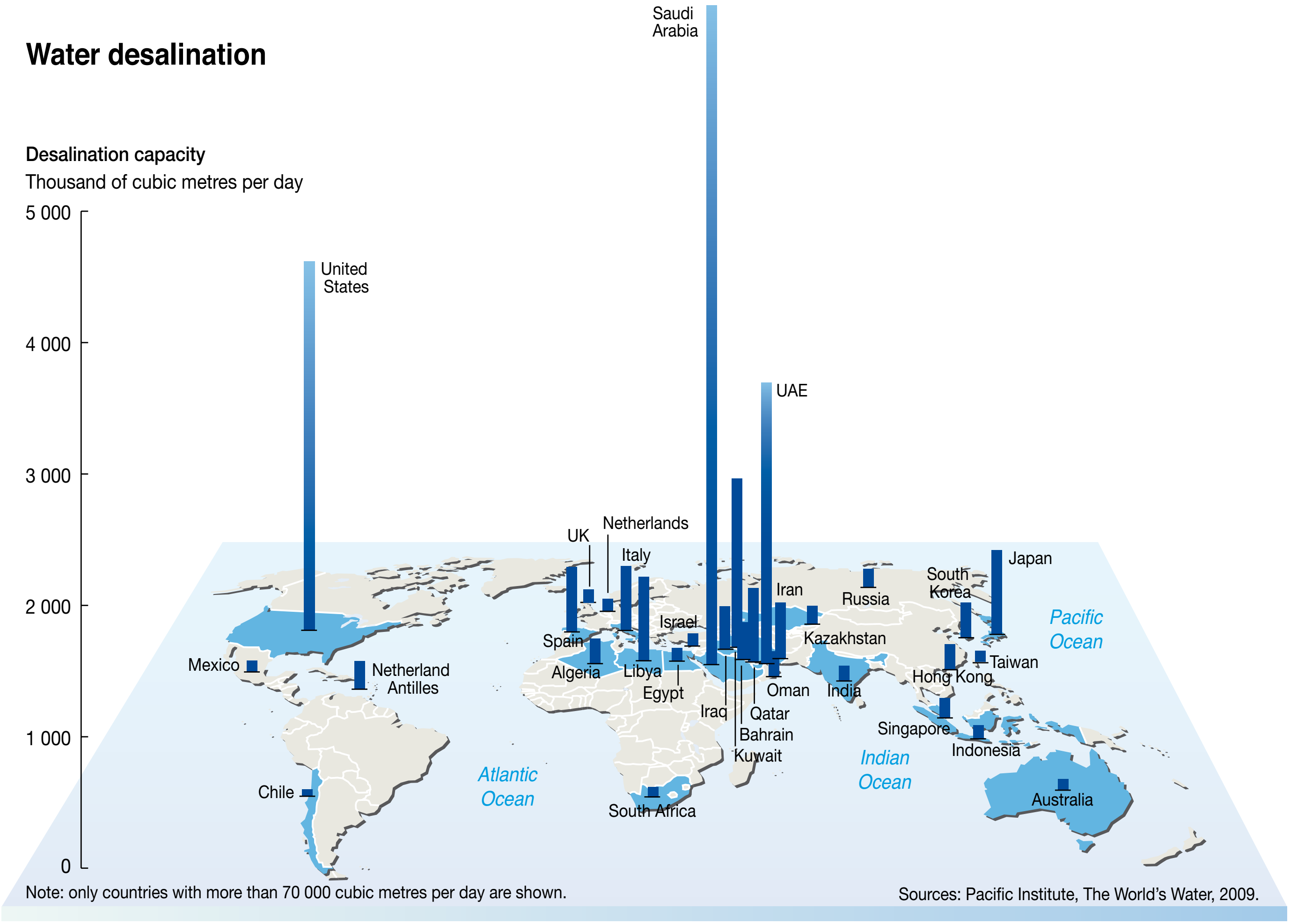


Figure 18: Desalination is an increasingly important practice to secure clean water in a number of countries. Monitoring is key to minimize negative impacts on the ecosystem.




WASTEWATER AND GLOBAL CHANGE

Global populations are rapidly expanding with urban populations expected to double in the next 40 years (UNFPA, 2009), increasing demands on food and water resources and already inadequate wastewater infrastructure. This is in the light of changing climatic patterns, and water availability, weakened ecosystems and inconsistent and poorly integrated management. The challenges that unmanaged wastewater poses in the urban environment, to food production, industry, human health and the environment are interconnected and becoming ever more severe. It is critical that wastewater management is dealt with urgently and given very high priority to become an integral part of urban planning and integrated watershed and coastal management.

POPULATION GROWTH

The world's population is expected to grow by almost a third to over 9 billion people in the next 40 years (UNFPA, 2009), resulting in increased water usage, and increased demand for food and products. The amount of available fresh water resources, however will not increase. Over the period to 2050 the world's water will have to support the agricultural systems that will feed and create livelihoods for an additional 2.7 billion people (UN, 2010).

Urban populations are projected to see the fastest growth rising from a current 3.4 billion to over 6.4 billion by 2050 (UNDESA, 2008). Most cities in developing countries have an aging, inadequate or even non-existent sewage infrastructure, unable to keep up with rising population. Effective treatment also requires a transportation infrastructure to deal with the growing masses and frequently unorganized settlement patterns.

Slum dwellers of the new millennium are no longer a few thousand in a few cities of a rapidly industrializing continent, but include one out of every three city dwellers, close to a billion people, or a sixth of the world's population and are projected to increase to 1.4 billion within a decade (UN-HABITAT 2009), meaning another 400 million people without basic sanitation or water supply by 2020. Over 90 per cent of slum dwellers today are in the developing world. In sub-Saharan Africa, urbanization has become virtually synonymous with slum growth. The slum population of sub-Saharan Africa almost doubled in 15 years, reaching nearly 200 million in 2005. Seventy-two per cent of the region's urban population lives under slum conditions, compared to 56 per cent in South Asia. (UNFPA, 2007)

As cities continue to expand their size, footprint and slum areas, it is essential that wastewater management is brought into urban management and planning. Currently one fifth or 1.2 billion people live in areas of physical water scarcity. It is estimated that this will increase to 3 billion by 2025 as water stress and populations increase (UNDP, 2006 and DFID,2008)

CLIMATE CHANGE

The relationship between wastewater and climate change can be seen from three perspectives. Changing climatic conditions change the volume and quality of water availability in both time and space, thus influencing water usage practices. Secondly changes in climate will also require adaptation, in terms of how wastewater is managed. Finally, wastewater treatment results in the emission of greenhouse gases, particularly carbon dioxide (CO_2) and methane (CH_4) and nitrous oxide (N_2O).

Changes to global climate patterns are a reality which impacts our daily lives (IPCC, 2007) and may affect water availability,

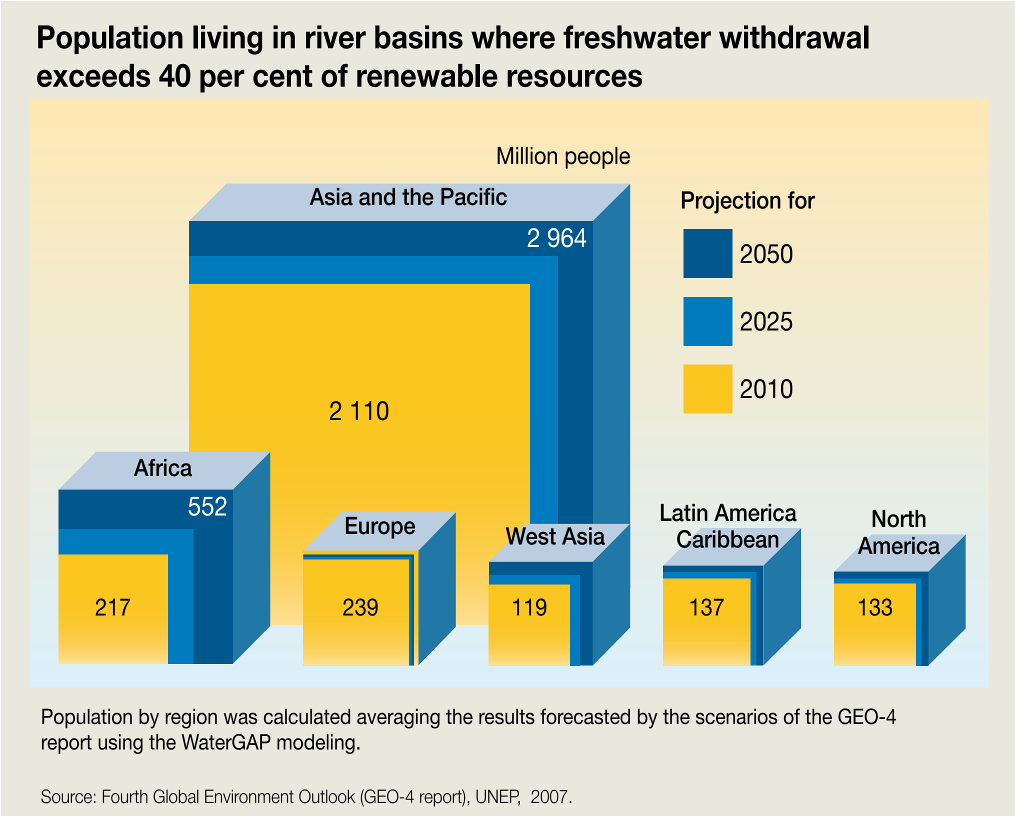


Figure 19.

in the timing and intensity of rainfall, or the period of time without rain, as well as affecting the quality of water in rivers and lakes through changes in the timing and volume of peak discharge and temperature (IPCC, 2007).

Anticipation of more droughts and extreme rainfall events has impacts for non-existent or old, inadequate wastewater treatment facilities highlighting the need for infrastructure that can cope with extreme surges of wastewater. Changes in the reliability of the water supply have major impacts on the livelihoods and health of the poorest communities which rely on rainfall or surface waters and tend to settle in the available low-lying flood-exposed land, where floods also spread diseases and cause diarrhoea through the flooding of open sewage or inadequate sewage infrastructure. Increased capacity to capture and store water, as well as efficient use of water, and maximizing resources that are available will be important adaptation strategies.

Increasing pressure on water resources through increasing populations and more unreliable rainfall has in some regions pushed the exploitation of groundwater resources as other sources decline. Eighty per cent of drinking water in Russia and Europe comes from these slowly repleating resources (Struckmeier *et al*, 2005).

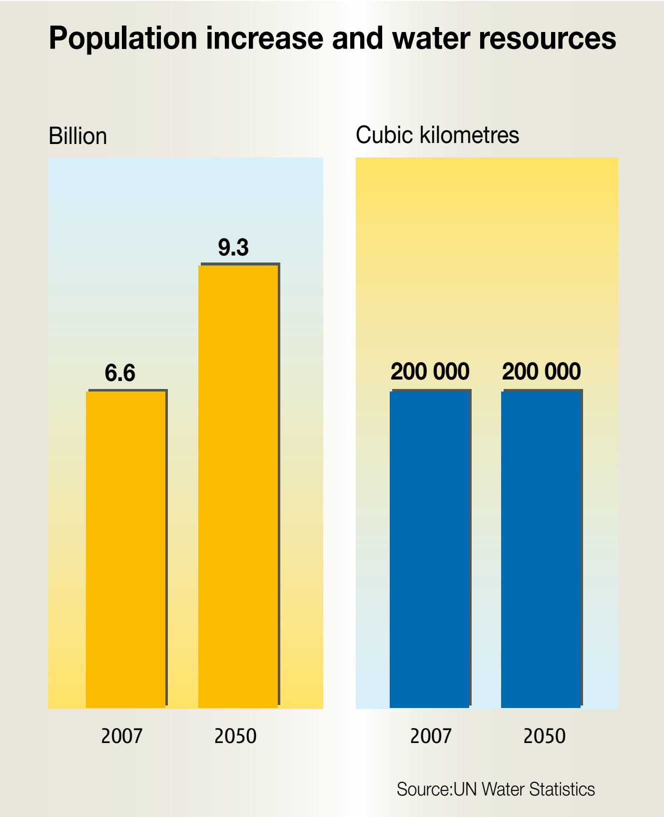


Figure 20: The world's water resources will not change, but the human population and its demands on supply are growing rapidly. Meeting these demands will require wise investment in how we use and reuse our water (UN Water Statistics).

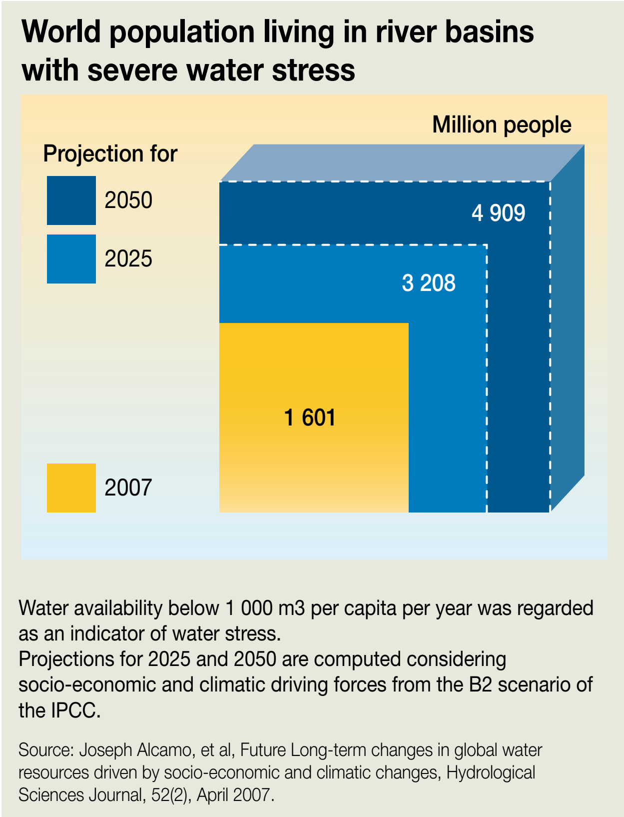


Figure 21: Increasing water scarcity with population increase.

The effects of climate change are exacerbated by the rapidly increasing physical expansion of cities, deforestation and grazing of uplands surrounding cities, and the heavy build-up of infrastructure and lack of green rain-absorbing vegetation and areas inside cities. With extensive build-up of concrete, housing, roofs and roads in cities, no ground and vegetation is available across larges areas to absorb and slow the water, resulting in massive run-off and flooding of cities (Nyenje *et al*, 2010), especially the low-lying slums.

How wastewater is treated can in turn have an impact on climate change. Wastewater and its treatment generates methane and nitrous oxide and carbon dioxide. It is worth noting that methane has an impact 21 times greater than the same mass of carbon dioxide. Nitrous oxide is 310 times more potent (AAEE, 2008). Although a relatively small contributor to global emissions, wastewater and its management is a growing impact. Methane emissions from wastewater are expected to increase almost 50 per cent between 1990 and 2020, while, estimates of global N_2O emissions from wastewater are incomplete they suggest an increase of 25 per cent between 1990 and 2020 (IPCC, 2007). There is a pressing need to investigate and implement alternatives to current wastewater treatment, which minimize the production of greenhouse gases and power consumption.

PART II
REALISING THE OPPORTUNITIES OF WASTEWATER

Reducing unregulated discharge of wastewater and securing safe water are among the most important interventions for improving global public health and achieving sustainable development. Part I demonstrated the enormous impacts and high cost to the environment, society and thus to economies, that wastewater can have when inadequately or inappropriately managed. Part II provides another perspective. Where are the opportunities for using wastewater? How can wise investment and appropriate management of wastewater reveal a resource, a tool that can help tackle the global water crisis, urgent health issues, food security and economic productivity, and maintain or improve environmental integrity?

It is critically important how investment is made. Inappropriate financing that does not produce results can have serious knock-on effects, leading to diminished public and political confidence and a lost opportunity to simultaneously tackle a problem and generate capital. The UNGA declared 1981–90 the International drinking water supply and sanitation decade. Approximately US$700 billion was spent, yet absolute numbers of people without safe drinking water stayed static (Elimelech, 2006; Mintz *et al*, 2001). The task in hand is not a small one, but the technology and know how exist. It can be done.

RECOGNISING WASTEWATER AS A RESOURCE

As its name implies, wastewater is grossly undervalued as a potential resource. All too frequently wastewater is ignored and left to drain away. Smart and sustained investment in wastewater management will generate multiple dividends in society, the economy and the environment. It can involve both private and public sectors, fulfilling public needs as well as social equity and enhance food security. Immediate, targeted and sustained investments should take multiple forms. They should be designed to (i) reduce the volume and extent of water pollution through preventative practices; (ii) capture water once it has been polluted; (iii) treat polluted water using appropriate technologies and techniques for return to the environment; (iv) where feasible safely reuse and recycle wastewater thereby conserving water and nutrients; and (v) provide a platform for the development of new and innovative technologies and management practices. If investments such as these are scaled up appropriately they will generate social, economic and environmental dividends far exceeding original investments for years to come.

It is acknowledged that water is a limited resource for which demand is growing. Managing wastewater is intrinsically linked to management of the entire water chain. How we use and reuse water is the key to successfully meeting the vast water requirements of an urban population twice its current size, expanding agriculture to feed another three billion people and satisfy rising demand for meat, while coping with increasing food waste.

Climate, geography and healthy ecosystems together control the initial supply of water in the water chain, maintain water quality and regulate water flow. Forests and wetlands, including salt marsh and mangrove forests, have an important natural role to play in wastewater management, capturing water, filtering out nutrients and other contaminants and releasing water into lakes, rivers and coastal seas. Worldwide, these ecosystems are being lost and with them the services they provide for buffering extreme weather and assimilating wastewater.

Developing strategies to improve environmental governance, including improving watershed, coastal and riparian management, irrigation efficiency and the greening of agricultural practices, provides an enormous opportunity for maximizing the benefit derived from natural ecosystem processes, greatly reducing the negative impacts of wastewater, and increasing the availability of water to cities.

Climate conditions and watershed management, particularly with regard to deforestation, cropland development and inland aquaculture, are crucial factors in determining the quantity and quality of the water which will eventually be available for irrigation in food production, processing in industry, human consumption and recycling.

Worldwide, water tables and aquifers are declining (IWMI, 2006). With climate change, rainfall patterns are likely to become more variable and extreme rainfall events more frequent.

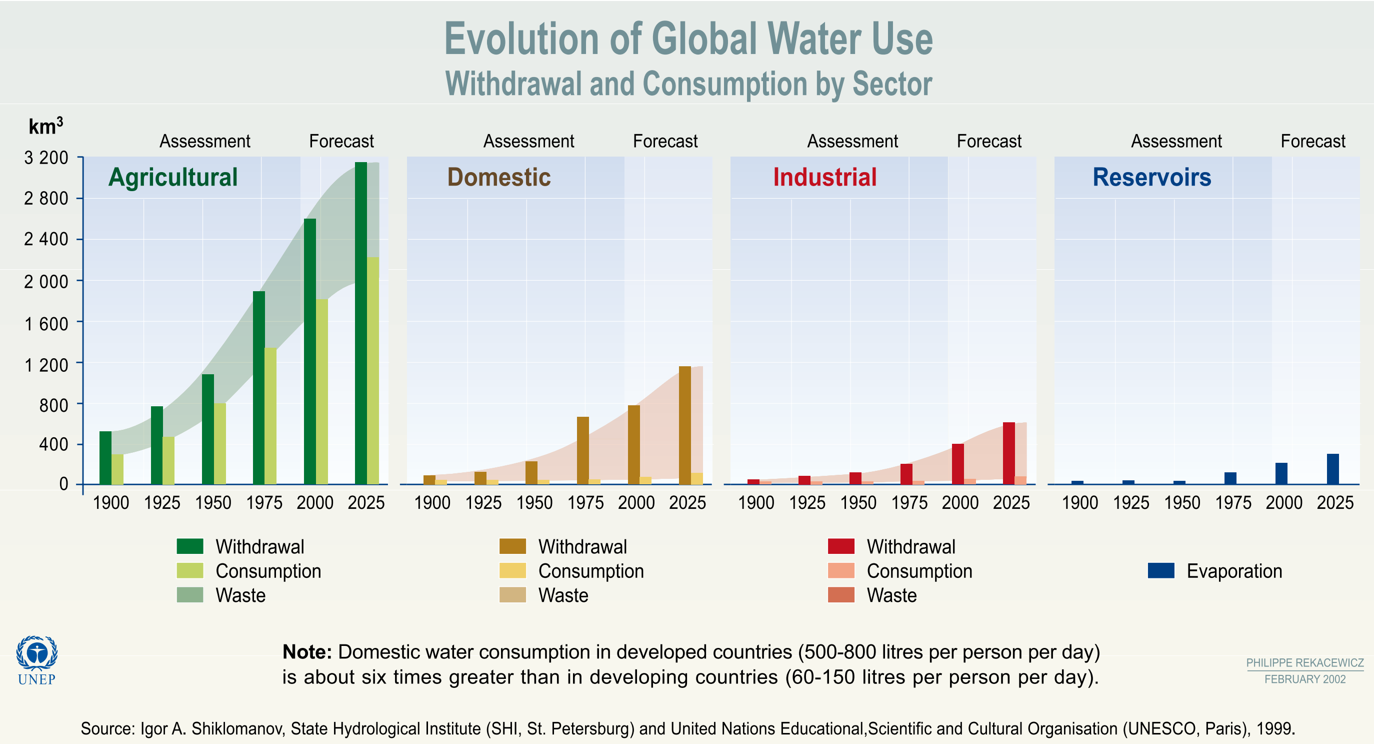


Figure 22: Global water withdrawal and waste over time.

Improving watershed management will be crucial and finding ways to reduce, optimize and recycle water will become increasingly essential in the future. Wastewater is already being used for irrigation and fertilization and can continue to expand this role, particularly for peri-urban or urban agriculture and home gardens. But maximizing water efficiency in the entire water chain including before water enters the cities, and reducing production of wastewater should be a primary goal throughout the entire management scheme.

WASTEWATER AS A MANAGED RESOURCE FOR IRRIGATION AND FOOD PRODUCTION

With proper management, wastewater can be an essential resource for supporting livelihoods. Wastewater treatment and reuse in agriculture can provide benefits to farmers in conserving fresh water resources, improving soil integrity, preventing discharge to surface and groundwater waters, and improving economic efficiency. In the US state of California, 31 per cent of reclaimed water is used for crop or landscape irrigation. In Mexico, most of the wastewater from Mexico City is used in irrigation districts surrounding the city, notably the Tula valley. Untreated wastewater is often used in the informal, unregulated sector and directly benefits poor farmers who would otherwise have little or no access to water for irrigation. Even untreated wastewater can improve soil fertility and reduce water contamination downstream, since the wastewater is not fed directly into the water flow but is first filtered through soil during irrigation. Through FAO's Farmer Field Schools in developing countries, training in risk-reduction and management strategies in safe food production and crop selection have been implemented from International Guidelines (WHO-FAO 2006) to simple and adoptable 'farm-to-fork' techniques. Safe reuse of untreated and partially wastewater for agriculture production has been tested in Ghana and Senegal where various options at farm, markets, and food-vendor

levels were operationally monitored, farming adjustments and management measures trained and verified on the effectiveness in reducing health risks. In many countries, farmers prefer wastewater for irrigation due to economic benefits in fertilizer savings. Typical concentrations of nutrients in treated wastewater effluent from conventional sewage treatment processes are as follows: 50 mg/litre of nitrogen; 10 mg/litre of phosphorus; and 30 mg/litre of potassium. Assuming an application rate of 5 000 m^3/ha/year, the fertilizer contribution of this effluent would be 250 kg/ha/year of nitrogen, 50 kg/ha/year of phosphorus and 150 kg/ha/year of potassium. Thus, the effluent would supply all of the nitrogen and much of the phosphorus and potassium normally required for agricultural crop production. Other valuable micro-nutrients and the organic matter contained in the effluent would also provide benefits.

Community-based project in Cambodia addresses water supply and wastewater treatment challenges

The project was initiated under the Joint Communiqué of the UNDP GEF Small Grants Programme and PEMSEA. More than 600 families are located in Stung Hav. Most of the families derive their income from fishing, with supplemental income derived from agriculture. The Reservoir Utilization and Community-based Sustainable Ecotourism Development project was implemented to: (1) rehabilitate a 5.9-hectare water reservoir to abate the impact of climate change on water levels and recharge the dried wells in the surrounding area; and (2) provide a water source for other supplemental livelihood activities, particularly agricultural production.

The project resulted in the rehabilitation of a community reservoir with holding capacity of 40 550 m^3. Community members estimated monthly savings of up to US$34 on water-use fees. The rehabilitated reservoir also serves to recharge groundwater in nearby water wells, thereby reducing the time and effort by family members – mostly women and children – in accessing water for household use.

A wastewater garden was created as a natural water treatment system to prevent water contamination from household wastewater discharge for irrigation. Planting of about 380 trees around the reservoir was also done to prevent soil erosion, maintain the reservoir's water-holding capacity and improve the landscape.

(Source: Personal communication, Adrian Ross, PEMSEA, 2010)

DEFUSING THE CRISIS: MANAGING WASTEWATER EFFECTIVELY

Historically water has been viewed as a common resource – for the people – a public good. "Water controls all geological and biological processes necessary for life's sustenance" (Narasimhan, 2008). In 2002, the UN Committee on Economic, Social and Cultural Rights declared that: "The human right to water is indispensable for leading a life in human dignity. It is a prerequisite for the realization of other human rights." The European Union has declared that: "Water is not a commercial product like any other but, rather, a heritage which must be protected and defended...," EU Water Framework Directive.

These positions pose questions as to how the right to water can be achieved, how this affects how water is managed and who takes responsibility for managing supply and the water itself once it has been used, in other words wastewater. And critically, who should pay?

This section looks at different tools, strategies and technologies that have been employed to manage wastewater, using case studies to illustrate various instruments, and the opportunities and challenges of implementation.

Defusing the wastewater crisis is achievable and measurable, but will require an entirely new dimension of investments. Currently, most of the wastewater infrastructure in many of the fastest growing cities is either non-existent, inadequate or outdated and therefore entirely unable to keep pace with the demands of rising urban populations. Experience has shown that substantial investments done in the right manner can provide the required returns. However, finding a solution will require not only investment but also carefully integrated national to municipal water and wastewater planning that addresses the entire water chain – drinking water supply, production and treatment of wastewater, ecosystem management, agricultural efficiency and urban planning.

UNDERSTANDING THE COSTS AND BENEFITS OF WASTEWATER MANAGEMENT

Wastewater management has many associated environmental benefits, enabling ecosystems within watersheds and the productive coastal zone to thrive and deliver services on which healthy communities and economies depend. Inadequate management in turn incurs heaving costs, threatening to undermine these ecosystems. However the value of these benefits is often not calculated because they are not determined by the market, due to inadequate property rights, the presence of externalities, and the lack of adequate information. Valuation of these benefits is nevertheless necessary to justify suitable investment policies and financing mechanisms (Hernández-Shancho *et al*, 2010).

THE ROLE OF ECONOMIC VALUATION IN UNDERSTANDING THE COSTS AND BENEFITS OF WASTEWATER MANAGEMENT

In order to develop effective policies and instruments in the management of water and water quality, it is necessary to understand the total value of the resource needs to be measured and incorporated into policy design (Hernández-Shancho *et al*, 2010). Economic valuation is often used as a tool to understand the costs and benefits of different choices. It can be applied in the context of sustainable development to show how dependent the economy is on an ecosystem (Lange and Jiddawi, 2009). The economic valuation of non-market ecosystem services (e.g. gas regulation, waste assimilation) is still very much in development. Despite limitations and caveats on this tool, a benefit is that it uses a common language – money. This can help overcome fragmentation in cross-sectoral decision making and build a broad alliance of stakeholders by quantifying the common interests and mutual dependence of different stakeholders, and providing a scientific basis for assessing tradeoffs among options for development (Lange and Jidawwi, 2009).

Valuation of wastewater assimilation by ecosystems can be looked at in terms of costs or damage avoided by reducing the amount of wastewater (Lange and Jiddawi, 2009). There is an increasing entrepreneurial interest developing for investing in private ecosystem markets such as carbon and nitrogen trading – although these are still emerging, there is evidence to suggest that the total values derived from the services of intact

The story of Xiamen – when wastewater management becomes part of the plan, investments can have many returns

Decades ago, Xiamen pursued economic development with little regard for the environment. The surrounding coastal waters were heavily impacted by aquaculture ponds with pollution from excreta and excess fish food. Nearly all the domestic and industrial wastewater was also discharged untreated into the coastal waters and there was a history of industrial and shipping accidents spilling oil and chemicals into the area.

The situation was especially bad in Yuandang. By the early 1980s, the bay had been cut off from the sea by a causeway and untreated industrial and domestic wastewater was being discharged into the bay. The water body shrank to just one-fifth of its original surface area. The foul smell repulsed would-be investors and red tides often occurred in the poorly flushed water body. Residents began leaving the area (PEMSEA, 2006b). In 1988, Xiamen began the Yuandang rehabilitation. Infrastructure was built to capture and treat the waste. The city government dredged silt out of the bay and built tidal channels to increase water exchange with the West Sea. They also enforced regulations on the disposal of waste more strictly. Dissolved oxygen rose from 0 to 5.2 mg/litre and water quality met the national standards. The public and the national government praised the government achievements in Yuandang. High-rise buildings rapidly increased in number around Yuandang and attracted big business. Fifty-three per cent of 173 investors cited the good environment as a reason for locating around Yuandang. Despite the estimated total rehabilitation cost of more than US$43.75 million, Yuandang's central location helped it yield a benefit-cost ratio estimated at 9:1! This helped convince Xiamen's leaders that good environmental management could return social and economic benefits.

The city government generated funds by levying fees for the use of sea areas, waste disposal, and exceeding waste standards. Landscaped areas were developed into business parks and property sold or leased for large sums. Funds generated from use of the sea area were allocated to marine management and helping support the cost of the management programme. Xiamen has invested a total of US$2 billion in sewage treatment over the last 20 years (XOFB, 2009). Treatment of industrial sewage rose from 20 per cent in 1994 to nearly 100 per cent in the 2000s while treatment of domestic sewage rose from 28 per cent in 1995 to 85 per cent in 2007 (Zhang, unpublished; PEMSEA, 2006a). Xiamen has not only become more sustainable, its beauty has also attracted immigrants, tourists, and real-estate development. A sense of pride in the beauty of their city has also grown in Xiamen's people.

Learning from past mistakes: unsustainable investments in wastewater management

During the decade from 1970 significant investments in wastewater management were made in several African countries, in particular Côte d'Ivoire and Senegal. Schemes were financed by bilateral and multilateral donors, but despite political good-will few of these investments survived. Little attention was paid to the arrangements needed to sustain the effectiveness and sustainability of these investments. The following examples from Saly Portudal and Louga in Senegal and Daloa in Côte d'Ivoire illustrate how good intentions can turn into white elephants.

Senegal: The village of Saly Portudal experienced a tourist boom in the 1970s. This resulted in a significant increase in wastewater production, justifying the construction of a sewage treatment plant. The chosen system was based on stabilization ponds, designed to treat a flow equivalent to 6 000 hotel guests. The project was funded by the World Bank in 1977 for a total cost of 270 million XOF (ca. US$0.54 million). In 1984 the State of Senegal, through the National Company of Sanitation (ONAS), financed the construction of a similar treatment facility in the city of Louga, with a capacity of 200 m^3 a day for nearly 7 000 households. About 20 years later a review (Maiga *et al*, 2002) revealed the following:

- No dedicated institution was established to manage the facility in either of these two cities. The plant of Saly Portudal was managed by the ONAS office in Rufisque, located 205 km away, while that of Louga was run remotely by the ONAS office of Saint-Louis at 60 km.
- At each site, only one staff member, a guard without relevant technical qualification and virtually no supervision, was supposed to ensure the maintenance of the service.
- No monitoring of the quality of the treated water was carried out
- Many cases of non-functioning equipment were reported but there were no financial resources, staff or equipment dedicated to follow up.

Côte d'Ivoire: In 1994 the African Development Bank financed a sewage treatment plant in Daloa to treat wastewater from the regional hospital complex. A follow-up review in 2002 (Maiga *et al*, 2002) noted that the plant was no longer operational. It had been left to fall into disuse and vegetation had invaded and covered the ruins of its basins and dams.

(Source: Personal communication, Dr. S. Kenfack, CREPA and R. Bechtloff, UNEP, Maiga *et al*, 2002)

ecosystems, e.g. wetlands, salt marsh, mangroves, could equal or surpass the current opportunity costs to individuals and society, if for example land-owners change from an agricultural regime to restore wetlands. For this to succeed, requires sufficient economic incentive for the land-owners to participate, and if subsidized, sufficient societal benefit for tax-payers to fund it.

In an assessment of the restoration of the wetlands of the Mississippi alluvial valley, a valuation exercise was undertaken using existing market values. The total value of the wetlands was assessed at just US$70 a hectare – significantly lower than the anticipated opportunity costs of the land owners. However when a broader range of ecosystem services was incorporated (e.g. social welfare, GHG mitigation, nitrogen mitigation, waterfowl, recreation, etc.) the estimate rose to US$1 035 a hectare. This market potential was higher than the land-owner opportunity costs, and provides a viable incentive to land owners to consider joining the wetlands restoration programme (Jenkins *et al*, 2009). The challenge however remains in developing these potential markets for ecosystem services. The developing Nitrogen Credit Trading market is described by Jenkins *et al*.

The use of economic valuation as a tool for prioritizing investment

Shadow pricing is a valuation methodology that can be used to assess choices regarding activities discharging by-products which, although they have no market value, may have significant environmental impact, such as wastewater (Hernández-Shancho *et al*, 2010). This method is useful for helping to prioritize management options relevant to wastewater management and treatment, taking into account both the economic and environmental aspects. Table 2 shows the price of water, and the average shadow prices for the five undesirable outputs of wastewater treatment. The negative value reflects the environmental value of damage avoided, or in other words, environmental benefit. Here, for example, action to reduce phosphorus levels would have the greatest environmental benefit per unit volume, followed by nitrogen (Jenkins *et al*, in press). The overall environmental benefit resulting from the treatment of wastewater can be shown in the volume removed per year and its shadow price (Table 3) (Jenkins *et al*, in press).

Table 2: Reference price of water treated (€/m³) and shadow prices for undesirable outputs (€/kg). (Jenkins *et al*, in press)

Destination	Reference price water €/m³	Shadow prices for undesirable outputs (€/kg)				
		N	P	SS	BOD	COD
River	0.7	– 16.353	– 30.944	– 0.005	– 0.033	– 0.098
Sea	0.1	– 4.612	– 7.533	– 0.001	– 0.005	– 0.010
Wetlands	0.9	– 65.209	– 103.424	– 0.010	– 0.117	– 0.122
Reuse	1.5	– 26.182	– 79.268	– 0.010	– 0.058	– 0.140

Table 3: Environmental benefit of treatment in €/year and €/m³ (Jenkins *et al*, in press)

Pollutants	Pollutant removal (kg/year)	Environmental value pollution (€/year)	Environmental value pollution (€/m³)	%
N	4,287,717	98,133,996	0.481	59.6
P	917,895	50,034,733	0.245	30.4
SS	60,444,987	448,098	0.002	0.3
DOB	59,635,275	2,690,421	0.013	1.6
COD	113,510,321	13,364,429	0.066	8.1
Total		**164,671,677**	**0.807**	**100.0**

The greatest environmental benefit is associated with the removal of nitrogen because it represents nearly 60 per cent of the total profit. The next most important factor is phosphorus with a percentage weight of 30 per cent. It is important to note that the removal of these nutrients creates most of the environmental benefit (90 per cent) resulting from the treatment process. This is because these pollutants have the highest shadow prices. Even though large volumes of suspended solids are removed from wastewater during treatment, their low shadow price means that their removal contributes a very low percentage (0.3 per cent) of the total environmental benefit. The share of the environmental benefit accounted for by organic matter (COD and BOD) is only 9.7 per cent because, despite the fact that a great deal is removed during the treatment process, their shadow prices are comparatively low (Jenkins *et al*, in press).

POLICIES AND INSTRUMENTS – MIXING POLICY COCKTAILS

To succeed in the face of some of the largest threats to environmental degradation, human health, and productivity, it is not sufficient to address only urban contamination or wastewater, we also need to consider water supply. Governance frameworks should clarify and link the roles of central and local authorities and communities, including rural areas and industry; promote public responsibility; and where appropriate, facilitate private investment and involvement in wastewater processes, particularly with regard to operational quality, maintenance and upgrading. The use of environmentally sound technologies including green technologies and ecosystem management should be used more actively and encouraged, particularly in rural areas, both with regard to water supply and wastewater production and management.

Wastewater management must address not only urban but also rural water management throughout the watershed and into the coastal zone. It must also look to the future and be able to meet the needs of a growing population under changing climatic conditions. Meeting these challenges requires long term, coordinated and integrated national plans and organization as this cannot be dealt with alone by municipalities, individual sectors and rarely individual nations. It will require a much stronger role for good governance and an active public sector working across sectors and perhaps international boundaries to solve these challenges drawing on a range, or cocktail of possible strategies, policies and instruments.

THE ROLE OF PARTNERSHIP BETWEEN THE PRIVATE AND PUBLIC SECTORS IN SANITATION AND WASTE-WATER MANAGEMENT

Governments facing challenges of water and wastewater management are always confronted by the issue of attracting investments and the need to achieve broad public and national benefits with improved water management.

Water privatization is the outsourcing of central public water management services and responsibilities to the private sector, such as in drinking water or wastewater management. Privatization can range from management contracts, lease contracts to direct concessions, in which the latter gains responsibility for the entire water system, or even asset sale, where the government actually sells the entire water rights. Because these water services are often viewed as a key public service and human right, privatization is often met with heavy resistance. The Cochabamba Water Wars are an example of a series of protests that took place in Cochabamba, Bolivia's third largest city, between January and April 2000, when the municipal water supply was privatized, due to fears of increased prices (Laurie, 2005).

Currently at least 84 per cent of all water and sanitation systems are publicly owned and managed, with more than 93 per cent in some developing countries (World Bank, 2009). Only an estimated seven per cent of the urban population in the developing world is served by private companies (World Bank, 2009). While the population served by privatized water utilities increased from six million to 94 million in developing or transition countries from 1991 to 2000, and the number of countries involved in such schemes from four to 38, the outsourcing of water management to private contractors has decreased in the last decade (World Bank, 2009).

There are many cases where privatization has led to improved water services by generating cheaper loans and higher investments, while bringing in expertise. However, it is also clear that unless the process is guided and under the close supervision of government agencies there is a risk that the wider public interest will not be served and only wealthy customers will receive services. Impoverished communities are unlikely to be the primary target for companies operating under a cost-benefit investment-return scheme.

Following a move to privatization in the 1990s, there has been a high return of wastewater services from private back to public management (World Bank, 2009). The critical factor seems to be how far privatization goes, with full control or concessions to private companies proving the most controversial. Whilst experience has shown that privatizing water management as a means to gain more investments rarely results in positive results, the private sector has demonstrated improvements in operational efficiency and service quality. Hence, rather than outsourcing management, integrated partnership models where the private sector is given responsibility not for the full water management, but mainly for certain operational segments, can work best.

USE OF ECONOMIC POLICY INSTRUMENTS

Economic development is an important factor in environmental quality (Lee *et al*, 2010). As countries develop their economies, their citizens obtain higher living standards, yet during this process of economic development and industrialization, levels of pollution increase to a point at which citizens begin to demand a higher environmental quality – when measures come in to manage the polluting waste products of many goods (Lee *et al*, 2010). The construction and operation of waste

The role of multinational corporations in wastewater management

Multinational companies dominate the private water, energy and waste management business, many of which have a close relationship to the public sector. Two French multinationals – Suez and Vivendi – control 70 per cent of the world's privatized water concessions, with an Anglo-German company, RWE-Thames, a distant third. (Hall, 2002), and the five largest operating some 80 per cent of all the privatized water concessions (World Bank, 2009). The same companies dominate the waste business – Suez and Vivendi are the largest two waste management multinationals in the world, having bought up the overseas operations of the former USA global giants, Waste Management Inc and BFI. RWE is number three in Europe (Davies, 2001). Many multinationals have changed names or merged with one another. In 2007 Veolia Environment (ex-Vivendi) reported US$47 billion revenue with a workforce of about 300 000 people (MSE, 2010).

treatment facilities, including those for wastewater requires a huge amount of capital – acting as a barrier to wastewater management in many regions. Creative solutions are required to finance management over the long term (Rammont and Nurul Amin, 2009). Economic Instruments (EI) are tools which can be used to support regulatory frameworks by recovering some of these costs. They generate market-conforming incentives, both positive and negative, that are directed to bring about behavioural change (Rammont and Nurul Amin, 2009). There are challenges in the implementation of economic policy instruments, in particular that they tend to require a high level of institutional capacity (Russell and Powell, 1996), other challenges include administration, politics, inconsistencies, need for enforcement of legislation and flaws in design (O'Connor, 1998).

ECOSYSTEM-BASED MANAGEMENT AND WASTEWATER

Ecosystem-based management is an integrated approach to management that considers the entire ecosystem, including

Challenges of applying economic instruments to finance wastewater management in Thailand

Following a period of economic growth and environmental degradation in 1987–96, Thailand started to give priority to environmental issues in the early 1990s when increased economic performance allowed for environmental protection and management. In 1992 Thailand reinvigorated its environmental acts of 1975 and 1978 as the Enhancement and Conservation of the Environmental Quality Act (NEQA 1992), which featured the implementation of two Economic Instruments – the polluter-pays principle (PPP) and the establishment of an Environmental Fund (EF) (Rammon and Nurul Amin, 2009).

Thailand focused on the use of EIs for central wastewater management. Capital investment for basic infrastructure was managed by central government (Ministry of Natural Resources and Environment). Once constructed, responsibility was handed over to local government for operation and management. In 1999 the government established the Determining Plans and Process of Decentralization to Local Government Organization Act. Local government organizations were then handed responsibility for environmental management, including wastewater management – guided by the National Economic and Social Development Plan which focuses on improving water quality, reducing water pollution, applying the PPP and promoting the involvement of the private sector in water pollution management. However due to the high costs in dispensing this responsibility, LGOs needed the continuing support of central government.

This support was provided through two main channels: (1) budgetary allocation, and (2) grants and soft loans through the Environmental Fund. This fund provides financial support for both government and the private sector for provision of control, remedial and disposal systems, and to support the implementation of activities on enhancement and conservation of environmental quality. Fees collected under the PPP contribute to the EF. Authority for making the charges under the PPP also falls to the local government authorities.

Rammon and Nurul Amin, 2009 identified a number of challenges to the uptake of these EIs in Thailand:

- Failure to follow up with concrete laws and regulations to support charge implementation
- Lack of willingness by local authorities to charge under the PPP.
- Lack of cooperation between water and wastewater authorities (water supply is administrated by two centralized authorities; wastewater under local governments as part of their mission to provide environmental management).
- Willingness of local government to charge and residents' acceptance to pay.
- Complexities in accessing the EF: long process of approval, lack of active public relations, lack of contributory fund, personnel problems and loopholes in the law and regulations are commonly cited problems related to accessing the EF
- Within Thailand, different cities and districts have different waste management approaches.

Thailand's two-pronged strategy of providing financial support from EF and levying charges to implement the PPP for use of EIs in WWM is far from being a success. Even if the subsidy part of the strategy works, the PPP part does not. The confusion between willingness to pay and willingness to charge has resulted in a deterioration in water quality. It is suggested that greater efforts to explain the benefits of wastewater management to local populations would result in greater acceptance to pay charges, and therefore make it easier for local authorities to ask.

humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors. Specifically, ecosystem-based management emphasizes the protection of ecosystem structure, functioning, and key processes. It is place-based, focusing on a specific ecosystem and the range of activities affecting it. Ecosystem-based management explicitly accounts for the interconnectedness within systems, recognizing the importance of interactions between many target species or key services and other non-target species. It acknowledges interconnectedness between systems, such as air, land and sea, and it integrates ecological, social, economic, and institutional perspectives, recognizing their strong interdependences (COMPASS, 2005).

Tackling the broad and cross-sectoral nature of wastewater and its management successfully and sustainably requires an ecosystem-based perspective, applied to integrated natural resource management approaches. To those working in water management, the concept of Integrated Water Resource Management (IWRM) is familiar. To those working in the marine environment, it would be Integrated Coastal Zone Management (ICZM), or a variant of this. There is a need for the bridging of these communities to ensure that the entire water supply chain and wastewater impact can be addressed coherently. These approaches are based on natural ecological boundaries and have strong merit. However, it is very much an ideological construct as often political and administrative boundaries do not align, and this makes implementation and governance challenging. Additional challenges are social pressures and power over the management and interests of water resources and usage (Molle, 2009).

Nutrient credit trading

Farmers are able to earn nitrogen-reduction credits when they go beyond legal obligations to remove nitrates from the watershed. These credits can then be traded. This can be achieved by changing fertilizer application rates; by changing production practices; by growing different crops, or retiring cropland. (Restoring wetlands is not yet included as a mitigation option because, it has been demonstrated (Ribaudo *et al*, 2001) that wetlands restoration is currently more expensive than fertilizer management and therefore a less attractive alternative for farmers, Jenkins *et al*, in press).

Although there are more than 40 nutrient trading programmes on the books in the United States as well as the development of online tools such as the Nitrogen Trading Tool (http://199.133.175.80/nttwebax/), very few trades have taken place to date (Ribaudo *et al*, 2008). As such, the market value under existing markets is essentially zero for N mitigation. Nevertheless, there is some interest in nutrient trading and it is possible that nitrogen mitigation will gain a market value in the future. One estimate puts the annualized potential market value at US$624/ha/year for nitrogen mitigation (Jenkins *et al*, in press).

Pesticide management in Sri Lanka

Pesticides used in agriculture, public health, industrial, veterinary and domestic use can potentially end up in the water, either through seepage into groundwater, run-off into streams or via the municipal wastewater collection systems. On their way they often threaten human and environmental health. Balancing the desired benefits of pesticide use, whilst minimizing the potentially harmful side effects of these potent chemicals primarily remains the responsibility of governments.

Sri Lanka's high yielding crop varieties, such as tea and rice, are susceptible to pest damage, resulting in a need for safe and effective pest control. Sri Lanka has prohibited a large number of highly toxic chemicals without affecting its agricultural production and today produces one of the world's cleanest teas with regards to all persistent organic pollutants (POPs) and WHO hazard class Ia and Ib chemicals. How was this achieved?

The Office of the Registrar of Pesticides, established within the Department of Agriculture looks at product registration, provides laboratory analysis for monitoring programmes and coordinates enforcement of the Control of Pesticides Act No 33 of 1980, guided by a multi-disciplinary and multi-sectoral Technical Advisory Committee. One of the keys to pesticide management is chemicals registration. Prerequisites are the conformation to international standards such as those of FAO and WHO; and the registration status in other countries. The Rotterdam Convention is one of the key international instruments providing governments with guidelines and detailed information on product use and risk profiles.

The adoption of international standards and cooperation is cost-effective in countries with limited financial and laboratory capacity. Some challenges remain, but given that most of Sri Lanka's pesticide control only started a little over two decades ago, the progress that has been made thanks to the institutional arrangements, legislation, and enforcement, has been remarkable.

(Source: Manuweera, 2007; Manuweera *et al*, 2008)

APPROPRIATE TECHNOLOGY AND INNOVATION

There are numerous examples where attempts to transfer technologies from one place to another fails. Different approaches to wastewater management are required for different regions, rural and urban areas, with different population sizes and different stages of economic governance depending on capacity to manage wastewater and capacity for governance. Approaches can also vary depending on the quality standard required for end users or end-point disposal. The sanitation ladder provides a useful instrument to assess the local status of sanitation in a community, municipality or region, pointing to optimal wastewater management strategies.

Cradle-to-cradle – can we do away with wastewater?

The cradle-to-cradle philosophy suggests a new form of production using processes that rely on reusable, biodegradable or consumable materials. No waste, as we know it at all and in fact the possibility of using production methods to improve the environment, for example water going out cleaner than it came in. With cradle-to-cradle there is no end, as discarded products once they have served their purpose should provide food for the biosphere or be completely recyclable in the technosphere. Examples include carpets that are made of a polymer that is completely recyclable – it can be depolymerized and used again and again or textiles that are made from completely non-toxic material, tested down to parts per million, that are completely biodegradable and nutritious for the environment.

Why is it currently acceptable, even in developed countries with environmental guidelines, for manufactures and consumers to demand products whose production and or disposal damage the environment? We tolerate products that are inherently poisonous, are poisonous to make and have a toxic legacy. We need international regulations to drive innovation so that cradle-to-cradle becomes the norm. Companies are now starting to adopt cradle-to-cradle production and finding that it is economic to have design principles, that are "good" rather than "less bad".

(Source: McDonough and Braungart, 2002)

Reducing wastewater impacts in the Coral Coast, Fiji

On the Coral Coast of Fiji it was estimated that 35–40 per cent of the anthropogenic nutrients entering the fringing reefs resulted from local pig-rearing. The nearby tourist hotels give leftover food to workers for their pigs, which encourages people to keep pigs. Pigs produce three times as much nitrogen waste per unit weight compared to humans and many of the pig pens are near or over water. Luckily the community found a simple low-cost system to manage pig waste and reduce contamination of the surrounding reefs.

The technique of using sawdust beds to assimilate and stabilize piggery wastes is generally known as shallow bed composting. This technique has the potential to offer pig farmers some real advantages in both economic and waste management terms. For example, the capital and maintenance costs of this system are significantly lower than the original piggery. Additionally, as liquid waste from washing pens is eliminated, the waste management of the unit is dramatically simplified.

The sawdust must be raked and renewed weekly and kept dry. It is replaced and taken to the farm about every three months to fertilize crops. With good management of these systems foul odours are not a problem, with the final composted product having an earthy smell. The system was initially trialled at one piggery at the National Youth Training Centre in the Sigatoka valley. The manager noted bigger, healthier pigs in the sawdust pens and has since applied this in all the centre's piggeries. If sawdust is not readily available other high-carbon, high-absorptive material can be tried.

(Source: UNEP/GPA and UNESCO-IHE, http://www.training.gpa.unep.org/content.html?id=199&ln=6)

It is important that management approaches form part of the planning and development process, reflecting regional realities and cultural differences as well as externalities such as exposure to natural hazards or extreme conditions. Incremental approaches to wastewater management can contribute to long-term success.

Innovation is important to continue to address evolving challenges in a changing world – to reduce the energy demands of wastewater management, and encourage solutions that promote using raw materials that do not contaminate, rather than focusing on end of pipe solutions.

THE ROLE OF EDUCATION, AWARENESS AND STEWARDSHIP

Wastewater is everyone's concern in the home and at work and using education to help change behaviour to both reduce wastewater discharge and also see the opportunities of managing wastewater is part of the solution. Increased understanding of the links between wastewater and health, ecosystem functioning and the potential benefits of wastewater reuse in contributing to development and improved wellbeing can increase uptake of initiatives.

It is vital that education in wastewater management and engagement of stakeholders in all sectors should include access to solutions and be culturally specific. Education, awareness, advocacy and stewardship should be addressed at multiple levels, including the development of professional skills for improved inter-sectoral collaboration and multi-year financial planning.

No one size fits all – wastewater treatment in Bali

As an internationally famous tourist destination, protecting the environment, maintaining natural beauty, and conserving the natural resources of the area are consistent priorities in Bali. Faced with the threats of environmental pollution and deterioration that comes with rapid tourist development, the government and various stakeholders have recognized the critical importance of wastewater treatment and sanitation for the sustainability of Bali.

This was a key consideration in the development of the 300-hectare Nusa Dua Tourist Resort, which has integrated a wastewater treatment system that not only treats wastewater from the hotels and other establishments in the area, but also provides water for maintaining hotel gardens, public gardens and the golf course. The system was also designed to blend with the natural physical surroundings and socio-cultural setting of Nusa Dua. The final wastewater station, called the Eco Lagoon, attracts various species of birds and further adds to the charm of the area. The wastewater treatment system is operated by the Bali Tourism Development Corporation in local government, hotels, and commercial and tourism establishments.

In Denpasar City, one of the focal areas for coastal recreation and tourism in Bali, the three-phase Denpasar Sewerage Development Project (DSDP) is now on its second phase. The first phase of the project completed a sewerage treatment system with a capacity of 51 000 m^3 a day, which currently serves around 9 000 homes in Denpasar. The second phase of the project will expand the treatment facility to the other areas in Denpasar all the way to the Sanur area, with additional pipe connections to 8 000 homes. The project is a collaboration between the Government of the Republic of Indonesia, Bali Province, Denpasar City, Badung Regency and the Japan Bank for International Cooperation (JBIC).

For areas that could not be served by the centralized sewerage system, a community sanitation programme called Santasi oleh Masyarakat, or SANIMAS, which involves construction of community wastewater treatment systems with a capacity of 60 m^3 a day has also been implemented in Denpasar City and other areas in Bali. The system was set up through a multi-financing scheme with contributions from central and local government and the beneficiary community. Ecological and low-cost wastewater gardens have also been developed in various areas in Bali.

(Source: Personal communication, Adrian Ross, PEMSEA; 2010)

Political and public support for change – Salmon in the Rhine

The Rhine is Western Europe's largest river basin and one of the world's most important trans-boundary waterways, flowing 1 320 km through Switzerland, Austria, Germany, France, Luxembourg and the Netherlands. Established as a navigable river in 1816, the Rhine has seen several major engineering projects proceed without prior bilateral agreement or environmental concern. The river became the "sewer of Europe" in the mid 1900s when large amounts of liquid waste from towns, industry and agriculture were increasingly discharged into the river. Salmon and most other fish species vanished, phosphorus reached alarming levels and it had become difficult to draw drinkable water from the river.

The need to set up a basin-wide body to deal with pollution issues in the Rhine became clear, leading to the formation of the International Commission for the Protection of the Rhine (ICPR) in 1950. However, it took another 20 years to see significant results, partly due to the loose set-up and lack of authority of the commission. The final catalyst came in 1987, when an accident at a Basel chemical plant led to the discharge of tonnes of toxins into the river, an environmental disaster causing the deaths of more than half a million fish.

After the 1987 accident, environmental awareness rose and the affected population and their representatives demanded much tougher measures against polluters. The 15-year Rhine Action Plan – also known as Salmon 2000 – was adopted as a result, one of its goals being the return of salmon and other fish by the end of the century. With an active water-quality monitoring regime, the plan also deployed pollution patrols to industry and communities, penalties for polluters and flood control and bank restoration measures.

Since 1987 point discharges of hazardous substances have decreased by 70 to 100 per cent, the fauna has almost completely recovered, including salmon, and accidental toxic discharges have been greatly reduced. However, several challenges remain, including fish passages, the release of toxic mud from the port of Rotterdam and pollution from farm fertilizers. On completion of the Rhine Action Plan, the Rhine 2020 Plan was adopted in 2001 for further sustainable development of the river.

(Sources: UNEP/DEWA/GRID-Europe, 2004; ICPR, 2010; UNESCO, 2000)

UNEP's response to capacity building needs in developing countries

The UNEP/WHO/UN-HABITAT/WSSCC Guidelines on Municipal Wastewater Management propose sustainable wastewater management based on an approach that integrates water supply, sanitation, and wastewater treatment. http://www.training.gpa.unep.org/documents/guidelines_on_municipal_wastewater_english.pdf

These guidelines also reflect needs for capacity development in this field and in response to these needs, UNEP/GPA jointly with the UNESCO-IHE Institute for Water Education and in the framework of the UN/DOALOS Train-Sea-Coast Programme offer training courses on wastewater management to municipal staff.

The Train Sea-Coast programme trained 1 800 experts from 67 countries between 2003 and 2009. It aims to increase the ability of participants to identify and formulate sustainable and financially viable proposals for the restoration of existing municipal infrastructure. It also develops capacities for new projects to either collect and treat wastewater, or to use alternative technologies to reduce or recycle nutrients from human waste.

Post-training evaluation for 2007–9, demonstrated that the UNEP-UNESCO-IHE training programme was delivering results, providing participants with knowledge and skills that they were able to apply in their work. It identified a further training need for senior management and high level policy makers of municipalities and utilities providers of wastewater management services.

The evaluation also identified areas of the course that can be strengthened. There are few practical examples and little data on wastewater management solutions that have been implemented locally under the guidance of the course materials. It was proposed that UNEP/GPA and its partners embark on a new phase of the programme to link institutional capacity building with demonstration projects, which should be documented and shared. In addition, the lack of multi-year financial planning for municipal infrastructure projects in many countries severely undermines, and sometimes even prevents, the operation and maintenance of already existing infrastructure, such as sewerage systems and treatment plants. The capacity building needs of lifecycle budgeting processes have not yet been met.

More information about the UNEP wastewater management training programme is available at: http://www.training.gpa.unep.org, it is supported by the governments of Belgium, Ireland the Netherlands and the United States, the European Union ACP Water Facility and UNDP-GEF.

Building capacity and stewardship for environmental management of the Iraqi marshlands

The Iraqi marshlands are the most extensive wetland ecosystem in the Middle East and Western Eurasia. The marshlands of the Tigris and Euphrates delta are spawning grounds for Gulf fisheries and home to a wide variety of bird species. By 2002 the 9 000 km^2 of permanent wetlands had dwindled to just 760 km^2, drained by the former Iraqi regime and contaminated by sewage and chemical waste. With poor water circulation and low flows, salinity had also increased. The weak management sent the marshes into serious decline, and this impacted the surrounding communities. UNEP´s Iraqi Marshlands project is contributing to restoration and sustainable management of the area, through the identification and implementation of suitable mitigation options, particularly for provision of safe drinking water, but also for sanitation systems and water quality management. Implemented by the International Environmental Technology Centre, the Marshlands project includes training of Iraqi partners, coordination with Iraqi and other stakeholders, communication and data sharing through the Arabic-English Marshlands Information Network, and pilot projects to introduce environmentally sound technologies for safe water and sanitation to marshlands communities.

(Source UNEP and UNESCO: http://marshlands.unep.or.jp/)

PART III
POLICY RECOMMENDATIONS

A TACKLE IMMEDIATE CONSEQUENCES

1 Countries must adopt a multi-sectoral approach to wastewater management as a matter of urgency, incorporating principles of ecosystem-based management from the watersheds into the sea, connecting sectors that will reap immediate benefits from better wastewater management.

On its journey through the hydrological cycle, water is used and reused an infinite number of times by various industries, communities and ecosystems. With 70–90 per cent of the water being used and some 50 per cent of the nutrient loading added before water even enters urban areas, wastewater management must address not only urban but also rural water management through improved forestry, agriculture and ecosystem management. This requires national plans and organization as it cannot be dealt with solely by municipalities or single ministries.

Eventually water reaches the coastal plains, estuaries, ports and harbors where communities, agriculture and industry are burgeoning. More wastewater is generated and finally it is discharged to the sea, frequently with little or no treatment, contaminating seafood, polluting critical ecosystems and threatening biodiversity. Wastewater management should reflect the community and ecological needs of each downstream ecosystem and user. Improved ecosystem management, including integrated forestry, livestock, agriculture, wetland and riparian management, will reduce and mitigate the effects of wastewater entering rivers, lakes and coastal environments. The best option is to close the nutrient loop and harness the potential of wastewater for re-use in agriculture, or to generate biogas, thus turning the nutrients contained therein into resources.

2 Successful and sustainable management of wastewater requires a cocktail of innovative approaches that engage the public and private sector at local, national and transboundary scales. Planning processes should provide an enabling environment for innovation, including at the community level.

To succeed in the face of some of the largest threats to human health, productivity and environmental degradation, it is not sufficient to address only one source of contamination. Governance frameworks should clarify and link the roles of central and local authorities and communities, including rural areas; promote public responsibility; and where appropriate, facilitate private investment and involvement in wastewater management. The use of technology in wastewater management should also be multi-faceted and should reflect the needs and capacity of local communities. Incentives should encourage innovative, adaptable approaches to reduce the production of wastewater and potency of its contaminants. The use of green technologies and ecosystem management practices should be used more actively and encouraged, including in rural areas with regard to both water supply and wastewater management.

Whilst experience has shown that privatizing water management as a means to gain more investments rarely results in positive results, the private sector has demonstrated improvements in operational efficiency and service quality. Hence, rather than outsourcing management, integrated partnership models where the private sector is given responsibility not for the full water management, but mainly for certain operational segments, can work best

3 **Innovative financing of appropriate wastewater infrastructure should incorporate design, construction, operation, maintenance, upgrading and/or decommissioning. Financing should take account of the fact that there are important livelihood opportunities in improving wastewater treatment processes.**

Investment, including ODA, in wastewater infrastructure must reflect the full lifecycle of the facility, not just capital project costs. This should not just be about new financing, but also making current investments more effective and sustainable. Full life-cycle financing may involve linking the cost of wastewater treatment with water supply – while many contend that access to safe water is a human right, the act of polluting water is not, and water users should bear the cost of returning water at a quality as close as possible to its natural state.

The valuation of non-market dividends, e.g. public amenity, ecosystem services such as carbon sequestration, nutrient and waste assimilation, must be further developed to enable more comprehensive cost benefit analysis of the potential returns from wastewater management and for the development of effective market based incentives, such as pollution cap and trade schemes.

B THINKING TO THE LONG TERM

4 **In light of rapid global change, communities should plan wastewater management against future scenarios, not current situations.**

Wastewater management and urban planning lag far behind advancing population growth, urbanization and climate change. With forward thinking, and innovative planning, effective wastewater management can contribute to the challenges of water scarcity while building ecosystem resilience, thus enabling ecosystem-based adaptation and increased opportunities for solutions to the challenges of current global-change scenarios.

Population growth and climate change are not uniform in time or space, and so regionally specific planning is essential. Wastewater management must be integrated as part of the solution in existing agreements and actions.

5 Solutions for smart wastewater management must be socially and culturally appropriate, as well as economically and environmentally viable into the future.

Different approaches to wastewater management are required for different areas, rural and urban, with different population sizes, levels of economic development, technical capacity and systems of governance. Approaches can also vary depending on the quality standard required for end users or end point disposal. The sanitation ladder provides a useful instrument to assess the local status of sanitation in a community, municipality or region, pointing to optimal wastewater management strategies.

It is important that wastewater management approaches form part of the planning and development process, reflecting regional realities and cultural differences as well as externalities such as exposure to natural hazards or extreme conditions. Incremental approaches to wastewater management can contribute to long-term success.

6 Education and awareness must play a central role in wastewater management and in reducing overall volumes and harmful content of wastewater produced, so that solutions are sustainable.

Wastewater is everyone's concern in the home and at work. Education and awareness can influence behaviours to reduce wastewater discharge and also to see the opportunities of managing wastewater in an environmentally friendly and financially sustainable way as part of the solution. Increased understanding of the links between wastewater and health, ecosystem functioning, food production and the potential benefits of wastewater reuse in contributing to development and improved wellbeing can increase uptake of initiatives.

It is vital that education and training in wastewater management and systematic engagement of stakeholders in all sectors throughout the entire project cycle is culturally specific and exemplifies or suggests solutions that can be modified to suit different settings. Education, awareness, advocacy and stewardship should be addressed at multiple levels, including the development of professional skills for improved inter-sectoral collaboration and multi-year financial planning.

GLOSSARY

Aquifer
Huge storehouses of water comprising the saturated zone beneath the water table (USGS 2009 http://ga.water.usgs.gov/edu/earthgwaquifer.html)

Carbon sequestration
The removal of atmospheric carbon dioxide, either through biological processes (for example, photosynthesis in plants and trees), or geological processes (for example, storage of carbon dioxide in underground reservoirs) (Department of Climate Change 2008)

Dead zone
Hypoxic (low-oxygen) areas in the world's oceans (Science Daily undated http://www.sciencedaily.com/articles/d/dead_zone_(ecology).htm)

Desalination
Any mechanical procedure or process where some or all of the salt is removed from water (EMWIS 2010 http://www.semide.net/portal_thesaurus/search_html)

Downstream ecosystem
Ecosystem of a lower watercourse (WaterWiki 2009 http://waterwiki.net/index.php/Downstream_ecosystem)

Economic instruments
Fiscal and other economic incentives and disincentives to incorporate environmental costs and benefits into the budgets of households and enterprises. The objective is to encourage environmentally sound and efficient production and consumption through full-cost pricing. Economic instruments include effluent taxes or charges on pollutants and waste, deposit-refund systems and tradable pollution permits (United Nations Statistics Division 2006 http://unstats.un.org/unsd/environmentgl/gesform.asp?getitem=738)

Economic valuation
The assessment, evaluation, or appraisal of business performance in matters involving ecology and finances (Oxford English Dictionary, quoted in KPV http://kpv.arso.gov.si/kpv/Gemet_search/Gemet_report/report_gemet_term?ID_CONCEPT=2938&L1=94&L2=94)

Ecosystem-based management
An integrative and holistic approach to management based on the idea of systems in contrast to the traditional procedure of managing sectoral activities like fishing, shipping, or oil and gas development. This approach is intended not only to draw attention to linkages among the various components of complex systems but also to consider the non-linear dynamics of socio-ecological systems (Arctic Governance 2010 http://www.arcticgovernance.org/ecosystem-based-management-ebm.4668250-142904.html)

Ecosystem services
The processes by which the environment produces resources that we often take for granted such as safe water, timber, and habitat for fisheries, and pollination of native and agricultural plants (Ecological Society of America undated http://www.esa.org/ecoservices/comm/body.comm.fact.ecos.html)

Equity
The quality of being fair or impartial (Dictionary.com 2010 http://dictionary.reference.com/browse/equity). A core proposition is that future generations have a right to an inheritance (capital bequest) sufficient to allow them to generate a level of wellbeing no less than that of the current generation (European Community 2005 http://biodiversity-chm.eea.europa.eu/nyglossary_terms/I/intergenerational_equity)

Eutrophication
A process of pollution that occurs when a lake or stream becomes over-rich in plant nutrient; as a consequence it becomes

overgrown in algae and other aquatic plants. The plants die and decompose. In decomposing the plants rob the water of oxygen and the lake, river or stream becomes lifeless. Nitrate fertilizers which drain from the fields, nutrients from animal wastes and human sewage are the primary causes of eutrophication. They have high biological oxygen demand (BOD) (EMWIS 2010 http://www.semide.net/portal_thesaurus/search_html)

Food security
When all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life (WHO 2010 http://www.who.int/trade/glossary/story028/en/)

Green city
Today, many city mayors are working to get their cities focused on the environmental movement. For many of those mayors, their goal is to convert their city into a green city. By thriving to achieve green city status, leaders are acting to improve the quality of the air, lower the use of non-renewable resources, encourage the building of green homes, offices, and other structures, reserve more green space, support environmentally-friendly methods of transportation, and offer recycling programmes (Wisegeek.com undated http://www.wisegeek.com/what-is-a-green-city.htm)

Green technology
A continuously evolving group of methods and materials, from techniques for generating energy to non-toxic cleaning products. The goals that inform developments in this rapidly growing field include sustainability, "cradle-to-cradle" design, source reduction, innovation, viability, energy, green building, environmentally preferred purchasing, green chemistry, and green nanotechnology (Green Technology 2006 http://www.green-technology.org/what.htm)

Groundwater
Freshwater beneath the earth's surface (usually in aquifers) supplying wells and springs. Because groundwater is a major source of drinking water, there is a growing concern over leaching of agricultural and industrial pollutants or substances from underground storage tanks (United Nations Statistics Division 2006 http://unstats.un.org/unsd/environmentgl/gesform.asp?getitem=586)

Irrigation
Artificial application of water to land to assist in the growing of crops and pastures. It is carried out by spraying water under pressure (spray irrigation) or by pumping water onto the land (flood irrigation) (United Nations Statistics Division 2006 http://unstats.un.org/unsd/environmentgl/gesform.asp?getitem=685)

Marine pollution
Direct or indirect introduction by humans of substances or energy into the marine environment (including estuaries), resulting in harm to living resources, hazards to human health, hindrances to marine activities including fishing, impairment of the quality of sea water and reduction of amenities (United Nations Statistics Division 2006 http://unstats.un.org/unsd/environmentgl/gesform.asp?getitem=738)

Market and non-market values
Most environmental goods and services, such as clean air and water, and healthy fish and wildlife populations, are not traded in markets. Their economic value -how much people would be willing to pay for them- is not revealed in market prices. The only option for assigning monetary values to them is to rely on non-market valuation methods. Without these value estimates, these resources may be implicitly undervalued and decisions regarding their use and stewardship may not accurately reflect their true value to society (GreenFacts 2009 http://www.greenfacts.org/glossary/mno/non-market-value.htm)

Megacity
Massive migration out of the country and into the city has lead to the rise of the megacity, a term typically used to describe a city with a population of over 10 000 000 inhabitants (Wisegeek.com undated http://www.wisegeek.com/what-is-a-megacity.htm)

Peri-urban
Peri-urban areas are the transition zone, or interaction zone, where urban and rural activities are juxtaposed, and landscape features are subject to rapid modifications, induced by human activities (Scientific Committee on Problems of the Environment 2008 http://www.icsu-scope.org/projects/cluster1/puech.htm)

Polluter Pays Principle
Principle according to which the polluter should bear the cost of measures to reduce pollution according to the extent of either the damage done to society or the exceeding of an acceptable level (standard) of pollution (United Nations Statistics Division 2006 http://unstats.un.org/unsd/environmentgl/gesform.asp?getitem=902)

Population connected to urban wastewater collection system
Percentage of the resident population connected to the wastewater collecting systems (sewerage). Wastewater collecting systems may deliver wastewater to treatment plants or may discharge it without treatment to the environment (United Nations Statistics Division 2009 http://unstats.un.org/unsd/ENVIRONMENT/wastewater.htm)

Population connected to urban wastewater treatment
Percentage of the resident population whose wastewater is treated at wastewater treatment plants (United Nations Statistics Division 2009 http://unstats.un.org/unsd/ENVIRONMENT/wastewater.htm)

Private sector
That part of an economy in which goods and services are produced by individuals and companies as opposed to the government, which controls the public sector (Dictionary.com 2010 http://dictionary.reference.com/browse/private%20sector)

Public sector
That part of the economy controlled by the government (Dictionary.com 2010 http://dictionary.reference.com/browse/public+sector)

Resilience
Ecological resilience can be defined in two ways. The first is a measure of the magnitude of disturbance that can be absorbed before the (eco)system changes its structure by changing the variables and processes that control behaviour. The second, a more traditional meaning, is as a measure of resistance to disturbance and the speed of return to the equilibrium state of an ecosystem. http://biodiversity-chm.eea.europa.eu/nyglossary_terms/E/ecological_or_ecosystem_resilience

Saphrogenic
Formed by putrefaction, for example by bacteria http://dictionary.reference.com/browse/saprogenic

Sanitation
A range of interventions designed to reduce health hazards in the environment and environmental receptivity to health risks, including management of excreta, sewage, drainage and solid waste, and environmental management interventions for disease vector control.
Adapted from: http://www.who.int/water_sanitation_health / hygiene/sanhygpromotoc.pdf

Slums
Areas of older housing that are deteriorating in the sense of their being under-serviced, overcrowded and dilapidated (Unit-

ed Nations Statistics Division 2006 http://unstats.un.org/unsd/environmentgl/gesform.asp?getitem=1046)

Tailings

Wastes separated out during the processing of crops and mineral ores, including residues of raw materials (United Nations Statistics Division 2006 http://unstats.un.org/unsd/environmentgl/gesform.asp?getitem=1119)

Transboundary

Crossing or existing across national boundaries (Encarta World English Dictionary 2009 http://encarta.msn.com/dictionary_1861721403/transboundary.html)

Urban wastewater collection system

A system of conduits which collect and conduct urban wastewater. Collecting systems are often operated by public authorities or semi-public associations (United Nations Statistics Division 2009 http://unstats.un.org/unsd/ENVIRONMENT/wastewater.htm)

Urban wastewater treatment

All treatment of wastewater in urban wastewater treatment plants (UWWTP's). UWWTP's are usually operated by public authorities or by private companies working by order of public authorities. Includes wastewater delivered to treatment plants by trucks (United Nations Statistics Division 2009 http://unstats.un.org/unsd/ENVIRONMENT/wastewater.htm)

Waste assimilation

Both forests and wetlands provide a natural buffer between human activities and water supplies, filtering out pathogens such as Giardia or Escherichia, nutrients such as nitrogen and phosphorus, as well as metals and sediments. This benefits humans in the form of safe drinking water, and plants and animals by reducing harmful algae blooms, reduction of dissolved oxygen and excessive sediment in water (The University of Vermont 2004 http://ecovalue.uvm.edu/evp/modules/nz/evp_es_definitions.asp)

Water stressed

A country is water stressed if the available freshwater supply relative to water withdrawals acts as an important constraint on development (WHO, WMO and UNEP 2003 http://www.who.int/globalchange/publications/cchhbook/en/index.html)

Water table

Level below which water-saturated soil is encountered. It is also known as groundwater surface (United Nations Statistics Division 2006 http://unstats.un.org/unsd/environmentgl/gesform.asp?getitem=1205)

White elephant

Something costly to maintain; an expensive and often rare or valuable possession whose upkeep is a considerable financial burden (Encarta World English Dictionary 2009 http://encarta.msn.com/encnet/features/dictionary/DictionaryResults.aspx?lextype=3&search=white%20elephant)

Willingness to charge

There is growing evidence that many urban and rural communities are willing to pay more than the prevailing rates for water and sanitation, to ensure a better or more reliable service. However, governments seem unwilling to match this with a willingness to charge consumers for these services and the result is a continuing cycle of low revenues, high costs, unsatisfactory services and financial crisis (UNDP-World Bank 1999 http://124.30.164.71/asciweb/kwa/site/Content%20Resources/Financial%20Aspects/National/Willingness%20to%20Pay%20Dehradun.pdf)

Willingness to pay

The amount an individual is willing to pay to acquire some good or service. This may be elicited from stated or revealed preference approaches (UNEP 1995)

ACRONYMS

AMD	Acid Mine Drainage
BFI	Browning Ferris Industries
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CREPA	Le Centre Régional pour l'Eau Potable et l'Assainissement à faible coût
DALY	Disability-Adjusted Life Year
DFID	UK Department for International Development
DSDP	Dempasar Sewerage Development Project
€	Euro
EF	Environment Fund
EI	Economic Instruments
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Green House Gas
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
Ha	Hectare
HAPPC	Hazard Analysis of Critical Control Points
ICPR	International Commission for the Protection of the Rhine
ICZM	Integrated Coastal Zone Management
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resource Management
JBIC	Japan Bank for International Cooperation
JMP	Joint Monitoring Programme
Km^2	Square Kilometres
MA	Millennium Ecosystem Assessment
MDG	Millennium Development Goal
Mg	Milligramme
N	Nitrogen
NPV	Net Present Value
ODA	Overseas Development Assistance
ONAS	National Company of Sanitation
P	Phosphorus
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
POPs	Persistent Organic Pollutants
PPP	Polluter Pays Principal
SIDS	Small Island Developing States
SOPAC	Pacific Islands Applied Geoscience Commission
SS	Suspended Solids
UN	United Nations
UN CESCR	UN Committee on Economic, Social and Cultural Rights
UN-HABITAT	United Nations Human Settlements Programme
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFPA	United Nations Population Fund
UNGA	United Nations General Assembly
UNICEF	United Nations Children's Fund
UNSGAB	UN Secretary General's Advisory Board on Water and Sanitation
USA	United States of America
US$	US Dollar
WFD	EU Water Framework Directive
WHO	World Health Organization
WIO-LaB	Addressing Land Based Activities in the Western Indian Ocean
WSP	Water and Sanitation Programme
WWAP	World Water Assessment Programme
WWM	Wastewater Management
WWTP	Wastewater Treatment Plant
XOF	Central African Franc
Yr	Year

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LAYOUT

GRID-Arendal

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