TEC BACKGROUND PAPERS NO. 13

Managing the other side of the water cycle: Making wastewater an asset

By Akiça Bahri

Global Water Partnership
Technical Committee (TEC)

Global Water Partnership (GWP), established in 1996, is an international network open to all organisations involved in water resources management: developed and developing country government institutions, agencies of the United Nations, bi- and multilateral development banks, professional associations, research institutions, non-governmental organisations, and the private sector. GWP was created to foster Integrated Water Resources Management (IWRM), which aims to ensure the co-ordinated development and management of water, land, and related resources by maximising economic and social welfare without compromising the sustainability of vital environmental systems.

GWP promotes IWRM by creating fora at global, regional, and national levels, designed to support stakeholders in the practical implementation of IWRM. The Partnership's governance includes the Technical Committee (TEC), a group of internationally recognised professionals and scientists skilled in the different aspects of water management. This committee, whose members come from different regions of the world, provides technical support and advice to the other governance arms and to the Partnership as a whole. The TEC has been charged with developing an analytical framework of the water sector and proposing actions that will promote sustainable water resources management. The TEC maintains an open channel with the GWP Regional Water Partnerships (RWPs) around the world to facilitate application of IWRM regionally and nationally. The Chairs of these RWPs participate in the work of TEC.

Worldwide adoption and application of IWRM requires changing the way business is conducted by the international water resources community, particularly the way investments are made. To effect changes of this nature and scope, new ways to address the global, regional, and conceptual aspects and agendas of implementing actions are required.

This series, published by the GWP Secretariat in Stockholm has been created to disseminate the papers written and commissioned by the TEC to address the conceptual agenda. Issues and sub-issues with them, such as the understanding and definition of IWRM, water for food security, public-private partnerships, and water as an economic good have been addressed in these papers.

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Foreword

The Global Water Partnership's vision is for a water-secure world, in which communities are protected from floods, droughts, and water-borne diseases, and where environmental protection and the negative effects of poor management are effectively addressed. Its mission is to support the sustainable development and management of water resources at all levels. At the beginning of 2009, GWP launched its 2009–2013 Strategy, which covers the run up to 2015 – the target date for the Millennium Development Goals – and articulates the way in which GWP will pursue its vision and mission in the years ahead.

As part of its new Strategy, the Partnership is actively seeking solutions for critical challenges to water security. One of these critical challenges is growing urbanization. Sixty percent of the world's population will live in urban areas by 2025. Improving urban water and wastewater management in the growing cities of the developing world is urgent. Impacts both upstream and downstream and across basin and aquifer boundaries must be considered, and it is essential to connect city and countryside in terms of water and nutrient flows. GWP believes that the provision of environmentally sound systems in an integrated way, taking into account the whole water cycle of water supply, wastewater, solid waste collection, treatment and reuse, is the best way forward to addressing this critical challenge.

Accordingly, *Managing the Other Side of the Water Cycle* focuses on the management of the whole water/waste cycle at the city level within an integrated approach, outlining what it will take to put into practice a sustainable approach to water supply, sanitation and reuse. It looks at options for closing the loop between human settlement discharges and their surrounding watersheds based on an integrated approach to water resources management. Special attention is given to the full spectrum of technical, planning, management, institutional, economic and policy aspects. Managing the Other Side of the Water Cycle is thus an important contribution towards widening the debate on the management of the "after use" part of the water and waste cycle.

We therefore view this paper as an integral part of our efforts to meet the GWP strategic goals for 2009–13. Coming at the end of the International Year of Sanitation – and just ahead of the Fifth World Water Forum in Istanbul – it is also exceptionally timely. I am grateful to Akiça Bahri for her leadership in preparing Managing the Other Side of the Water Cycle. I am also grateful to the members of the GWP-wide working group on IWRM and sanitation – Hartmut Bruehl, Michael Scoullos, Björn Guterstam and Alan Hall – who have supported Akiça in the preparation of this paper. Special thanks are also due to the members of GWP's Technical Committee, who have fostered the development of this paper since inception and have greatly enriched it through ideas, experiences and lessons contributed in the course of extensive discussions of earlier drafts. I am confident that the paper will provide a strong head start to GWP's efforts to contribute to and advocate solutions to address the critical challenge to water security posed by growing urbanization.

Roberto Lenton
Chair, Global Water Partnership Technical Committee
January 2009

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1. INTRODUCTION

From a natural resources perspective, human settlements can be seen as transformers of valuable resources such as water and food into nutrients and organic material mixed in water, or better known as wastewater/sewage and excreta. Almost all the cities in developing countries discharge wastewater without any treatment. It is estimated that 90% of the urban areas worldwide do not have proper sanitation. In modern cities, discharges of wastewater create small rivers before they reach the sea or other recipients. These untreated wastewaters are causing major health and pollution threats to downstream and underground waters and to the aquatic life. Uncontrolled and direct reuse of wastewater is commonplace. Often the urban or rural poor rely on this resource for their livelihood to grow foods and vegetables. This practice will put at risk their own health, the health of the consumers and the environment as a whole. In few cases, these wastewater "rivers" are treated with the aim to protect the environment from gross pollution. Only in a few cases, however, the concept of resources management has been implemented for planning and design when dealing with municipal and industrial wastewaters.

Today ongoing degradation of freshwater and marine ecosystems is amplified by climate change effects such as droughts and floods. These threatening impacts have given incentives to redesign water and waste management systems of human settlements to meet sustainability criteria, i.e. planning the discharges of wastewater should be safely integrated into water resources management and ecosystem preservation. The World Panel on Financing Water Infrastructure concluded that a high proportion of the extra US $100 billion required annually is needed for wastewater services (Camdessus Report, Winpenny, 2003).

Traditionally, water supply, sanitation and water management investments are planned, designed and managed separately and for different time-scales. The provision of environmentally sound systems that take into account the whole water cycle in the communities – water supply, wastewater, solid waste collection, treatment and reuse – requires an integrated approach involving a variety of stakeholders and overcoming sector-boundaries and the rural-urban divide.

However, several interlinked key questions need to be first addressed such as: which barriers should be overcome to improve the prospects of reaching the water supply and sanitation targets in the rural, urban and peri-urban areas? How can known technologies be best applied to solve development questions? How can we make the management of wastewater effective, sanitation affordable and reuse safe? Can cities in developing countries cope with the infrastructure and capacity requirements needed to simultaneously face the (i) water supply and (ii) sanitation needs of growing urban populations, (iii) to reuse the municipal wastewaters in a safe, productive and efficient way, and (iv) to protect the public health and the urban and peri-urban environment? Does linking management of human excreta and wastewater to water reuse help meet the MDG water and sanitation target together with food security targets? Which institutional settings are suitable for sanitation and reuse in these areas? How can we make a strong economic and environmental case for sanitation by turning waste and wastewater into a resource? How can financing (waste)water reclamation and reuse be made a key part of dependable future water supply strategies? Can sustainable solutions be found through dialogue involving practitioners, researchers, policymakers, and local communities?

This paper looks at options for closing the loop between human settlement discharges and their surrounding watersheds in an Integrated Water Resources Management (IWRM)[1] context. It gives an overview of the sanitation challenges, of the related development and management issues, and of attempts to answer some of the above mentioned questions. Several examples are used to illustrate different approaches in *Managing the Other Side of the Water Cycle.*

2. THE UNFINISHED BUSINESS

The concern for the integrity of the water cycle as a whole, and the principle of Integrated Water Resources Management entails resourcing all component parts of the water sector. The 2008 declared International Year of Sanitation (IYS) has put sanitation on the international agenda and provided the opportunity to identify the barriers to achieving the sanitation target in the MDGs, and to formulate realistic strategies to address them (Wright, 2007).

[1] IWRM is defined by the Global Water Partnership (GWP-TAC, 2000) as "a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems".

The foci of the IYS and the larger ambitions of the Millennium Development Goals (MDGs) are targeted at the poorest, under-served, and neglected populations. This paper intends to complement and provide feasible solutions to the IYS/MDG agendas.

Wastewater/sewage is both a problem and a resource with a big impact on the lives of poor communities. Achievement of the water and sanitation MDGs will magnify the urgency and desirability of the next great challenge – that of safe management and beneficial exploitation of wastewater. Poor communities bear the brunt of the current situation, and will be major beneficiaries of this initiative.

With the IYS and beyond the 2015 MDG milestone, it is becoming urgent to apply international energy and imagination to mobilizing the resources needed – technological, creative and societal as well as financial – for the "downstream" parts of the water and waste cycle – the collection and treatment of wastewater, and the recycling and reuse of treated effluent and its by-products. If the wastewater challenge is not tackled, there is a danger that the potential health and other benefits from the investments being made to meet the MDGs will be negated by the pollution that ensues. It takes many years to introduce a new paradigm and it is timely for preliminary steps to be taken now in order to put this on the political agenda for the post-2015 period when new global policy priorities will have to be agreed.

The management of wastewater rests on several compelling arguments:

- It is necessary for the welfare of several billion people, whose health, dignity and amenity is compromised by the squalor and hazards of current arrangements.
- It is necessary to rescue human and natural environments that are being ruined by pollution.
- It is necessary to start recycling the essential resources from wastewater, e.g. nutrients and water itself in order to sustain human livelihoods and ecosystems.
- It is equally imperative for economic reasons, since ill-managed wastewater has a high economic cost, and can act as a brake on investment and further development.
- Finally, the growing shortage of water that is expected from population growth, urbanization and climatic changes increases the importance of re-using water to the maximum extent that is feasible.

3. SANITATION

The early history of sanitation

The history of sanitation goes back to the early historic times (Cooper, 2001). In the Mesopotamian Empire (3500-2500 BC), some homes were already connected to a stormwater drain system. In Babylon, latrines were connected to 450 mm diameter vertical shafts in the ground. In the Indus city of Mohenjo-Daro, in Pakistan, from about 2500 to 1500 BC, many houses had drains that led to closed sewers. Some earthenware pipes, latrines and cesspools were connected to drainage systems in the streets.

At King Minos Royal Palace at Knossos, Crete, by 1700 BC, four separate drainage systems emptied waste through terra cota pipes. The oldest known flushing device, a latrine with a rooftop reservoir, served King Minos and was reborn 3000 years later. In Greece, from 300 AC to 500 AD, public latrines drained into sewers which carried sewage and stormwater to a collection basin outside the city. Brick-lined conduits transported the wastewater to agricultural lands to irrigate and fertilize crops and fruit orchards.

Around 600 BC, the Romans built the *Cloaxa Maxima*, the central sewer system. This brick-lined covered sewer had seven branches – one for each hill – and rich customers had to pay to be connected to the sewer. These sewers were also used to drain the streets during rainstorms. Urine was collected in public urinals and sold to dyers, tanners and other merchants. Those who could not afford to get connected to the sewer system used jars in their rooms, which were emptied into public cesspits. These cesspits were daily emptied by city-paid workers and the contents were used as fertilizer. Cloacina was the Roman goddess of the sewer and was responsible for the preservation and hygiene of the public drainage systems.

In the Dark Ages, sanitation practices regressed to a primitive level. Paris' first covered sewer was built in Montmartre in 1370 and dumped sewage into the River Seine by the Louvre. Once plagues began ravaging the cities of Europe in the 16th century, François I in 1539 ordered property owners to build cesspools for sewage collection. The first water closet was designed in 1596 and the first chemical treatments of wastewater (use of lime in Paris) were recorded in the 18th century.

Cholera and typhoid epidemics drove change: they raged throughout Paris, London, Hamburg and other European cities killing thousands between 1830-1850. British and European engineers researched the sewage disposal solutions implemented by ancient civilizations such as Greek, Minoan and Roman and adopted the long forgotten strategy of the "solution to pollution is dilution". Sewers originally designed for stormwater became combined. With the rapid expansion of the cities, the first wastewater treatment process applied on a large scale in the mid 19th century was land treatment. The first septic tank was patented in 1895. Biological treatment of sewage (activated sludge) was applied at the end of the 19th century. Wastewater treatment process development took place during the 20th century mainly focusing on environmental protection and on organic matter removal, then on nutrients removal to protect sensitive water bodies and finally on disinfection.

Recycling and resource management concepts were used in early industrial Europe. In Germany, the sewers introduced in cities during the 19th and 20th centuries led in many cases into systems of ponds and fields for direct recycling through sophisticated agriculture and aquaculture systems (Prein, 1990). In the Danish capital Copenhagen, in the early 20th century, new investments in a traditional dry sanitation system linking agriculture with the city were soon replaced by a sewer system discharging untreated sewage for decades into the Baltic Sea (Wrisberg, 1996).

Table 1 summarizes the different approaches to sanitation – waste management adopted with time and according to the spacial scale.

Table 1. Summary of different approaches to waste management typical of its time scale and spacial scale (Czemiel-Berndtsson, 2004).

Approach	Typical for	Reasons behind	System requires	Examples
No waste	Rural societies Old practice	Food production Water protection	Space Labor	Dry sanitation Application of fertilizer in agriculture Waste-fed aquaculture
Waste	Urban societies Modern times	Health protection	Water to transport waste Energy to drive the system	Conventional wastewater system
Reuse	Recent developments in rural and urban areas	Resource conservation Environment protection	Energy Labor Space	Source control (urine and fecal matter, greywater, stormwater) End of pipe

Meaning of sanitation

There is a need to agree on the meaning of sanitation and why an IWRM approach is needed to address the sanitation issue. Some UN bodies, the Water Supply and Sanitation Collaborative Council (WSSCC), the Joint Monitoring Program (JMP) of UNICEF, the World Health Organization (WHO), and others have proposed different definitions of sanitation, basic sanitation, improved sanitation and environmental sanitation. A definition adapted from the definition of the Millennium Task Force is that "Sanitation is access to, and use of, excreta and wastewater facilities and services that ensure privacy and dignity, ensuring a clean and healthy living environment for all [both at home and in the immediate neighborhood of users]" (COHRE *et al*., 2008). The key aspects to sanitation are: 1. Hygiene promotion; 2. Excreta management, encompassing collection, transport (including sewerage networks), treatment and disposal or reuse of human excreta; and 3. Wastewater, solid waste and stormwater removal.

In this paper, we will refer to the various dimensions of sanitation that according to SIWI (2005) include:

- safe collection, storage, treatment and disposal/reuse/recycling of human excreta (faeces and urine),
- management/reuse/recycling of solid wastes,
- drainage and disposal/reuse/recycling of household wastewater (grey water),
- collection, treatment and disposal/reuse/recycling of sewage effluents,
- drainage and management of stormwater,
- collection and management of industrial wastes,
- management of hazardous wastes, and
- hygiene and behaviour change, with a focus on human excreta and sewage effluents.

These sanitation challenges cannot be addressed all at once. Their implementation requires a phased approach. According to Wright (2007), there is a need to differentiate the barriers to meeting the sanitation targets facing the different settlement types: rural communities, megacities and large urban areas and slums. Rural communities face poverty issues and have accessibility difficulties. In rural communities and in slum and poverty-prone areas, there is a failure to use a pro-poor governance approach. In megacities and large urban areas, the centralized approach to planning and delivery of services has usually been adopted.

The most important consequences of improved sanitation are health, economic value, social and environmental benefits. Sanitation therefore needs to be treated as a right and a responsibility. People in a community are entitled to a safe and clean physical environment, free from conditions for transmission of communicable diseases. Every member of a community owes it to his/her community to ensure that his/her wastes do not adversely affect conditions in their living environment. These call for joint community responsibility for sanitation, and shared community pressure to push for political will and pull sanitation projects.

In Central and Eastern Europe, the Global Water Partnership CEE regional council with members from 12 countries, including the non-EU countries Moldova and Ukraine, identified a gap in sanitation policies for rural settlements. The needs for sanitation improvements of 20-40% of the population in these countries are not covered by the far reaching EU policies to improve water quality through the EU Water Framework Directive. This has left 20 million people without access to safe sanitation only within the EU.

In order to assist local authorities to find appropriate methods to solve the rural sanitation problems, GWP CEE has published a book focusing on sustainable sanitation options which are affordable and safe from health and environmental standpoints. A key to find ways forward is to create consensus among involved stakeholders (Bodik & Ridderstolpe, 2007). In this context, the term *"sustainable sanitation"* is defined as *sanitation that protects and promotes human health, does not contribute to environmental degradation or depletion of the resources base, is technically and institutionally appropriate, economically viable and socially acceptable* (Kvarnström & af Petersens, 2004).

Urbanization and the sanitation challenge

The proportion of the population that is urban is rapidly growing as a consequence of a significant increase in overall population and in rural-urban migration. The projection is that, by 2030, the towns and cities of the developing world will make up 81% of urban humanity (UNFPA, 2007). This translates into the urgent need for thoughtful urban planning and sound investments in basic services, especially in the emerging mid-size cities to avoid the omissions we face today in many larger urban centers. Population increase in rapidly growing urban and peri-urban areas is putting enormous pressure on land and water resources and has resulted in serious water stresses, poor waste management and severe diffuse pollution.

Urban population growth has led to the spread of poorly-planned settlement areas surrounding many major cities in the developing world and to a rapid increase in the number of slums, in unemployment and poverty. According to the UN-Habitat (in UNFPA, 2007), slum dwellers account for 43% of the urban population in the developing world and for 72% of the urban population in sub-Saharan Africa (SSA). At the current growth rates, half of the humanity will live under slum conditions by 2030.

A growing proportion of the urbanization is becoming informal with the proliferation of scattered housing. Construction of spontaneous housing on city outskirts is also leading to annual loss of farm land and causing deterioration in living conditions. Also the use of inappropriate sites, such as flood-prone areas and near solid waste landfills, presents major risks. Providing sanitation to the slums and informal settlements requires a different approach given the scale of the problem, the high population density, the complexity of the situation, the difficulty to provide standard services in such conditions (insecure tenure, lack of infrastructure, lack of space, etc.), and the resulting aggravated health, environmental, and other socio-economic problems.

Supply of water and sanitation and the Millennium Development Goals

About two fifths of the world's population does not have access to adequate sanitation (Table 2). Nearly 80% of the unserved population is concentrated in sub-Saharan Africa, Eastern Asia and Southern Asia (4WWF, 2006). Sanitation facilities are critical to ensure supply of clean water but so far little progress has been made.

Table 2. Distribution of global population without access to safe drinking water and sanitation (in millions) (4WWF, 2006).

		Low income countries	Middle income countries	Total
Drinking water	Below poverty line	320	96	416
	Above poverty line	30	259	289
	Total	350	355	705
Sanitation	Below poverty line	540	93	633
	Above poverty line	565	730	1295
	Total	1105	823	1928

These statistics stress the infrastructural gaps and the dramatic increase in investments needed in water and wastewater collection, storage, treatment and management to "make" safely usable water out of surface water, groundwater, stormwater, or wastewater, maintain its quality, and reduce possible health risks. They underline the need to develop innovative approaches to meet the 2015 MDG water and sanitation target. They also show that it will be necessary to increase significantly the speed at which people are provided with safe and affordable drinking water and sanitation – although the significance of the current definitions of "improved"[2] systems and "coverage"[3] are being questioned. There are increasing voices pointing to local definitions of "improved" systems instead of referring to internationally admitted standards.

Basic sanitation is not necessarily dependent on water: the disposal of wastes can be on-site (self-regulating through septic tanks or pits) or emptied by municipal or private tankers. However, the use of water-borne sewerage through public drains takes the problem onto a different level. Where sewerage networks have to be installed, the resulting accumulation of wastewater has to be treated as well as the sludge. These infrastructure networks are very costly and in most urban environments there is no clear alternative. "[In Asia] sewerage costs are in the $300 per capita range, septic tanks cost $100 per capita, and latrines cost $25 per capita" (McIntosh, 2003).

Urban sanitation differs from its rural counterpart. For the latter the central collection and treatment of the waste is exceptional, and discharges are made into pits that are left to percolate naturally. However, the world is rapidly urbanizing, and hundreds of millions of people are on the sanitation "ladder", upgrading from no latrines to pit latrines, on to septic tanks, and eventually to condominial or full-scale public sewerage.

Sanitation in megacities and large urban areas

Only Europe, North America and parts of Asia have large proportions of their cities sewered (Figure 1). However, of the major cities in Western Europe only about 80 have advanced treatment facilities (mainly in the north). Many countries in Europe lag behind in wastewater treatment with coverage in Belgium

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[2] According to WHO et al., (2000), "improved drinking water coverage" includes services by either household connections or access within one kilometer to a constructed public water point (standpipe, borehole with hand pump, protected wells, protected springs, rainwater collection) where at least 20 liters of safe water per person per day are available. "Improved sanitation coverage" is defined as a household connected to a public sewer or a constructed on-site disposal system (septic tank, pour-flush, ventilated improved pit latrine or pit latrine).

[3] Coverage is the proportion of people using improved sanitation facilities: public sewer connection; septic system connection; pour-flush latrine; simple pit latrine; ventilated improved pit latrine (WHO, 2008).

and Portugal at 40%, and Greece, Italy and Poland running at 60%. The City of Brussels, where environmental legislation is made for the EU countries, only began treating all its sewage in 2006. The same year and after 40 years of discussion, Milan got its plants on line (Rosemarin, 2008).

Romania has over 10 million inhabitants who are not connected to any centralized sewer system. The World Bank Romania estimates that at least 25% of groundwater nitrate pollution originates from pit latrines and not well designed septic tanks. In Romania, there are 1,310 wastewater treatment plants and wastewater storage installations (municipal and industrial). In 2005, only 492 plants were functioning adequately (*Women in Europe for a common Future, "Dialogue on EU sanitation policies and practices in the IYS", 29 January 2008).*

In India, 24% of wastewater from households and industry is treated, 2% in Pakistan (IWMI, 2003; Minhas and Samra, 2003). In Accra, Ghana, 10% of wastewater is collected in piped sewage systems and undergoes primary or secondary treatment (Drechsel et al., 2002; Scott et al., 2004). In Africa, only 1% of wastewater is treated (WHO and UNICEF, 2000). These small volumes of wastewater are not always adequately treated because of low financial, technical and/or managerial capacity or treatment plants that are out of commission or overloaded and thus discharge into the environment (rivers, lakes, sea, etc.) effluents that may contaminate food and downstream water supplies, creating public health risks, environmental damage, and unpleasant living conditions. As the volumes of untreated wastewater are continuously increasing, the pollution of water bodies tapped for irrigation is worsening. The rapid and unplanned growth of cities continues to outpace improvements in sanitation and wastewater infrastructure, making the management of urban wastewater more complex and ineffective. The prospects regarding the increase in wastewater treatment capacity in these cities are gloomy.

"Municipal water utilities have now become the main polluters of surface waters in many East European, Caucasus and Central Asian countries. Up to 90% of nitrogen and phosphorus discharges into the Black and Caspian Seas originate from riverine inputs, which mostly transport municipal wastewaters" (OECD EAP Task Force, 2007)).

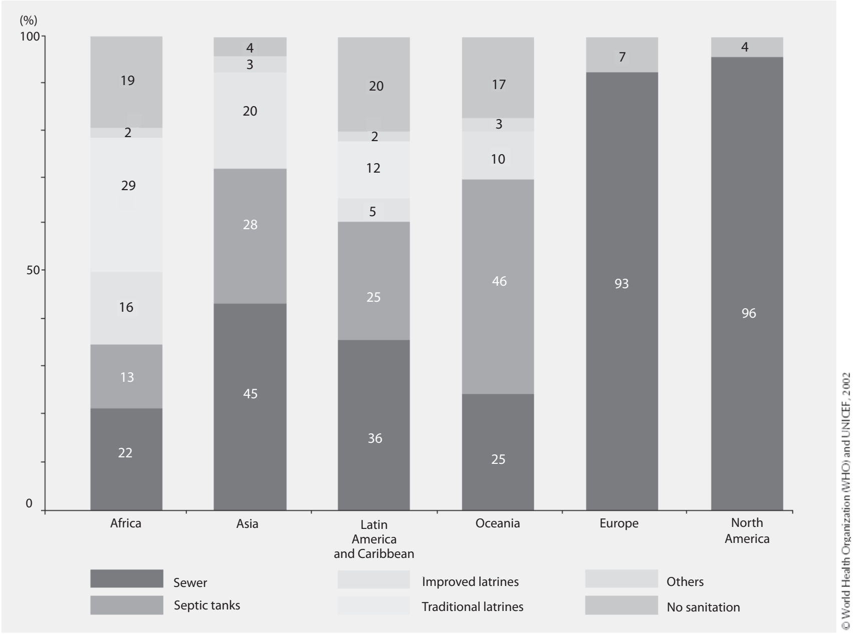

Figure 1. Distribution of sanitation technology across the world (WHO and UNICEF, 2002).

Problems related to off-site and on-site sanitation systems are frequently reported. The International Water Association's (IWA) Task Force on Sanitation (IWA, 2006) analyzed the different reasons leading to the failure of these sanitation systems. It was found that these systems are either inappropriate to the cities they are meant to serve, badly planned, badly implemented, or poorly managed. Other reasons were the gap which exists between the interests of households and the incentives of utilities/cities; the lack of resources and capacities; lack of focus on long-term operation, and no planned provisions for maintenance requirements.

Sanitation in the peri-urban areas and small communities

A small percentage of households located in the peri-urban areas and small communities of emerging and developing countries are connected to a collective sewage system or have on-site sanitation facilities (dry-toilet, composting toilet, cesspool, septic tank and subsurface infiltration) and this should grow rapidly (WHO and UNICEF, 2002). In India, only 232 of the nation's 5003 towns have sewer systems. Citizens of the other 4771 communities use dry latrines or nothing at all. The Sacred Ganges is a source of drinking water as well as a place that festers with untreated sewage. Wastewater that is not properly treated is literally "wasted" because it cannot safely be used for other purposes. Much wastewater is in this state, because of deficiencies in its collection and treatment. The management of fecal sludge, wastewater collected from on-site sanitation systems (public toilets, septic tanks and pit latrines), is also a major issue. Problems can also be associated with the prevailing use of fecal sludge in agriculture and aquaculture. With the tendency of scattered populations to cluster more closely together and to get connected to the water supply network, the issue of the safe evacuation of wastewater is becoming a matter of pressing concern. On the other hand, extending the area covered by public sanitation systems is costly. For social equity and environmental concerns, there is a need to consider appropriate sanitation and treatment systems for these communities.

Sanitation in the coastal zones and islands

In the coastal zones and islands, the sea has long been used for the disposal of human wastes counting on the sea's self-purification capacity. Partially treated and in most cases untreated wastewater originating from land-based (municipal, industrial and agricultural) activities (80%) and from coastal cities is directly discharged to the sea on the shore, through sea outfalls of variable length, or reaches the sea by seepage.

The impacts of inadequate supply of water and sanitation

What is generally known is that lack of clean, adequate, safe and affordable water and of safe sanitation facilities affects people's life, health, growth and development. It affects more particularly women and children in charge of water collection and raises issues of personal safety and dignity (Norström, 2007). It jeopardizes children's education and gender equity (WHO and UNICEF, 2006). It has a huge impact on human suffering and productivity. It is a barrier to economic development through (1) the labor hours lost due to disease and time spent fetching water (overall average for Africa is about half an hour) and (2) the human capital lost when sick children miss school. It may deepen the inequities between the urban rich and the urban poor who pay more for water provision, and are usually the last to be extended water and sanitation services.

Lack of water access and sanitation increases the emergence of endemic and epidemic diseases and illnesses (cholera, typhoid, etc.) (WHO, 2006). Diseases and productivity losses linked to water and sanitation amount to 2% of GDP in developing countries. Water-related diseases cost 443 million school days every year. Polluted water and poor sanitation account for most of 5000 child deaths every day from diarrhoea. According to Fewtrell *et al*. (2005), diarrheal morbidity can be greatly reduced through water and sanitation investments: up to 45% reduction from improved hygiene, up to 39% reduction from household water treatment, up to 32% reduction from improved sanitation, and between 6 and 25% reduction from improved drinking water. The impact of providing clean water and sanitation is huge as it can increase economic well being at the household level, mainly through saving large amounts of people's time and energy. It is also a matter of safety for women and children during night time and in school.

Only a small percentage of septic tanks is appropriately sited, designed, constructed, maintained and connected to an efficient soil infiltration system. On-site facilities create the most acute problems because they pollute the environment while stormwater gutters also receive and channel greywater, wastewater and fecal sludge from spilling over latrines to larger drains and inner-city streams. These appear in many cities as large wastewater drains absorbing in addition all kinds of plastics and solid wastes. Moreover, lack of access to safe water and sanitation, inadequate waste management, poor drainage, etc, lead to aggravated health, environmental, and other socio-economic problems. Solid wastes and storm water drainage exacerbate these problems. In many regions, the quality of life does not meet acceptable health and social standards. This situation creates critical environmental, security and health problems.

In the coastal zones, waste disposal contributes to the degradation of water quality. It has created marine pollution and considerable hazards to human health and also endangered the marine environment. The risk of (1) dispersion of pathogen organisms capable of endangering human health, (2) toxic effects on aquatic life and human life, (3) eutrophication resulting from the widespread dispersion of nutrients, (4) oxygen stress, and (5) the emergence of red tides and toxic micro-organisms may increase. Health problems due to wastewater pollution can become severe for the large populations living in coastal areas. These problems may have global impacts beyond country borders. As coastal areas are also used as fish catchments, conservation areas, and holiday resorts for recreation and swimming, economic impacts of wastewater on coastal ecosystems are likely to be extensive (UNEP/WHO/UN-Habitat/WSSCC, 2004).

4. WATER RECLAMATION AND REUSE

Water reclamation and reuse is rapidly developing worldwide. Compared to desalination, it is a cost-effective and energy saving option to increase water supplies and mitigate the impact of climate variability and climate change. There are different reuse opportunities with different social, economic and environmental values: agricultural irrigation, aquaculture, non-potable urban uses and landscape irrigation, drinking water augmentation and aquifer recharge, restoration of water bodies and wetlands, and industry (cooling, boiler-feed or process water).

Wastewater reuse through irrigation and aquaculture

Agricultural wastewater reuse is an element of water resources development and management that provides innovative and alternative options for agriculture. Reuse of reclaimed water for irrigation enhances agricultural productivity: it provides water and nutrients, and improves crop yields (Bahri, 1999). On the other hand, the urban poor depend heavily on rising agricultural productivity to reduce food prices. Ensuring jobs and food security for the urban poor is a challenge. Peri-urban agriculture is clearly one of the options to address the increasing urban food demand, complement rural supply and for poverty reduction.

Wastewater reuse through irrigation and aquaculture can serve the inherent function of food production while recycling urban waste products. Reuse of wastewater means making a productive asset out of a waste product, while contributing to natural purification towards sustainable natural resources management schemes. It is a way of “outsourcing” part of the sanitation services, maximising water use efficiency, as well as closing the water and nutrient loops to sustain and promote food production. The agricultural sector can then provide to the urban sector an "environmental function" which can be valued as an "environmental service". Urban and peri-urban agriculture can, at the same time, provide food to the urban areas and act as an "environmental manager" (Thiébaut, 1995).

This leads to reconsidering the relationship between urban, peri-urban and rural areas and requires holistic thinking about urban water management.

Reuse of human excreta has a legacy in many cultures. The production of large amounts of domestic wastewater is a life-style trend originating from western industrialised countries. Per capita water use of households in urban areas has increased from a bucket a day a century ago to about 200 litres per person in European cities (Guterstam, 1997). The use of water closets cannot be regarded as a sustainable sanitation concept when introduced in water scarce urban areas or when necessary wastewater treatment is lacking.

Wastewater irrigation is a common established practice in urban and peri-urban areas in most developing countries. More than 800 million farmers are engaged in urban and peri-urban agriculture worldwide (UNDP, 1996). Many of the 200 million farmers who specialize in market gardening rely on raw or diluted wastewater when higher quality sources are unavailable. Practices range from the use of polluted surface water and raw wastewater to the piped distribution of secondary or tertiary treated wastewater to irrigate different kinds of crops and trees. This illustrates the challenge of estimating the extent of "wastewater" irrigation, with global figures ranging from 4 to 20 million ha (IWMI, 2006).

In most developing countries, urban wastewater/sewage is widely used, partially treated or untreated, to irrigate vegetables, rice and fodder for livestock. Due to lack of refrigerated transportation, 70-90% of the most perishable vegetables consumed in many cities are also grown within the city boundary, and this involves the use of usually highly polluted water sources, mostly of domestic origin (sewage). Examples include Hanoi (80% of the vegetable production is from urban and peri-urban agriculture (UPA)); Dakar (70% of the vegetable consumption in the city is met by UPA); Dar es Salam (caters to 90% of its vegetable needs through UPA); Bamako (produces all of its vegetables from UPA and even exports them in some seasons); Pakistan (26% of national vegetable production is from UPA); similar situations are in Ouagadougou, Accra, Addis Ababa and Nairobi.

There are only a few developing countries with experience in planned reuse and a record of wastewater treatment plants producing a safe effluent. In Africa, Namibia, South Africa and Tunisia have such policies in place with wastewater treatment through a range of conventional and non-conventional systems and national guidelines and regulations for reuse. Salient aspects of (waste)water reuse in Africa, Asia, Latin America, Europe and Australia are highlighted to illustrate the variety of the situations and approaches adopted in various contexts. Wastewater reuse in Ghana (Box 1) demonstrates the potential health risks and the socio-economic benefits to the farmers as well as the overall benefit to the city.

Box 1: Sanitation and Wastewater Reuse in Ghana

In Ghana, urban sanitation infrastructure is poor. Less than 5% of the population has sewerage connections and only a small share of the wastewater is treated (Keraita and Drechsel, 2004). Twenty per cent of households do not have access to any form of toilet facility; about 31% relies on public toilets, while 22% has access to pit latrines. About 7% of households uses KVIP (Kumasi Ventilated Improved Pit) latrines and 9% has access to water closets. Access to water in rural and urban areas has generally improved gradually resulting in increased generation of fecal sewage and wastewater with increasing waterlogging and stagnant pools of water in many towns and cities because of lack of drains. Inadequate water and sanitation have a significant impact on public health and contribute to 70% of the diseases in Ghana (WaterAid, 2001). About 20% of the 44 existing wastewater treatment plants are functional, and these are usually below design standards. Waste stabilization ponds and trickling filters are some of the common systems. Very little extension of the sewerage network has taken place since its construction in the early 1970s. Due to the limited number of sludge treatment sites and their poor accessibility and/or status, more than 60% of all collected excreta is dumped into the ocean.

Studies have been carried out to improve sewerage, effluent disposal and sanitation through off-site and on-site sanitation facilities. The Accra Sewerage Improvement Project will provide two new sewage treatment plants, based on waste stabilization ponds, with outfalls discharging into the sea and into watercourses, etc. (ADB, 2005). Transfer of sanitation and sewerage functions from central Government agencies to the Assemblies is considered in the National Environmental Sanitation Policy, which is however not automatically combined with a corresponding transfer of capacities and operational funds.

Urban and peri-urban agriculture is developing wherever land is available close to streams and drains (Obuobie et al., 2006). Around Kumasi, informal irrigation, which often uses polluted stream water, is estimated to cover 11,500 ha (Keraita and Drechsel, 2004). Typical concentrations of fecal coliforms in irrigation water range from 104 to 108 CFU/100 ml (Keraita et al., 2003). Watering cans are the most common irrigation method used in the country. Buckets, motorized pumps with hosepipe and surface irrigation are also used to fetch, pump and water crops. In Accra, 800-1000 farmers irrigate more than 15 kinds of vegetables (lettuce, cabbage, spring onions, cauliflower, cucumber, tomatoes, okra, eggplants, and hot pepper). All-year-round irrigated vegetable farming can achieve annual income levels of US$400-800 per actual farm size. The annual value of the production, a significant part of which is irrigated with wastewater, has been estimated by Cornish et al. (2001) for dry-season farming as US$5.7 million around Kumasi (Keraita and Drechsel, 2004) and for year-round production as US$ 14 million in the case that the same crops have to be imported from neighboring countries with safer water sources (Drechsel et al., 2006).

Every day, about 200,000 urban dwellers from all classes in the capital Accra benefit from this production when consuming raw salads as part of urban fast food, but the same number is also at risk due to vegetable contamination. Irrigated vegetables sold in the markets showed fecal coliforms and helminth eggs (> 103 FC/g fresh weight and up to 3 helminth eggs per gram of vegetables) (Keraita et al., 2003). Both municipal food supply and safety are therefore significantly affected by the urban sanitation situation. This is a major concern of the authorities who tried to ban the use of polluted water for irrigation purposes, with the same success as to stop water pollution. Alternative interim health risk reduction strategies are currently explored as proper wastewater collection and treatment infrastructure is not yet available and the existing one not functional.

Wastewater irrigation can be both a major health risk for farmers and consumers and a major economic contribution in terms of jobs and food supply (Table 3).

Table 3. Trade-offs between the economic value of water and nutrients and environmental and public health risks.

Economic value of water and nutrients	Environmental and public health risks
• Conserves water and reduces freshwater demand • Provides a reliable water supply to farmers • Acts as a low-cost method for disposal of municipal wastewater • Reduces pollution of rivers, canals and other surface waters • Recycles organic matter and nutrients to soils, thereby reducing the need for artificial fertilizers • Increases crop yields and has therefore direct positive income effect for farmers	• Health risks for the irrigators and communities in contact with wastewater (increased incidence of diarrheal diseases) • Health risks for the consumers of vegetables irrigated with wastewater • Pathogens in wastewater can cause health problems for the cattle • Contamination of groundwater (nitrates, trace organics, pathogens, etc.) • Build-up of chemical pollutants in the soil (salts, heavy metals, etc.) • Creation of habitats for disease vectors (mosquitoes) in peri-urban areas

Health risks related to wastewater irrigation should be targeted in the general context of poor water supply and sanitation, and not in isolation. Wastewater irrigation raises also issues related to environment protection, as its nutrient, salt and other contaminant contents can be high. Farmers who use wastewater for irrigation are, in different circumstances, both the perpetrators and the victims of water contamination. Many farmers use polluted water, both from municipal outlets and water discharged by other farms. Contaminated farm effluent is both a problem and an opportunity: it is a problem for downstream water users, and as pollution worsens it increases tensions amongst rival users. Farm effluent does, however, present an opportunity to create more useable water for others if contamination can be reduced at source (e.g. by more organic methods, less use of chemicals, better drainage lessening salinity, etc). Animal waste can also be converted into energy (e.g. methane) and fertilizer.

Industrial pollution from large industries is of concern in some cities. Uncontrolled discharge of hazardous contaminants from these industries also results in build-up of toxic constituents in surface water (sediments) and contamination of groundwater. Heavy metals (Fe, Cu, Zn, Mn, Ni, Pb and As) have been found in concentrations of concern (Itanna and Olsson, 2004) in vegetables (an estimated 400 ha producing 11,100 tons of more than 14 different vegetables) irrigated with water from the Akaki river in Addis Ababa.

However, it is usually not a choice for farmers to use "wastewater" but rather a necessity, as it is often difficult to find clean water sources in and around most cities. Wastewater has many advantages for farmers as it can contain – depending on the degree of dilution – significant amounts of nutrients for food crop production that reduce the need for chemical fertilizers. Wastewater content of organic matter, nitrogen, phosphorus, and potassium may improve soil fertility, enhance plant development and increase agricultural productivity. More importantly, however, it is a reliable water supply, usually free-of-charge, and continuously available in the vicinity of urban markets. Wastewater reuse supports the livelihood of many farmers and traders and plays a significant role in poverty alleviation. It also provides a niche for urban food supply complementing rural production (Drechsel et al., 2006, 2007) that can assist in fighting the water and food crises.

Relatively few people in developing countries are served by waterborne excreta collection systems or sewerage systems, but there are several commercially viable recycling systems that use sewage. India and China have the largest areas of sewage-fed fisheries in the world (Edwards, 1992) (see Box 2 and 3).

Box 2: India – Calcutta Wetlands

"Waterlogged areas on the edges of cities are poised to gain newfound significance in India. For a number of municipalities such areas have been identified and taken over by the government for transformation into low-cost sanitation and resource recovery ecosystems under the provisions of the Ganga Action Plan under the Ministry of Environment and Forests of the Government of India. This action is the beginning of an ecosystem approach for solving the problems of municipal sanitation in a developing country." (UN Global 500 Laureate, Dr. Dhrubajyoti Ghosh, Government of West Bengal, 1991).

In 1875, the main sewers of Calcutta began to function. The sewer system uses the natural slope towards east of the city. In the 1930s sewage-fed fish farming started. The fisheries developed into the largest single excreta-reuse aquaculture system in the world with around 7,000 ha in the

1940s, supplying the city markets with 10-12 tons of fish per day. The history is described by Ghosh (1997) and Edwards (1992).

In the 1980s, the wetlands east of Calcutta were restored in the context of the Ganga Action Plan. The Calcutta Wetlands using wastewater both in agriculture and in aquaculture covered an area of about 12,000 ha, known as the Waste Recycling Region (Ghosh, 1996). In recent years, there has been a general decline due to threatening urbanization and the fish-pond area decreased to about 2,500 ha (Edwards, 2000).

Lessons learned from Calcutta are that the wastewater reuse system meets modern criteria of sustainable development of a mega-city in terms of:

- The Environment by providing low-cost wastewater treatment, stormwater drainage and a green area for the city.
- Social and economic benefits, including employment for about 17,000 poor people and production of about 20 tons of fish per day for the urban poor (Edwards, 2000).
- Serving as a model to be replicated elsewhere in India (and other countries).
- Reducing environmental impacts of contamination from heavy metals from major industries, like chromium from the tanneries in Calcutta (Biswas and Santra, 2000).

Finally, it needs to be mentioned that strong government policy intervention is needed to prevent the reuse system from being converted into land for urban construction development.

Box 3: Chinese Wastewater Reuse Systems

China has a long tradition of effective management of natural resources. This includes reuse of garbage and human excreta in agriculture and aquaculture. The classical night soil system[4] was reported to reuse as much as 90% in agriculture (Edwards, 1992). Still the predominant types of sanitation are dry systems, but sewerage is being installed in the fast growing larger cities.

Of the total amount of wastewater in China, which reached almost 80 billion tons annually around year 2000, 75% was of industrial origin (Ou and Sun, 1996). Wastewater treatment has fallen behind with only 24% treatment of industrial wastewater and 4% of domestic sewage.

Irrigation with municipal wastewater began in large scale in the late 1950s, and it reached about 1.5 million ha in 1995 covering around 1% of the total cultivated land of China (Ou and Sun, 1996). Problems with contamination of heavy metals and persistent organic pollutants were also reported.

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[4] *The Chinese Night Soil System provided that human excreta should be taken out of the urban areas before dawn.*

Reuse of wastewater from large cities in aquaculture started in 1951 in Wuhan, reaching a peak of 20,000 ha by the 1980s (Edwards, 2000). The reuse of wastewater in aquaculture systems has been linked to traditional concepts of "Integrated Farming" and "Fish Polycultures" (Li, 1997).

The Chinese Government scenario for the year 2050 estimates that half of the rural population will migrate to urban areas. This means that another 400 million Chinese citizens will need sanitation supplied by urban systems (Wang, S., Minister of Water Resources, 2002).
In China, the MDG Target 10 on water supply and sanitation is a gigantic task. According to the 2003 UN Progress report, "China has made enormous progress toward achieving its MDGs". The policy is to provide water for all and to introduce the concept of the water saving society. During the present 5-year plan 2006-2010, another 160 million people will be supplied with safe drinking water. At the same time, according to UNICEF, over 700 million people, mainly in rural areas lack basic sanitation (Spruijt, 2008).

Mexico City (Box 4) gives a good example of incidental aquifer recharge in the Mezquital Valley resulting from wastewater irrigation.

Box 4. Wastewater irrigation and aquifer recharge in the Mezquital Valley in Tula, Mexico

North of Mexico City, in the Mezquital Valley, 85,000 ha are irrigated with mostly untreated wastewater produced in Mexico City. Wastewater allows agricultural development in an area with 550 mm rainfall and soils with low organic matter and nutrient content. Farmers are therefore against wastewater treatment that could remove the fertilizing matter and promote the reuse of water within Mexico City. Wastewater contributes to the soils 2400 kg of organic matter, 195 kg of nitrogen and 81 kg of phosphorus per hectare per year. After 80 years of irrigation, phosphorus content in the soils has increased from 6 to 20 g/m^2, nitrogen from 0.2 to 0.8 kg/m^2 and organic matter from 2 to 5%.

Wastewater has increased microbial activity and soil denitrification capacity. However, in sites irrigated over more than 65 years, it has been observed that salinity in soil and plants has increased (e.g. in alfalfa, from 1.5 to 4 g/kg) (Siebe, 1998) and has reduced soil microbial activity. The heavy metal content in soils has also increased from 3 to 6 times their original values, but crops did not show elevated heavy metal concentrations.

Due to the high irrigation rate (1.5-2.2 m/year), and to the storage and transport of wastewater in unlined dams and channels, the aquifer is being recharged. In 1998, it was found by the British Geological survey that the water infiltration rate was at least 25 m^3/s. This unplanned recharge, which took place during several decades, has raised the water table in some places from 50 m deep to the surface. Springs have appeared with flows between 40 and 600 l/s. These springs have become the only source of water supply for more than 500,000 people. The transport of wastewater in channels and its use in irrigation has improved its quality. By the time water enters the aquifer, organic matter has been reduced by 95%, heavy metal concentration by 70-90%, microorganisms by 6-7 logs and levels of more than 130 organic compounds by >99%. Salt concentrations have increased.

To bridge a gap of 5 m^3/s for fresh water in Mexico City and owing to the increasing demand, the Government is considering returning 6-10 m^3/s from the water recharged in the Mezquital Valley. This option would be more attractive compared to imports from more than 1000 m lower than Mexico City and 200 km away, or from sites closer but whose population is opposed to the idea, or treating Mexico City's wastewater and reinjecting it into the aquifer for human consumption.

Sources: Jimenez and Chavez (2004), Jimenez, Siebe and Cifuentes (2004)

Tunisia (Box 5) offers an example of water reuse operations integrated in the planning and design of sanitation projects. A phased approach was taken to set up a planned water reuse strategy.

Box 5: Integrated wastewater treatment and reuse in Tunisia

In Tunisia, most residents of large urban centres have access to various adequate sanitation systems and wastewater treatment facilities. The sanitation coverage is 87% for all the population – 96% in the urban areas and 65% in the rural areas. Industries have to comply with the Tunisian standards (INNORPI, 1989) prior to discharging their wastewater into the sewerage system. They are given subsidies to equip their industrial units with pre-treatment processes. Of the 287 Mm^3 of wastewater collected annually, 224 Mm^3 (78%) are treated in 98 treatment plants (mainly secondary biological treatment).

About 30-43% of the treated wastewater is used for agricultural and landscape irrigation. Reusing wastewater for irrigation is viewed as a way to increase water resources, provide supplemental nutrients, and protect coastal areas, water resources and sensitive receiving water bodies. Reclaimed water is used on 8,100 ha to irrigate industrial and fodder crops, cereals, vineyards, citrus and other fruit trees. Regulations allow the use of secondary-treated effluent on all crops except vegetables, whether eaten raw or cooked. Regional agricultural departments supervise the water reuse decree enforcement and collect charges (about \$0.02 m^3). Golf courses are also irrigated with treated effluent.

Tunisia launched its national water reuse program in the early 1980s. Treatment and reuse needs are combined and considered at the planning stage. Some pilot projects have been launched or are under study for industrial use and groundwater recharge, irrigation of forests and highways and wetlands development (Bahri, 2000). The annual volume of reclaimed water is expected to reach 290 Mm^3 in the year 2020. At that point, the expected amount of reclaimed water will then be approximately equal to 18% of the available groundwater resources and could be used where excessive groundwater mining is causing seawater intrusion in coastal aquifers.

The Mejerda catchment area sanitation program has equipped the 11 largest towns of that area with sewerage networks, treatment plants, and reclaimed water irrigation schemes in order to protect natural resources, and particularly the major source of water supply for the Grand Tunis and other southern areas, the Sidi Salem dam (550 Mm^3), from contamination by raw wastewater. One new large water reuse project is planned for Tunis West area with a design capacity of 224,700 m^3/d (82 Mm^3/yr) by the year 2016, which will enable the irrigation of about 6,000 ha. By 2020, the area irrigated with reclaimed water is planned to expand up to 20,000-30,000 ha, i.e. 7-10% of the overall irrigated area.

Inter-departmental coordination and follow-up commissions with representatives from the different ministries and their respective departments or agencies, the municipalities and representatives of the users (Water users' associations) have been set up at national and regional levels so as to bridge the gaps between the needs of different parties, ensure the achievement of development objects, and preserve the human and natural environment.

A water reuse strategy aimed at developing water reuse and considering reclaimed water as a water resource has been drafted. Forthcoming projects aimed at meeting a real water demand – in quantity and quality – should allow a higher utilization of reclaimed water primarily for agricultural purposes and secondarily in other sectors. By upgrading the water quality and with more widespread information, reclaimed water reuse should gain wider acceptance in the future.

Reuse systems for wastewater also have a legacy in developed, northern countries. In the new contexts of climate change with its impact on hydrology as well as the global common goal towards sustainability, it is important to highlight these experiences as options for a great number of cities which need to improve their sanitation systems. Two cases are presented here, one from Europe (Box 6) and one from Australia (Box 7).

Box 6: Europe – Munich

Within the European Union, there is an ambitious regulatory framework for protection of the aquatic environment. In the European Communities Commission Directive (91/271/EEC), it is stipulated that "treated wastewater shall be reused whenever appropriate", and that "disposal routes shall minimize the adverse effects on the environment" (European Economic Community, 1991). Still, in the 21st century, a majority of EU cities lack adequate wastewater treatment systems. The City of Brussels where environmental legislation is made for the EU countries launched only recently the construction of its first wastewater treatment plant.

In humid north European countries, ecological engineered wastewater technologies are introduced, e.g. constructed wetlands serve as polishing steps for nitrogen reduction in order to prevent eutrophication of recipient waters. The most extensive and sophisticated recycling system of wastewater was constructed in Munich, Germany. The system involved active participation by the citizens in a total recycling through agriculture and aquaculture. Awareness campaigns encouraged people only to flush harmless wastes that could be recycled.

In 1929, a wastewater-fed aquaculture for fish production was established (Prein, 1990). The fish-farming was adapted to the northern climate with a seasonal production period lasting from April to October. In winter, the wastewater was stored in a lake, while the fish ponds were cleaned. The Munich system was dimensioned for the entire population of at that time 500,000 p.e. using 200 litres of water per day. The total size of the aquaculture is 233 ha with an annual fish production of 100-150 tons. Depuration studies on the fish showed that depuration lasting up to one year was effective for Cd and Pb but not for Hg and PCBs.

The Munich fish pond system is still in operation. Today a sophisticated pre-treatment is installed, which has changed the system from a wastewater treatment facility to a polishing facility, i.e. tertiary treatment. It is high time to use the Munich type of legacy in order to enforce EU environmental policies.

Box 7: Melbourne

Australia has an arid climate and most parts of the country are short of freshwater resources. In the state of Victoria in Southern Australia, the largest regional water authority Baron Water manages several examples of wastewater reuse with irrigation of different agricultural enterprises such as wine industry, potato and tomato crops, horticulture, and tree lots (Baron Water website).

In Melbourne, the Werribee wastewater system was opened in 1897. Half of the wastewater from the 4 million citizens is used for irrigation of grazing fields for cattle and sheep. The public water company, Melbourne Water, manages 54% of its wastewater in 11,000 ha of ponds, wetlands and grazing fields, i.e. 500,000 cubic metres of wastewater per day. The present livestock grazes on 3,700 ha of pastures irrigated with raw or sedimented sewage and 3,500 ha non-irrigated pastures. The livestock yields a substantial return of about 3 million Australian dollars per year, which significantly reduces the cost of sewage treatment (Melbourne Water, 2001).

From the IWRM perspective, water reuse is desirable as it conserves freshwater and contributes to reduce unplanned wastewater discharge and pollution of water bodies and the environment in general. It should be considered as critical in cities and should be integrated into urban sustainable sanitation planning.

Water reuse for other purposes

Wastewater may be reused for municipal purposes such as landscape irrigation (parks, green areas, golf courses, etc), groundwater recharge, recreational and environmental uses (restoration of water bodies and wetlands), industrial uses, toilet flushing, and potable reuse. For microbiological safety and for some reuse options, advanced technologies such as UV disinfection and membrane processes will be required (Mujeriego and Asano, 1998). Regulations will vary with the type of reuse application, the most stringent being for potable reuse. Two examples from the United States are presented in Boxes 8 and 9.

Water Conserv II Winter Garden, Florida, (Box 8) includes inter alia a reliable and cost-effective supply of reclaimed water for agricultural and other users, conservation of groundwater supplies, and groundwater recharge via rapid infiltration basins.

Box 8: Water Conserv II, Winter Garden

Water Conserv II is the one of the largest water reuse projects with a combination of agricultural irrigation and rapid infiltration basins (RIBs). It is also the first water reuse project in Florida permitted by the State of Florida Department of Environmental Protection to irrigate crops produced for human consumption with reclaimed water. Jointly owned by the City of Orlando and Orange County, it has taken a liability (effluent previously discharged to surface water bodies) and turned it into an asset (reclaimed water) that benefits the City, the County, and the agricultural community.

The system encompasses two water reclamation facilities connected by 34 km of transmission pipeline to a distribution center. From the distribution center, a 78 km pipeline network distributes reclaimed water to 76 agricultural and commercial customers. The reclaimed water that is not used for irrigation is distributed to RIBs. The RIB network contains seven sites with 74 RIBs over a total of 809 ha. Both the distribution network and RIB site network are monitored and controlled from a central computerized control system. In summary, (1) Water Conserv II has eliminated discharge of wastewater effluent to surface waters, (2) the RIB sites have provided a preserve for endangered and threatened species for plants and animals, as officially cited by City and County decree, and (3) The Water Conserv II replenishes the Floridan aquifer through the discharge of reclaimed water to the RIBs. It also reduced the demand on the aquifer by eliminating the need for well water for irrigation.

Multiple reuses of reclaimed water – landscape irrigation, agricultural irrigation, industrial reuse, and toilet flushing – are successfully implemented at Irvine Ranch Water District, California (Box 9).

Box 9: Irvine Ranch Water District (IRWD), Irvine, CA

Reclaimed water now makes up 20% of IRWD's total water supply, reducing the need to import expensive water and helping to keep water rates low. The reclaimed water is delivered through a completely separate distribution system that includes more than 394 km of pipeline, eight storage reservoirs and 12 pump stations. The system provides reclaimed water to approximately 405 ha of fields and orchards planted with a variety of fruits, vegetables and nursery products. Eighty percent of all business and community landscaping (parks, school grounds) is irrigated with reclaimed water. A few estate-sized residential lots also use this water for front and backyard irrigation. Many water features such as fountains and the lake at Mason Park are filled with reclaimed water. In 1991, IRWD became the first water district in the nation to obtain permits for the interior use of reclaimed water from a community system.

The primary uses for reclaimed water within IRWD are: (1) Landscape irrigation – parks, golf courses, school playfields, athletic fields, and many common areas maintained by homeowner associations. Over 2,818 landscape meters receive reclaimed water, providing irrigation to over 2,287 ha of landscaping. (2) Agricultural irrigation – reclaimed water is used to irrigate most crops grown in this area. The District provides reclaimed water to 44 agricultural users, irrigating over 405 ha of crops. (3) Industrial uses – Some industries use reclaimed water in their production processes. One carpet mill converted its carpet dyeing process from domestic to reclaimed water. This one conversion alone saved 1,892 m^3/d to 3,785 m^3/d of drinking water. (4) Toilet flushing – reclaimed water is used to flush toilets in a few dual-plumbed high-rise and other commercial buildings. In a typical office setting, approximately 80% of the water is used for toilet flushing. By using reclaimed water instead of drinking water to flush toilets, major savings can be realized.

Water reuse in islands

The majority of the islands, particularly those of small size, suffer from water shortage due to lack of sufficient water resources and increasing water demand. They are facing increasing problems to ensure their water supply. These difficulties are all the more sensitive as tourism takes an increasing and often dominant share in the economic activity of these islands. This has led to most of them running water reuse projects such as in the Caribbean Islands, Hawaii or Singapore. In the Mediterranean area, the Balearic Islands (see Box 10), Cyprus and Malta constitute particularly significant examples of this evolution. These projects which cover various reuse options from agricultural irrigation, to landscaping, groundwater recharge or indirect potable use, should be an integral part of plans for coastal zone development.

Box 10: Palma of Majorca Island

Palma of Majorca Island used to be mainly rural. Tourism development goes back to the beginning of the sixties, when the population was only of 363,000 inhabitants. It favored jobs creation and induced immigration from various Spanish areas, which increased the permanent population to more than 700,000 inhabitants in 2001. Tourist flow is estimated at more than 10 million visitors per year.

Majorca suffers from serious water scarcity. There are no permanent surface water bodies. The water resources are made up of the water stored in two dams (around 7 Mm^3/year) and, essentially, the aquifers of the island, i.e. a renewable resource estimated at 250 Mm^3/year. Llano de Palma and Na Burguesa aquifers are over-exploited and water quality is deteriorated by seawater intrusion. So, the water pumped from the two aquifers has to be desalinated in a 30,000 m^3/day reverse osmosis treatment plant (Son Tugores) operating since 1995. S'Estremera aquifer, which provides high quality water, is experiencing a dramatic depletion of water level (in 1995, the aquifer water level dropped by 20 m below sea level). Water consumption is approximately equivalent to the resources, which were estimated on average at the beginning of 2000 at 238 Mm^3/year, i.e. 88 Mm^3 for drinking water supply and 148 Mm^3 for irrigation. The latter accounted for 62% of the consumption.

During the severe drought from 1995 to 1997, 17 Mm^3 water was shipped from the mainland. New resources were therefore needed. A seawater desalination plant was put into operation in Palma in 1999 with a daily capacity of 42,000 m^3/day and enlarged to 60,000 m^3/day afterwards. Additional facilities increased the total desalination capacity in Palma up to 80,000 m^3/day in the summer 2001. In peak period, about 50% of the potable water demand was met through seawater desalination. Moreover, water management authorities were more inclined to regard reclaimed water as a reliable alternative resource. Reclaimed water is used for irrigation in the Llano de Palma area, which was a horticultural area irrigated with groundwater pumped by means of hundreds of windmills. Reuse started in 1975 on a perimeter of 250 ha, quickly extended to 500 ha, Polygon I, with the use of 3 to 3.5 Mm^3/year of secondary effluents, either directly injected into wells located close to the wastewater treatment plant or used for irrigation purposes. In 1990, a new perimeter of 640 hectares, Polygon II, was set up with the construction of the second wastewater treatment plant, Palma II. Ninety five percent of the irrigated area is devoted to alfalfa and cereals production and became an important dairy production zone. Reclaimed water accounts for about 11% of total agricultural irrigation consumption in the island, the rest being provided by groundwater of good quality. About 15.2 Mm^3/year of secondary effluents are used for agricultural over-irrigation and subsequent aquifer recharge. Water reuse for agricultural irrigation is also implemented to control seawater intrusion; it allows "fresh" water supply for irrigation in an area where groundwater became salt-affected. In spite of some over-exploited or salt-affected aquifers, groundwater is still the most important, convenient and free source for irrigation. Farmers have obtained high quality reclaimed water but it will be difficult to convince them to abandon their rights to pumping groundwater. They regard reclaimed water as an alternative resource in the event of severe drought – *a drought insurance* resource. In addition and since the end of the nineties, about 7 Mm^3/year of tertiary treated (coagulation, flocculation, sand filtration and gaseous chloride disinfection) water is used for public parks, landscape and golf courses irrigation, thus saving equal amounts of potable water.

Thus, water reuse allowed (1) to increase the value of land that became unsuitable to crop production, (2) to reverse salt intrusion through groundwater recharge and reduction of agricultural water pumping, (3) to limit the salinity of drinking water and reduce the cost of potable water treatment, (4) the development of public parks and new golf courses in an eminently tourist area, without encroaching upon the drinking water resources.

Source: Xu et al. (2003), Brissaud (2008)

When outfall structures have to be put in place, it is important (1) to reduce the pollution load of the wastewater discharged to an as low as possible content to avoid eutrophication of the receiving water, (2) to treat the effluents up to the discharge requirements (BOD, COD, bacteria) and (3) to have outfalls discharging further offshore into the deeper sea.

5. SUSTAINABLE APPROACH TO WATER SUPPLY, SANITATION AND REUSE

Shifting paradigms

"Most of the people in developing countries do not have access to safe sanitary systems. If we are going to tackle this problem we have to leapfrog the centralized end-of-pipe sanitary systems of the industrialized world. New affordable technologies based on ecological sanitation, which save water, recycle local nutrients and extract energy open sustainable options for all both in rich and poor countries" (Jenssen et al., 2004). Water and nutrient recycling has however so far not been considered as an objective sufficiently important to modify the general approach to sanitation. When conventional technology is adopted for treating wastewater, treatment plants are designed with no concern for reuse and independently of reuse requirements. The key elements of sustainable sanitation therefore require shifting paradigms. The reuse potential of different waste products as a function of crops, soil and climate conditions, including health, socio-cultural, economic, and reuse policy aspects has to form an integral part of future sustainable sanitation strategies (Rijsberman, 2006).

1. *Water reuse to play a key role in sustainable development – Wastewater as a Water Resource.* Wastewater is a water resource management and water quality issue. It should be integrated into the global water cycle as an integral component of water resources management (Figure 2). As for conventional water resources, a strategy for management and optimal use should be devised at different scales.

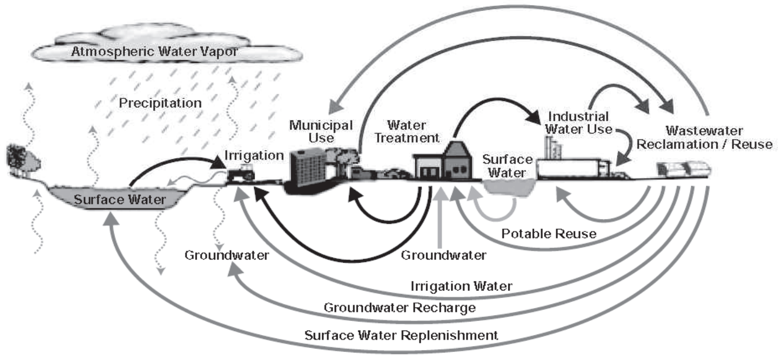

Figure 2. The role of engineered treatment, reclamation, and reuse facilities in the multiple uses of water through the hydrologic cycle (Asano and Levine, 1995).

2. *Watershed approach to urban IWRM: Managing water, wastewater, pollution control and water reuse in an integrated way*. Urban population growth and economic development may exacerbate inter-sectoral and upstream-downstream competition for water and have effects on drinking water quality, wastewater and stormwater management. Urban development is changing the quantity and quality of water flows that extend beyond the urban watershed. Competition between urban water demands and those for agriculture and industries is increasing due to urban expansion and political priority given to cities. Comprehensive understanding of the entire urban water system is required in urban watersheds considering various levels and modes of interactions such as watershed spatial scale, upstream-downstream and socio-economic domains. Innovations and investment interventions in technological, institutional change and sociological learning are needed. Urban water supply, sanitation and environment conservation need to be addressed across different scales, i.e. city watersheds and districts, with a watershed/basin perspective applying an integrated urban watershed management approach.

3. *Appropriate and cost-effective treatment levels to correspond to each reuse option*. Wastewater treatment must be linked to the type of reuse. When treatment is available, the general approach adopted up to now is based on producing an effluent in compliance with water quality discharge requirements. Treatment plants are designed with no concern for reuse and there are no guarantees for the quantity or quality of the effluent. Reuse is generally considered in a second step. It is rarely the starting point. For agricultural reuse, conventional treatment plants, such as activated sludge processes, are generally designed for pollution control with BOD and SS removals as main objectives and the standards for these parameters are often higher than required; in addition, these conventional systems are ineffective to remove helminth eggs,

bacteria or viruses. So, the approach to treatment generally adopted is not how to make the best use of the water components which means, first, how to keep nutrients and get rid of micro-organisms and the undesirable components, and, second, what would be the most appropriate technology for such a target. The application of performance criteria that describe the desired effects on human health (reduced exposure to pathogens), environment (ecosystems to be protected), and human activity (agriculture, in the specific case) would be a more innovative approach (Krauss and Boland, 1997). The setting of water-quality objectives depending on the type of reuse has to be the result of a balance between what is desirable from an environmental and public health point of view and what is feasible from a technical and economic point of view.

Development of treatment systems that make the wastewater biologically and chemically safe, but keep the nutrients that replace fertilizer for farmers, is still the challenge. It is urgently needed to design a range of cost-effective solutions that addresses the technical, institutional, social, behavioural and cultural obstacles that constrain making a full complement of sanitation alternatives available to communities. A well articulated portfolio of sanitation alternatives would help both communities and planners choose and access viable sanitation options (IWA, 2006; GWP CEE, 2007).

The development and implementation of strategies and options to cope in particular with solid waste, fecal sludge and urine adapted to the conditions prevailing in developing countries is still under-researched despite an increasing number of organizations having the expertise, such as CREPA (Centre Régional pour l'Eau Potable et l'Assainissement à Faible Coût based in Ouagadougou (Burkina Faso)), WASTE in The Netherlands, EAWAG-SANDEC (Swiss Federal Institute of Aquatic Science and Technology – Water and Sanitation in Developing Countries), the Asian Institute of Technology, Murdoch University and the Water Research Commission in South Africa. A major challenge in view of urine reuse from urine diverting toilets is its transport and storage from urban areas to farms. To faciliate this, SANDEC is working on a low-cost transformation of liquid to solid urine. In December 2008, the German Association for Water, Wastewater and Waste (DWA) has published a handbook with design criteria on Innovative Sanitation Sysytems, with the aim to minimize water losses and to maximize the reuse of valuable components in the household wastewater (DWA, 2008).

Low implementation costs, proven technology, ease of operation and flexibility of upgrade in subsequent stages are all desired features of appropriate wastewater collection and treatment technologies. Where land is available, natural systems such as waste stabilisation ponds or constructed wetlands may be used. Land treatment techniques could also be implemented, such as rapid infiltration, overland flow, slow rate or subsurface infiltration. Chemically enhanced primary treatment and upflow anaerobic sludge blanket reactors are other examples of applicable and affordable technologies. The choice should depend on local capacities and downstream uses. Adaptation and standardisation of some unconventional processes and combinations of treatment and non-treatment measures still need to be tested. There are opportunities for the design of sanitation systems using local materials, technology, and know-how. Systems based on conventional practices or combining natural and conventional systems may be used when land is not available or in the case of topographical or others constraints. Financial savings both in terms of investment and O&M costs may be achieved in addition to ecological advantages and landscape fit-in. Land application of sludge may also be practised after proper treatment (composting, digestion, etc.). As regulations become more and more stringent, the amount and the quality of the sludge produced are becoming a key factor in the choice of a treatment system. An important partner to be explored and supported is the private sector in view of business models for low cost toilets, urine marketing, etc. which can tailor sanitation services for different users.

4. *Place of agriculture in the wastewater treatment cycle.* Agriculture may be integrated, as a land treatment system, into the treatment cycle and considered as the nutrient recycling part of the loop. The soil may act as a bioreactor and attenuate contaminants. The water used for irrigation purposes should however meet quality requirements. Irrigated areas are devoted to the production of different crops, vegetables being highly rated. If reclaimed water is going to be reused to irrigate fodder crops, field crops (cereals, industrial crops) or forest trees, a secondary treated effluent should be of sufficient quality. For vegetables eaten raw, further wastewater treatment is required for public health protection. In order to provide an effluent of the desired quality, secondary effluent quality has to be improved through different processes such as maturation ponds, surface or underground storage, disinfection, etc.

5. *Consider the full range of sanitation options.* For social equity and environmental concerns, there is a need to consider all options available for collection, treatment and reuse systems from pit latrines to water borne sewered systems – from the safe collection, storage, and disposal/re-use of human excreta to the treatment and disposal, re-use and recycling of sewage effluents. A

combination of different technology solutions, depending on local conditions and available resources and capacities, may help solve the problem in a sustainable and environmentally sound manner. In order to overcome the financial constraints faced in providing wastewater services, these services may be developed in a phased manner moving gradually along the "sanitation ladder" (4WWF, 2006).

In view of the current freshwater shortages in most cities of the developing world, planners are increasingly skeptical about extending the coverage of flushing toilets and sewer systems. Adopting dry toilets where possible combined with closed-loop systems appears to be an appropriate way forward. Related technologies are today widely available and installed, e.g. around Durban, South Africa, at a rate of 1500 toilets per month, reaching so far 60,000 units. The Swedish EcoSanRes project assists developing countries with knowledge transfer and implementation of sustainable sanitation solutions adapted to local conditions, e.g. dry sanitation in the drought prone Inner Mongolian city of Dongsheng in Northern China (www.ecosanres.org). In Germany, in the context of the World Exhibition 2000, a new quarter of the city of Luebeck has been equipped with similar sanitation systems.

6. *Decentralized approaches.* For optimized water collection, distribution, sewerage and reuse systems, the challenge lies in the development of a decentralized approach to infrastructure planning and design to address the needs of urban and rural settings. Decentralized systems such as water harvesting for domestic and agricultural purposes or satellite wastewater treatment plants may better protect watersheds and water resources and avoid transfers over long distances. Senegal which is increasing its urban sanitation coverage with on-site sanitation systems as its main focus is treating (ONAS in collaboration with SANDEC) the increasing volumes of fecal sludge in decentralized treatment plants. The design of simple and multiple facilities with locally-capable O&M instead of sophisticated and large facilities would leave a needed resource close at hand and facilitate reuse at local scale (Kreissl, 1997). Local recycling and reuse may reduce the total water withdrawal. Smaller amounts of wastewater flows will be generated and more easily controlled; less energy might be consumed and less sludge produced (Harremöes, 1997).

7. *From an end-of-pipe to a source approach.* The most frequent approach is, up to now, the centralised water supply and sewerage system. The end-of-pipe technology reduced or eliminated, in a first step, problems such as waterborne diseases, eutrophication, etc. However, it also transferred pollution from

one place to another when it would often be more convenient to remove pollutants closer to pollution sources. Since wastewater may be recycled or reused for different purposes, wastewater quality should be protected from different kinds of pollution sources. Major pollutants such as persistent trace organics, trace minerals, and radioactive components, which might affect human health through the food chain, should be prevented from being discharged into public sewers. Pollutants should be removed at the source and, to the extent feasible, be retained in closed-loops and reused within the industry by which they are produced (Goodland and Rockefeller, 1996). Many industrial pollutants can be removed more easily in their concentrated form at the source than in a dilute form after introduction into a municipal sewer system. Some industrial or commercial pollutants are toxic to biological systems commonly used for municipal wastewater treatment. Treatment at the source is then required to minimise costs and environmental exposure to hazardous materials and to protect the integrity of municipal wastewater treatment systems. Realistic regulations for the discharge of industrial wastewaters have to be set up and, moreover, really enforced in order to protect treatment plants and prevent the accumulation of potentially toxic compounds in the soil and aquifers. In order to facilitate recycling and reuse schemes, discharge of industrial waste in public sewers must be minimised. Uses of clean production and energy- and water-saving processes and technologies have to be promoted. Waste material composition will then be closer to that of reusable products. Changes in attitudes and consumption patterns as well as innovative, efficient and sustainable ways for waste management are needed. Urban water management should then shift from an end-of-pipe approach to a source approach.

8. *Combine treatment and non-treatment options to reduce health risks*. A complementary approach is combining treatment and non-treatment measures for health risk reduction (WHO, 2006). Such a multiple barrier approach can combine source control, and farm-level and post-harvest measures to minimize risks and protect agricultural workers and consumers (Lazarova and Bahri, 2005; WHO, 2006; Qadir et al., 2007; Asano et al., 2007). Risk reducing alternatives are for example currently tested in Ghana to explore their potential impact (Drechsel et al., 2007). This approach is directly addressing the common lack of sustainable or comprehensive wastewater treatment by outsourcing its functions according to the needs and potential of the stakeholders involved in wastewater reuse. It comprises small wastewater sedimentation ponds on farm as well as safer irrigation techniques and appropriate washing of crops to be eaten raw. Where possible, these should be combined with wastewater treatment.

Challenges and the way forward

Several prerequisites should be fulfilled to make water reuse operations successful: water reuse requires forward looking planning, good management, and institutions in place, public health protection, appropriate wastewater treatment technology and siting, treatment reliability, water management and public acceptance and participation. It must also be economically and financially viable.

Planning, management and institutional settings

The planning and management of reuse operations into a water resources management program require careful consideration of the institutional, organizational, regulatory, socio-economic, policy pricing, environmental, and technical aspects (Asano, 2005). For the sake of efficiency, and for the future planning and implementation of sanitation projects, alternative options have to be examined with the involvement of the inhabitants. Responsibility for wastewater management should be granted, with the involvement of communities, to municipalities or to a special agency that would link water supply, sanitation and reuse strategies.

An important degree of planning and coordination is required for a safe reuse program. Storage, allocation, timely availability of effluent for reuse, and means of cost recovery, are also important issues that need to be addressed. The willingness to pay for water is related to availability of water in quantity and quality. These issues also require cooperation among agencies and sectors that often perceive their interests to be conflicting, such as health, municipal wastewater treatment, irrigation water distribution, etc. Skills and administrative responsibilities are also often spread over different governmental offices. To ensure efficient agricultural water reuse, cross-sectoral collaboration is required at the national and local levels. Perceptions of interdependence have to be strengthened. A complete wastewater discharge, treatment, and reuse system requires an integrated view and adapted legislation and institutional structures. An interagency coordination and control of water use or an institutional body or executive committee empowered to properly regulate and enforce standards and procedures for water reuse (monitoring - information - enforcement of the regulations, etc) might be required.

Technical aspects

Wastewater may be reused for different purposes such as irrigation, landscape irrigation (parks, green areas, golf courses, etc), and toilet flushing, recreational and environmental uses, industrial uses, groundwater recharge, and other water uses. Before designing a wastewater treatment plant, the final end uses of the water should be first considered. The treatment objectives and standards need then to be clearly defined. This will lead to reconsidering the treatment approach, required treatment levels and processes, and the indicators that should be taken into account. It may also reduce conflicts of interest between wastewater producers and users due to the differences in objectives among each group. But reuse has so far not been considered as an objective sufficiently important to modify the approach to treatment and disposal practices. Conventional technology has been adopted for treating wastewater independently of the type of reuse. The performance criteria that are appropriate for a given type of reuse are generally not carefully considered.

Appropriate technologies, that are suitable to a particular socio-economic context, may require supporting industries and logistics or new technological solutions. They have to be affordable, operable, and reliable (USEPA, 1992; Kreissl, 1997). Low technologies often consistently reach the standards. Using a combination of different high and low technology solutions (Dodds *et al*., 1993), depending on local conditions, the site, etc., will help to solve the problem in a sustainable and environmentally sound manner. In order to overcome the financial constraints faced in providing wastewater services to small communities, these services may be developed in a phased manner (Bakir, 2001).

Therefore, systems that do not harm the environment and provide proper treatment should be developed. A wide range of potential wastewater treatment methods is available and several unconventional and low-cost wastewater technologies could be implemented for individual and collective (combination of composting toilet and grey water treatment) sanitation systems (Niemczynowicz, 1994; Rose, 1999; Bodik and Ridderstolpe, 2007). Because each area is unique, there is a need to establish different kinds of sanitation facilities for each set of technical, economic, environmental, and institutional conditions. Implementation of source reduction, source separation, and resource recovery and recycling technologies may then be accomplished.

Since conventional gravity sewers constitute the major part (80-90%) of the total cost of wastewater facilities, it would be beneficial to look for alternative collection systems (with small diameter and lightweight piping buried at shallow depths). These processes can meet both the objectives of treatment and reuse. Infiltration-percolation systems may be applied when hydro-geological conditions are favourable. Sanitary precautions would have to be considered in the event of groundwater use for domestic water supply, however, and soil capacity to absorb and attenuate pollutants has to be evaluated for each site where a land treatment system is to be implemented in order to provide for a pre-treatment system, if necessary. There might also be opportunities for the design of sanitation systems using local materials, technology, and know-how. Financial savings both in terms of investment and O&M costs may be achieved in addition to ecological advantages and landscape fit-in.

Economics of water supply, sanitation and (waste)water reuse

Wastewater farming can achieve substantial annual incomes: urban farmers in Kumasi gain about USD 700-1000 per year (net) (Keraita *et al*., 2002). Urban farmers in Dakar earned USD 2234 annually (Faruqui *et al*., 2002). In Haroonabad, the net value of product from wastewater irrigated land was USD 840/ha (van der Hoek et al., 2002). In Hyderabad, earnings varied between USD 830-2800 per year. Indirect beneficiaries of a wastewater agricultural system accounted for 34% of the total beneficiaries (IWMI, 2002). But there are at the same time diseases associated with inadequate provision of water and sanitation services and wastewater irrigation.

According to Wright (2007), recent studies by WHO (Hutton and Haller, 2004) have demonstrated that high returns are possible from investments in water supply and sanitation (about $6-$8 per $1 invested). The reported economic benefits are, however, contingent upon presumed health benefits from investment and use of water supply and sanitation facilities. In a recent unpublished study at the World Bank, investments in water supply and sanitation over a 10-year period (1997-2006) were analyzed to determine if expected health benefits were achieved. The results showed negligible health improvements. The reason for this appears to be that the investments were not always accompanied by complementary measures like hygiene education and hand washing that would have helped with the realization of the health benefits. This implies that pursuit of economies of scope was not planned as part of the investments. The application of IWRM principles could have helped to address this problem. Thus application of IWRM principles could be an instrument for securing a higher priority for water in the allocation of national capital resources.

There is a need to make a strong economic case for sanitation and in quantifying benefits (internal and external) and to include impact on aspects of the economy – tourism, trade, agriculture, and other beneficial uses of water in the economic case for sanitation investment. Wastewater treatment units should be linked with city economic development agenda. The location of large (centralized) or small (decentralized) treatment should be planned close to the reuse sites such as peri-urban farmers/users preferred zones. In Djenné, Mali, for example, the introduction of simple greywater infiltration systems has improved the environment and led to tourism promotion and economic development (Morel and Diener, 2006). In Tunisia the environmental results (restoration of the water quality of the Lake of Tunis, etc.), the land and financial gains and the perspectives of development and enhancement of the Lake resulting from the construction of a wastewater treatment plant and a reclaimed water irrigation scheme are presented in Box 11.

Box 11: Economic and financial benefits resulting from urban sanitation – The Lake of Tunis

In Tunis, Tunisia, treated wastewater from the La Cherguia wastewater treatment plant used to be discharged into the Lake of Tunis creating several negative impacts such as eutrophication of the Lake, emission of sickening smell, anoxia and massive mortality of fish. The restoration of the Lake through the reduction of anthropic disposal, elimination of organic matter (through the dredging of the Lake bed), urban sanitation, sewage works, treatment plant implementation, reclaimed water irrigated scheme and modification of the shores have led to the decrease of the level of eutrophication and to the development of land for residential purposes. The investment costs related to the wastewater transfer line (from the discharge point into the Lake to the wastewater treatment plant), the construction of the wastewater treatment plant of Choutrana and of the reclaimed water irrigated scheme of Cebala (3000 ha) have been paid back by the several indirect economic benefits (in addition to the creation of a newly irrigated area), i.e., (1) the water quality of the Lake has been restored, (2) 3100 ha of land have been reclaimed on the embankments of the Lake of Tunis and became one of the most expensive residential areas of the Capital City of Tunis, (3) fisheries have been recovered, and (4) tourism has been enhanced. These unaccounted economic benefits need to be acknowledged: (1) Land and financial results: a profitable property operation with positive financial investment and spatial and economical development of the city; (2) Environmental results: increase of the water flows in the Lake, positive evolution of the physico-chemical parameters, balance of the oxygen rate, decrease of the nutrients, reduction of eutrophication, increase of the biological diversity, decline of nitrophilic algae, recolonization by the phanerogames; and (3) Perspectives of development and enhancement of the Lake: establishment of a leading scheme for the Lake development (Kennou, 2006).

Rethinking finance for sanitation and water reuse

An encouraging start has been made on the water supply financing agenda, thanks to the work of the Camdessus Panel, the Gurria Task Force and the UNSGAB. The neglected area of funding household sanitation in both urban and rural areas and reuse should also receive its overdue attention.

Large financial sums have been attached to tackling global sanitation and wastewater management needs. Although *household sanitation* costs are of a lower order and can be spread in various ways, *public infrastructure* for sewage collection, wastewater treatment and re-use can be very costly. It should be recalled that in GWP's original Framework for Action an estimated $70 billion (out of a total of $180 billion) of annual investment required in the water sector before 2025 was accounted for by municipal wastewater treatment, and a further $30 billion by the treatment of industrial effluent. Thus $100 billion out of the total of $180 billion of annual investment requirements are down to the account of wastewater. In comparison, the estimate of investment needed for meeting the sanitation MDG is a more modest $17 billion per annum.

A different and more creative mindset is required for dealing with human waste and wastewater. Such an approach would make these challenges both more soluble and easier to finance by treating these "wastes" as potential resources, and drawing unconventional sources of enterprise and funding into the solutions. As the MDG target on drinking water and sanitation is progressively realized, and urbanization grows, the management and exploitation of wastewater will become more critical.

Each of these steps on the sanitation "ladder" entails a quantum leap in unit costs (Figure 3), and the incremental benefits obtained may not justify the extra outlays in every situation (ref. TEC Background Paper 11 on Urban Water and Sanitation Services).

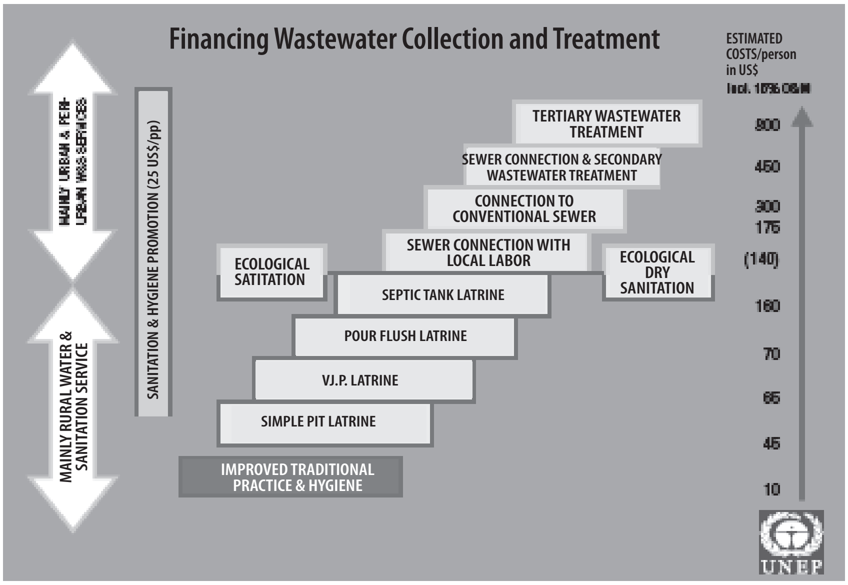

Figure 3. Costs of various services on the "sanitation ladder" (Water Supply and Sanitation for All, 4WWF, 2006).

But this is only the beginning of the waste treatment cycle. The treatment of this waste and wastewater itself involves increasing incremental costs, starting with simple mechanical separation, progressing through secondary treatment and on to tertiary and other advanced treatment methods. In communities with comprehensive sewerage and wastewater treatment to advanced standards, the sewerage component may account for an equal part of the combined household water and sanitation tariff (sewers constitute the major part (80-90%) of the total cost of wastewater facilities).

With increased urbanization there is a need for a shift in mindsets from seeing waste as a drain on resources to seeing it as an economic and environmental opportunity. Sewage, household grey water and wastewater in general contain elements which are potential sources of fertilizer and energy, while treated effluent can re-enter water courses or be directly re-used for many purposes. New technologies offer opportunities for the treatment and use of waste. Water drunk in London, which is of good quality, has been "used" on average by at least half a dozen other households on its way to the Londoner's tap. On the other hand, there have been protests in the US and Australia to the use of recycled water for domestic purposes.

Better management and finance of wastewater would release useable effluent and other products, helping towards a solution to water *scarcity* as well as water *pollution*. In some regions, businesses are willing to buy sewage water for the reuse of the treated effluent (see Box 12). This is likely to spread in water-scarce areas, where the alternative to wastewater is no water: wastewater in these areas is simply too valuable to waste. Even *sludge*, the irreducible end-product of wastewater treatment plants, has potential value in construction, in biogas production, and as a soil amendment for its beneficial use in agriculture.

Box 12: Durban Water Recycling

The objective of the project was to demonstrate that a tri-sector partnership between private companies, NGO's and public authorities brings added value to both the communities and to all three parties. The project partners included Vivendi Water, the World Bank, WaterAid of the UK and locally Durban Metro, City of Pietermaritzburg, Umgeni Water, Mvula Trust (NGO) and the Water Research Commission.

The water system implemented included a low-pressure water distribution that feeds a potable water tank in the customer's property with a maximum of 200 liters/person/day. Trained water bailiffs selected by the community manage the system as well as the standpipes available for those who are not connected to the low-pressure system. Trained local staff works with the water bailiffs to provide maintenance. Customers prepay for the water at $1.2/month following an initial $24 connection fee.

Durban Water Recycling, which started operation in May 2001, is a Durban Metro - Vivendi Water public private partnership that provides a 20-year build-own-operate and transfer service to Durban Metro. The project includes treating and recycling 47,500 m3/day of reclaimed water. This system treats 7% of the wastewater being discharged to the sea and guarantees a lower cost, high quality water supply to be sold to industries in the Durban South Industrial Basin (the Mondi Paper mill, Sapref Refinery and Sasol textile factory).

These solutions in Durban provide the following benefits:
1. Community partnership with affordable water supplies in poor informal settlements.
2. An additional 8% potable water made available for the community.
3. Lower water costs guaranteed to industry (25% higher than potable).
4. Reduced flow to overloaded long-sea outfall thereby extending its life.

Source: Durham et al., 2002

At all stages of the wastewater cycle, technical and social choices are possible, each with cost and financing implications. Communities have, for instance, a choice between the standard of treatment of wastewater (primary, secondary, tertiary, etc). Partial treatment of effluent can be done at a fraction of the cost of full-scale advanced treatment, but with clear benefits, yielding a very favourable benefit-cost result that would be affordable to many poor communities. Many cities have realized the advantages of making progress towards advanced wastewater treatment in several affordable stages, rather than immediate adoption of the most sophisticated option (Figure 4).

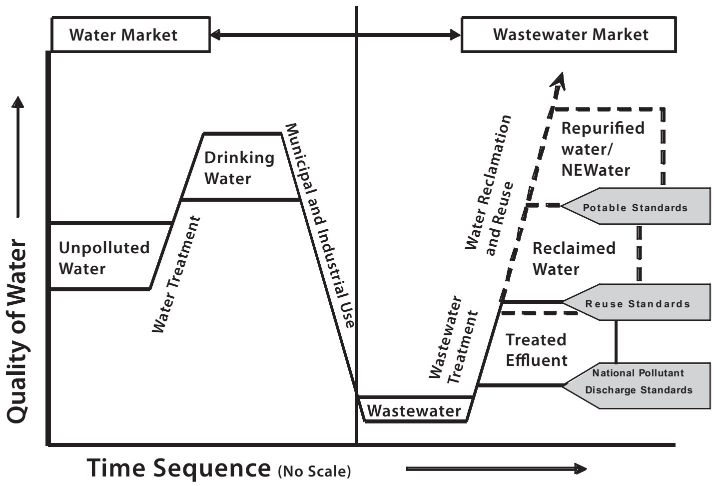

Figure 4. Quality change and multiple uses of water (after Asano, 2002).

The reuse of effluent is important in water-scarce regions of the world and this is where most of the significant developments in wastewater reclamation and reuse have occurred including Australia, Middle East, Mediterranean countries, and the west and southwestern United States. In Windhoek, Namibia, because of extreme drought conditions, extensive research was conducted in 1968 on direct potable reuse technology and an epidemiological study was conducted to assess the health effects of reclaimed water consumption (Box 13). Highly treated wastewater has been blended with other drinking water sources. In Singapore, wastewater reclamation and reuse has been implemented recently as a source of raw water to supplement Singapore's water supply. Newer technologies such as membrane bioreactors, membrane filtration, and ultraviolet disinfection are important in the production of high quality reclaimed water reliably. The majority of water reuse in the world is for non-potable water reuse applications such as agricultural and landscape irrigation and industrial recycling and reuse. Windhoek and Singapore are exceptions that undertook planned potable water reuse among their wastewater reuse options.

Box 13: Namibia – Windhoek's Goreangab Water Reclamation Plant

Namibia is a sparsely populated country of about 1.9 million people. It is the most arid country in sub-Saharan Africa. There are no perennial rivers in the interior of the country, no permanent natural lakes, and the total length of the western coastline is covered by desert. The average annual evaporation in Windhoek is 3,400 mm and the rainfall is 370 mm.

Windhoek's Goreangab Water Reclamation Plant. The nation's capital city, Windhoek, has been practicing direct potable reuse since 1968. The Windhoek Water Reclamation Plant serves a population of 220,000. Domestic wastewater from the city is first treated in a conventional biological wastewater treatment plant; the treated wastewater then flows through a series of maturation ponds to a water reclamation plant. The reclamation plant has undergone many re-configurations and upgrades since 1968, most recently with the construction of the new Goreangab Water Reclamation Plant (WRP) in 2002. Industrial effluents in the city are diverted to a separate sewer and treatment system.

Goreangab WRP has a capacity of $2{,}100 \times 10^3$ m^3, and it is internationally renowned as the first in the world to reclaim municipal wastewater to potable water quality as a supplement to Windhoek's very scarce water source. The treatment train consists of dissolved air floatation, sedimentation, rapid sand filtration, ozonation, carbon adsorption (both granular and powdered), ultrafiltration, and chlorine disinfection. After treatment, reclaimed water is mixed with water from other sources, so that reclaimed water makes up at most 35% of the city's drinking water. Potable reuse, despite its potential difficulties elsewhere, is an indispensable element of the Windhoek water system and has proven to be a reliable and sustainable option for over 36 years.

In many countries industries are heavy water polluters, despite environmental statutes. This worsens water scarcity and raises the costs of other water uses. Financing in-plant recycling and pre-treatment of industrial effluent can be a key part of future water *supply* strategies, apart from their environmental benefits.

Policies and institutions relating to water reuse

Protect and compensate the poor. Policies to protect the poor will be needed in conjunction with improvements in wastewater management. The greatest challenge might be ensuring that low-income residents of peri-urban and rural areas who rely on wastewater for crop production are not deprived of their livelihoods. Many poor farmers have been using wastewater for years without formal water rights. Improving water management practices in upper portions of a watershed or urban area, to reduce wastewater volume, will also reduce a portion of the irrigation supply for those farmers. Improvements in wastewater treatment can also reduce water supply if the treated wastewater is transferred from its original point of use. Policies can be implemented to compensate poor farmers by providing them with alternative sources of irrigation water or giving them payments or training that would enable them to pursue alternative livelihood activities. Policies that enable the poor to reduce wastewater use gradually, while seeking other livelihood activities, might be wiser than policies that cause sharp disruptions in wastewater supply (Qadir *et al.*, 2007).

Strengthen political will. In many areas, inadequate public involvement reflects a lack of political will, inadequate investment, or insufficient institutional capacity or coordination. Public officials must appreciate the scarcity value of water and the impacts of poor water quality and inefficient use on public health, economic growth, the environment, and rural and urban households. They must appreciate the potential for improving livelihoods and enhancing public welfare by improving water management practices. International agencies, donors, and non-governmental organizations can provide political leaders with information, encourage innovative policy choices, and motivate greater public involvement in water management efforts (Qadir *et al*., 2007).

Rights to wastewater. Wastewater users may be resistant to the installation of infrastructure or treatment facilities unless they have some confidence that they will continue to have access to the wastewater. This access may be regulated by permits and dependent on efficient or sanitary practice by the farmer. In Mexico, the authorities' power to withhold water from farmers who do not comply with crop restrictions is a major factor in their success. Legislation may therefore be required to define the users' rights to access to the wastewater and the powers of those entitled to allocate those rights (see Box 14).

Box 14. Rights to wastewater

Customary rights to water are widely recognized. Thus, the present use of wastewater for agriculture may create rights even if it is not a planned activity and does not fulfil health and environment norms. These rights can conflict with future planned wastewater use projects, especially if treated wastewater is expected to be sold at a higher price than that paid by the original user of the wastewater. For example, in Mexico, the development of a new wastewater treatment plant caused problems for traditional downstream users of the wastewater. The new treatment plant was able to treat the wastewater to a high quality standard and, as part of its planned cost recovery activities, has been investigating potential sales of the water to industrial users. Untreated wastewater has traditionally been discharged into canals and used for downstream irrigation. Mexico issues water concession titles, which guarantee a landowner access to water. However, only 30% of the wastewater-irrigated land has a concession title linked to it. If the wastewater treatment facility goes through with water sales to industrial users, a significant portion of the water might be diverted from downstream users. Since many of the users do not have officially recognized water rights, they will lose their livelihoods (Silva-Ochoa & Scott, 2004).

In Pakistan, a large number of court cases initiated by local water utilities or sanitation agencies have been brought against local farmers, challenging their rights to use wastewater resources. The outcome of these court cases was that farmers were forced either to pay for wastewater or to abandon its use. In Faisalabad, a group of wastewater farmers successfully appealed against one of these court orders once they proved that they did not have access to another suitable water source (Ensink *et al.*, 2004).

Implement economic incentives. Incentives for reusing treated wastewater are helpful where water users can choose among different water sources. Lower water prices and subsidies for purchasing new equipment can speed the pace at which farmers begin using wastewater. Incentives can be combined with monitoring to ensure compliance with incentive programs and safe use of wastewater (Qadir *et al.*, 2007).

International trade. The "Agreement on the Application of Sanitary and Phytosanitary Measures" (WTO, 1999), which applies to all members of the World Trade Organization governs the international trade. Food-importing countries are entitled to take measures to protect their citizens from hazards in imported foods. Irrigation with wastewater of export food crops is acceptable to the importing country if all the recommendations in the WHO Guidelines are followed (Mara, 2008). Europgap, a European organization for sustainable agriculture and the certification of food imports into the EU, prohibits the use of untreated wastewater for crop production but has accepted the use of treated effluent in accordance with the WHO 1989 guideline values.

Fear of economic repercussions in trading agricultural products may make governments reluctant to acknowledge wastewater irrigation, thus excusing them from not implementing food safety and other phyto-sanitary measures. Jordan's export market was seriously affected in 1991 when countries in the region restricted imports of fruits and vegetables irrigated with inadequately treated wastewater (McCornick *et al*., 2004). Jordan implemented an aggressive campaign to rehabilitate and improve wastewater treatment plants and introduced enforceable standards to protect the health of fieldworkers and consumers. The government continues to focus on this sensitive situation, given the importance of international trade. This example reveals that the impacts of wastewater use can be indirect and wide-ranging.

Improve financial management. Public agencies in many developing countries have limited ability to invest in wastewater treatment plants and programs to optimize wastewater reuse. Policies and institutions can be helpful in raising the needed funds. Volumetric charges will encourage wastewater reuse and discourage discharge into natural waterways or facilities operated by a wastewater agency. There is conceptual justification for programs that generate revenue by charging water users a fee per unit of effluent they generate (the polluter pays principle), particularly when the revenue is used to construct facilities for collecting, treating, and reusing wastewater.

Inter-departmental coordination. Public agencies can improve the coordination of policy targets and methods to ensure that public goals regarding wastewater management are achieved. For example, coordination among the ministries of agriculture, water resources, public health, and economic development is needed to ensure that the goals and programs of one agency are not in conflict with the goals and programs of another. The total cost of achieving public goals will be minimized with effective inter-ministry coordination (Qadir *et al*., 2007).

Stakeholder participation. Conventional sanitation planning does not empower end-users to "add" their knowledge and perception of progress to the process. There is therefore a need for platforms through which appropriate blending of knowledge systems and requirements can occur. The use of participatory approaches will allow community participation, personal involvement in decision-making processes, appropriation of sustainable sanitation and adequate operation and maintenance, and facilitate greater consensus between key municipal, state, and national stakeholders. It can improve the dissemination of information and enhance the success of wastewater reuse projects. This can also ensure participatory technique development to gain acceptance.

In order to enable the community of stakeholders to participate in the decision-making process and optimize the management process and the output, two approaches are being investigated: The "Household Centred Environmental Sanitation" (HCES) approach (SANDEC/WSSCC, 1999) and the "learning alliance" stakeholder approach (LA). The HCES puts people and their quality of life at the centre of any environmental sanitation system (rather than trying to change people's behavior to accommodate technology). The learning alliance stakeholder approach seeks to facilitate dialogue and breaks down barriers to information sharing at multiple levels. It is designed to speed up identification, development and uptake of innovation and the scaling up of research outputs through their alliances of practitioners, researchers, policy-makers, activists and local communities. The SWITCH (http://www.switchurbanwater.eu) and Cities Farming for the Future (RUAF) projects are two examples of projects implementing the LA or similar multi-stakeholder approaches.

The SWITCH project is being carried out in a number of cities across the globe. Its key proposition is that sustainable urban water management is only possible if the entire urban water cycle is managed in a holistic manner adopting IWRM principles. The RUAF project aims at integrating agriculture in urban planning, with pilot cities worldwide including the western, eastern and southern Africa regions. The main objective of this program is to contribute to urban food security, urban poverty reduction, environmental management, empowerment of urban farmers and participatory city governance through capacity development of stakeholders in urban agriculture and participatory multi-stakeholder policy formulation and action planning.

"Implementable" guidelines. Reuse operations imply the application of risk management strategies with the promotion of appropriate treatment options and the development of guidelines and mechanisms meant to decrease the risks associated. Health risks include microbiological and chemical risks. Water reuse regulations are directed primarily at health protection and address as well environment protection. Wastewater quality guidelines or standards vary with the type of reuse application. They should reflect the potential for regional variations in climate, water flow and wastewater characteristics and

should be designed to protect individuals against realistic maximum exposures. In practice, these factors are expressed through different water quality requirements, as well as treatment process requirements and criteria for operation and reliability. They should be (1) realistic in relation to local conditions (epidemiological, socio-cultural and environmental factors), (2) affordable, and (3) enforceable. For the sake of integrated water resources management and to gain public understanding and acceptance, water reuse regulations should be part of a set of consistent water regulations applying to drinking water, bathing water, irrigation water, discharge, etc. (Bahri and Brissaud, 2002).

The two benchmark references on water reclamation and reuse are the World Health Organization guidelines (2006) and the Californian water recycling criteria (2000) (Box 15).

Box 15: Benchmark references – The WHO guidelines and the Californian water recycling criteria

An expert committee of the **World Health Organization** (WHO) first examined the health concerns of wastewater use in agriculture and aquaculture in 1971. Based on findings of the epidemiological studies of wastewater irrigation, the proposed microbial water quality guidelines for unrestricted irrigation (WHO, 1973) were relaxed in 1989 to 1,000 fecal coliforms per 100 mL. In addition, the guideline for intestinal nematodes was recommended as less than 1 intestinal nematode egg per liter (WHO, 1989). Recent studies from India, Pakistan, and Vietnam have challenged the validity of the global (helminth) water quality guideline. The latest guidelines for safe use of wastewater in agriculture have been revised considerably (WHO, 2006). They are based on health risk assessment and management approaches to address hazards associated with wastewater. They provide a framework for informed national and local decision making. They aim at preventing communicable disease transmission while optimizing resource conservation and recycling. They allow incremental and adaptive change which is cost-effective in reducing health and environmental risks. The fecal coliform guideline has been replaced by a focus on attributable risks and disability-adjusted life years. In addition, governments in developing countries have been given greater flexibility in applying the guidelines (WHO, 2006).

The first **Californian water reuse regulations** were established in 1918 by the State of California. At that time, the only application considered was irrigation. In 1933, the first microbial effluent standards for the "irrigation of garden truck produce eaten raw" were set up by the California State Board of Health at a coliform concentration of ≤ 2.2 MPN/100 mL (Ongerth and Jopling, 1977). The coliform concentration was equivalent to that required for drinking water and based on the concept of "zero risk". Since then, standards were continuously revised to address new reclaimed water applications and to take into account advances in wastewater treatment technology and updated knowledge in public health protection (Crook, 1998). Several investigations, beginning in the late 1960s, helped to develop comprehensive water reuse regulations addressing a broad variety of uses in several states of the U.S.A. Florida and especially California were leaders in this process. In 1978, the California Wastewater Reclamation Criteria were issued by the California Department of Health Services (DHS). They have been recently revised (State of California Title 22 Water Recycling Criteria, 2000). These standards, which apply to the wastewater reclamation, include water quality standards, treatment process requirements, operational and treatment reliability requirements. The desirability and benefits of wastewater reclamation and reuse have been well recognized by most States in the United States. For example, in the California State Water Code it is clearly noted that "it is the intention of the Legislature that the State undertake all possible steps to encourage development of water recycling facilities so that recycled water may be made available to help meet the growing water requirements of the State".

The wastewater reclamation and reuse activities in the countries belonging to the European Union (EU) are heavily influenced by the EU Water Framework Directive promulgated in 2000. In the European Communities Commission Directive (91/271/EEC), “treated wastewater shall be reused whenever appropriate”, and that “disposal routes shall minimize the adverse effects on the environment” (European Economic Community, 1991). More substantial pan-European guidelines for wastewater recycling and reuse have been proposed and are being studied, but no actions have been taken.

6. CONCLUSION

Globally, only a small volume of wastewater is treated. With a few major exceptions, most developing countries in Asia and Africa are characterized by inadequate water supply, poor environmental sanitation services and food insecurity. The approaches followed over the past 40 years have not succeeded in achieving sustainable water supply and sanitation services. They need a move beyond the conventional sector boundaries between water supply and sanitation and water management investments. New concepts and directions that fit capacities, needs and possibilities are required.

The growing water demand and the discharge of mostly untreated wastewater pose a huge challenge for managing water resources in an integrated manner. Direct reuses of untreated wastewater as well as the use of freshwater resources polluted by wastewater in farming are very common throughout urban and periurban areas. Despite a positive impact on local economies with large socio-economic benefits from the irrigated areas, public health risks are undeniable.

This practice will only increase with increasing water scarcity and urbanization. Wastewater and biosolids/sludges are therefore important resources that can assist in fighting the water, food and energy crises. The use of wastewater, excreta and greywater in agriculture offers opportunities for water and nutrient recycling and can have a positive impact on the environment by preventing pollution.

The key question coming from both preceding observations is how to maintain sanitation services in the future especially the treatment of domestic wastewater in a situation where most conventional approaches fail and polluted stream water and raw wastewater are already used by ten-thousands of farmers?

The answer is a paradigm shift where water reuse defines the required degree of treatment, where technical solutions have to match capacities, and where urban source treatment will be implemented along a multiple-barrier approach combining treatment and different health protection measures.

As water reuse for food crop production will remain a major option, the challenge is to integrate agriculture into urban sanitation concepts with the additional advantage of water and nutrient recycling as two of the major ways of closing the water and nutrients loops in the urban-rural interface addressing the MDG targets on sanitation and hunger simultaneously.

Alternative wastewater treatment methods based on the principles of closing cycles exist and several unconventional wastewater technologies can be implemented for individual and collective sanitation systems. Designing a range of cost-effective solutions that addresses the technical, institutional, social, behavioral and cultural obstacles for the adoption of such an approach remain one of the major challenges. A long-term strategy taking action step-by-step and the creation of new local business models are needed. But most of all, local capacities have to be built which value realistic standards and local solutions more than any imported sanitation curricula.

As stated by Brissaud (2008), "The potential contribution of water reuse to integrated water resources management still remains considerably undeveloped, though a wide range of reliable, efficient and cost effective technical solutions are available for each type of reuse application. Economic considerations will inevitably lead the decision makers to opt for economically efficient reuse applications, i.e. urban and industrial water reuse in the short term and indirect potable reuse in the long term."

Lessons can be drawn from experiences that can lead to more effective programs at the national and community levels. A key need is to ensure that proposals for technological solutions are based on holistic scientific, economic and social overviews of the entire urban water system where, for example, limitations in water supply are fully considered in setting sanitation targets, and where local communities can express their needs and suggestions in open multi-stakeholder platforms.

7. TEN KEY POLICY RECOMMENDATIONS

Ten key policy recommendations partly based on the "Guidelines on Municipal Wastewater Management" jointly developed by UNEP/WHO/UN-Habitat/WSSCC (2004) are presented in the following.

1. A political climate in which high priority is given to all aspects of sustainable wastewater management should be created and sufficient domestic resources allocated.

2. Governments have a key role to play in planning, financing and maintaining the water supply-sanitation-reuse infrastructure. National authorities should create an enabling environment at national and local levels.

3. An integrated framework to manage water, stormwater, wastewater, non-point source pollution and water reuse should be adopted. Sustainable urban water management is only possible if the entire urban water cycle is managed in a holistic manner in the context of the entire catchment.

4. Wastewater reclamation and reuse should be incorporated into any sustainable and integrated water resources management policy.

5. Each community, region or country should find out what is the most sound and cost effective solution in the short and long term and act accordingly. A stepped and phased approach should be taken to implementation and will help to achieve long-term management objectives.

6. Selection of appropriate technologies for efficient and cost-effective treatment and reuse of wastewater is key. In terms of health safety and economic viability, this requires the adequate combination of wastewater treatment and best practices taking into account the environmental issues. A multiple

barrier approach (treatment and non-treatment options) will ensure that risks are anticipated and overcome.

a.Modest change in behaviour could significantly reduce the risk from the reuse of wastes.

b.Awareness campaigns from "farm to fork" are needed.

7. For reuse purposes, source control remains essential for separate collection and treatment of different fractions of wastewater inflow (e.g., segregation of industrial wastewaters).

8. Users' preference and their ability to pay should be taken into consideration.

9. Involve all stakeholders from the start in water reuse operations and ensure multi-stakeholder platforms to facilitate dialogue, participatory technology development, innovation uptake and social learning.

10.Ensure financial stability and sustainability:

- Link waste management with other economic sectors for faster cost-recovery, risk reduction, financial stability and sustainable implementation.
- Develop mixed public/private, public/public sector solutions for investment, service delivery and operation and maintenance.
- Consider social equity and solidarity to reach cost-recovery.

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References

ADB (African Development Bank). 2005. Accra Sewerage Improvement Pro ject, (Republic of Ghana), Summary report of the Environmental and Social Impact Assessment. Country Department November 2005. Cen tral Region.

Asano T. and Levine A.D. 1995. "Wastewater Reuse – A Valuable Link in Water Resources Management", Water Quality International, No. 4 (1995) 20–24.

Asano T. 2002. "Water from (waste)water – The dependable water resource", Water Science & Technology 45/8 (2002) 23–33.

Asano T. 2005. Urban water recycling. Water Science & Technology 51/8 (2005) 83–89.

Asano T., Burton, H. Leverenz, R. Tsuchihashi, and G. Tchobanoglous. 2007. Water Reuse: Issues, Technologies, and Applications. McGraw-Hill, New York.

Bahri A. 1999. Agricultural reuse of wastewater and global water manage ment, Wat. Sci. Tech., Vol. 40, No. 4-5, pp. 339-346.

Bahri A. 2000. The experience and challenges of reuse of wastewater and sludge in Tunisia, 15 p., Water Week 2000, 3-4 April 2000, World Bank, Washington D.C., USA.

Bahri A. and F. Brissaud. 2002. Guidelines for municipal water reuse in the Mediterranean countries, prepared for WHO/EURO Project Office, Mediterranean Action Plan (World Health Organization, Regional Office for Europe), December 2002, 42 p. + annexes.

Bakir H. 2001. Guiding principles and options for accelerated extension of wastewater management services to small communities in EMR countries. Technical Expert Consultation on Innovative Wastewater Management for Small Communities in EMR Countries. World Health Organization – Regional Office for the Eastern Mediterranean– Regional Centre for Envi ronmental Health Activities (CEHA), Amman, 6-9 November 2000, 36 p.

Baron Water. 61-67 Ryrie Street, Geelong, 3220, Victoria, Australia. Web: www.baronwater.vic.gov.au

Biswas J.K. and S.C. Santra 2000. Heavy metal levels in marketable vegetables and fishes in Calcutta Metropolitan area, India. In: B.B. Jana, R.D. Baner jee, B. Guterstam, J. Heeb (Eds.) Waste recycling and resource manage ment in the developing world. University of Kalyani, India and Interna tional Ecological Engineering Society, Switzerland. pp. 371-376.

Bodik I. and P. Ridderstolpe. 2007. Sustainable Sanitation in Central and East ern Europe – addressing the needs of small and medium-size settlements.

88 pp., Global Water Partnership Central and Eastern Europe, ISBN 978-80-969745-0-4, download from: www.gwpceeforum.org

Brissaud F. 2008. Technologies for water regeneration and integrated manage ment of water resources. Water scarcity and management under the Mediterranean climate. Girona, 24-25 November.

COHRE, WaterAid, SDC and UN-HABITAT. 2008. Sanitation: A human rights imperative (Geneva 2008).

Comprehensive Assessment of Water management in Agriculture (CA). 2007. Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. Molden, D.J. (Ed.). London, Earthscan, and Colombo: International Water Management Institute.

Cooper P.F. 2001. Historical aspects of wastewater treatment. In eds. Lens P. Zeeman G. and Lettinga G. Decentralized sanitation and reuse. IWA Pub lishing 2001, UK.

Cornish, G.A. Aidoo, J. and I. Ayamba. 2001. Informal irrigation in the peri-urban zone of Kumasi: An analysis of farmer's activity and productivity. Report OD/TN 103, February 1999, HR Wallingford Ltd, Wallingford, UK, 86 pp.

Crook J. 1998. Water reclamation and reuse criteria. In Asano T. ed. Wastewa ter Reclamation and Reuse. Lancaster, PA, Technomic Publishing, 627-703.

Czemiel-Berndtsson J. 2004. Urban wastewater systems: from disposal to reuse – An analysis of the performance of different systems with focus on water and nutrients flows. PhD Thesis. Report No 1031. Lund, Sweden 2004.

Durham B., Rinck-Pfeiffer S. and D. Guendert. 2002. Integrated water resources management – through reuse and aquifer recharge. Watermark. Issue 16. August 2002.

Dodds A.A., Fisher P.J., Paull A.J. and J.R. Sears. 1993. Developing an appro priate wastewater management strategy for Sydney's future urban develop ment, Wat. Sci. Tech., 27(1), 19-29.

Drechsel P., Blumenthal U.J. and B. Keraita. 2002. Balancing Health and Livelihoods: Adjusting Wastewater Irrigation Guidelines for Resource-poor Countries. Urban Agricultural Magazine, 8: 7–9.

Drechsel P., Graefe S., Sonou M. and O. Cofie. 2006. Informal irrigation in urban West Africa: An Overview. IWMI, Colombo. Research Report 102. www.iwmi.org

Drechsel P., Keraita B., Amoah, P., Abaidoo, R.C., Raschid-Sally, L., and A. Bahri. 2007. Reducing health risks from wastewater use in urban and peri-urban sub-Saharan Africa – Applying the 2006 WHO Guidelines. Paper submitted to 6th IWA Conference on Wastewater Reclamation and Reuse for Sustainability, 9-12 Oct 2007, Antwerp, Belgium.

Drechsel P., Graefe S., and M. Fink. 2007. Rural-urban food, nutrient and virtual water flows in selected West African cities. Colombo, Sri Lanka: International Water Management Institute. IWMI Research Report 115, 35 pp. www.iwmi.org

DWA (German Association for Water, Wastewater and Waste). 2008. Innovative sanitation systems, (in German), December 2008, 333 pages, www.dwa.de/portale/dwahome/dwahome.nsf/home?readform, www.dwa.de/news/news-ref.asp?ID=4339

Edwards P. 1992. Reuse of human wastes in aquaculture, a technical review. UNDP-World Bank, Water and Sanitation Program, 350 pp.

Edwards P. 2000. Wastewater-fed aquaculture: state of the art. In: B.B. Jana, R.D. Banerjee, B. Guterstam, J. Heeb (Eds.) Waste recycling and resource management in the developing world. University of Kalyani, India and International Ecological Engineering Society, Switzerland. pp. 37-49.

Fewtrell L., Kaufmann R.B., Kay D., Enanoria W., Haller L. and J.M.Jr. Col ford. 2005. Water, sanitation, and hygiene interventions to reduce diarrhea in less developed countries: a systematic review and meta-analysis. Lancet Infectious Diseases, 5(1): 42-52.

Fourth World Water Forum. 2006. Water Supply and Sanitation for All. Financing wastewater collection and treatment in relation to the Millenni um Development Goals and World Summit on Sustainable Development targets on water and sanitation, Governing Council of the United Nations Environment Program, Eighth Special Session/Global Ministerial Environ ment Forum.

Ghosh D. 1996. Turning around for a community based technology, towards a wetland option for wastewater treatment and resource recovery that is less expensive, farmer centered and ecologically balanced. Calcutta Metropoli tan Water and Sanitation Authority, 21pp.

Ghosh D. 1997. Ecosystems approach to low-cost sanitation in India: Where people know better. In Etnier, C. and Guterstam, B. (Eds.), Ecological engineering for wastewater treatment. Proceedings of the International Conference at Stensund Folk College, Sweden, 24-28 March, 1991. 2nd Edition, CRC Press Boca Raton, USA, pp. 51-65.

Goodland R. and A. Rockefeller. 1996. What is environmental sustainability in sanitation? Periodical Newsletter, IETC's Insight. 6 p.

Guterstam B. 1997. Sustainable urban lifestyles. In: Brune, D. Chapman, D.V., Gwynee, M.D., and Pacyna, J.M. (Eds.). The Global Environment. Volume 2: Science, Technology and Management, Scandinavian Science Publ., VCH, Weinheim, Germany, pp. 1209-1221.

GWP–TAC. 2000. 'Integrated water resources management', Background paper No 4. Global Water Partnership – Technical Advisory Committee, 71 p.

GWP CEE. 2007. See Bodik & Ridderstolpe 2007.

Harremöes P. 1997. Integrated water and waste management. Wat. Sci. Tech., 35(9), 11-20.

INNORPI (Institut National de la Normalisation et de la Propriété Indus trielle). 1989. Environment Protection - Effluent discharge in the water bodies - Specifications relative to discharges in the marine environment, hydraulic environment and in the sewers (in French), Tunisian standards, INNORPI, NT 106.002.

Itanna F. and Olsson M. 2004. Land degradation in Addis Ababa due to industrial and urban development. Ethiopian Journal of Development Research 26(1): 77-100.

IWA (International Water Association) 2006. Sanitation 21, Simple Approach es to Complex Sanitation - A Draft Framework for Analysis. Sanitation 21 Task Force.

IWMI (International Water Management Institute). 2003. Confronting the Realities of Wastewater Use in Agriculture. Water Policy Briefing 9. Colom bo.

IWMI (International Water Management Institute). 2006. Recycling Realities: Managing health risks to make wastewater an asset. Water Policy Briefing 17; IWMI and GWP, Colombo, Sri Lanka, www.iwmi.org

Jiménez B. and A. Chavez. 2004. Quality assessment of an aquifer recharged with wastewater for its potential use as drinking source: "El Mezquital case" case. Water Science and Technology 50 (2): 269-273

Jimenez B. Siebe C., and E. Cifuentes. 2004. [Intentional and non-intentional reuse of wastewater in the Tula Valley.] In: Jimenez B, Martin L, eds [The water in Mexico: a view from the Academy] Mexico City, Mexican Acade my of Sciences, pp. 35-55 (in Spanish)

Jenssen P.D., Heeb J., Huba-Mang E., Gnanakan, K., Warner W.S., Refsgaard K., Stenström T-A, Guterstam B. and K-V. Alsén. 2004. Ecological Sanita tion and Reuse of Wastewater – A Thinkpiece on Ecological Sanitation. 17 pp. The Agricultural University of Norway (presented at CSD-12, New York)

Kennou H. 2006. The case of Tunis Lake. Alamin Project, EC – SMAP III, Training Course on ICZM, Alexandria, 2-3 September 2006.

Keraita B., Dreschel D., Huibers F., and L. Raschid-Sally. 2002. Wastewater use in informal irrigation in urban and peri-urban areas of Kumasi, Ghana. Urban Agriculture Magazine 8:11-13.

Keraita B., Drechsel P. and P. Amoah. 2003. Influence of urban wastewater on stream water quality and agriculture in and around Kumasi, Ghana. Envi ronment & Urbanization 15 (2) 171-178.

Keraita B. and P. Drechsel. 2004. Agricultural use of untreated urban wastewa ter in Ghana. In C.A. Scott, N.I. Faruqui, and L. Raschid-Sally, eds., Wastewater Use in Irrigated Agriculture: Confronting the Livelihood and Environmental Realities. Wallingford, UK; IWMI, Sri Lanka; and IDRC, Canada.

Krauss G.D. and J.J. Boland. 1997. Water and sanitation services for megaci ties, WQI, May/June, 9-12.

Kreissl J.F. 1997. Appropriate wastewater treatment technology for small com munities. Note presented at a World Bank Seminar, 5 p.

Kvarnström E. and af Petersens. 2004. Open Planning of Sanitation Systems. Report 2004-3, EcoSanRes Publication Series. Stockholm: Stockholm Envi ronment Institute.

Lazarova V. and Bahri A. (Ed.) 2005. Water Reuse for Irrigation: Agriculture, Landscapes, and Turf Grass, Catalog no. 1649, ISBN: I-56670-649-I, CRC PRESS, Boca Raton, FL, USA, 456 p.

Li S. 1997. Aquaculture and its role in ecological wastewater treatment. In Etnier, C. and Guterstam, B. (Eds.), Ecological engineering for wastewater treatment. Proceedings of the International Conference at Stensund Folk College, Sweden, 24-28 March, 1991. 2nd Edition, CRC Press, Boca Raton, FL, USA, pp. 37-49.

Mara D. 2008. Guide to the Guidelines – A numerical guide to Volume 2 of the Guidelines and practical advice on how to transpose them into nation al standards. WHO, FAO, IDRC, IWMI.

McCornick, P.G., Hijazi, A., and B. Sheikh. 2004. From wastewater reuse to water reclamation: progression of water reuse standards in Jordan. In: Scott, C.A., Faruqui, N.I., Raschid-Sally, L. (Eds.), Wastewater Use in Irri gated Agriculture, CABI Publishing, UK.

McIntosh A.C. 2003. Asian water supplies: reaching the urban poor. Asian Development Bank.

Melbourne Water. 2001. Infostream. Western Treatment Plant, PO Box 2251 Werribee, Victoria 3030, Australia. Website: www.melbournewater.com.au

Minhas P.S., and J.S. Samra. 2003. Quality Assessment of Water Resources in the Indo-Gangetic Basin Part in India. Karnal, India: Central Soil Salinity Research Institute.

Morel A. and S. Diener. 2006. Greywater Management in Low and Middle Income Countries, Review of different treatment systems for households or neighbourhoods. Eawag: Swiss Federal Institute of Aquatic Science and Technology. Dübendorf. pdf download: www.sandec.ch/greywater

Mujeriego, R. and T. Asano. 1998. "The role of advanced treatment in wastew ater reclamation and reuse", IAWQ Advanced Wastewater Treatment, Recy cling and Reuse, Milan, 14-16 September 1998.

Niemczynowicz J. 1994. New aspects of urban drainage and pollution reduc tion towards sustainability, Wat. Sci. Tech., 30(5), 269-277.

Norström A. 2007. Planning for drinking water and sanitation in peri-urban areas. Swedish Water House Report 21. SIWI, 2007. 15 p.

Obuobie E., Keraita B., Danso G., Amoah P., Cofie O.O., Raschid-Sally L. and P. Drechsel. 2006. Irrigated urban vegetable production in Ghana: Charac teristics, benefits and risks. IWMI-RUAF-IDRC-CPWF, Accra, Ghana: IWMI, 150 pp. http://www.cityfarmer.org/GhanaIrrigateVegis.html

OECD EAP Task Force. 2007. Financing water supply and sanitation in EEC CA countries and progress in achieving the water-related MDGs.

Ongerth, H.J. and W.F. Jopling. 1977. Water reuse in California. In: Water Renovation and Reuse (H.I. Shuval, éd.). Academic Press, New York.

Ou Z.Q. and T.H. Sun. 1996. From sewage irrigation to ecological engineering treatment for wastewater in China. In: Staudenmann, J., A. Schönborn, and Etnier C (Eds.). Recycling the Resource, Ecological Engineering for Wastewater Treatment. Environmental Research Forum Vols. 5-6 (1996) pp. 25-34.

Prein M. 1990. Wastewater-fed fish culture in Germany. In: Edwards, P. and Pullin, R.S.V. Wastewater-Fed Aquaculture. Proceedings of the Internation al Seminar on Wastewater reclamation and Reuse for Aquaculture, Calcut ta, India, 6-9 December, 1988.

Qadir M., Wichelns D., Raschid-Sally L., Minhas P.S., Drechsel P., Bahri A. and P. McCornick. 2007. Agricultural use of marginal-quality water - opportu nities and challenges. In: D. Molden (Ed.) Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. Earth scan, London, UK.

Rijsberman F. 2006. What can water science and technology do for Africa. Note presented to British parliamentarians on December 12, 2005.

Rose G.D. 1999. Community-based technologies for domestic wastewater treatment and reuse: options for urban agriculture. Cities Feeding People Series. Report 27. IDRC Intern.

Rosemarin A. 2008. In discussion panel at Seminar on Europe's Sanitation Problem, World Water Week , Stockholm, 19 August 2008.

SANDEC/WSSCC. 1999. Household-Centered Environmental Sanitation; Report of the Hilterfingen Workshop on Environmental Sanitation in the 21st Century (15-19 March 1999) Duebendorf, Switzerland.

Scott, C.A., Faruqui, N.I. and L. Raschid-Sally. 2004. Wastewater Use in Irri gated Agriculture: Management Challenges in Developing Countries. In C.A. Scott, N.I. Faruqui, and L. Raschid-Sally, eds., Wastewater Use in Irrigat ed Agriculture: Confronting the Livelihood and Environmental Realities. Wallingford, UK; IWMI, Sri Lanka; and IDRC, Canada.

Siebe Ch. 1998. Nutrient inputs to soils and to their uptake by alfalfa through long-term irrigation with untreated sewage effluent in Mexico. Soil Use and Management 13: 1 -5.

SIWI (Stockholm International Water Institute). 2005. Securing Sanitation: The Compelling Case to Address the Crisis. A report commissioned by the Government of Norway.

Spruijt H. 2008. New Incentives to Accelerate China's Sanitation and Hygiene Efforts. A Special Report by UNICEF. In: GWP China Proceedings of The High-Level Roundtable Meeting on Water and Sanitation of China, 8 April 2008, pp 122-123. www.gwpchina.org

State of California. 1978. Wastewater Reclamation Criteria, An Excerpt from the California Code of Regulations, Title 22, Division 4, Environmental Health, Dept. of Health Services, Sacramento, California.

State of California. 2000. Code of Regulations, Title 22, Water Recycling Cri teria, 24 p. November 2000.

Thiébaut L. 1995. Les fonctions environnementales de l'agriculture péri-urbaine: flux, externalités, services?" In: L'agriculture dans l'espace péri-urbain: des anciennes aux nouvelles fonctions. Atelier INRA-ENSH, Berg erie Nationale de Rambouillet.

UNDP (United Nations Development Program). 1996. Urban Agriculture: Food, Jobs and Sustainable Cities. Publication Series for Habitat II, Volume One. New York.

UNEP/WHO/UN-Habitat/WSSCC. 2004. Guidelines on Municipal Wastewater Management. UNEP/GPA Coordination Office, The Hague, The Nether lands (2004).

UNFPA (United Nations Population Fund). 2007. State of world population 2007 - Unleashing the potential of urban growth.

U.S. Environmental Protection Agency (USEPA). 1992. Wastewater treat ment/disposal for small communities, Manual, EPA/625/R-92/005, U.S. Environmental Protection Agency, Office of Research and Development, Office of Water, Washington D.C., September 1992.

Van der Hoek, W., M. Ul Hassan, J.H.J. Ensink, S. Feenstra, L. Rashid-Sally, S. Munir, M.R. Aslam, N. Ali, R. Hussain, and Y. Matsuno. 2002. Urban Wastewater: A Valuable Resource for Agriculture. Research Report 63. Colombo: International Water Management Institute.

Warner D.B. 2000. Africa 2000: Water supply and sanitation. New World Water.

WaterAid. 2001. Country Review Survey Report – Water Aid-Ghana, Country Strategy, London, UK.

WHO (World Health Organization). 1973. Reuse of effluents: Methods of wastewater treatment and health safeguards, Tech. Bull. Ser. 51, WHO, Geneva, Switzerland.

WHO (World Health Organization). 1989. Health guidelines for the use of wastewater in agriculture and aquaculture, Tech. Bull. Ser. 77, WHO, Geneva, Switzerland.

WHO (World Health Organization). 2000. Water Supply and Sanitation Sector Report Year 2000 - Africa Regional Assessment.

WHO (World Health Organization), UNICEF (United Nations Children's Fund) and WSSCC (Water Supply and Sanitation Collaborative Council). 2000. Global Water Supply and Sanitation Assessment 2000 Report, WHO/UNICEF, Geneva and New York, 80 p.

WHO (World Health Organization). 2006. Guidelines for the Safe Use of Wastewater, Excreta and Grey Water. Volume 2. Wastewater Use in Agriculture. Geneva.

WHO (World Health Organization) and UNICEF (United Nations Children's Fund). 2006. Meeting the MDG drinking water and sanitation target: the urban and rural challenge of the decade. WHO/UNICEF, Geneva and New York, 41 p.

WHO (World Health Organization). 2008. Health through safe drinking water and basic sanitation

http://www.who.int/water_sanitation_health/mdg1/en/index.html

Winpenny J. 2003. "Camdessus Report", Financing Water for All, Report to the World Panel on Financing Water Infrastructure. Global Water Partner ship, World Water Council, and Third World Water Forum, ISBN 92-95017-01-3, download from: www.gwpforum.org

Wright A. 2007. Barriers to Meeting the Sanitation Target in the MDGs. A Presentation at UCLA WaterAid Event on Meeting the Sanitation Target. October 1, 2007.

Wrisberg S. 1996. Urinseparation i København; Genopprettelse af forbindelsen mellem land og by. Institut for Jordbrugsvidenskap. Sektion For Agroøkologi, Den KGL. Veterineer Og Landbohøjskole, Fredriksberg (in Danish).

WTO (World Trade Organization). 1999. Sanitary and phytosanitary measures (WTO Agreements Series). Geneva. World Trade Organization.

Xu P., Brissaud F. and M. Salgot. 2003. Facing Water Shortage in Mediter ranean Tourist Area: Seawater Desalination or Water Reuse? Wat. Sci. Tech. / Wat. Supply 3(3), 63-70.

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