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Every Drop Counts

Environmentally Sound Technologies for Urban and Domestic Water Use Efficiency

United Nations Environment Programme

TU Delft

Delft University of Technology

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In collaboration with:

environmental management centre

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Environment Management Centre (EMC), India

UNITED NATIONS ENVIRONMENT PROGRAMME

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Environmentally Sound Technologies (ESTs) encompass technologies that have the potential for significantly improved environmental performance relative to other technologies. Broadly speaking, these technologies protect the environment, are less polluting, use resources in a sustainable manner, recycle more of their wastes and products, and handle all residual wastes in a more environmentally acceptable way than the technologies for which they are substitutes. The adoption and use of ESTs carefully considers both human resource development and local capacity building.

Information on ESTs is not always available in a form that can be easily understood by decision-makers and those without technical expertise. To encourage greater understanding about ESTs and their benefits, this booklet has been prepared using a minimum of technical jargon. We hope that you find the information in this booklet both interesting and useful.

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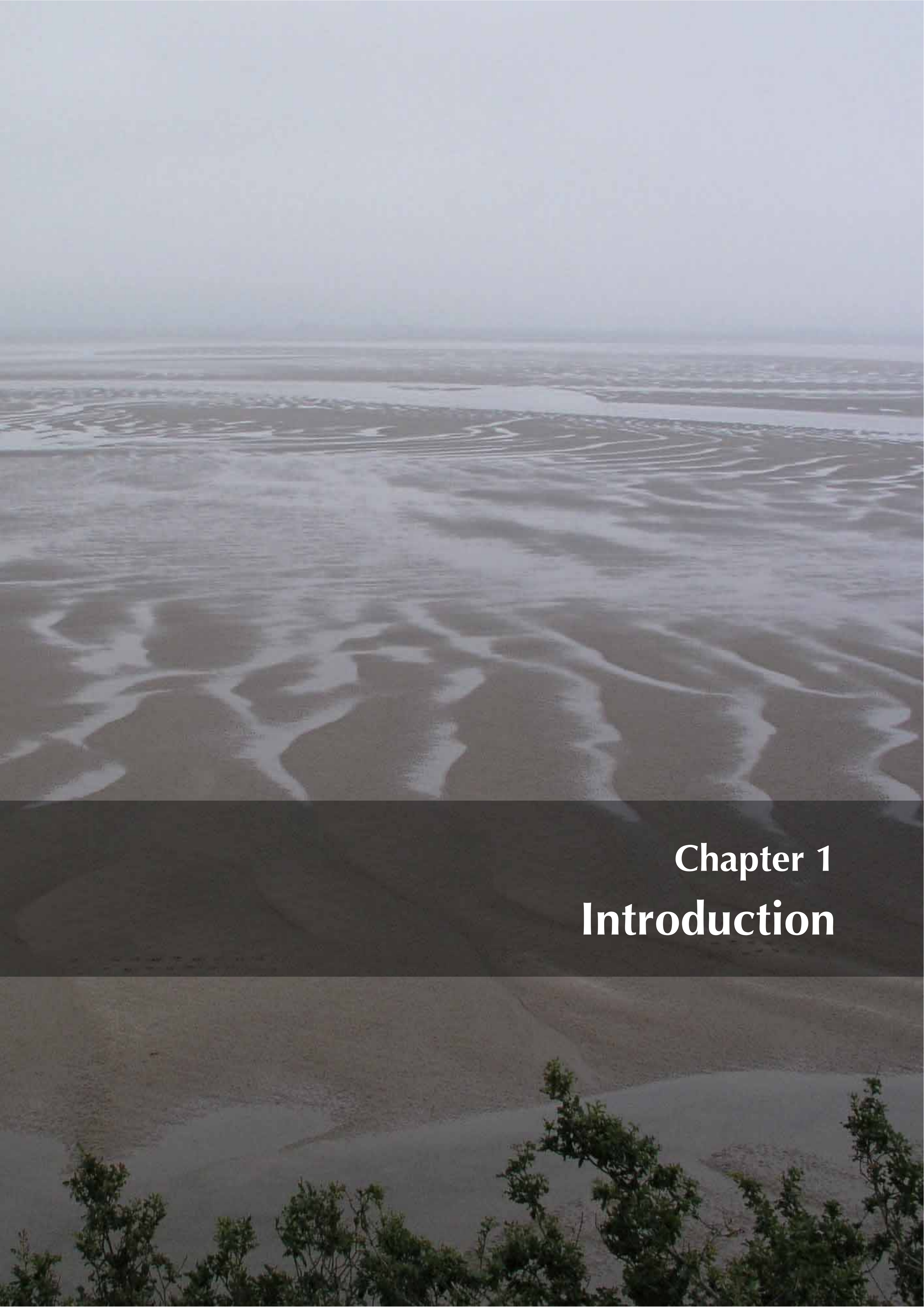
CONTENT



Chapter 1
Introduction

1.1 Focus and scope of the book

The focus of this book is efficient water use in urban and domestic environments and the context is decision making about sustainable development of human settlements. Rather than trying to be comprehensive and discuss all technical, institutional and spatial aspects of possible decision situations, the book is written as a Sourcebook, highlighting essential questions that will have different answers in different situations. For detailed descriptions the Sourcebook refers to existing publications and websites. Some concepts in this brief overview of the focus and scope of the book require further explanation.

efficient and sustainable

By looking at water use *efficiency* within the context of *sustainable* water use, the emphasis is on the *means* for optimizing the balance between safe and sufficient supply and demand of water, which implies a key role for Environmentally Sound Technologies (ESTs). Decision makers will not only look at the *efficiency* of means in a limited goals-and-means situation. They will also have to consider a wider perspective of closing eco cycles, health and safety. Moreover, they will be confronted by situations of complexity and uncertainty, conflicts and disagreement. Therefore, ESTs do not only have to be efficient. Decision makers will also use *fit* as a criterion: do ESTs *fit* to the economic, the social and the ecological characteristics of the decision situation? This is a central question in *Integrated Water Resource Management (IWRM).* Practical experiences in IWRM have nourished this book that is returning the lessons learned to this field of practice.

water use

The focus on *water use in the urban and domestic environment includes water* for drinking and sanitation purposes. Therefore the availability and storage, the supply and distribution and the actual use and reuse of water are the key issues of this book, addressed by different categories of ESTs. Other water issues, such as flooding, erosion, drainage and irrigation will only be discussed if relevant in the context of water use.

urban and domestic

The emphasis on *urban and domestic environments* implies the focus is on concentrated settlements. However, many of the decision situations that will be discussed are also relevant for smaller villages. The book addresses urban activities such as watering gardens and parks and to a certain extent also water use by vegetable gardens in peri-urban agriculture. Larger irrigation schemes for agriculture, however, are not within the scope of this book although in most cases their share in water consumption far exceeds urban water use.

These key aspects of focus and scope will be elaborated in the following sections of the introduction.

1.2 Decision making: users of the book

The Sourcebook is meant for politicians and other participants in decision making in the public sector dealing with water management with particular focus on water use efficiency and recycling in the urban and domestic environment. The book is not written for a narrow group of water specialists that have to take technical decisions. Rather, it addresses all participants in interactive decision making processes related to the role of water in an urban environment. Thus, the Sourcebook is for politicians, policy makers in public works, health and spatial planning departments, water board and drinking water company officials, NGO (Non Governmental Organisation) members and local residents.

This book gives a comprehensive overview about available ESTs for water use efficiency in the urban and domestic environment. It aims enabling the target audience in making plans for the identification and application of adapted ESTs and to Influence water use policy in the public sector through the application of ESTs. Based on the concept of

Integrated Water Resource Management (IWRM) political strategies and instruments are illustrated which create conditions for the capacity building and awareness raising of actors on all levels (from local to city to country) and from all fields (from private to commercial to public).

The Sourcebook aims to inspire decision makers in implementing interactive decision making processes for the planning and design of Integrated Water Resource Management systems. Each location has its own problems as well as complex and different basic conditions (including environmental, social and economical aspects) that are the starting point for a case-specific planning process for the selection and application of ESTs. However, a comprehensive assessment of all ESTs regarding water efficiency criteria and concerning their adaptability for specific individual cases is not possible in the framework of this Sourcebook. The attempt would definitely omit detailed information and options that might be appropriate for specific cases and therefore should not be excluded from the decision making process. Instead, this book gives ideas for the adaptability and feasibility of more general concepts and ESTs for specific situations. In the framework of the description of ESTs, their efficiency and fit will be briefly illustrated in general and also by means of selected case studies. In many places, the text will highlight essential questions that will have different answers in different situations.

To identify the most appropriate technologies for a specific system, detailed knowledge is required about the properties of technologies and about their relatedness to other components of the system. Generally politicians are overstrained with such specific technological demands. It is important not to get drowned in details but to oversee the implications of choices and the opportunities of synergy between policy sectors. Hence, there is a need for cooperation between different stakeholders from political, administrative and technical sectors.

1.3 The urban and domestic environment: focal area of the book

The ESTs described in this publication focus on the urban and domestic environment. The domestic environment includes all structures, like single and multifamily buildings as well as huts and shelters (e.g. in slums) that are used for residential purpose.

The definition of urban is according to UN-Habitat "An urban agglomeration is a built-up or densely populated area, containing a single political jurisdiction, suburbs and continuously settled adjoining territory. It may be smaller or bigger than a metropolitan area and comprise thickly settled adjoining territories." (UN-Habitat, 2006) Most statistics assume a minimum of 20,000 inhabitants for a settlement to be called urban, but the definition varies in different countries. The transition between rural and urban areas is smooth. *(UN-Habitat; Meeting Development Goals in Small Urban Centres - Water and Sanitation in the World's Cities 2006; Earthscan, London, 2006).*

Urban population

Today more than 50% of the global population lives in urban areas and it is expected that it will be 60% by the year 2015. *(UN-Habitat; UN-Habitat's Strategy for the Implementation of the Millennium Development Goal 7, Target 11; Nairobi, 2005).* It is expected that small cities with less than 0.5 million inhabitants and intermediate cities with between 1 to 5 million inhabitants will absorb most of the urban population around the world in the future. In 2006 already 75 per cent of the urban population lived in such cities. Fifty-three per cent of the world's urban population lived in cities with fewer than 0.5 million inhabitants and 22 per cent lived in cities of 1 to 5 million inhabitants. *(UN-Habitat; The State of the World's Cities Report 2006/7; The Millennium Development Goals and Urban Sustainability: 30 Years of Shaping the Habitat Agenda; Earthscan, London, 2006).*

This publication pays special attention to urban settlements in developing countries because they are facing the biggest challenges meeting the Millennium Development Goals, providing safe water supply and appropriate sanitation to world population. On the one hand there is an urgent need for positive change and on the other hand they face economic pressure due to the limited financial resources. While overall almost 1/3 (31.2 percent in 2001) of urban populations are poor and are living in slum areas, the proportion is only 6 percent in developed regions, but it is 42.7 percent in developing regions. The slum growth rate of 2.37 percent in developing regions and of 2.22 percent in developed regions is significantly higher than the average urban growth rate of 1.78 percent. Therefore there is urgent need for the implementation of Millennium Development Goals for urban dwellers in developing countries and in slums respectively.

1.4 Sustainable water use: objectives of the book

The objective of this Sourcebook is to support the efforts by governments and decision makers in improving water use efficiency in the urban and domestic sectors through the application of Environmentally Sound Technologies (ESTs) as well as the institutional strengthening in water use efficiency in the urban and domestic sector. Some of the key concepts will be introduced briefly in this section.

1.4.1 ENVIRONMENTALLY SOUND TECHNOLOGIES

For those who are unfamiliar with the expression "Environmentally Sound Technology" (EST), UNEP's understanding of this terminology is briefly explained.

Environmentally Sound Technologies (ESTs) encompass technologies that have the potential for significantly improved environmental performance relative to other technologies. Broadly speaking, these technologies protect the environment, are less polluting, use resources in a sustainable manner, recycle more of their wastes and products, and handle all residual wastes in a more environmentally acceptable way than the technologies for which they are substitutes.

Furthermore, as argued in Chapter 34 of Agenda 21, the programme that resulted from the 1992 Rio Conference on Environment and Development, Environmentally Sound Technologies are not just "individual technologies, but total systems that include know-how..., goods, services, and equipment as well as organizational and managerial procedures". Consequently, when considering technology transfer, UNEP-IETC's approach incorporates both the human resource development (including gender relevant issues) and local capacity building aspects of technology choices. The need to ensure that Environmentally Sound Technologies are compatible with nationally determined socio-economic, cultural and environmental priorities and development goals is also recognized in this book.

In the complex relationship between development and the environment, technology provides a link between human action and the natural resource base. Faced with limited global natural resources, the people of the world must seek to achieve more sustainable forms of development. As a result, the application of new, resource efficient ESTs have become crucial for both development and the environment. While it is recognized that technology cannot compensate for, or mitigate, the deep-rooted social causes of environmental problems or the short-comings of political and social policies, the need for sustainable development in the world today is real. The availability of ESTs via cooperative technology transfer depends largely on political willingness at the international level to pursue an innovative environmental agenda for the new millennium.

The dynamics of technological change will not be limited to specific technologies for developed countries and another for developing countries. Instead, cutting-edge and traditional technologies will coexist across the globe. In order to make the best use of ESTs, countries, regions and cities must increase their ability to assess, analyze and choose technologies based on their own specific needs and development priorities, and then adapt these technologies to specific local conditions. The application of well-adapted ESTs will be an essential factor on the path towards sustainability.

(Further reading: United Nations; Agenda 21 Chapter 34: Transfer of Environmentally Sound Technology, Cooperation and Capacity-Building; 2004, available at http://www.un.org/esa/sustdev/publications/publications.htm)

1.4.2 INTEGRATED WATER RESOURCE MANAGEMENT (IWRM)

A second key concept is Integrated Water Resource Management (IWRM). The Global Water Partnership, in its Policy Brief 4 (2006) underlines the role IWRM can play to realise the Millennium Development Goals set by the World Summit on Development and Environment.

Integrated Water Resource Management is based on the four Guiding Principles of the Dublin Statement which was commended to the world leaders assembled at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992:

1. Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
2. Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.
3. Women play a central part in the provision, management and safeguarding of water.
4. Water has an economic value in all its competing uses and should be recognised as an economic good.

(See: http://www.gwpforum.org/, Dublin Statements and Principles)

IWRM stresses the need for a policy framework to overcome the many problems that can arise in a watershed area as a result of uncoordinated use and abuse of increasingly scarce water resources (concerning water quantity and quality). Better management of upstream water resources is important to achieve sustainable urban water systems but will not automatically lead to an improved access to water among already currently deprived residents. Better water provision and sanitation creates conditions for health improvements but these do not automatically follow. Similarly, avoiding urban water pollution and waste is important, but if urban water policies focus narrowly on saving water, the water that is saved is unlikely to find its way to the poor urban residents who need it most. Hence IWRM explicitly addresses the integrated improvement of water and sanitation provision by the application of adapted ESTs.

Spatially IWRM has to work with water-relevant boundaries, such as watersheds and river basins. Neither the boundaries of private properties nor those of government agencies correspond with those of watersheds. The water related decisions of one stakeholder (e.g. the Ministry of Agriculture) can have adverse consequences for uses outside their concern (e.g. for residential users). The tools associated with IWRM rely on economic instruments, stakeholder consultation and/or negotiation. *(See: UN-Habitat; Water and Sanitation in the World's Cities: Local Action for Global Goals; Earthscan, London, 2003)*

IWRM is defined as a process that promotes the coordinated development and management of water, land (e.g. urban, agricultural or wild) and related resources (e.g. energy, money, material, nutrients, chemicals) in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Generally it can be assumed that the complexity of Integrated Water Resource Management rises with the size of the concerned watershed and the involved actors. *(See: Global Water Partnership - Technical Advisory Committee; Integrated Water Resource Management, TAC Background Papers No 4; Global Water Partnership,* *Stockholm, 2000. For more detailed information on IWRM and river basins, see International Network of Basin Organizations website: http://www.inbo-news.org)*

Moreover, nowadays a new dimension needs to be added to the IWRM concept in order to include water availability problems caused by climate change impacts. *(Jiménez, B. and Asano, T.; Water reuse around the World in Water Reuse: An International Survey; IWAP Inc., London, 2008)*

The anthropogenic change of Earth's climate is altering the means and extremes of precipitation and streamflow. It is predicted that water availability will increase in some areas, probably substantially in high latitudes of the northern Hemisphere and some tropical regions, while it will decrease in others, probably substantially in the Mediterranean basin, southern Africa and south-western North America. This process is asking for adaptation of rational water resources planning framework to the changing climate. Therefore the analytical strategies used for planning new infrastructure and renewing decaying one have to be updated under conditions of non-stationarity. Observations of changing precipitation patterns should be synthesized by new higher-resolution models which are able to represent surface- and ground-water processes more explicitly. These models need to include water infrastructure and water users. *(Milly, P. C. D., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z. W., Lettenmaier, D. P. and Stouffer, R. J.; Stationarity is Dead: Whither Water Management? In: Science 31; pp. 573-574, 2008. Potsdam Institute for Climate Impact Research; available at: http://www.pik-potsdam.de/)*

To make the overall approach of Integrated Water Resources Management work, an extensive

Projected regional impacts of climate change related to water issues

- Africa: By 2020, between 75 and 250 million of people are projected to be exposed to increased water stress due to climate change
- Asia: By the 2050s, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease
- Australia and New Zealand: By 2030, water security problems are projected to intensify in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions
- Europe: In Southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity
- Latin America: By mid century, increases in temperature and associated decreases in soil water are projected to lead to gradual replacement of tropical forest by savanna in eastern Amazonia. Semi-arid vegetation will tend to be replaced by aridland vegetation
- Changes in precipitation patterns and the disappearance of glaciers are projected to significantly affect water availability for human consumption, agriculture and energy generation
- North America: Warming in western mountains is projected to cause decreased snowpack, more winter flooding, and reduced summer flows, exacerbating competition for over-allocated water resources
- In the early decades of the century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by 5-20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilized water resources
- Small Islands: By mid-century, climate change is expected to reduce water resources in many small islands, e.g. in the Caribbean and Pacific, to the point where they become insufficient to meet demand during low-rainfall periods

(Intergovernmental Panel on Climate Change; Fourth Assessment Report, Climate Change 2007: Synthesis Report; Summary for Policymakers, 2007)

ToolBox has been generated (GWP ToolBox, available at: www.gwptoolbox.org). This toolbox provides an overview of policy instruments and addresses a wide variety of issues such as:

- o Equitable access to water resources through participatory and transparent management (including support for effective water user associations, involvement of marginalized groups and the consideration of gender issues)
- o Improved policy, regulatory and institutional frameworks (e.g. water quality standards and pollution control)
- o Inter-sectoral approach to decision making for water development, management and use
- o Supply, optimization, including assessment of surface and groundwater supplies, non-conventional supplies such as rainwater harvesting, water balances, waste-water recycling, water conservation where possible and capitalizing on potential synergies with other sectors, including developing water supply schemes that provide people water for domestic and productive uses *(See also: GWP ToolBox, 2004, op. cit.)*
- o Demand management, including water use efficiency technologies, cost-recovery policies and decentralized water management. *(See also: UN-Habitat; Meeting Development Goals in Small Urban Centres - Water and Sanitation in the World's Cities 2006; p.231, Earthscan, London, 2006)*

1.4.3 WATER AND SANITATION IN DEVELOPING COUNTRIES

In most cities water demand for domestic use is responsible for a big part of the total water consumption, beside industrial use. Many cities are located along rivers and have often water borne sanitation systems. Only approximately 10% of wastewater worldwide is treated, leading to surface and groundwater contamination by the discharge of untreated sewage and stormwater runoff. *(See also: Werner, C.; The role of Appropriate Technologies in Cooperation Projects; CeTAmb - International Conference, Desenzano del Garda (Brescia - Italia), 16-17 December, 2005)*

In the beginning of the second millennium over 25% of the developing world's urban population lacked adequate sanitation. The water provision of urban dwellers in 2002 was worldwide 95%, but only 2/3 of the residents got their water from a tap. Less than 1/3 of the world urban population has tap water within their dwelling. Only 10% of the inhabitants have access to public taps while 8% rely on hand pumped water or water from protected wells. *(UN-Habitat; The State of the World's Cities Report 2006/7 - The Millennium Development Goals and Urban Sustainability: 30 Years of Shaping the Habitat Agenda; Earthscan, London, 2006)*

An analysis of 43 low- and middle-income nations drawn from demographic and health surveys showed that provision of water and sanitation is usually worse in small urban centres. In world

Adaptation and mitigation options to reduce the vulnerability of the water sector to climate change

Adaptation option/strategy:	Expanded rainwater harvesting; water storage and conservation techniques; water re-use; desalination; water-use and irrigation efficiency
Underlying policy framework:	National water policies and integrated water resources management; water-related hazards management
Key constraints to implementation:	Financial, human resources and physical barriers;
Key opportunities to implementation:	Integrated water resources management; synergies with other sectors

(Intergovernmental Panel on Climate Change; Fourth Assessment Report, Climate Change 2007: Synthesis Report; Summary for Policymakers, 2007)

average, urban centres with less than 100,000 inhabitants have the lowest proportion of their population served with piped or well water on premises, with flush toilets and with sewer systems. On average in these areas less than 40% of the population have flush toilets while in cities with 1 to 5 million inhabitants the proportion is more than 70% and in cities with 5 million plus it is more than 80%. *(UN-Habitat; Meeting Development Goals in Small Urban Centres - Water and Sanitation in the World's Cities 2006; p. 37, Earthscan, London, 2006)*

Domestic sewage contributes to the contamination of ground and surface water (beside contamination by other sources), leading to quality problems in the receiving water bodies. This can affect their potential use as a drinking water resource and put pressure on the water resources of areas surrounding the city. Therefore, enhancing the water and sanitation service is an urgent issue.

In the last 30 years many innovations demonstrate how good water management, including, water supply, sanitation and wastewater management is financially feasible in low-income areas of cities. The awareness of the rapidly widening gap between the growth of income of the richest countries compared with the poorest countries, understandably led to an emphasis on additional international funding for water and sanitation projects. However, without the improvement of local governance, additional resources may bring only a few benefits to low-income groups and little improvement in overall water management. *(UN-Habitat; Water and Sanitation in the World's Cities: Local Action for Global Goals; p. 125, Earthscan, London, 2003)*

1.5 ESTs for sustainable urban and domestic water use: structure of the book

This Sourcebook is structured in different chapters according to its envisaged use, the focal area and the substantive objectives. ESTs can be differentiated into *soft* and *hard* technologies. Technical infrastructure, equipment and machines can be defined as "hardware" (*hard-tech*). The overall policies, regulations, economic instruments and management strategies can be defined as the "software" (*soft-tech*). Before describing the hardware of ESTs, two chapters prepare the ground for a better understanding of decision making by elaborating the role of the software.

The second chapter discusses the overall policies. A discussion of the institutional framework clarifies how decisions are embedded in informal and formal institutions such as traditions and legislation and how these rules of the game are used in governance and policy practice. Policy is then described as a way to formulate principles and create conditions for strategies and operational projects. Special attention is given to specific aspects of urban water policies. A critical discussion of the governance cycle explores the options for a process of learning that is fundamental to transformation processes for more sustainable urban water management.

Water quality

"Water pollution and degradation of aquatic ecosystems directly affect human health. Contaminated water remains the greatest cause of sickness and death on a global scale. Microbial pollution from inadequate sanitation facilities, improper wastewater disposal and animal waste is a major concern, with an estimated three million people dying of water-related diseases every year in developing countries, mostly children under five. Global population with access to improved water supply rose from 78 to 82 percent during 1990-2000, while access to improved sanitation rose from 51 to 61 percent during this same period. But an estimated 2.6 billion people still lack adequate sanitation facilities. Improved sanitation alone could reduce related deaths by up to 60 percent and diarrhoeal episodes by up to 40 percent. *(United Nations Environment Programme (UNEP), GEO 4 Environment for Development; GEO-4 Fact Sheet 6; 2007, available at: www.unep.org/geo/geo4/)*

In the third chapter the focus is on criteria and the decision making process. The two basic criteria are *efficiency* and *fit* and a case study from Africa illustrates the difference and the complementary nature of the two. It is important to understand their role in decision making at a strategic planning level, aiming at consensus and commitment among the leading stakeholders and at the operational level, aiming at feasible and practical performance. UNEP-DTIE-IETC already developed a method for Sustainability Assessment of Technology (SAT), focussing primarily on efficiency and operational planning. In addition to this, an approach is developed for choosing Technologies in Sustainable Strategies (TISS). By focussing on the strategic stage and *fit* criteria the approach mobilises the imagination and creativity required to generate the best strategy for integrated water resource management making optimal use of the local opportunities.

Chapter four provides an overview of ESTs in different parts of the water cycle, from supply to use and disposal to water augmentation and back to supply. The management of specific parts of the water cycle has consequences for other parts. These have to be taken into account in the design of water management systems. The four sections of chapter 4 describe the ESTs in relation to the four parts of the water cycle (see *Illustration 1*).

- Water storage and augmentation
- Water supply and distribution
- Water use and saving
- Water reuse, recycling and disposal

The sections *storage and augmentation* as well as *supply and distribution* can be assigned, in principle, to supply-side measures, whereas the sections *water use and saving* and *reuse, recycling and disposal* may be listed as demand-side measures.

The fifth chapter will provide illustrative cases and promising combinations of ESTs. A comprehensive assessment of specific ESTs regarding sustainability criteria and concerning their adaptability for specific individual cases is not possible in the framework of this Sourcebook. The attempt would definitely exclude detailed information and options that might be appropriate for specific cases. That would incur the risk that specific ESTs which might be appropriate for a specific case would be eventually excluded from the decision making process. In chapter 5 cases are discussed that represent common decision situations and may illustrate the way criteria can be used to generate practical questions in the making of plans and in the assessment of plans. In this way the book gives ideas for the adaptability and feasibility of specific concepts and ESTs for specific situations.

The sixth chapter provides information about the training material for capacity building which is available in electronic format. A CD-ROM with a Microsoft Power Point presentation and a Microsoft Excel-based water tool (WiseWater) is attached to this Sourcebook.

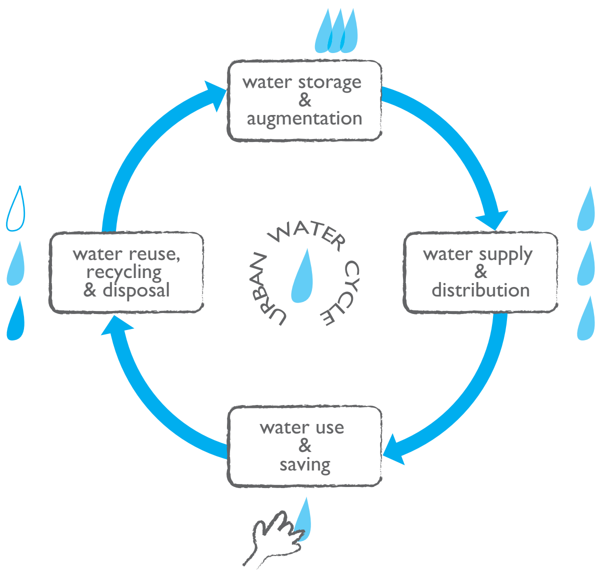
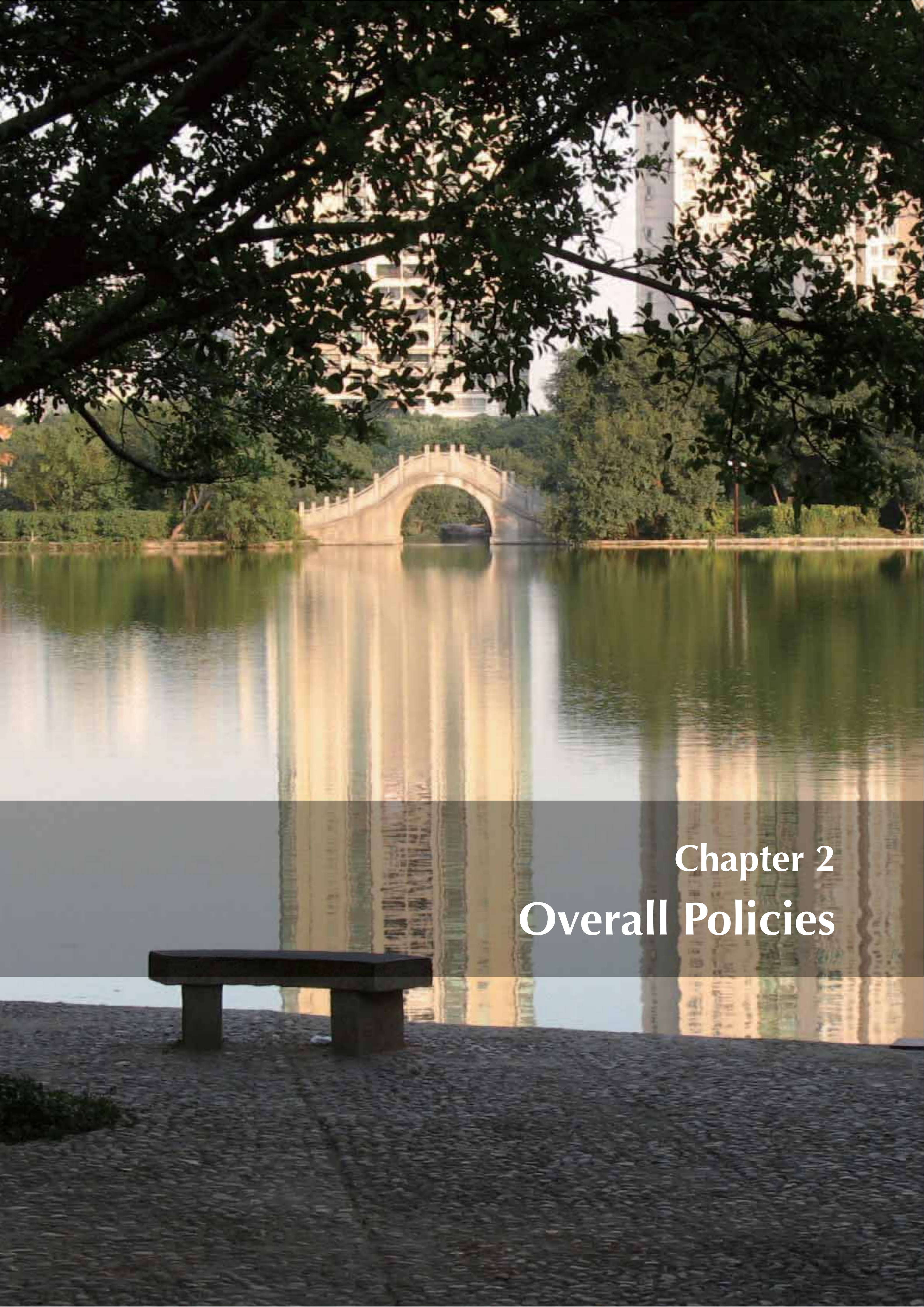


Illustration 1: The four sections of the urban water cycle.



Chapter 2
Overall Policies

2.1 The challenge of urban water management

2.1.1 THE INSTITUTIONAL FRAMEWORK

The decision-making process, as well as the operational aspects and the exploitation and use of the EST, are governed by rules and arrangements between the actors involved. These rules and arrangements are commonly described as the legal and institutional framework and are established in the process of policy-making and in negotiations between the several public and private stakeholders involved. This chapter will provide an overview of the main components of this institutional framework and address some key considerations of the process of policy-making and planning.

A crucial element of the encouragement of the use of ESTs in urban water management is the 'environment' in which the choice for specific ESTs is made, and in which the system of appliances are operated. The challenge is to achieve an appropriate 'fit' between the 'hard' technical and physical characteristics, the economics of ESTs and the institutional environment that facilitates their selection, construction and operation (*see Illustration 2*). The fit of this triangle of interactions between these facets is crucial to the operational and environmental sustainability of whatever EST. From domestic water-saving appliances to a large-scale water supply system at the municipal scale, a successful process of introduction and the operation of such ESTs requires coherence between the technological, the economic and the institutional facets.

The decision-making process in respect of urban water management generally takes place in a complex institutional environment, or network, with a large number of public and private actors, each of them with its own interest and responsibilities. Some of these actors, like the national, state or provincial governmental bodies, are in a relatively distant position from the actual projects or measures taken. Yet, they are influential via general or water specific legislation and overall planning procedures and policies. Moreover, a main objective of water works and sanitation is to protect health while environmental objectives may be involved as well.

More closely involved are local actors, like bodies for water management, municipalities, water supply corporations, sewerage operators, public health policy makers, housing corporations, project developers, financing parties, which have to deal with actual projects and approaches at the local level. Other influential actors in this respect are construction companies and equipment suppliers. Finally, there are the users of the water systems, domestic households in owned and rented houses, small and medium size enterprises, and the citizens living in the areas.

To start with, these parties play more or less specific roles within the formal policy-making and development process in respect of water management. This includes the whole path of planning, the legal obligations, and the requirements and rights of choice that parties have at the several moments in the decision making process. Sometimes, choices will be made on the basis of top-down policies and public objectives; sometimes choices will be based on private ambitions, preferences and initiatives. These choices can be based on economic motivations and cost-benefit analysis, but other interests and traditions may be of crucial importance in this process.

Illustration 3 provides a schematic overview of the institutional framework in which the process

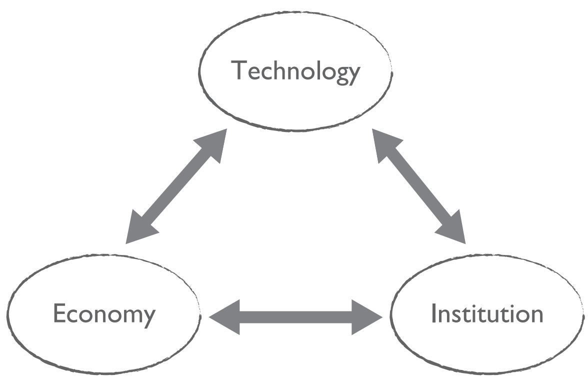


Illustration 2: Triangle of interaction.

of urban water management takes place. This overview links the informal institutions of the upper panel, embedded in customs, traditions, norms and beliefs, to formal institutions, including the body of laws and regulations.

These laws and regulations are the basis for contracts and other public-private arrangements that govern the actual behaviour and transactions between the actors directly involved, at the bottom layer of the scheme.

The main message of this scheme is that any initiative for urban water management approaches to introduce ESTs will have to be considered within the context of the four layers of the institutional framework. Depending on the nature and the scale of the project involved, the focus will be on different types of actors and the institutional framework will be more or less formalized. In smaller villages, the role of central and local government will be small and self organization will be a dominant mode. In this Sourcebook, the distinction is made between: 1) Public and centralized systems, which are technologically and institutionally embedded; 2) Collective and semi decentralized systems, which may be technologically and institutionally embedded; and 3) Individual and decentralized systems which are for the most part not technologically and institutionally embedded. ESTs will have to meet national health and safety standards, however. In large cities, public agencies will have a much larger role in building, operating and controlling the water systems. Moreover, there will be a need for extensive coordination with public agencies in other fields, like transport, land use and spatial planning, health services, etc. In any case, ESTs will have to fit the informal and formal institutions. These institutions will have to facilitate the development of contracts and arrangements that allow for the effective introduction and operation of these ESTs at the actual levels of the suppliers, operators and users.

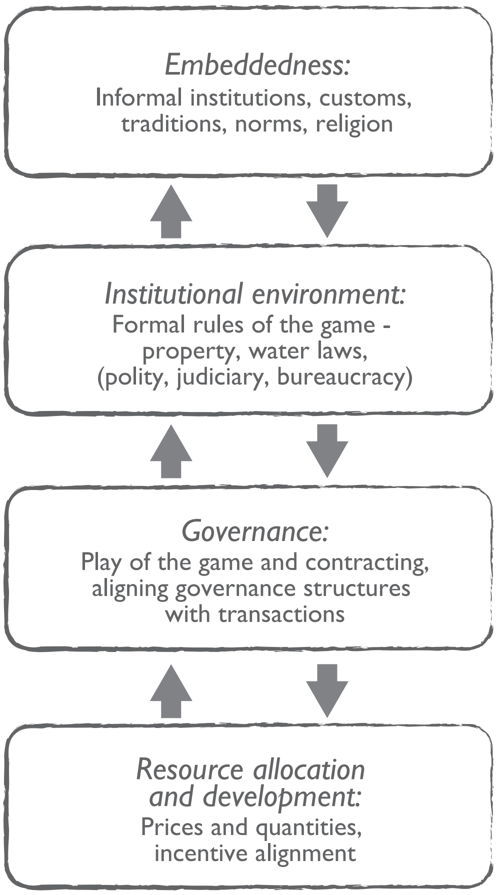


Illustration 3: Layers of Institutions.

(Williamson; Transaction Costs economics: How it Works, where is it Headed; in: De Economist, 146, no. 1. pp. 23-58, 1998)

It is clear that this scheme is rather abstract and that, depending on the specific country and situation, specific informal and formal institutions and arrangements will have to be identified, explored and understood before any decisions can be made. Often this will also include alterations to specific rules and provisions. Indeed, the bi-directional arrows in the scheme suggest that interactive relationships are foreseen between the several layers. Yet, the alteration of formal laws and codes is normally a burdensome and complex process, bringing about changes to informal customs and beliefs is even more time consuming, if possible at all.

Nevertheless, over periods of decades, these customs and beliefs may transform under the influence of economic and social development or new insights in environmental aspects or changes in ideologies, etc. Another important driver for change in the institutional framework is the effect of 'learning'. Positive and negative experiences with particular technologies, modes of governance and institutional arrangements will affect later choices in respect of these aspects. Failures - if they are known at all - will be avoided while successes will be copied and imitated.

Within the legal and policy context and given existing contracts and arrangements, the individual choices and preferences of the actors matter at the lowest level. In that sense the framework has to be examined and interpreted as a minimalist structure.

As regards the actors, the specific roles of different levels of government (central or federal government, provincial or state government and local or municipal government) should be clearly established. This may involve responsibilities in the setting of standards and norms, the powers of enforcement, fiscal and budgetary arrangements, and inter-governmental transfers and subsidy schemes.

In addition, important roles may be played by the private sector, public utility or parastatal organisations, universities, research institutes, professional and trade associations, NGOs, bi-lateral and multi-lateral aid agencies, bodies for social development, interest associations of economic sectors, international development agencies and development financing institutions. Often new ideas, technologies and approaches for the exploitation or financing are inspired by these types of actors. Moreover, they may have the oversight of what is going on elsewhere, thus facilitating the learning effect referred to. Therefore, given circumstances and objectives, it may be indispensable to achieve commitment of these parties in the development of EST projects in specific phases.

The (potential) roles of the several types of actors involved and their relationship with the introduction of specific ESTs should be examined by means of an analysis of the network of actors. This analysis should address their position in respect of the EST project, their potential contributions or the need to deal with them, and ways to achieve their commitment in the process of policy-making and planning.

2.1.2 THE ROLE OF POLICY

In general terms, two situations can be distinguished in respect of "policy" when a process of selecting and introducing ESTs takes place. Either the EST is implemented as a consequence of - and in line with - water policy. Then the objectives and provision of the policy are guidelines for the specific choice of an EST and the particular arrangements that will govern its implementation and operation. Alternatively, there may be no explicit policy. In that case, ESTs are selected bottom-up and they should fit to the general policy and institutional framework of a country, or a region. Obviously, such early bird projects may inspire the formulation of policy and act as an example for other EST projects.

Policy is the set of decisions made ultimately by the highest political level in a country after a process of dialogue and consultation to determine what and how things will be done in any given sector. Policy sets out the framework for the sector - the guidelines as to how development should take place and how the environment should be protected. Policy, once adopted, provides the mandate for the civil service. A government department's role is to implement the policy.

Based on the experience of several countries, one of the most frequent causes of failure to wholly or partially implement reforms is a lack of coordination, understanding and interaction between different government ministries and departments as well as municipalities or other regional bodies. Unless it is specifically planned for and avenues of dialogue are purposefully opened, it is often the case that different ministries which have overlapping or at least complimentary functions and responsibilities work in isolation from each other. Examples are the ministries responsible for water resources management and the ministry responsible for the largest user of water, agriculture. Clear political commitment and leadership at the highest level is required to ensure that adequate intra-governmental interaction happens (*Abrams, L.; Water Resources Management Reform Process; October, 2000, available at: http://www.africanwater.org/water_sector_reform.htm*).

Policy statements provide the principles by which the management of specific activities or sectors are governed in the broader sense. Such statements may address the following aspects, objectives and definitions:

- o A conception of the water cycle, requiring integrated water resources management, aligning surface water, groundwater, catchments and land use;
- o Principles in respect of the preservation of the environment as the source of water, addressing abstraction control, water quality and pollution control;
- o Principles for water use by the domestic households, agriculture, industry, tourism, etc.;
- o The economic principles of water management, addressing water pricing, financing water resources management and the role of the private sector;
- o The roles, responsibilities and authority of water institutions, like federal and state institutions, user engagement, basin organizations, etc.;
- o The development of water resources, involving infrastructure development and asset management;
- o The organization of water services, like including water supply and sanitation;
- o Legal aspects of water, outlining who owns water and how is it distributed and utilized.

Generally, policies and policy statements do not provide precise indications how they should be implemented. To implement and enforce policies, more detailed rules and arrangements have to be developed, which are often linked to and carried out by specific actors in the framework. These rules and their practical application are normally combined in a strategic plan or program. These plans and programs are often endorsed by specific actors at the various levels and provide the detailed guidelines, norms and standards for the implementation of ESTs in a specific local context.

While not being the same as legislation, policy is facilitated by legislation, which provides ministries and governments with the responsibility and mandate to develop policies on specific issues, indicating particular aspects that should be dealt with. At the same time, legislation prescribes the rights and obligations for the different public bodies and private actors involved and provides for instances where these actors can seek their protection if they experience that policies or their implementation policy violate their rights. Legislation often also demands consistency between different sectoral policies.

The policy should provide a framework for planning and the integration with other sectors. Policy can be considered as thematic or sector related bundles of contemporary social, political, economic and technological views in a country. As these views are dynamic and responsive to experiences and new insights, policy always has a time-dependent component. Moreover, political discussion will take place about the appropriateness of the objectives of policies, the instruments they provide and the apparent trade offs with other objectives. Policies are reviewed more or less regularly to stay up-to-date with new developments and preferences in the policy field.

Policies are the object of politicians, who in a societal process of political decision-making set the objectives and approaches vis-à-vis certain issues. The process, as well as the principles that should guide policy-making, are laid down in the legal framework. The implementation and daily execution of policies are the realm of civil servants in the national or local administration, or of specialized agencies which carry out the policy provisions. They require technical and social expertise.

2.1.3 LOCAL DECISION MAKING

The actual development and implementation and the operation of the several types of ESTs generally requires a decision-making process at the local level. These processes involve local actors, including relevant public actors, parties that implement or provide the ESTs, the end-users and possible stakeholders. The circle of parties involved is dependent on the scale and the scope of an EST and the parties that will be affected.

Often, the choice and introduction of specific ESTs will take place in the context of a local, regional or municipal program. As stated above, such a program may be installed as a consequence of national policy, or it can be a deliberate choice of the local authorities and policies. National policy may provide guidelines of how the program should be set up, financed and executed and what the technologies, instruments, objectives and targets should be. Otherwise these elements have to be formulated locally. Referring back to the layered institutional framework in *Illustration 3*, such executive programs are located at the third level.

It is crucial that EST programs fit their local context. Generally, this implies that their selection and implementation should take place in a process that involves the local stakeholders as much as possible in all phases of the project. Particularly when new approaches are introduced that deviate from local traditions and customs, there is a need to develop a new way of dealing with these ESTs in all aspects. To this end it is necessary to engage all stakeholders in decision making, even over details.

Generally, this involves the municipality and its relevant departments. Depending on the EST envisaged, this may include water supply and sanitation, spatial planning, housing, social issues, public works, finance, etc. Issues to be dealt with include the technical design, the execution of the plan and the actual construction, and issues of maintenance and operation. Whereas municipal civil servants will be crucial in carrying out the actual planning process, often the presence of local politicians is crucial to ensure commitment, from the political leaders as well as from the population. Other important parties are the private "project developers" if relevant, possible funding and financing agencies and banks, construction and engineering firms, etc. As regards information and inspiration, there may be a role for universities, research institutes, professional and trade associations, NGOs, bi-lateral and multi-lateral aid agencies, bodies for local social development, etc. These actors should be given a clearly delineated role, to avoid misunderstandings and conflicts over mandates and responsibilities.

If the program is large and complex, it may be advisable to establish taskforces, which more or less independently carry out the planning and development of specific elements of the introduction and operation of the ESTs. With a sufficient degree of coordination, such specialized groups will be able to operate in a more or less adequate and flexible way, than one single project group that has to discuss every detail. These groups may involve representatives of the stakeholders involved supported by relevant specialists if necessary.

Illustration 4 presents a policy development cycle which looks simple. A *diagnosis*, or review, phase, seeks to identify the main characteristics of the situation and the ensuing options for introducing ESTs. Most likely, this is the phase of the project in which the contribution of this Sourcebook will fit best. When the options and trade-offs are clear, the following step is the *planning* phase, in which actual decisions are taken as regards objectives and approaches. This phase, eventually, culminates in the decision making on detailed aspects of the technical design and operational arrangements. Subsequently, there is the *implementation* phase, including the construction of the EST facilities and the role out of the associated operational structures and systems.

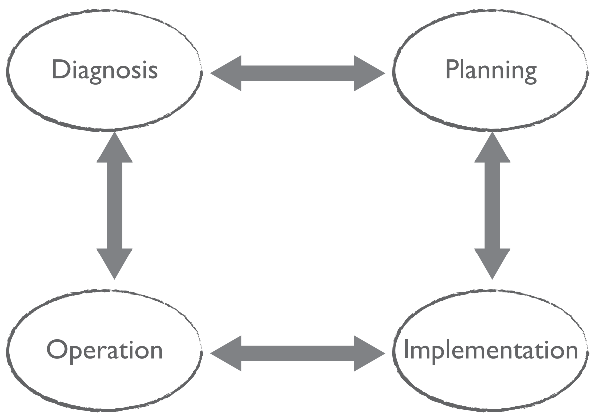


Illustration 4: Policy development cycle.

When the system is working and in *operation*, a new phase of *diagnosis* follows, to evaluate the adequacy of the functioning and management of the EST. On the basis of these experiences, a new cycle will be entered, seeking and suggesting adjustments to the several technical and institutional components of the system.

Whereas this cycle looks simple, the real world execution may become very complex. Firstly, as stated already, the design, introduction and operation of an EST, should be consistent with overall higher level and adjacent policies, including high level principle as regards private sector involvement and decentralization. Yet, it may be necessary to reassess certain national policies, sometimes. Moreover, the cycle should be seen as dynamic and not rigid. The cycle is dynamic in that once a reform process has been undertaken the sector requires ongoing review which may in turn lead to new policy development, legislation, etc.

The *diagnosis* phase is to review the current local situation with the help of relevant stakeholders and experts and to identify problems and possible solutions. It is important to take a broad perspective in this phase, allowing for a wide range in both the problem analysis of water supply and sanitation, as well as the consideration of potential EST solutions. This phase should provide the main insights required in the subsequent phase of actual decision making, The diagnosis should address and evaluate the importance of a broad range of facets, including:

o Patterns of water supply and sanitation;

o Patterns of (sectoral) water use;

o Environmental aspects;

o Institutional arrangements;

o Social and cultural factors;

o The position of stakeholders and interest groups;

o The legal framework;

o Economics and the engagement of the private sector;

o The interaction with other adjacent and other infrastructure and assets.

In the *planning* process, clear objectives and approaches should be adopted and particular technical solutions and operational and exploitation arrangements should be agreed upon. Moreover, the implementation plan should be developed and turned into concrete actions by clearly identified parties, which will have to commit to the plans. The development of plans for technical aspects as well as the institutional and contractual arrangements is complex. For the latter, it is obvious that introducing new institutions and arrangements and/or altering existing ones is an intricate and difficult task. Institutions are made up of people and therefore any amendment to institutions is a complex process where changes that may be in the public interest are not perceived to be in the personal interest of individuals with vested interests. Institutional change and the introduction of new approaches and arrangements may meet significant resistance. It therefore should be carefully undertaken, in a way which involves as many of the affected parties as possible. It is not only a matter of changing institutions, but also of helping the people who work with the new arrangements to get a new idea about their role vis-à-vis the arrangement and the technical system. Tensions and competition between different (local and central) public agencies is common. The actual pattern of authority and responsibilities will develop during the implementation of the new approach. This calls for continued dialogue and negotiation and the sharing of experiences and idea. Throughout the policy development and reform phases, attention needs to be continuously given to determining what is implementable and practical.

In the *implementation* phase, the developed plans are executed and the technical as well as the institutional and contractual arrangements are enforced. It may well not be possible to implement all new policies immediately. In some instances policy options may need to be tested through the use of pilot programmes. New measures may be introduced gradually either in different phases over time or in different locations. As suggested by Abrams *(See: Abrams, L.; Water*

Resources Management Reform Process; October, 2000, available at: http://www.africanwater.org/water_sector_reform.htm) barriers to implementation may result from a number of factors:

o Technically inadequate plans;

o Socially and culturally unacceptable plans;

o Economically infeasible plans;

o Plans which make too great a demand on available human resources;

o Plans which go counter to legal provisions;

o Plans which are blocked by other local departments because of lack of coordination and consultation;

o External factors such as poor public servant morale or public resistance.

Implementation needs to be continuously monitored and evaluated. After a reasonable period it will be necessary *to review* the functioning of the EST. Hence, the policy cycle an ongoing dynamic process, which allows for learning and development.

2.2 Urban water as a part of integrated catchment management

This section addresses the context in which ESTs may be adopted and operated. Main elements that should be addressed are the mode(s) of water supply, water utilization, water quality and environmental aspects. It is obvious that some of the facets indicated below belong at the national institutional level, whereas others are regional and local aspects. As indicated above, there should be a consistent relationship between the legislation, national policies, arrangements for implementation and their translation in local executive programs, instruments, transaction and activities. This implies that, even though the focus of this Sourcebook is on urban systems, it is important to take the higher-level determinants into consideration.

2.2.1 WATER SUPPLY

In respect of water supply, a main element is its conception in terms of the water cycle, addressing integrated water resources management, aligning surface water, groundwater, catchments and land use:

o Policy should cover the methods of water supply, like rainwater harvesting, desalination and inter-basin transfer schemes.

o Specific policies on the exploitation of groundwater, particularly where renewable groundwater can substitute "fossil" ground water resources which are not replenished by surface recharge.

Reference should be made to the basic principles of the national policy and programs, like equity of access, polluter pays, user payment, etc. This may include:

o The economics of water supply including cost recovery, water tariffs, capital financing, instruments such as stepped tariffs etc.

o Minimum standards of supplies, for example daily per capita quantities, maximum cartage distances and quality constraints.

o Sanitation, health and water supply.

A further main element involves the roles and responsibilities in water supply of different central, regional and local spheres of government.

o The role of utilities, private parties and local communities in construction, ownership, management, administration, operation and maintenance of water supplies.

o The role of NGOs, ESAs (Environmental Services Association) and women in all aspects of water supply.

o Hygiene and health education to increase the beneficial impact of water supplies.

o Legal aspects of water outlining who owns water and how is it distributed.

2.2.2 WATER UTILISATION

Water utilisation should take into consideration main principles in respect of water use by the domestic households, agriculture, industry, tourism, etc. and economic principles of water management, addressing water pricing and financing water resources management.

- o Programmes should address the achievement of regional and local social and economic development by providing clean water to all groups in society, while ensuring environmental sustainability.
- o Methods of allocation should enable a balance to be struck between equitable apportionment among sectors and optimum efficiency of usage, taking note of the specific need to supply clean water to the poor.
- o Utilisation should take account of local demographic and social trends while ensuring the achievement of objectives such as food security, in respect of semi-urban agricultural activities.
- o Methods of utilisation control should suit the circumstances in terms of administrative capacity, enforcement ability and institutional sustainability of the local authorities.
- o The program should take account of water use by relevant sectors. In a (semi-)urban context this may include local agriculture, small industries and trades, municipal usage and leisure.
- o Legal aspects of how water is utilized.

2.2.3 WATER QUALITY

EST programs should ensure the maintenance of water quality for public health protection and adequate protection of the environment. To this end they should take into account the following issues:

- o The control of local wastewater discharges and water quality, including enforcement.
- o Objectives for the control of discharges and the setting of standards.
- o Different circumstances such as special measures in situations of particular sensitivity and during different seasons.
- o Factors such as sedimentation and diffuse pollution.
- o Inter-sectoral interaction to review the impact of programs on water quality from, for example, the effects of agricultural inputs and industrial development.
- o Legal aspects of water quality control, including the role of relevant authorities.

2.2.4 ENVIRONMENTAL ISSUES

Closely related to water quality issues is the question of sustaining the environment. Increasingly, the environment is being regarded as the resource base - the source of the water on which so much depends.

- o Policy development should seek to establish an understanding amongst all interested parties of the importance sustaining the environment.
- o Sustaining the environment entails conserving several elements including water quality and water quantity above certain minimum levels.
- o Policy should be formulated which will ensure that internationally accepted methods of environmental impact assessments are undertaken when developments are planned.
- o Adequate monitoring and ongoing assessment of key environmental indicators should be accommodated in the policy and legal framework, including the role of relevant authorities.
- o Particular attention should be paid to sensitive environmental areas such as upper catchment areas, forests, wetlands and deltas.
- o Policy is also required relating to the control of invasive plant species in catchment areas, i.e. water hyacinth, nutrient levels in water bodies and other important environmental aspects.

2.3 Infrastructure integration issues

It is a fact that the effects of ESTs may interact with other infrastructures, either water-related or not. This is particularly true if they achieve a certain scale and scope which extends beyond those of the domestic households and commercial end users. This implies that the parties responsible for the operation and management of these tertiary infrastructures should be involved in the process of planning and development. This may involve transport activities, via water or land, other utilities like power and telecoms, and spatial planning in respect of land use.

2.4 Some considerations regarding water supply and sanitation

2.4.1 SUSTAINABILITY

There are increasing concerns regarding the environment and the role which the environment plays in ensuring that water, as a renewable resource, is able to meet the needs of the country into the foreseeable future. This aspect should always be balanced with the need to promote economical development in poor regions.

2.4.2 THE ECONOMIC VALUE OF WATER

In recent years increasing emphasis has been given to the economic value of water. The economics of water is one of the most important sections of water resource management policy and needs to be balanced with cultural and social concerns. The policy should aim to accord water its proper economic value and enable the water economy of the country to be integrated with the broader economy seamlessly and transparently. There are increasing numbers of examples of the commercialisation of water services and the establishment of mechanisms through which water can be traded so that its "real" value is attained.

2.4.3 PUBLIC PARTICIPATION

The importance of public awareness and the participation of stakeholders cannot be over emphasised. When Departments develop national water policy and new legislation in isolation which is locally implemented in program and plans for ESTs, it is very unlikely that the results will be implementable and enforceable, respectively. This is primarily because the main implementing agents at the local level in the long run are the users of water and not the government itself. Not only will implementation not be possible if users have not been consulted but the policy itself is unlikely to be sound. Local people, farmers, industrialists, environmentalists and civil society in general who use water every day in their particular fields have practical experience of what works and what does not work and this experience is invaluable in the preparation of policy.

2.4.4 GENDER ISSUES

Much attention has been given to the role of women in development over the past few years. A failure to ensure that the voice of women and their management abilities contribute to the introduction of ESTs and their operation result in a weak implementation and a lack of connection with the daily use of systems. Women play a major role in many aspects of water management, from the micro-situations of the home to the role played on a daily basis in agriculture. Therefore, special effort and consideration needs to be made in order to ensure that women play an adequate role.

2.4.5 EXPERTISE

It is critically important that a planning process is motivated, managed and run by professionals and experts from the country concerned and not only by outside experts and or partners, or financial and development agencies without direct interaction with the national and local governments and authorities, NGOs, etc. There are several cases in Africa where substantial input has been made by foreign sources which have inevitably been based upon foreign experiences within different sociological, hydrological, economic and political environments with the result that some of the policy measures and locally implemented ESTs are inappropriate and ineffective. This does not mean to say that foreign expertise has no contribution to make to a reform process, but it implies that south-south cooperation should be enforced. The key factor, however, is to ensure that the final judgment is made by knowledgeable local expertise and to ensure that policy and institutional arrangements are coherent with national and regional circumstances.

2.5 Economic and financial aspects

The objective of EST institutional arrangements should be to ensure optimum efficiency and the most beneficial use, balancing social and environmental requirements, while recognizing at the same time that water has a value and water supply and sanitation have a cost. Programs should ensure a balance between ensuring that water for basic human needs is available to the poor, and that where it is used for production or other beneficial use, it is properly valued.

Pricing and tariff arrangements should be examined thoroughly, in respect of the effects of pricing alternatives on all involved stakeholders. In situations of scarcity, policy should be considered whereby demand management can be exercised through the proper pricing of water, together with or as an alternative to, conventional supply management practices.

Programs should determine the budgetary resources and what aspects of EST management and development should be subsidized and where recurrent costs should be met from water tariff revenue.

Clear policy rules should determine the role of the private sector in water management and development, and the role of foreign donors and financiers and the impact thereof in the introduction of ESTs.

Compensation of water users who suffer from the introduction of generally effective ESTs should be considered.

2.6 Social, institutional and regulatory issues

The literature on regulation in general, or governance, sees a main function for the system of governance in allocating business responsibilities and risks among the parties involved and to design tariff and other rules so as to achieve an allocation that stimulates the development of the industry and generates balanced trade patterns. Risk exists in an unpredictable world. The use of water may develop differently than expected. Costs may become higher or lower and exchange rates will vary. Some risks can be calculated and possibly hedged, others remain completely uncertain or even unknown. The main question, as regards the development of ESTs, is who should bear these risks and bear the losses, or harvest the profits associated *(This paragraph draws on: Berg, S. V. ;Infrastructure regulation: Risk, Return and Performance; Global Utilities 1 (May), pp 3-10, 2001. Estach, A., Martimort, D. ; Politics, Transaction Cost, and the Design of Regulatory Institutions; World Bank Policy Research Working Paper, No. 2073, March 1999. Baldwin, R., Cave, M.; Understanding Regulation: Theory, Strategy and Practice; Oxford: Oxford University Press, 1999.)*.

Risks are allocated through the rules that determine how shifts in the distribution of rents (including revenues, costs and profits) along the value chain of water supply affect the position of the several parties involved. It is, thus, necessary to connect the notions of business responsibilities and risks. A main issue in the design of the governance structures is then to align the business responsibilities of the operator and the public bodies involved with the risk resulting from functional tasks and responsibilities.

In essence, this involves the following steps: First, identify the main areas of responsibility involved and the risks associated; second, assign the responsibilities and associated risks to the party best able to manage it; third, establish the arrangement to achieve this allocation of risks and responsibilities.

It is obvious that there exists a wide variety of governance solutions, ranging from purely public operated systems, to predominantly privately owned and operated systems with only minor public involvement. Bearing risk has a cost and the party bearing the risk will likely demand something in return. The aim of the design of governance systems and arrangements should be to allocate responsibilities and risks between the operator(s) and public authorities such that, firstly, responsibilities are allocated to the parties best able to undertake them and, secondly, risks are borne by the parties best able to manage them. Allocating risk to a party, generally, gives the party an incentive to alter its behaviour to minimize its costs. Risk allocation therefore affects the parties' incentives to improve efficiency. Moreover, some risks cannot be controlled or anticipated and should be allocated to the party best able to diversify or absorb it. This latter notion means that parties should have the following abilities: to influence or control the risk factor; to predict changes in the relevant risk factor; to control the sensitivity of the business' value to the risk factor; or to absorb the risk. Allocating each risk to the party best able to manage it reduces costs to the customers and attracts sound private investment.

A particular element of risk is located precisely in the role of the regulator itself. The performance of regulatory frameworks is essential in securing investor's confidence. A regulatory system should be efficient, in the sense that the benefits of its involvement to society should outweigh the direct and indirect costs of its interventions. To operate effectively, regulators should have a clear and politically determined legislative mandate that establish in unambiguous terms their objectives, their tasks and the degree of freedom in developing guidelines and rules. To operate independently on behalf of their general public responsibilities, regulatory systems and regulators should seek to secure and carefully balance the interests of both the several segments of the industry and the (large and small) consumers.

To achieve an appropriate level of legitimization, regulators should be held accountable both in respect of the reasons they give for their decisions and by making the regulatory process fair, open and accessible to the firms and stakeholders alike. To gain trust in the industry and among consumers, regulators should have a more than adequate level of expertise, which is as independent as possible from industrial, consumer, or political interests.

Regulators can contribute to market transparency by publishing assessments of market developments and investment opportunities.

2.7 Outlook for the 21st century

Overall, the challenges with respect to urban water supply and sanitation are huge, particularly in the developing nations of the world. On the one hand, there is the need to enhance the use of ESTs to address a number of pressing global developments. These include the effects of climate change and its impact on water resources, which require adequate responses in the supply and use of water in urban concentrations of population. The application of the right ESTs in the right place is crucial in fighting this battle.

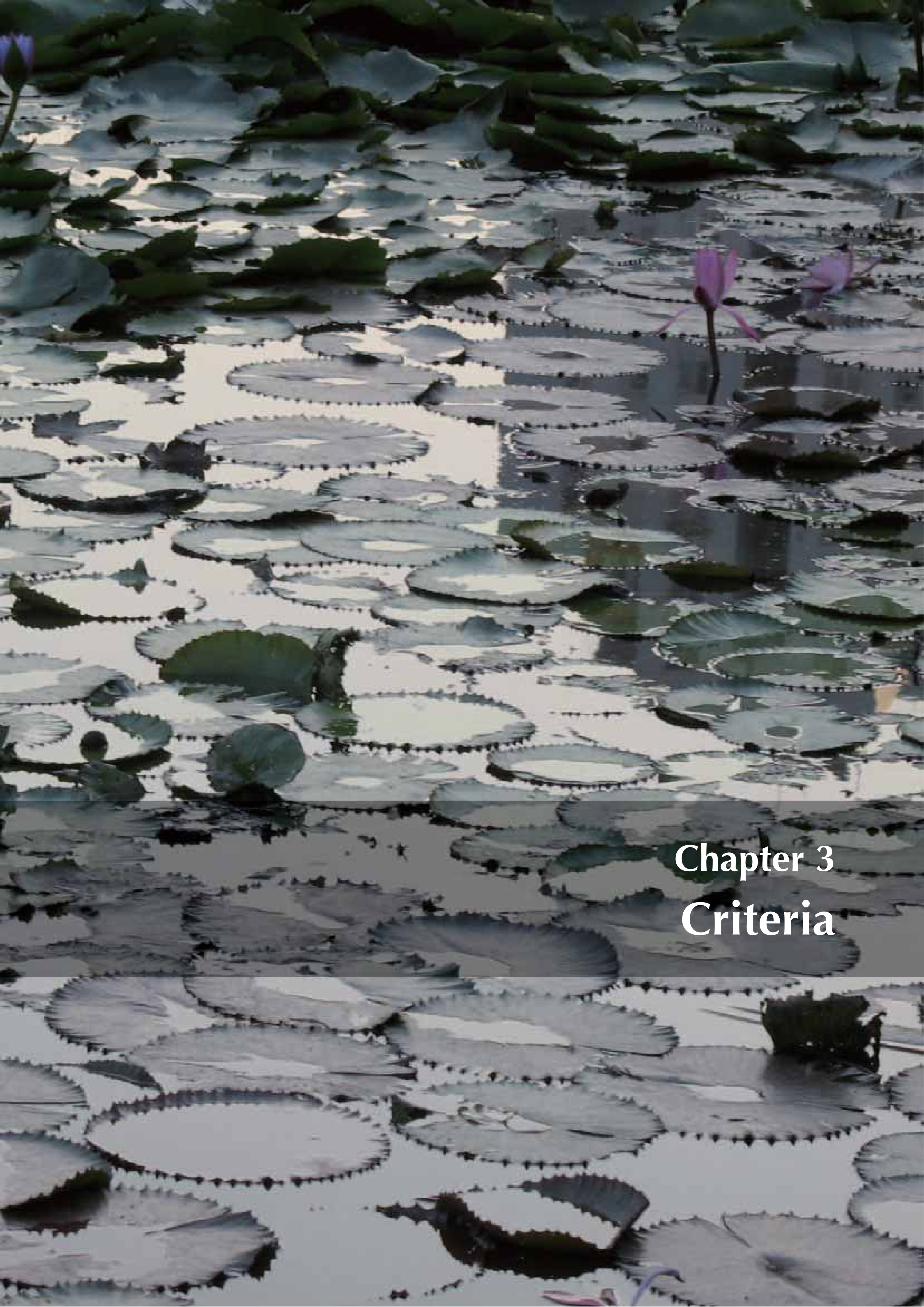
Another phenomenon driving the enhanced use of ESTs is the increasing urbanization of many developing countries and the development of mega-cities, where the rising demand for clean water and the need for an adequate system of sanitation will require unconventional measures, including various types of ESTs.

In general, safe access to water and sanitation is a prerequisite to achieve the Millennium Development Goals. Of particular importance in this respect is a balanced approach that addresses issues like health, education, poverty reduction and care for the environment. In general, it should be understood that an adequate supply of water, sanitation service, but also energy, are among the main preconditions to achieve these goals. Whereas there seems to exist a constant pressure from foreign NGOs to address environmental issues, the main direct concern for policymakers is to improve health conditions and foster socio-economic development. External support for these objectives is less prominent, however. Yet, eventually, the challenge is to implement ESTs in developing countries which take all these objectives into consideration.

The present Sourcebook is produced to support UNEPs Bali Strategic Plan for Capacity Building and Technology Transfer. A number of elements, as discussed in this Sourcebook, are parts of activities and projects taken under the auspices of this strategic plan. Examples are (integrated) water management, the development of urban sanitation approaches, water supply management and general local capacity building in respect to resources.

Bali Strategic Plan for Technology Support and Capacity Building

The need for environment-related technology support and capacity building in developing countries as well as in countries with economies in transition was recognized in General Assembly resolutions 2997 (XXVII) of December 1972 and 3436 (XXX) of December 1975, as well as in Agenda 21 and the Plan of Implementation of the World Summit on Sustainable Development 1992 and 2002 respectively. In 2002 UNEP Governing Council recognized the urgent need to develop a strategic plan for the provision of technology support and capacity building to developing countries as well as to countries with economies in transition. As a result the Bali Strategic Plan for Technology Support and Capacity Building came to light (Indonesia; 2005). The Plan provides, amongst other consideration, an effective strategy for strengthening technology support and cooperation by supporting the creation of an enabling environment for innovation and transfer through the enhancement of international cooperation conductive to innovation and the development, transfer and dissemination of technologies. *(The Bali Strategic Plan is available at: http://www.unep.org/GC/GC23/documents/GC23-6-add-1.pdf)*



Chapter 3
Criteria

3.1 Introduction - How to choose the right EST at the right place at the right moment?

Who is choosing?

This is a Sourcebook for decision makers. Who are they? The Sourcebook addresses not only a narrow group of water specialists that have to take technical decisions but all participants in interactive decision-making processes related to the role of water in an urban environment. Thus, the Sourcebook is for government officials, politicians, policy makers in public works, health and spatial planning departments, water board and drinking water company officials, NGO members and local residents. These actors operate at different levels of decision-making such as:

o Higher Government Institutions level

o Financing Institutions level

o Technical agencies and services level

o Local government and Community level

o Enterprise level

Basically, these are the levels also described in the Methodology for Assessment of Environmentally Sound Technologies. *(Modak, P.; Making Right Choices, a framework for Sustainability Assessment of Technology (SAT); UNEP IETC training course presentation, January 2006.)*

In this Sourcebook decision makers at all these levels should find technical information, policy experiences, ideas and arguments that may help them to take appropriate decisions.

How to choose?

What are appropriate decisions? A shared concern about water issues does not automatically produce appropriate decisions. The objectives of water use efficiency have to fit in with the objectives of hydropower, flood control, irrigation and other waterworks. In a wider perspective, of course, water policies should be part of overall sustainable development policies. In the Methodology for Assessment of Environmentally Sound Technologies (UNEP- IETC, January 2006) a framework for Sustainability Assessment of Technology (SAT) emerges. The findings of this search for methodology are the point of departure of this Sourcebook. SAT, however, focuses primarily on the *operational* assessment. This operational approach should be complemented by an elaboration of the *strategic* choices in planning processes. Therefore, this chapter will elaborate an approach for choosing Technologies in Sustainable Strategies (TISS). In the operational stage the central question is: *which EST works most efficiently?* In the strategic stage the central question is: *which EST fits best in a sustainable strategy?* At all the abovementioned levels of decision making both operational and strategic questions play a role. The operational questions, however, may be more in the foreground at the levels of financial institutions, technical agencies and enterprises. Strategic integration questions are pivotal at the national, regional, local and neighbourhood levels of general governance.

This chapter

In a given decision situation there are a number of feasible policies as discussed in the previous chapter.

SAT
(Sustainability Assessment of Technologies)
Efficiency,
Operational assessment,
financial institutions, technical agencies, enterprises

TISS
(Technologies in Sustainable Strategies)
Fit,
Strategic choices,
governmental institutions
at from national to neighborhood levels

Illustration 5: Relationship and complementarities of SAT and TISS approaches.

Moreover, there are a variety of environmentally sound technologies that will be discussed in the next chapter. This chapter is about the criteria for selecting the technical and policy options in a given spatial, cultural and political situation. First, *efficiency* and *fit* will be introduced as the central criteria for making sustainable choices in the operational and strategic stages of planning. Then, the TISS approach will be presented and the last section will discuss the way TISS and SAT will be able to complement each other in practical decision making.

3.2 Criteria: efficiency and fit

In this section the criteria efficiency and fit are described, combining traditional and environmental objectives by using a realistic approach.

Learning from a case

In operational decision making, usually *efficiency* is the dominant criterion. In general terms efficiency means *maximum results* with *minimal resources*. In urban water management practice *results* are defined in terms of safety, health, food supply and comfort, but sometimes also as accessible waterways and beautiful fountains. *Resources* can be defined as money, but also as existing infrastructure or as the natural and human resources. Thus *efficiency* can have a variety of meanings, as illustrated by the Bissau case:

The Bissau case

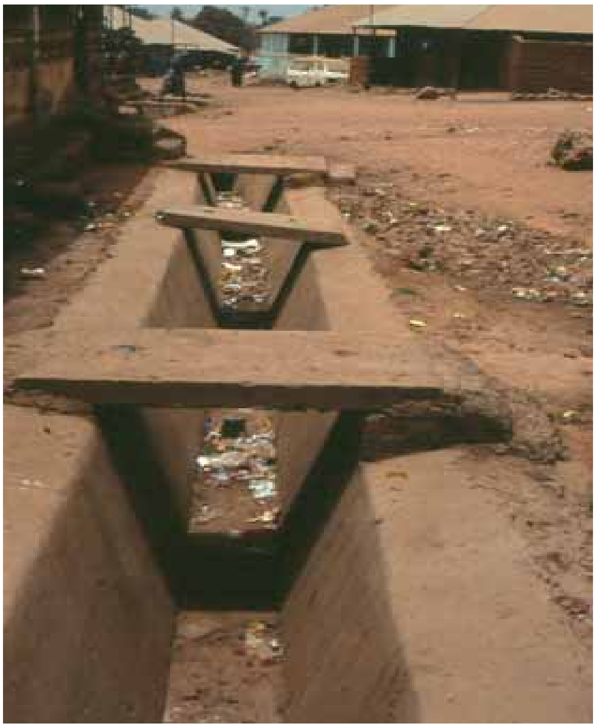
Bissau is the capital of Guinea Bissau in West Africa. As with many cities, Bissau is attracting huge numbers of people from the surrounding countryside and most of them have settled in squatter areas around the old colonial centre. In these districts a neighbourhood-upgrading programme is going on, coordinated by a local public organisation and supported by foreign aid. The description here is based on an assessment of this programme in the 1990s.

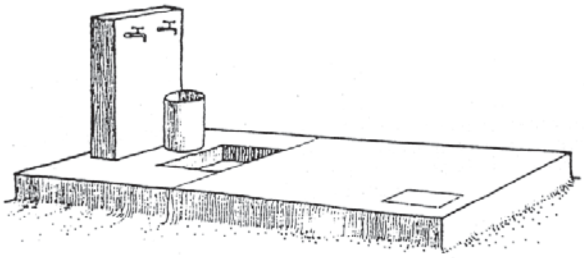
The programme has several upgrading activities.

- *Improving adobe houses* is necessary because of damage by moisture and termites. There is a project team of young men who are learning by doing under professional guidance. They construct new foundations using concrete blocks. While the team is doing this, the residents produce adobe blocks, often using the soil they dig from their own yard. Then the resident and his family rebuild the house. Finally the team helps with the construction of the roof.
- *Improving drainage* is essential because the tropical rains erode yards and roads and mix with wastewater that is spread over the whole area. The project team constructs a new network of 50 cm deep street gutters. In this way stormwater is carried to the edge of the settlements.
- *Improving access to healthy drinking water*. The old wells people used were contaminated by latrine overflows, wastewater and run-off water. This is considered one of the main causes of widespread diarrhoea and other diseases. New taps fed by the centrally piped water network of the city bring good quality water to several tap points in the neighbourhoods.
- *Improving sanitation.* Health problems are also caused by poor sanitation. Overflows from the old latrines and wastewater form green and black streams in backyards and streets and create stagnant pools. Thus, insects can breed and malaria can spread. The sanitation project involves the construction of new improved pour-flush pit-latrines with a water seal that prevents fly breeding and odours. The system works with two pits. If the latrine is used by the usual extended family of about 20 people the first pit will be full in two years. Then it is sealed and the faeces and liquids go to the second pit. After two years the first pit can be emptied and the content can be used as manure on the fields in the urban fringe. Wastewater of the latrines infiltrates into the ground.

The assessment of the combined project revealed several flaws. In short the new piped water taps ran dry several times per day. As a result many people returned to the old wells. These were often more contaminated than before because the new pit-latrines contaminated the groundwater close to the wells. Groundwater is also polluted by solid waste thrown into the pits dug for the production of adobe blocks for new houses. Moreover, the new network of gutters now removes efficiently most of the clean rainwater that used to recharge the groundwater for the wells. The gutters cause an extra problem. On the edge of the settlements, where the gutters end, storm water peaks cause serious erosion. This creates problems for a newly developed scheme of vegetable gardens in the urban fringe and even threatens houses.

The problem with piped water taps goes back to the electric power of the piped water network pumps. Power failures happen every day and the reasons behind are complex in particularly when the direct human component is involved. For example, in Guinea Bissau (1993) when a newcomer moved, a man of the power agency came to connect the house to the electricity grid informing that the existing regular grid was not very reliable, offering at the same time to make a connection with the special power line of the hospital in the nearby, this would have implied to pay for the extra "service". Similar problems can be encountered in many countries still nowadays where municipal and government officials are structurally underpaid hence they are bound to retort to unlawful practices. The situation shows that the problems are not easy to be solved as long as their roots are not properly tackled, which at times are beyond technical reasons. Furthermore, unlawful practices such as this one could be deeply rooted strongly affecting the administrative, financing and political stability of the system hence also affecting the quality of Governance itself. *(See also: Acioly, C. C.; Settlement Planning and Assisted Self-Help Housing, an approach to neighbourhood upgrading in a Sub-Saharan African City; Faculty of Architecture TU Delft, 1992. TAUW, WASTE, IBN-DLO; Guidelines*





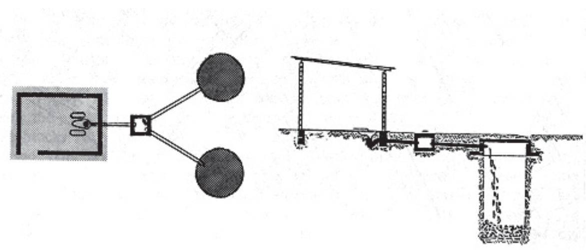


Illustration 6: Bissau case from top to bottom: - drainage, -new tap points, -new pour-flush pit, - erosion of discharge area.

for Environmental Impact Assessment, Projecto de Melhoramento dos Bairros de Bissau; Department of International Cooperation, Ministry of Foreign Affairs, The Hague, 1993.)

The Bissau case is not exceptional for the situation in developing countries and at a more general level we may learn from the case about the choice and use of criteria for the application of ESTs in many different situations.

What lessons can be learnt from does the Bissau case?

1. It is not sustainable to work -even with the best intentions- on improving the efficiency of drinking water supply, sanitation and drainage separately. Plans for *flows* must fit together. Different water flows and the flows of energy and waste materials must be tuned to each other.
2. It is not sustainable to only implement efficient methods for improving the quality of life in one neighbourhood. Problems should not be shifted to the urban fringe or to the neighbours. Plans for *areas* must fit together.
3. It is not sustainable to construct an efficient technical system if the organisation of management and maintenance fails to sustain it. Plans for *actors* must fit together. Both individuals and organisations must act together to make things work.

Thus, in planning processes for sustainable development, a strategic stage is important to reach consensus among the key actors to make things fit. In this stage *fit*, in the context of flows, areas and actors, is an important criterion.

It would be possible to include all of the above mentioned aspects in the *efficiency* criterion. However, to avoid confusion, this Sourcebook uses *efficiency* to refer to the direct resource-result relationships in terms of materials or funds. *Fit*, then, refers to the interaction of context and system variables.

This means that *fit* is linked to the strategic stage, where a compromise between conflicting interests, or more positively, shared understanding and consensus building about ambitions and responsibility, lead to a vision and a strategic plan that create the basis for the operational stage. In that stage the integrated vision is then translated into concrete operational plans with specific measurable targets that can be reached within a fixed time for a fixed budget.

3.3 Technologies in Sustainable Strategies (TISS)

The *fit* criterion

What does fit mean as a criterion for the selection of ESTs in the context of sustainable integrated water management? *Flows, areas* and *actor* perspectives provide a frame for detailed analysis and discussions that can specify *fit* in a concrete planning situation.

The frame stems from the so-called Ecópolis strategy, a conceptual framework for sustainable development conceived at the time of the Rio Conference in 1992 and first presented at the 1992 UN-ECE conference on Urban and Regional Research in Ankara (*Tjallingii, S.; Strategies for the Urban Ecosystem; in: UN Economic Commission for Europe: Urban Ecology, 7th conference on urban and regional research; Ankara, Turkey, Ministry of Public Works and Settlements, Ankara, Turkey, 1992. Tjallingii, S.; Ecópolis; Backhuys Publishers, Leiden, Netherlands, 1995.*). A decade later an assessment study demonstrated the value of the strategic frame in practical urban projects (*Tjallingii, S.; Sustainable and green: Ecópolis and urban planning; in: Konijnendijk, Schipperijn &Hoyer (ed.); Forestry serving Urbanised Societies; IUFRO, Vienna, 2004.*).

The Ecópolis frame is drawn as a triangle with three eyes looking at the plan in the middle. Instead of wedges of the cake, the different aspects are represented as viewpoints. At these points the specialised professions develop their expertise with the depth and details of their disciplines, but from these points the experts should look at the whole.

In a *flows perspective* flows should fit in a chain-management approach, from cradle to grave or, even better, from cradle to cradle. The basic idea is closing circles as far as possible, a common policy objective in strategies for sustainable development such as the Chinese policy for a circular economy or the general 3R strategy: reduce, reuse, and recycle. The underlying research practice is Life Cycle Analysis or Material Flow Analysis. Urban systems are connected to other links in the chain. The city should be responsible for incoming and outgoing flows. In decision making about the making of the plan the priorities are: first, think about reducing use (demand); then, look at sustainable resources; and finally, pay attention to the external effects of supply and discharge flows. Water is not just one flow. The Bissau case of water and sanitation projects illustrates the importance of making the rainwater run-off, groundwater, drinking water and wastewater flows fit together.

In an *area perspective*, the spatial quality should turn neutral spaces to places, where people can feel at home or feel responsible for. Smaller areas must fit in larger territorial systems like catchment areas. All place-bound qualities should be considered here. The basic research is landscape ecological analysis and studies about the socioeconomic strengths and weaknesses of the planning area at the regional, urban and neighbourhood levels. The city should be treated as a living system. In decision making about the making of the plan the first priority is to think about how to use the potential of the existing urban landscape, for instance for water resources and water storage. The second priority is to create conditions for safety, health and quality of life in the area of the plan without shifting the problems to the neighbours. The third point is to look at conditions for wildlife. The Bissau case demonstrates how much it matters to look at the places for new latrines, to use the rainwater infiltration capacity of

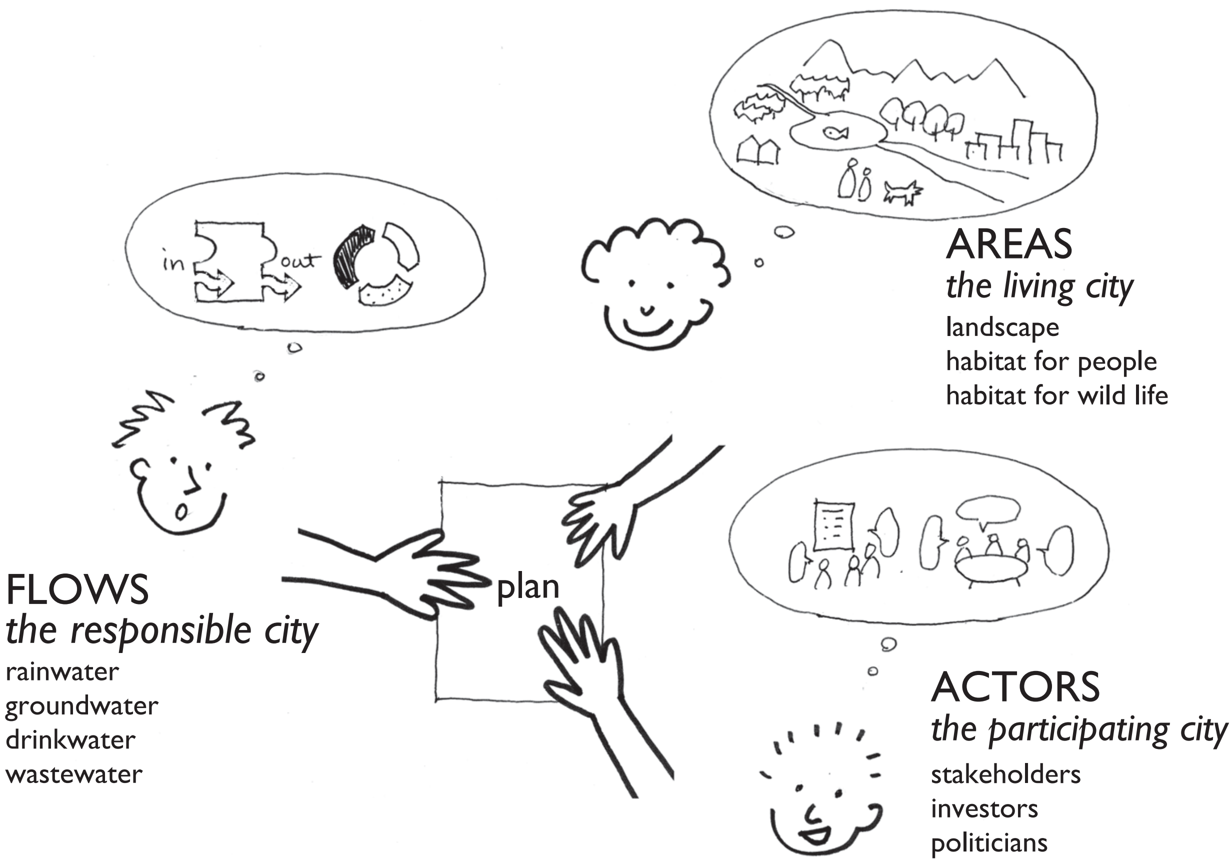


Illustration 7: The Ecópolis framework.

the building sites near the wells and to consider the erosion effects to neighbouring areas. Spatial design matters.

In an *actor perspective* the stakeholders should develop commitment by participating in a process that creates a basis for financing the plan and creating public support for its realisation. The relevant research starts with a stakeholder analysis. Economic and socio-cultural studies may further explore the sustainable development options in this situation with these actors. In decision making about the making of the plan the first priority is to create consensus about a legal, financial and spatial frame for sustainable development. The infrastructure networks for traffic and water, for instance, should create an environmentally sound and socially fair frame with flexible infill for a variety of activities. A framework for learning by doing, for instance through pilot projects and assessment studies is essential for required innovations towards more sustainable development. The second priority is to integrate use and management practices in the plan. Also here, a context of interaction and learning is valuable. Last but not least, enforcement of the rules is necessary. Among other things, the Bissau case shows the importance of a learning organisation and the role of management and maintenance.

Illustration 8 summarises sustainable planning priorities for flows, areas and actors. Together, these priorities specify the fit criterion for the selection of ESTs.

This set of criteria may give *fit* a place on the strategic stage of a planning process where the main issue is how to use the opportunities of the planning situation to make the best sustainable plan. Thus, a general frame is created for the interactive process of specifying the focus and the values of *fit* in a given situation with and for the stakeholders in the plan. This does not imply the reinventing of the wheel in every plan. The criteria represent general questions that need to be answered in any case, but the answers can be different. Moreover, there is a whole literature about the experiences in other cases that may guide the selection of ESTs in the framework of practical planning processes. *(See for example: the case studies in the GWP Toolbox: http://www.gwptoolbox.org)* Lessons learnt can be translated into guidelines, guiding principles or guiding models.

Fit **related to people, planet and prosperity**

Fit, as a criterion for the selection of ESTs relates to the context of sustainable development. The most common criteria for sustainable development world-wide are the *People, Planet and Prosperity* (PPP, not to be confused with *Public-Private Partnership*, or *Poor People Pricing*!) criteria. How does fit in a flow, area or actor perspective relate to these three? PPP has played an important role to create consensus among policy makers at the international level. It also appeals to the general public because it makes it easier to understand the essential strategy for sustainable development: making social and economic development ecologically sound. At the local level or at the level of concrete water management decisions, however, PPP is too general. People, planet and prosperity indicate the direction of *what* should be done, but the general titles do not help us very much in our search *how* to do things.

Flows	Areas	Actors
1. prevent unnecessary use.	1. use landscape potential (natural and cultural).	1. create consensus about sustainable legal & spatial frame.
2. use resources in a sustainable and durable way.	2. create safe, healthy environmentally sound conditions.	2. organise interactive management of use and maintenance.
3. take responsibility for supply and discharge of flows.	3. create conditions for wildlife (biodiversity).	3. follow the rules and enforce them.

Illustration 8: Priorities for flows areas and actors in sustainable urban development. (Tjallingii, 1995)

The concept of *planet* is given a more practical meaning by dividing it into *flows* and *areas,* two categories corresponding to environmental and resource policy on the one hand and spatial policy on the other. At the local level these policies have their own governors, legislation and institutions. They also have their own experts, trained in different disciplines. It seems sensible to distinguish between the flow and area perspectives if we want them to co-operate in making plans for one part of the planet. *People* and *Prosperity*, on the other hand, are first combined in the *actors*' perspective. In planning, it is important to first make an actor analysis (stakeholder analysis) and then elaborate the actual and potential social and economic roles of the actor groups in the context of the plan. Only by linking social and economic aspects to the concrete actors, governance issues can be addressed. Who benefits? Who carries the burden?

The two tables (*Illustration 9*) demonstrate how the flows area and actor perspectives relate to each other in the practical situation of selecting ESTs in the context of plan evaluation and in the context of designing plans.

TISS methodology

TISS (Technologies In Sustainable Strategies) focuses on the strategic stage of planning, starting with the initiative in which the key stakeholders commit themselves to work together in the making of a strategic plan that will create conditions for further operational planning. Chapter 2 discussed the interrelations between overall policies and strategies for a concrete project. Here, the emphasis is on the role of strategic and operational planning.

TISS and SAT methodologies

Illustration 10 shows the different positions of SAT and TISS in the planning cycle. This indicates how the two approaches can complement each other. Their role is different. SAT focuses on the rigorous methods in context of testing and selecting the best technology to serve the targets chosen. This suits operational planning where the results are measured for their conformance to the targets.

TISS, on the other hand, focuses on the imagination and creativity required to generate the best strategy for integrated water resource management taking an optimal use of the local opportunities. This suits strategic planning where the success or failure can be assessed by looking at the performance. To make good decisions, we need them both.

3.4 Strategy and performance

To assess the capacity of the TISS approach to perform well, we should look at the way it can generate sustainable and practical solutions, keeping in mind that we will need operational plans to realise these solutions. To illustrate the TISS perspective, we return to the Bissau case (*see section 3.2*).

The description of the case in section 3.2 can be considered as the ORIENTATION study in the planning cycle scheme of *Illustration 10*. The conclusions of this orientation study can be formulated in a SWOT analysis scheme that considers the Strengths, Weaknesses, Opportunities and Threats. The result may look like the points listed in *Table 1*. Typically, the items in the SWOT scheme should result from joint site visits, meetings and discussions with the key stakeholders who will then decide to engage in a planning process for improvement by agreeing to a starting document.

The 'starting document' can create conditions to launch a project team that can carry out the study that will lead to a strategic plan. The first step is a deeper ANALYSIS of the flows, areas and actors issues at stake. (*See Illustration 10*) The questions are:

- *Which flows are relevant?* In this case rainwater, groundwater, drinking water and wastewater are relevant and so are the solid waste materials and energy flows.
- *Which flow choices can be made?* In this case specific questions are, for example: Improving the old wells or switching to new taps? Opting for wet pit latrines or for dry ones?

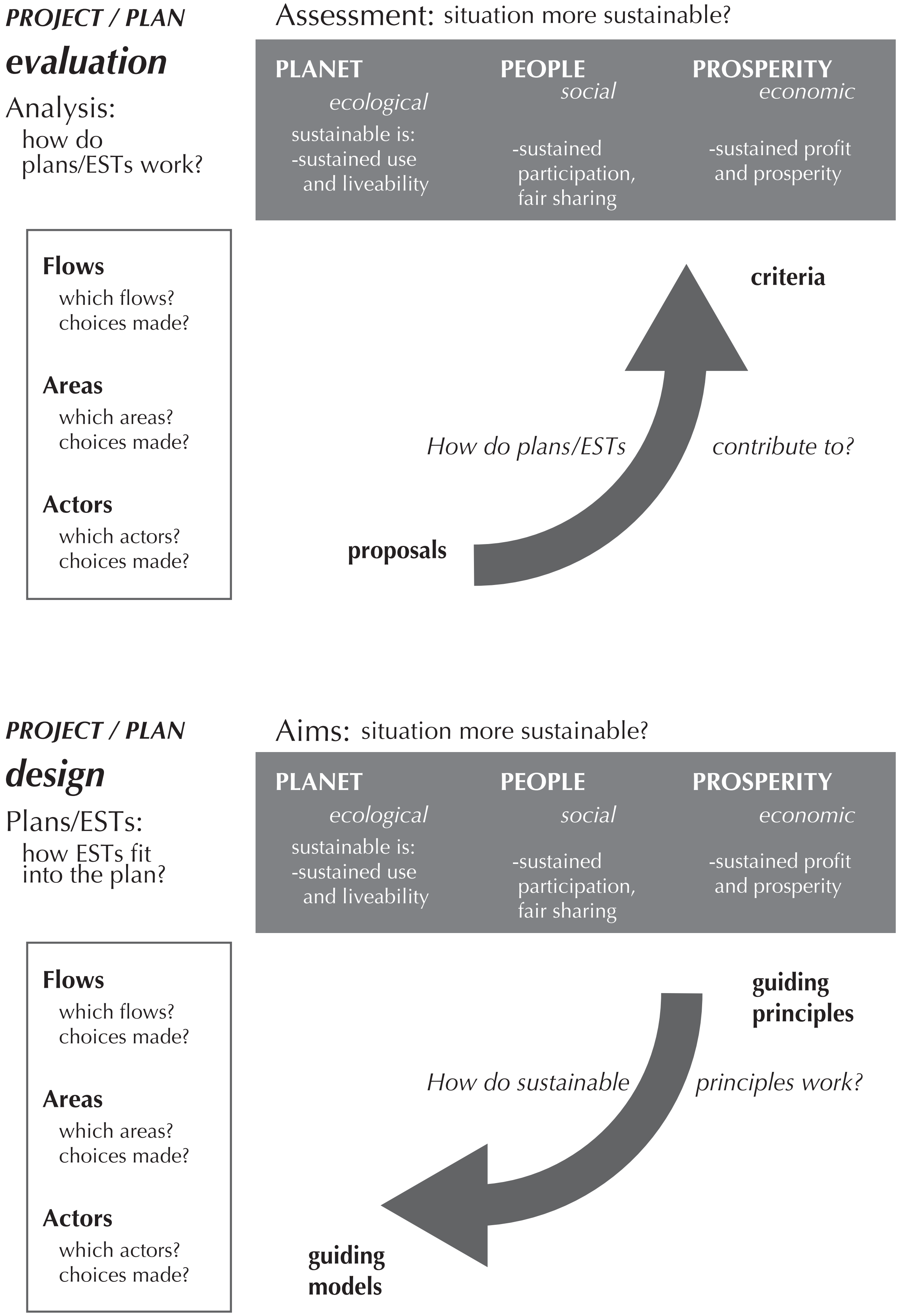


Illustration 9: Top: Plan evaluation for sustainable urban development. Bottom: Planning and design for sustainable urban development.

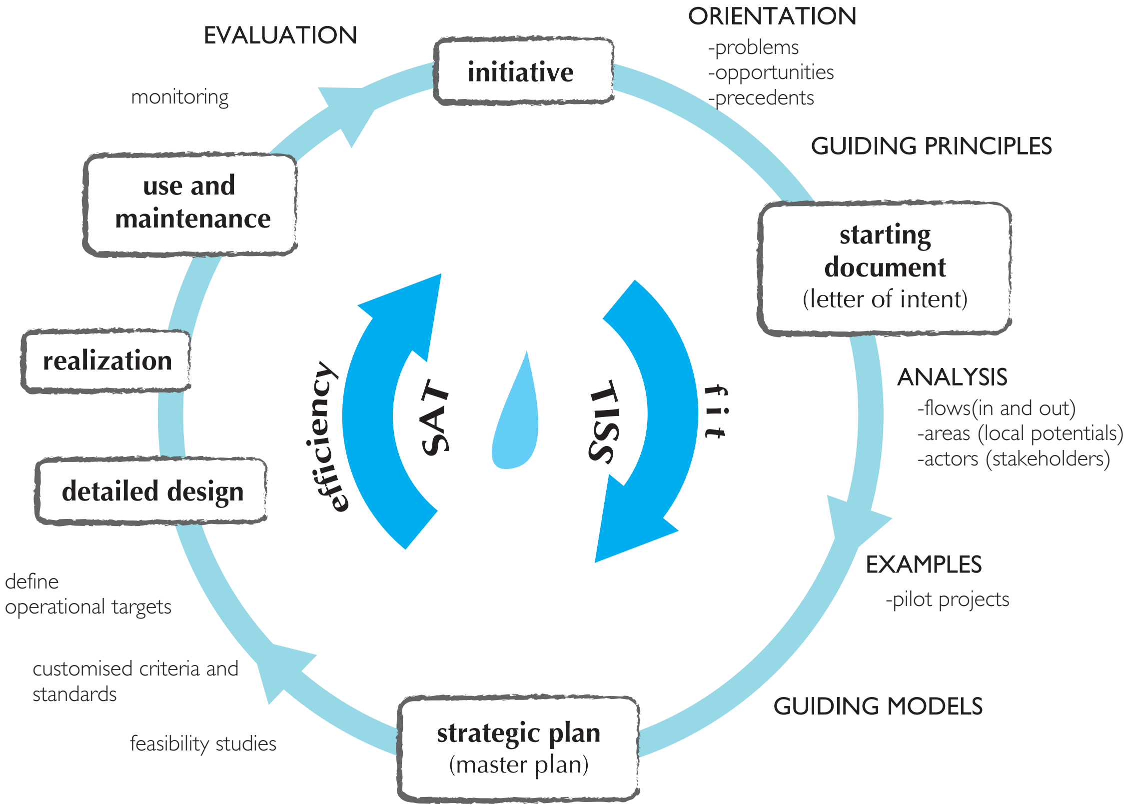


Illustration 10: Planning Cycle. Steps in strategic and operational planning considering SAT and TISS.

STRENGTHS > co-operation with residents (house building) > capacity-building of professionals for realisation of water and sanitation construction work	WEAKNESSES > unreliable power system > water taps running dry frequently > latrines located too close to wells > drainage gutters increase erosion > polluted wells
THREATS > failure of parts may drag down the whole > weak governance may weaken the neighbourhood upgrading process	OPPORTUNITIES > organisation of neighbourhood upgrading process has created a good organisational structure > potential for improvement is visible for all actors

Table 1: SWOT analysis of the Bissau case.

- o *Which are the relevant areas?* In this case the individual houses with their backyards, the streets and the whole neighbourhood are relevant spatial units to consider. But one should also pay attention to adjoining neighbourhoods and to the urban periphery where the drainage gutters lead to and the municipal dumping site for solid waste is situated.
- o *Which area choices can be made?* In this case specific questions are, for example: Should the drinking water system be based on taps or wells in many places or just a few in every neighbourhood? Should places inside the settlement be kept free for growing rice seedlings in the wet season, to plant them in the irrigated urban fringe rice paddies in the dry season? Or should further densification of the settlement be promoted?
- o *Who are the relevant actors?* In this case the residents in their extended families, women, children, small business keepers are relevant actors, but also government agencies and NGOs, such as the neighbourhood upgrading teams active in Bissau.
- o *Which actor choices can be made?* In the case of Bissau, as in many others, the choice is between centralised piped water supply, dependent on weak municipal institutions and a more decentralised approach in which individual residents have more responsibility for the quality of drinking water from the wells.

Obviously, the answers to these questions are interrelated and it will take time and effort to generate solutions that fit together and create conditions for a sustainable future in these neighbourhoods. In the process of generating planning concepts, as indicated in *Illustration 10*, EXAMPLES from other cities may be very helpful, and so do GUIDING MODELS based on lessons learnt from other cases. Solutions cannot be copied, but the ideas incorporated in the examples and conceptual models may be helpful in generating solutions that fit. It will be the task of the project team to engage other stakeholders in the process of making the strategic plan. Excursions to similar projects and meetings to discuss planning alternatives can all be part of this process. Professional assistance to make drawings and to do some first calculations for assessing the efficiency of alternative plans are essential elements of the planning process at this stage.

Chapter 4
Environmentally Sound Technologies and Policies

4.1 Introduction

This chapter describes a selection of Environmentally Sound Technologies (ESTs) for urban and domestic water use. A difference can be made between "soft" and "hard" technologies, as already discussed in chapter 1. However, the application of technical infrastructure, equipment and machines is in general closely connected to the overall economic, social and legal policies, regulations, and management strategies. This chapter therefore combines both "hard" technologies and policies. Together they will be referred to as ESTs.

Selected technologies that can be used to support Integrated Water Resource Management (IWRM) and in particular water management in the urban and domestic sectors are the focus of the brief descriptions in this chapter. It provides an overview of a large number of technologies available and aims to support politicians and water-related professionals to develop plans for innovative and sustainable solutions under consideration of the specific basic conditions and potential of each local case and problem.

The specific basic conditions of each case offer immense potential for the development of sustainable solutions. Each section of the urban water cycle has an introduction with questions that suggest a stepwise analysis of the local decision situation as a basis for the choice of ESTs out of the large number of technologies available, followed by a general discussion of the pros and cons of the respective ESTs. Basic information about different ESTs concludes each of the four sections. For the introduction of an effective and creative planning process with participation of all involved actors, it is crucial to have an idea about the general properties of specific ESTs. For more detailed information about specific EST applications there are a number of sources available which can be sought, e.g.:

- o UNESCO International Hydrological Programme (IHP); Sixth Phase, 2002-2007, available at: *http://typo38.unesco.org/en/ihp-sitemap.html*
- o Habitat, Rand Water; Water Demand Management Cookbook; Nairobi/Johannesburg, 2003, available at: *http://www.unhabitat.org/pmss/getPage.asp?page=bookView&book=1781*

The ESTs described in the following sections are classified in three categories, not only to allow the allocation of the potential application scale but also to give an insight in the related management practices:

- o Public and centralized systems, constructed, managed and supervised by public agencies.
- o Collective and semi decentralized systems, constructed and managed by technical specialists employed or hired by schools, hospitals, hotels etc. Usually, public agencies supervise quality control.
- o Individual and decentralized systems, operated by individual residents or shopkeepers. Usually, public agencies supervise and support construction, technical maintenance and quality control.

The boundaries between the three categories are not rigid. In some cases the distinction between centralized and decentralized applications may be difficult to make, as the differences are gradual and include semi-decentralized or semi-centralized applications. The definition of centralized and decentralized is here related to the urban environment. Applications, which are serving cities or districts, are defined as centralized or semi-centralized, while applications serving housing estates, buildings or households are defined as semi-decentralized or decentralized.

The most important ESTs, are included in the following table and are assigned to the four main sections of the urban water cycle *(see also Illustration 1)* that are also the sections of this chapter. The table gives an overview about the principal options and the possible application scales.

- o Water storage and augmentation
- o Water supply and distribution
- o Water use and saving
- o Water reuse, recycling and disposal

Section of water cycle		EST Environmental Sound Technology / Technology, know how for & management of	Technologically and institutionally embedding: Public centralized system	Collective semi-decentralized system	Individual decentralized system
Water storage & augmentation	keeping quantity & quality	Ponds and reservoirs	+++	++	+
		Artificial recharge of groundwater	+	+++	+++
		Water tanks	+	++	+++
		Rainwater harvesting - runoff in surface water	++	+++	++
		Rainwater harvesting - runoff in groundwater	+	++	+++
		Rainwater harvesting - runoff in tanks	____	++	+++
		Treated sewage - effluent in surface water	+++	++	+
		Treated sewage - effluent in groundwater	+++	+++	+++
Water supply & distribution	providing water efficiently & safe	Surface water abstraction	+++	++	+
		Groundwater abstraction	++	+++	++
		Water supply reservoirs	++	+++	++
		Transfer of water	++		
		Single pipeline system (one water quality)	+++	++	+
		Dual pipeline system (two water qualities)	+	+++	++
		Water containers (bottles and tanks)	____	++	+
		Centralized treatment systems	+++	+	
		Point of use treatment systems	____	++	+++
Water use & saving	using water efficiently	Waterless toilets (e.g. compost & dry)	____	++	+++
		Water-saving toilets	____	+++	+++
		Water-saving urinals	____	+++	+
		Waterless urinals	____	+++	+
		Water-saving taps	____	+++	+++
		Water-saving showerheads	____	+++	+++
		Pressure reducers	+++	+++	+
		Water-saving household appliances	____	+	+++
		Economised water use for personal hygiene	____	++	+++
		Economised water use for cleaning and watering	+++	++	+++
Water reuse, recycling & safe disposal	purifying water safely	Domestic rainwater use	+	+++	+++
		On-site treatment of grey water		+++	+++
		Constructed wetlands	+	+++	+++
		On-site and near-site treatment of black water and mixed sewage	____	+++	+++
		Separating rainwater from sewer systems	____	++	+++
		Environmentally sound centralized sewage treatment in developing countries for reuse	+++	+	
legend					
Level technologically and institutionally embedding			low	medium	high
Active operation and maintenance			+	++	+++
Support and creating conditions (legal, financial, skills)			_	__	____

Table 2: Overview of ESTs assigned to the four main sections of the urban water cycle with potential scales of application.

For the sake of a clear presentation, the ESTs are allocated to the four sections of the urban water cycle. In an integrated planning perspective, however, this is an artificial choice. Decisions in practice have to consider promising combinations of ESTs from different sections. These integrated combinations will be the focus of chapter 5.

4.2 Water storage and augmentation ESTs

4.2.1 INTRODUCTION

The section *storage and augmentation* discusses appropriate technologies and policies for maintaining and replenishing sources for water supply, regarding quality and quantity issues in the urban water sector.

The stepwise analysis of flows, areas and actors (4.2.2) provides the required information for the discussion of the main arguments (4.2.3) for the selection and combination of specific ESTs presented in the final subsection (4.2.4).

The analysis of the existing situation should point out all available yet missing information. The aim of the analysis is a clear understanding of the facts and uncertainties as a basis for the decision making process. Selected ESTs should fit in this specific situation.

4.2.2 ANALYSIS OF THE DECISION SITUATION

4.2.2.1 Analysis of flows: Quantity aspects

- o The first step is to make a *potential water balance* of the urban area and relate this balance to the higher level of the (river) basin. This implies making an analysis of the natural input and output in annual averages. Due to climate change, precipitation and evaporation patterns as well as the related infiltration, runoff and river flow patterns are changing, which may lead also to declining water quality in open water bodies and aquifers (*see also Box "Earth's tropical belt is expanding" and "Effects of climate change"*). Therefore, relevant data and scenarios should be collected.
- o The second step is an analysis of the rhythms or patterns of rainfall and evapotranspiration and of the other ingoing and outgoing flows (primary infiltration and runoff). They can be measured, for instance, in monthly averages. Sometimes, the seasonal rhythm is most relevant, but in other cases the diurnal rhythm matters, as in the case of potential dew harvesting. Peak events have their own rhythm given in the return periods of 10 or 100 years.
- o The third step is to analyse and compare the actual man-made balance of water use: residential and industrial water use, the discharge of wastewater and storm water run-off. Although not strictly urban, agricultural water use, usually the biggest water consumer, cannot be left out from the balance, especially not at the river basin level. A comparison of the man-made with the natural balance may result in a better understanding of the problems and opportunities for storage and augmentation in the long run.

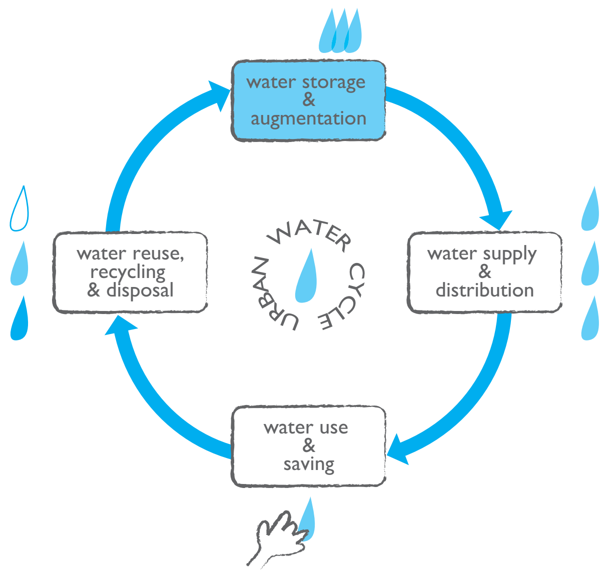


Illustration 11: Position of the section on water storage and augmentation in the urban water cycle.

4.2.2.2 Analysis of flows: Quality aspects

Water quality aspects can be added to the water balances established in the quantitative analysis. The result is a more detailed picture of the sources and impacts of pollution and of specific requirements urban and rural activities should comply with. This will further improve the understanding of problems and opportunities for storage and augmentation. A distinction should be made between *point sources*, such as industrial outfalls, sewer discharges and landfills, and *non-point sources* such as pesticides and washed out nutrients from peri-urban agriculture and atmospheric deposition from traffic.

4.2.2.3 Analysis of areas

- o Decisions about ESTs will be taken for area of various size. A first analysis of the spatial conditions would include a positioning of the decision area in the river basin or catchment basin. The basin is the basis. How do the water balances (quantity and quality) upstream and downstream relate to the decision area?
- o If the decisions are about an urban neighbourhood, district or larger urban area it is important to make a drainage pattern map of the area, both the natural pattern and the existing one. A possible role of rainwater run-off in storage and augmentation depends on the slopes and depressions that belong to this pattern. In situations of occasional heavy rainfall it would be interesting to combine the efforts of flood control and water storage.
- o In the urban environment, the sink of one activity can be the source of another. The issues of solid waste and wastewater disposal and drinking water production are linked, through air- and rainwater quality and through soil- and groundwater quality. It is important to locate on maps the key problems and key opportunities.

4.2.2.4 Analysis of actors

An analysis of the relevant actors, or stakeholders, should identify the specific roles that groups and individuals play in the funding, the legal permits and the operation and maintenance of different ESTs. Understanding these roles, the power of actors or the need for empowerment, is essential to decision making. In the context of storage and augmentation it is highly relevant to pay attention to the upstream and downstream actors. This is obvious in a river basin, but it is also important inside smaller areas, such as the neighbourhoods in the Bissau case of chapter 3, where pit latrines were built too close to the wells. Who carries responsibility for these problems and who can decide to prevent them?

Environmental Flows

One of the most important aspects when considering the use of water from rivers is the concept of Environmental Flow which basically relates to the water regime in a given river to maintain the ecosystem functioning and provision of benefits particularly in situations where competing water uses and flows are regulated. To fail in meeting the environmental flow requirements is likely to have negative impacts in various sectors as water becomes scarcer. (Environmental Flows rely on aspects such as defining water requirements, modifying water infrastructure, financial mechanisms to cover the costs, appropriate policy and legal framework, generation of political momentum, and building capacity for design and implementation.) Although, the concept is easy to understand, is quite challenging to put in practice as a number of disciplines need to be involved, nevertheless it is crucial to have it considered when river waters are to be used to provide water for the urban environment.

4.2.3 DISCUSSION OF ARGUMENTS FOR DECISIONS ABOUT ESTS FOR STORAGE AND AUGMENTATION

Each decision situation is different but there are some general arguments relevant to the role of surface water, groundwater, rainwater and treated wastewater as sources for storage and augmentation of drinking water. The appropriate treatment of wastewater will be discussed in detail in chapter 4.5.

4.2.3.1 ESTs based on the storage of river water

In many parts of the world, river water is used as a source for drinking water supply. Rivers may have varying water levels due to the specific climate and different seasons and hence have a limited water storage capacity. To make river water available all over the year and to buffer periods with low water quantity, rivers are often dammed. Usually, the dam projects are far from the cities. Water supply is taken for granted by the urbanites that do not see any of the related problems. From a water-quantity point of view, big *reservoirs and dams* have the advantage of big storage, although there is also a huge evaporation. Related to their nature and scale, the operation of the dams and reservoirs is in the hands of powerful centralised institutions. The problem with dams is the risk of mistakes in the view of profits. Their strength lays in combined benefits of the dam's hydropower with irrigation projects and drinking water production. Their weakness is that the dam projects tend to ignore the 'side effects' and there can be many of them: mass migration of poor farmers from the fertile grounds of the flooded valley to unfertile hills; sediment trapping in the new reservoir and as a result silting up of the lake; water quality problems in dams caused by inundated landscapes and contaminated soils as well as by wastewater discharge and runoff from agricultural areas. On the other side, discontinued fertile floods downstream lead to a lack of nutrients for the food chain that is the basis of fishing in the coastal waters where the river runs into the sea. And this is not all: the disruption of a river's ecosystem may also lead to increased eutrophication, microbiological contamination and increases in parasites (which can cause diseases like schistosomiasis (bilharzia)).

The lessons from these experiences are an argument for smaller projects within or closer to the urban areas. Such projects will be more visible and may have less risks and more time to investigate social, economic and ecological impacts. It is important to reconsider unsustainable big dam projects and to reduce the need for them by reducing the water demand, for instance through more efficient use of water, as discussed in more detail in chapter 4.4.

Artificial ponds, reservoirs and small dams (such as underwater beams or weirs) can be sustainable solutions for water storage but there are other options, such as pumping stations that directly take up river water or ESTs that pump up filtered river water from the groundwater near rivers. Sand dams, holding back the rare but powerful flows in wadi rivers, are examples of ESTs that use river water for the augmentation of groundwater. Generally speaking, these technologies are smaller and less problematic than dams and therefore may offer good options, consistent with a sustainable approach.

4.2.3.2 ESTs based on the storage of groundwater

In many parts of the world, *groundwater* is an important source for drinking water. In many cases it is virtually the only secure source of water, for instance in deserts or arid areas, which are e.g. located in the proximity of mountains that feed groundwater layers (aquifers). Often enough water is available to feed the population of villages and small towns, even in arid conditions. If smaller urban settlements start growing, however, growing cities may soon have to face the limits of this resource. The aquifer itself is the storage and often the replenishing comes slowly. Where cities are growing but also where industry and agriculture is intensifying, the groundwater-based EST usually is a big pumping station controlled by a central institution. In these situations sinking groundwater tables as well as the anthropogenic microbiological and chemical pollution of groundwater have become a well-known phenomenon. This happens in many parts of the world and in all climates. As a consequence of this, groundwater augmentation becomes crucial. Some ESTs, such as swales, recharge groundwater through the infiltration of rainwater or run-off stormwater. These ESTs combine infiltration with filtering and the uptake of nutrients by wetland vegetation. In a similar way other ESTs infiltrate treated wastewater. Sustainable use, in this context, should not exceed the quantity and the quality performance of the recharging process.

If groundwater is polluted (e.g. in India alone more than 30 million people suffer from fluorosis caused by excess fluorine) it has to be either treated for the production of drinking water, or alternative water resources have to be developed (e.g. rainwater). In many cases, however, groundwater is less polluted than other sources and therefore it requires less treatment if used for drinking water production. However, this may lead to an over-exploitation of groundwater resources and to diminishing the need for proper treatment of wastewater or run-off. If this is the case, it may be more sustainable to consider other solutions. It may be feasible to treat rainwater or wastewater or to use surface water as a source for drinking water. Over-exploitation and pollution of groundwater usually are invisible, if compared to surface water. This is an argument to give preference to surface water.

In case there is a well organised technical supervision and quality control, Aquifer Storage and Recovery (ASR) may be an option. This is a seasonal storage technology that stores storm water or treated wastewater in deeper aquifers during rainy seasons to be used again in dry periods. For arid and semi-arid areas it seems a promising technology that avoids high evaporation.

4.2.3.3 ESTs based on the storage of rainwater

Rainwater as a source may have many advantages compared with other options. ESTs for *Rainwater harvesting* may create an interesting alternative water supply. This is relatively easy in moderate and humid climates with sufficient rainfall, which is quite equally distributed over the year but it may be even more important in arid climates. It depends on the local climate and the local urban situation whether sufficient storage capacity can be installed to use rainwater as a main or supplementary source. Rainwater can also be used for the recharge of groundwater or surface water. However, the uncontrolled discharge of storm water, especially in extreme precipitation events, which are likely to occur more regularly in the future, may lead to declining water qualities in ground- and surface waters. Rainwater can also be stored in tanks or underground cisterns and be used as service water or even for drinking water purposes, depending on its quality and possible treatment. The pollution of rainwater in many urban areas limits its safe use generally to non-drinkable purposes. The rain itself brings the water to every roof and every garden and this favours the decentralized infiltration of rainwater as well as the small-scale water use in individual households. The visibility and the active role of individuals may contribute to awareness and commitment and this may favour efficient water use. Given the limited water resources in many areas, it is important to stimulate the safe use of rainwater. In this way urban systems can be made less dependent on bigger centralised storage systems. Rainwater-based storage and augmentation asks for ESTs that fit to the local landscape and the local community. Central institutions, public or collective, are important for the introduction and further promotion of rainwater harvesting technologies. Compared to the centralised systems, their task will be different, however, and will focus on technical assistance and quality control in interaction with the users. Measures for rainwater harvesting are not only applicable in new development areas where the decentralized management of storm water may save infrastructure cost due to savings in sewer construction. The disconnection of rainwater in existing areas with combined sewers can avoid combined sewer overflows and thus contribute to the improvement of surface water quality.

4.2.3.4 ESTs based on wastewater

Wastewater is often used indirectly as a source for drinking water. This is always the case when treated or untreated sewage is discharged in surface waters or infiltrated in the ground and the similar water bodies are used for the extraction of water for drinking water supply. However, *treated wastewater* can also be a direct source for water supply, depending on the degree of contamination. Appropriate purification ESTs, including wetlands, can produce the required quality, especially for lower grade purposes (service water). In this way, these ESTs not only reduce the pollution pressure of urban areas to the environment, but also increase the availability for drinking water purposes of clean fresh water sources, like aquifers or surface water systems.

4.2.3.5 Priorities

In the context of *Integrated Water Resource Management (IWRM),* storage and augmentation is not a single source story. The challenge is to create cost-effective access to the diverse water sources by providing a diversity of centralised and decentralised water infrastructure.

Summarising the arguments for efficient and sustainable storage and augmentation, decision makers may follow this sequence of options:

- o First realising the full potential of treated wastewater and rainwater options.
- o Then using the potential of surface waters.
- o And then turning to aquifer-based ESTs as a third option.

The main reason to first look at the surface water options is that over-exploitation and pollution of aquifers is a hidden threat. The invisible impacts are very hard to restore. Surface waters are also vulnerable but the problems are visible and recovery is less difficult. In all cases it remains vital to make an assessment of the social and ecological impacts and to give full attention to careful technologies and policies. Costs should be an integrated part of the project. Each case has to find its own detailed sustainable solution that fits to the local situation, but these priorities for storage and augmentation may be helpful in the decision-making process.

Desalination is a technology that is left out of consideration here, although it is increasingly popular and getting less costly than it used to be. The desalination process is highly energy consuming and under the present circumstances the plants are not powered by sustainable energy. Furthermore, the highly saline residual water resulting from the filtration process also poses an environmental problem. Thus the technology cannot (yet) be considered environmentally sound although it is likely that costs will be reduced in the future making this technological option much more attractive for areas with severe freshwater scarcity. Desalination is a rapidly expanding technology that will become more important in the future. However, presently the application is still limited in areas where there is no money or expertise for such expensive and complicated processes.

4.2.4 FACT SHEETS ON WATER STORAGE AND AUGMENTATION ESTS

The ESTs Fact Sheets below enlisted for "water storage and augmentation" are presented in the following Section 1:

4.2.4.1 Ponds and reservoirs

4.2.4.2 Artificial recharge of groundwater

4.2.4.3 Water tanks

4.2.4.4 Rainwater harvesting - stormwater in ponds and reservoirs

4.2.4.5 Rainwater harvesting - stormwater for the artificial recharge of groundwater

4.2.4.6 Rainwater harvesting - stormwater collected in tanks for domestic use

4.2.4.7 Treated sewage - effluent in ponds, reservoirs and small dams

4.2.4.8 Treated sewage - effluent for the artificial recharge of groundwater

Ponds and reservoirs

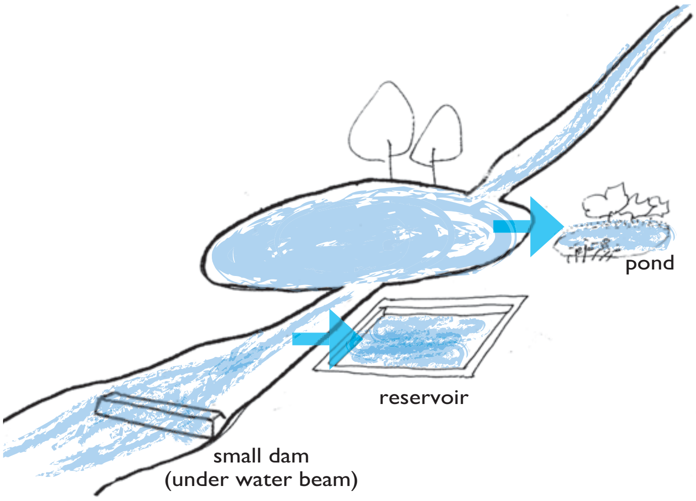


Illustration 12: Ponds, reservoirs and small dams (weirs or underwater beams).

4.2.4 fact sheet 1

Technological description:

Artificial ponds, reservoirs and small dams (underwater beams or weirs) are used for the storage of appropriate amounts of raw water for domestic water supply. Sources for the augmentation are river water as well as stormwater and sewage runoff from rural and urban areas. The collected water can be either stored in the form of surface water only, or also be infiltrated in the ground and used for the artificial recharge of groundwater. Often, ponds are also used for flood control and to purify stormwater. The main purifying mechanism is settling of pollutants. In addition, absorption to soil particles and microbiological degradation of pollutants take place. Storage and treatment ponds or lagoons for the treatment and storage of wastewater and stormwater (flood control ponds) are described in section 4.5.4, Constructed wetlands.

Construction, operation and maintenance:

- Can be constructed, operated and managed by communities or construction companies.
- IWRM and integrated watershed management is required to provide effective pollution control of freshwater reservoirs, involving actors from different sectors (domestic and non-domestic, like industry and agriculture).
- Require a variety of personnel skills ranging from high to low level depending on the scale and particular stage. It would involve actors from different sectors and skills i.e. professional to low trained individuals including the domestic realm.

Relative costs:

- o Construction costs for a specific storage capacity are low compared with closed tanks.
- o Construction work can be realised in many cases by manpower of community members and can therefore substitute for the required monetary costs for construction work by companies.
- o Pollution and environmental costs for management are low.
- o Costs for management and pollution control management can be diffused in the framework of integrated watershed management and may vary significantly depending on the basic conditions of each location.
- o The costs for wetlands may vary significantly depending on the conditions of each case. Therefore it is the difficult to give universal costs. Indicative capital costs may be 27 US$/$m^2$ (Brown and Schueler, 1997). For wet ponds the investment costs may be estimated as follows and are a function of the volume (Brown and Schueler, 1997): costs = $24.5 \times V^{0.705}$.
- o Average maintenance costs are 3 to 5 % of construction cost per year. (Debo and Reese, 2003).
- o Space demand: Ponds typically consume 2 to 3% of the contributing area (Debo and Reese, 2003).

Appropriate technological approach when:

- o Sufficient space is available, e.g. on properties or public space.
- o The construction of small dams is limited to a scale that allows coping with the negative side-effects of river regulation.
- o The pollution of the receiving waters by air, storm water runoff and sewage is controlled efficiently (*see sections 4.4 and 4.5*).
- o The quantity of runoff does not exceed the storage capacity of the receiving water (to avoid flooding and degrading of water quality). In case of stormwater storage, the volume is designed according to a certain Average Return Interval, e.g. 5, 10 or 100 years.
- o The extracted water quantity for water supply does not exceed the capacity of the water body (to avoid over-exploitation of the freshwater reservoir).
- o Freshwater reservoirs are located physically nearby the area of water use (crucial for the reduction of infrastructure costs).

Advantages:

- o Storage of relatively large amounts of water with comparably low effort.
- o Water quality of surface waters can be enhanced and the breeding of mosquitoes can be avoided by nature-orientated design with appropriate flora and fauna and the integration of measures for nature-orientated water purification (e.g. *Constructed wetlands, see section 4.5*)
- o Potential multifunctional use for recreation and water storage.
- o Relatively easy to build and maintain.

Disadvantages/Constraints:

- o Comparatively high water losses by evaporation.
- o Potential habitat for mosquitoes if not designed and managed appropriately.
- o Pollution by atmospheric exposition, polluted rainwater and sewage runoff as well as poor design and management.
- o Algae bloom may occur if nutrient load to the pond is too high or hydraulic resident times are too short.
- o Regular maintenance is required to guarantee sufficient hydraulic function.

<u>Cultural acceptability:</u>

- o Generally high regarding availability of water resources if issues and purpose of water management are communicated.
- o Generally high regarding multifunctional use of freshwater reservoirs as nature conservation and recreation areas.
- o Critical in case of poor design, bad water quality and the potential grow of mosquitoes.

<u>Extent of use:</u>

- o Frequently in areas where the capacity of natural freshwater bodies is limited and ground water is non-existent or limited.

<u>References, links and literature:</u>

- o *Brown, W. and Schueler, T.; The Economics of Storm Water BMPs in the Mid-Atlantic Region; Center for Watershed Protection, Ellicott City, MD, USA, 1997*
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- o *Engineers Australia; Australian Runoff Quality, A Guide to Water Sensitive Urban Design; 2006, available at: <u>http://www.engaust.com.au/bookshop/arq.html</u>*
- o *International Stormwater Best Management Practices (BMP) Database project website, which features a database of over 300 BMP studies, performance analysis results, tools for use in BMP performance studies, monitoring guidance and other study-related publications. Available at: <u>http://www.bmpdatabase.org/index.htm</u>*
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- o *UNEP DTIE IETC, Eutrophication Management PAMOLARE2; - Shallow Lakes; Model, Osaka/Shiga, 2005*

Artificial recharge of groundwater

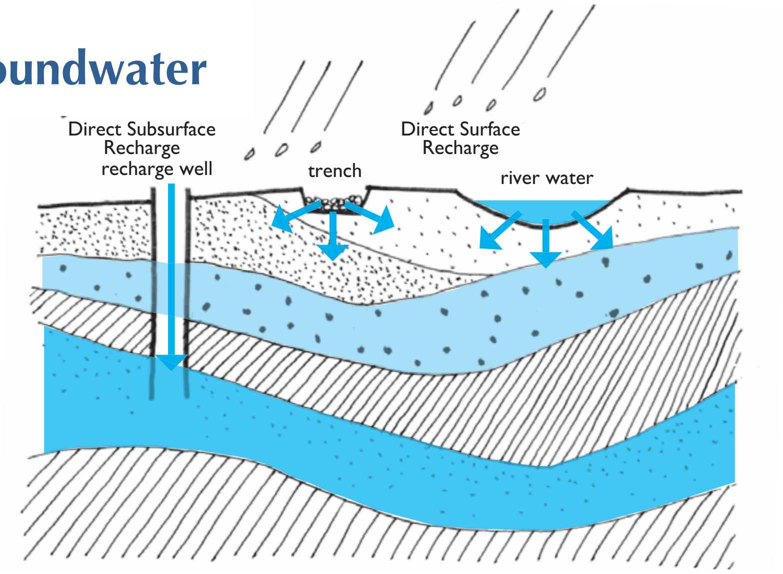

Illustration 13: Artificial recharge of groundwater.

fact sheet 2 4.2.4

Technological description:

Artificial recharge of groundwater is used to increase the natural replenishment or percolation of surface waters into groundwater aquifers, e.g. for the storage and augmentation of drinking water. The primary objective is to preserve or enhance groundwater resources but is also used for other beneficial uses, like the regulation of groundwater abstraction, the control of salt water intrusion into aquifers, the storage of water to reduce pumping and piping costs or for water quality improvement by removal of suspended solids by filtration through the ground or by dilution by mixing with naturally occurring groundwater (Asano, 1985). The process of seasonal storage of water in aquifers during times when there is abundance of water for the use during dry spells is called Aquifer storage and Recovery (ASR). Water sources for the augmentation of aquifers can be river water, rainwater and waste water.

The different recharge methods can be generally classified in the following categories:

- **Direct Surface Recharge** uses surface structures, like open surfaces, permeable pavements, infiltration basins (sand filters) or shallow pits for the enhancement of the natural percolation of water into the subsurface. The water moves from the land surface to the aquifer by means of percolation through the soil. The systems can be combined with bioretention systems or vegetated swales for the purification of stormwater runoff.
- **Direct Subsurface Recharge** use subsurface structures, like infiltration ditches, infiltration trenches or soakaway pits for the enhancement of the natural percolation of water into the subsurface. Recharge wells, commonly called injection wells, are generally used to replenish groundwater when aquifers are deep and separated from the land surface by materials of low permeability.
- **Combinations of Direct Surface and Subsurface Recharge** can be used in conjunction with one another to meet specific recharge needs.
- **Indirect Recharge** includes measures for the lowering of groundwater levels (e.g. by pumping) near hydraulically-connected surface waterbodies

(streams, lakes or artificial ponds) to induce infiltration elsewhere in the drainage basin. They also include the modification of aquifers or the construction of new aquifers to enhance or create groundwater reserves, e.g. barriers or dams to sustain the storage capacity of aquifers to meet water demands also during periods of greatest need.

Construction, operation and maintenance:

- o Before selecting the site and method of recharge, thorough and detailed hydrogeological studies must be conducted considering the locations of geologic and hydraulic boundaries; the permeability, depth to the aquifer and lithology, storage capacity, porosity, hydraulic conductivity, and natural inflow and outflow of water to the aquifer; the availability of land, surrounding land use and topography; the quality and quantity of water to be recharged; the economic and legal aspects governing recharge; and the level of public acceptance.
- o Easy and low effort but comparably high space demand **Direct Surface Recharge** technologies.
- o Comparably high effort for the construction, but easy operation and maintenance of underground structures call for **Direct Subsurface Recharge** technologies.
- o Effort for **Indirect Recharge** methods vary significantly dependent on the specific method or technology used.

Selected ESTs for the artificial recharge of groundwater

Bioretention systems

Bioretention systems have two important functions, the (flood) control of water quantity and the improvement of water quality through removal of pollutants such as heavy metals, nutrients and hydrocarbons and inorganic pollutants associated with runoff. Vegetation in a bioretention system keeps the soil open and enables all kinds of microbiological activities to remove organic pollutants. In addition, the soil itself functions as a filter medium in which pollutants are bound to soil particles. Fill material can range from coarse gravel to sandy soils. Bioretention systems are usually equipped with a subsurface drain to transport stormwater to the next stage after it has been treated. In addition, in areas with high groundwater tables, this drain can function as a groundwater control device. Overflow facilities are included in a bioretention system to process large rainstorms that occur only once in a few years.

Permeable pavements

Permeable pavements enable water to infiltrate into the ground rather than converting it to runoff. There are different types of permeable pavement. Ordinary tile and brick pavements have significant infiltration capacity. Permeable asphalt or concrete can also be applied. The foundation material under the pavement often consists of coarse gravel or sand. In the foundation material, sometimes a subsurface drainage pipe is constructed. Maintenance (street cleaning) is necessary to keep the infiltration capacity sufficient in intensively used areas.

Infiltration basins (sand filters)

Infiltration basins are ponds designed to infiltrate urban runoff and replenish groundwater resources. Other purposes are purification of runoff and flood control. Infiltration basins usually consist of two chambers. The first is the settling chamber, which removes coarse pollutants; the second is the filtration chamber, that infiltrates stormwater and removes fine particles. Infiltration basins can be lined with a filter medium and subsurface drainage pipes to promote infiltration. Pre-treatment of runoff is necessary to prevent clogging of the filter medium.

Infiltration trenches

Infiltration trenches are excavated ditches that are often filled with rocks. They are designed to treat runoff and infiltrate it to the groundwater. Infiltration trenches should be combined with pre-treatment technologies that remove pollutants. Examples are Gross Pollutant Traps (GPT's) vegetated swales and detention basins. Without these facilities, the life expectancy of infiltration trenches is less than 5 years (Schueler et al. 1992).

Relative costs:

o Low for construction but maybe high for required surface area of **Direct Surface Recharge**.

o Comparably high for underground construction of **Direct Subsurface Recharge** technologies, but potential savings by possible use of surface area above.

o Vary significantly for **Indirect Recharge**, dependent on the specific method or technology used.

o Infiltration basins have investment costs of 46 US$/$m^3$ (SWRPC, 1991).

o Infiltration trenches have investment costs of 141 US$/$m^3$ (SWRPC, 1991).

o Vegetated swales have investment costs of 18 US$/$m^3$ (SWRPC, 1991).

o An overview of base capital costs for common BMPs (Best Management Practices) is given in *Table 3* and an overview of maintenance costs is given in *Table 4*.

BMP Type	Base Capital Costs (S)	Reference
Detention ponds / Dry extended detention ponds	$C = 60{,}742V^{0.69}$; V in Mgal	*Young et al., 1996*
	$C = 12.4V^{0.76}$; V in ft^3	*Brown and Schueler, 1997*
Wet ponds / Retention basins	$C = 67{,}368V^{0.75}$; V in Mgal	*Young et al., 1996*
	$C = 24.5V^{0.71}$; V in ft^3	*Brown and Schueler, 1997*
Constructed wetlands	$C = 30.6V^{0.71}$; V in ft^3	U.S. EPA, 2003
Infiltration Trenches / Filter drains / Soakaways	$C = 173V^{0.63}$; V in ft^3	*Young et al., 1996*
	$C = 5V$; V in ft^3	*Brown and Schueler, 1997*
Infiltration basins	$C = 16.9V^{0.69}$; V in ft^3	*Young et al., 1996*
Sand and Organic filters	C = KA; A in acres; K ranges from 12,369 to 24,738	*Young et al., 1996*
Vegetated swales	$ 0.25 to $ 0.50/ft^2	*WERF, 2003*
Vegetated buffer strips	$ 0.30 to $ 0.70/ft^2	*WERF, 2003*
Porous pavement	$ 2 to $ 3/ft^2	*U.S. EPA, 2003*
Bioretention	$ 3 to $ 4/ft^2	*Coffman, 1999*
	$C = 7.3V^{0.99}$; V in ft^3	*U.S. EPA, 2003; Brown and Schueler, 1997*
Water quality inlets (enhanced catch basins)	$ 8,000 to $ 24,000	*Young et al., 1996*
	$ 2,000 to $ 3,000/basin for precast basins	*U.S. EPA, 2003*
	$ 400 to $ 10,000/basin drop-in retrofits	*U.S. EPA, 2003*

Table 3: Base capital costs for common BMP's (EPA, 2004)

Note: Costs in December 2002 dollars. Cost of land acquisition not included. V=BMP Volume and A=BMP Area.

BMP Type	Annual maintenance costs (% of construction cost without land cost)	Reference
Detention ponds / Dry extended detention ponds	<1%	*Wiegand et al., 1986; Schueler, 1987; SWRPC, 1991*
Wet ponds / Retention basins	3 to 6%	*Brown and Schueler, 1997; SWRPC, 1991*
Constructed wetlands	3 to 6%	*Wiegand et al., 1986; Schueler, 1987; SWRPC, 1991*
	2%	*Livingston et al., 1997; Brown and Schueler, 1997*
Infiltration trench	5 to 20%	*Schueler, 1987; SWRPC, 1991*
Infiltration basin	1 to 3%	*Livingston et al., 1997; SWRPC, 1991*
	5 to 10%	*Wiegand et al., 1986; Schueler, 1987; SWRPC, 1991*
Sand filters	11 to 13%	*Livingston et al., 1997; Brown and Schueler, 1997*
Grassed swales	5 to 7 %	*SWRPC, 1991*
Vegetated buffer strips	$350 / acre / year	*SWRPC, 1991*

Table 4: Maintenance costs of BMP's

Appropriate technological approach when:

o Aquifers are present at location.

o Permeability of soil is sufficient.

o Groundwater table is lower than 1 meter below the facility; otherwise subsurface drainage pipes should be installed.

o Renewable water sources (rain and river water as well as treated wastewater) with appropriate quality are available (the specific water quality is influencing the selection of the specific recharge technology).

o Uncontrolled rise of groundwater tables and negative effects on quality and urban infrastructure (e.g. flooded basements) are avoided.

o **Direct Surface Recharge**: relatively flat and gently sloped land is available above water permeable soils; enhancement of water quality is required, e.g. in the framework of Soil Aquifer Treatment (SAT, *see section 4.5.4*).

o **Direct Subsurface Recharge**: open surface area is limited (e.g. in urban areas with high density); clean water for recharge is available or water is sufficiently purified before recharge.

o **Indirect Recharge**: comparably low control over the quantity and quality of recharged water is required.

Advantages:

o Changing the rainfall-runoff pattern of an urban area by increasing the hydrological retention time can reduce pluvial flooding.

o Replenishment of groundwater resources.

o Control of groundwater levels.

o Improvement of the runoff quality.

o Integrated design of facilities in urban landscape architecture provides possibilities to use the system for public amenity and recreation.

o Potential of reduced pipeline length and closed loop economy in case of artificial groundwater recharge with rainwater or reclaimed waste water.

o Applicable in existing as well as in new urban developments with low and high density.

o Positive interdependencies with flood control in case of rainwater retention and infiltration.

o Positive interdependencies with decentralised wastewater management in case of infiltration of purified waste water.

Disadvantages/Constraints:

o Excessive rising of groundwater tables due to excessive groundwater recharge and damage on urban infrastructure.

o Pollution of ground water (e.g. with chemicals, heavy metals or micro-organisms).

o Dispersion of pollution by infiltration from upper to lower soil layers and aquifers or three dimensional by seepage (up- and downwards) as well as by flowing ground water in horizontal directions.

o Application requires restructuring of areas which are already equipped with centralized systems for water supply and sewage management.

o Infiltration facilities can lose their function by clogging due to wrong design or insufficient maintenance.

Cultural acceptability:

o **Direct Subsurface Recharge** and **Indirect Recharge** as well as small-scale **Direct Surface Recharge** technologies are easier acceptable in urban areas with high density and limited open space.

o Large-scale **Direct Surface Recharge** systems are most acceptable in areas with low density and much available open space, e.g. in parks.

Extent of use:

- **Direct Surface Recharge** methods are the simplest and most widely used. Due to the comparably high space demand it is traditionally used in rural areas (e.g. sand dams in Africa or Johads in India). The systems are used also with rising tendency in urban areas for the decentralized management of runoff from streets and paved surfaces, often in combination with drainage or subsurface facilities.
- **Direct Subsurface Recharge** in urban areas has been applied only recently due to overexploitation of ground water and the development of efficient and space saving technologies.
- **Indirect Recharge** is often used in the framework of water supply with groundwater and indirect recharge by riverbed filtration.

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- *Howard, K. W. F.; Urban Groundwater: Meeting the Challenge; Taylor & Francis, London, 2006*
- *Huisman, L. and Olsthoorn, T. N.; Artificial Groundwater Recharge; Pitman Publishing Inc., Massachusetts,1983*
- *International Stormwater Best Management Practices (BMP) Database project website, which features a database of over 300 BMP studies, performance analysis results, tools for use in BMP performance studies, monitoring guidance and other study-related publications. Available at: http://www.bmpdatabase.org/index.htm*
- *International Water Agency, Specialist Group on Groundwater Restoration and Management: (RWHM): http://www.iwahq.org*
- *Landphair, H. C.; Cost to performance analysis of selected stormwater quality best management practices; in: Irwin, C. L., Garrett, P. and McDermott, K. P. (Eds.); Proceedings of the 2001 International Conference on Ecology and Transportation; Center for Transportation and the Environment, North Carolina State University, Raleigh, NC, 2001, pp. 331-344. Available at: http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1069&context=jmie/roadeco*
- *Southeastern Wisconsin Regional Planning Commission (SWRPC); Costs of Urban Nonpoint Source Water Pollution Control Measures; Technical Report No. 31, Waukesha, WI, 1991*
- *Todd, D. K.; Groundwater Hydrology; Second Edition, John Wiley & Sons, New York, 1980*

Water tanks

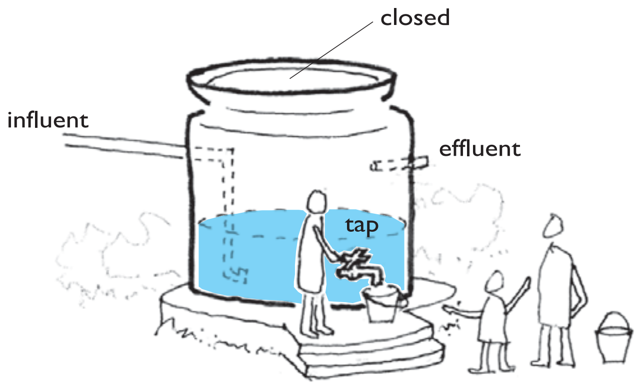


Illustration 14: Storage tank for collective water supply.

Technological description:

Water Tanks are closed containers for the storage of water. They can be constructed out of different materials, either prefabricated (e.g. out of metal, concrete and plastic) or made on site (e.g. clay, bricks, natural stones, metal and concrete) and in different sizes. Hence they are suitable for small decentralized systems as well as for large-scale centralized systems. They are generally part of systems for urban and domestic water supply and are used for the treatment and storage of raw water as well as for drinking water. Furthermore they can be used for the storage and treatment of storm water (for water supply and flood control) and waste water. Tanks can be also constructed for the mobile transport of water, e.g. on trucks.

Construction, operation and maintenance:

- Comparably high effort for construction, depending on the tank size, the used material and type of construction.
- Low effort for operation and maintenance, primary for cleaning.
- Effort for cleaning is primary dependent on the tank use. In case of content with low pollution load the effort is smaller than for content with high pollution load.

Relative costs:

- High, but dependent on tank size, material and construction technology.
- High monetary costs in case of tanks from industrial production.
- Monetary costs can be substituted by manpower in case of manual construction of tanks on site out of locally available materials with low cost (e.g. natural stones, clay, plastic foil).

Appropriate technological approach when:

o Additional water storage capacity to aquifers or reservoirs is required.

o Water has to be purified, stored or transported.

Advantages:

o Storage and treatment of water independent from natural basic conditions also in case of limited or unavailable surface waters or aquifers.

o Individual scaling adjusted for the specific purpose.

o Facilitates the protection of stored water from surrounding pollutants.

Disadvantages/Constraints:

o Limited storage capacity.

o Comparably high constructive effort and related costs limiting maximum capacity.

Cultural acceptability:

o Generally high, in case they are required for sufficient water supply.

Extent of use:

o Tanks are used in almost all urban and domestic infrastructures for the storage of water, in decentralised as well as in centralised systems.

References, links and literature:

o Ludwig, A.; Water Storage: Tanks, Cisterns, Aquifers, and Ponds for Domestic Supply, Fire and Emergency Use; Oasis Design, 2005

Rainwater harvesting
- stormwater in ponds and reservoirs

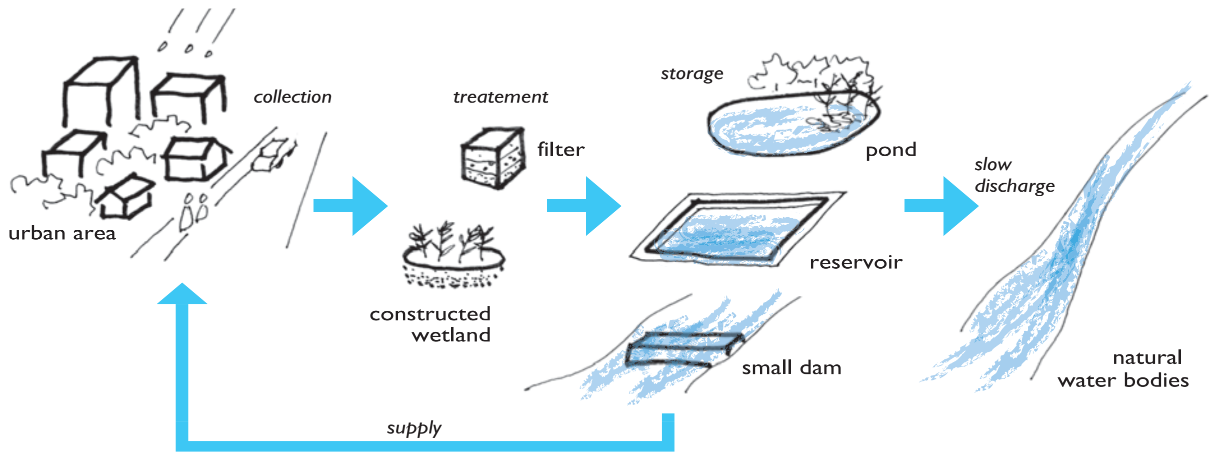


Illustration 15: Stormwater in ponds, reservoirs and natural water bodies.

4.2.4 fact sheet 4

Technological description:

Stormwater Harvesting for the augmentation of freshwater reservoirs involves the collection, treatment and storage of stormwater from all urban areas, like roofs, pavements, sidewalks, parking lots and driveways. Typically the collected stormwater is drained in open ditches and gutters or underground in sewers and discharged into surface water bodies which may function as storage for urban water supply. To avoid pollution of the receiving water bodies, the discharge streams have to be filtered and purified (e.g. by sand filters or artificial constructed wetlands) according to the degree of pollution (in areas with severe air pollution, rain water may contain several noxious pollutants and have low pH). Furthermore it has to be slowed down before entering the receiving water bodies to avoid erosion of nature-orientated water bodies. In a conventional water system, stormwater is drained away from the urban area by drainage pipes to either wetlands or waterways. By the collection, storage, treatment and distribution, stormwater can become an additional resource for urban water supply.

Construction, operation and maintenance:

o Low effort for harvesting from surface areas.

o Low operation and maintenance, primarily for cleaning and removing sediments.

o Construction effort is dependent on the required capacity and kind of the drainage system and the locations of catchment areas and storage facilities.

o Comparably low construction effort for the adaptation of existing open water bodies and high effort for the construction of new ponds and reservoirs.

Relative costs:

o Low for the collection of rainwater from surface areas as well as for operation and maintenance.

o Comparably low but greatly varying for the separate draining and treatment of rainwater, dependent on the kind of drainage and treatment system as well as its capacity and the construction effort for the adaptation or construction of surface water bodies.

o Decentralised and semi-decentralised discharge of rainwater in surface waters may save infrastructure costs due to less and smaller required drains.

Appropriate technological approach when:

o Open water bodies are located inside or near the rainwater collection area.

o Abundant rainfall for the natural filling of ponds is available.

o The total rainfall used for the augmentation of surface waters also in case of extreme precipitation events is not exceeding the capacity of the surface water body to avoid flooding and the destruction of its eco-system.

o Measures for the retention, slowing down and purification of storm water are considered to avoid pollution of the receiving water body.

Advantages:

o Visible rainwater harvesting and freshwater augmentation may enforce awareness and activities of individuals to create conditions for efficient water use.

o Surface water bodies can be integrated in urban areas on different scales and different design, from decentralised (e.g. building) to centralised (e.g. in parks)

o Freshwater augmentation by a renewable water source.

o Potential savings in infrastructure costs for complex sewer systems.

Disadvantages/Constraints:

o Potential pollution of the open water bodies by contaminated rainwater runoff in case of poor treatment.

o Insufficient rainfall for the naturally filling of ponds.

o Limited capacity and overflows of existing receiving surface water bodies in case of extreme precipitation events.

Cultural acceptability:

o Generally good for the harvesting itself and if the receiving open water bodies are managed in a way that the water quantity and quality are kept on a sufficient level all over the year.

Extent of use:

o Traditionally widespread in areas with open waterbodies in the urban and domestic environment.

References, links and literature:

o Danish Hydraulic Institute & The United Nations Environment Programme; Sourcebook of Alternative Technologies for Freshwater Augmentation in Africa; 1998

o Danish Hydraulic Institute (DHI) & The United Nations Environment Programme; Sourcebook of Alternative Technologies for Freshwater Augmentation in some Asian Countries; 1998

o Institute for Ecology of Industrial Areas (IEIA) & The United Nations Environment Programme; Sourcebook of Alternative Technologies for Freshwater Augmentation in East and Central Europe; 1998

o Matsushita, J.; Appropriate Basin Management systems under very rapid urbanization- strategic approach based on Japans previous experience; JICA Seminar 2006

o UNEP DTIE IETC, Murdoch University Environmental Technology Centre; Environmentally sound technologies for wastewater treatment for the implementation of the UNEP Global Programme of Action (GPA) Guidance on Municipal Wastewater; Technical Publication Series (21), Osaka/Shiga, 2001

Rainwater harvesting
- stormwater for the artificial recharge of groundwater

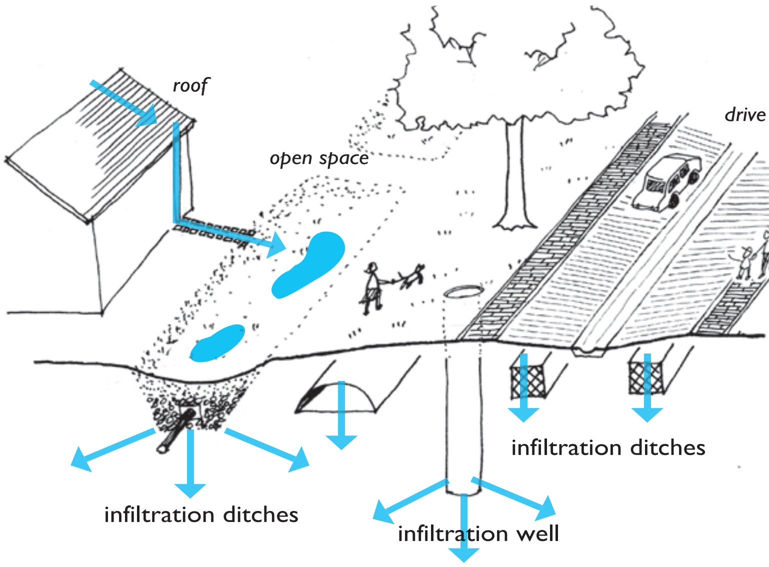


Illustration 16: Stormwater for artificial recharge of groundwater.

4.2.4 fact sheet 5

Technological description:

Rainwater Harvesting for the artificial recharge of groundwater involves the capture and retention of rainwater from areas, like roofs, or pavements, like sidewalks, parking lots and driveways. Typically the collected rainwater is drained in pipes and filtered before it is used for groundwater augmentation. To avoid pollution of the receiving aquifers, the rainwater has to be either infiltrated with technologies which allow purification of the water (direct surface treatment and SAT) or it has to be purified appropriately before (see also artificial recharge of groundwater). The rainwater can be infiltrated in case of sufficient freeboard through soils permeable to water. Infiltration swales and shallow pits can be combined with the design of open spaces in domestic and urban areas while infiltration ditches can be installed invisibly underground under open space or even under traffic areas. The construction of these systems allows the decentralised retention and infiltration of huge amounts of rainfall even in urban areas with high density. The related constructive and financial costs for purchase, installation and service are generally much lower than the installation of sewers or closed retention tanks. They are applicable to new urban developments but also possible in existing urban areas.

Construction, operation and maintenance:

- Low effort for the harvesting of rainwater from surface areas.
- Low operation and maintenance, primary for cleaning and removing sediments from filter devices.
- Construction effort is dependent on the required capacity and the kind of the drainage system, the required pipeline length as well as the basic conditions of each location (precipitation patterns, water quality and soil properties) and the required specific facilities for groundwater recharge.

Relative costs:

o Low for the collection of rainwater from surface areas as well as for operation and maintenance.

o Comparably low but greatly varying for the separate draining and treatment of rainwater, dependent on the kind of drainage and treatment system as well as its capacity and the specific facility for groundwater recharge.

o Low costs for direct surface recharge technologies directly connected to collection areas.

o Decentralised augmentation of aquifers with storm water can save infrastructure cost by the minimization of drainage systems.

Appropriate technological approach when:

o Aquifers, appropriate to the artificial recharge of rainwater (concerning quantity and quality) are located under or near the rainwater collection area.

o Pollution of aquifers is avoided by appropriate treatment of rainwater before recharge.

Advantages:

o Feasible also in urban areas with high density due to possible location underground and near buildings.

o Infiltrated rainwater can be compatible with native groundwater and can meet primary drinking water standards.

o Stabilisation of groundwater tables in case of groundwater use for water supply, e.g. in the framework of Aquifer Storage and Recovery (ASR).

o Purification of rainwater runoff by appropriate infiltration, e.g. Soil Aquifer Treatment (SAT)

Disadvantages/Constraints:

o Possible pollution of groundwater by contaminated rainwater.

o Damage of urban infrastructure by rising groundwater levels.

o Risk of clogging of infiltration system if appropriate pre-treatment or maintenance is lacking.

Cultural acceptability:

o Generally high if doubts concerning damages through rising groundwater levels can be excluded.

o High because measures can be integrated in urban areas on different scales and different design, from decentralised (e.g. building) to centralised (e.g. in parks) and from visible (e.g. ditches) to invisible (e.g. underground swales).

Extent of use:

o Infiltration swales often in combination with underground infiltration ditch systems to enlarge the capacity are used with rising tendency also in urban areas which suffer from declining ground water tables and drought.

References, links and literature:

o *Okui, H. and Imbe, M.; Consciousness survey towards promotion of wide use of rainwater infiltration facilities; in: Conference Proceedings 10th International Conference on Urban Drainage; Copenhagen/Denmark, 21-26 August 2005*

o *Schuetze, T.; Decentralized Rainwater management - Solution for sustainable (re)development and independency; proceedings IWA World Water Conference, Rainwater Harvesting Task Force, Rainwater Harvesting and Management, Beijing, China, 2006*

o *Town Panchayat (Tamil Nadu, India): available at: http://www.tn.gov.in/dtp/rainwater.htm*

o *UNEP DTIE IETC, Murdoch University Environmental Technology Centre; Environmentally sound technologies for wastewater treatment for the implementation of the UNEP Global Programme of Action (GPA) Guidance on Municipal Wastewater; Technical Publication Series (21), Osaka/Shiga, 2001*

Rainwater harvesting
- stormwater collected in tanks for domestic use

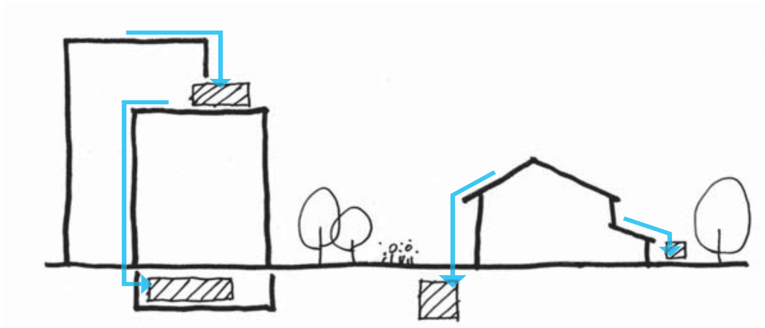


Illustration 17: Stormwater collected in tanks, for domestic use.

Technological description:

Rainwater Harvesting for the collection in tanks and for domestic use involves generally the capture and retention of rainwater from roofs which tends to be less polluted and of a higher quality than that from paved areas such as sidewalks, parking lots and driveways. The location and structure of tanks for the collection of rainwater can be planned freely without significant limitations by natural basic conditions. Rainwater tanks can be integrated in buildings or underground, desirably near the catchment area. The size of reservoirs for the storage of rainwater for urban water supply is primarily dependent on the catchment area, the water demand, the desired coverage rate of the water demand as well as the amount of rainfall and its distribution over the year. Due to the comparably high population density and high water demand related to the catchment areas, rainwater harvesting and utilization systems can cover in most cases only a limited portion of the water demand, even in countries with a relatively even distribution of rainfall over the year. The enlargement of tank volumes and catchment areas can contribute to higher coverage rates. While bigger tanks are related to higher costs, the collection of rainwater from polluted areas requires additional treatment effort for purification. The actual potential coverage rate for a specific situation should be calculated before detailed design. Due to the limited storage capacity of tanks, the described technology does not or only limitedly contributes to flood control. Tank overflows have to be connected desirably to other ESTs for rainwater management. Concerning the related construction costs as well as the potential savings of drinking water resources, the recycling of domestic sewage with low pollutant load (greywater) is therefore an additional or alternative EST in many urban domestic areas. According to the purpose of water use (either as service or drinking water), simple or extensive treatment may be required, ranging from filtering and sedimentation to multiple treatment steps, including disinfection, e.g. by UV radiation.

Construction, operation and maintenance:

o Low effort for operation and maintenance in case of appropriate design, mainly for the cleaning of filter and tank.

o Additional construction effort for treatment facilities (e.g. sedimentation tanks and soil filters) in case of polluted rainwater from traffic areas.

o Low construction costs for the drainage of rainwater drainage.

o Comparably high construction costs for tanks (depending on size, material, construction and location).

o Additional installation of a second pipeline network for service water supply might be required in addition to pipeline network for drinking water supply.

Relative costs:

o Low cost for drainage and piping.

o Varying costs for construction and installation of tanks. For cost reduction it is crucial to design rainwater tanks in a way that the size is minimized and pipeline length are reduced. They should be physically located near catchment areas and the destination for supply and distribution (preferably in or nearby buildings).

Appropriate technological approach when:

o Amount and distribution of rainfall over the year on a specific catchment area and the storage in a feasible tank size are contributing significantly to the daily water demand of a specific area.

o The installation of tanks is feasible (e.g. in the framework of new building constructions or renovation of buildings).

o Purified rainwater can be used as a source for drinking in case it is less polluted than other available (drinking) water sources (e.g. in case of contaminated ground- or tap-water).

o Decentralised rainwater systems on the building level are desired by owners and residents.

o No other space for the storage of rainwater is available (e.g. groundwater or freshwater reservoirs).

o Collection, filtration and storage facilities are designed appropriate.

o Part of integrated management of rainwater, e.g. in combination with other ESTs for surface and groundwater augmentation.

Advantages:

o Easy accessible alternative water resource in appropriate climates.

o Appropriate collected and stored rainwater from comparably clean surfaces (e.g. roofs) generally meets bathing water standards and can be used as service water without further treatment or purification for gardening, cleaning purposes, toilette flushing and doing laundry.

o Rainwater from comparably polluted surfaces (e.g. roads) can be purified by further treatment, e.g. by sedimentation, sand filtration and disinfection (e.g. by UV radiation) before it is stored as service water.

Disadvantages/Constraints:

o Efficiency is dependent on many factors (rainwater quality and quantity, distribution over the year, daily water demand and tank size).

o Limited feasibility in areas with high air pollution, unequal distribution of rainfall, high population density and high water demand.

o Potential present efficiency in arid climates may decline in future according to predicted effects of climate change.

o Declining water quality in case of poor treatment and wrong design of drainage and storage facilities.

Cultural acceptability:

o Generally high in areas where technology is used traditionally.

o High if facilities are designed, maintained and operated properly.

o Critical if facilities are not designed properly and water quality is declining.

o High because measures can be integrated in urban areas on different scales and different designs, from decentralised visible tanks (e.g. in building) to semi-decentralised invisible tanks (e.g. on properties in underground).

Extent of use:

o Traditionally used in rural areas and different climate zones.

o In urban and domestic areas generally limited to non drinkable purposes due to limited available water quality and quantity.

References, links and literature:

o Coombes, P. and Mitchell, G.; Urban Water Harvesting and Reuse; in: Engineers Australia; Australian Runoff Quality, A Guide to Water Sensitive Urban Design; 2006. Available at: http://www.engaust.com.au/bookshop/arq.html

o Furumai , H.; Reclaimed stormwater and wastewater and factors affecting their reuse; in: Novotny, V. and Brown, P.; Cities of the Future: Towards Integrated Sustainable Water and Landscape Management; 2007

o International Rainwater Catchment Systems Association (e.g. for factsheets), available at: http://www.eng.warwick.ac.uk/ircsa/

o International Water Agency, Specialist Group on Rainwater Harvesting & Management (RWHM), available at: http://www.iwahq.org

An extensive overview of pollutants in both stormwater and greywater is provided by:

o Malmqvist, P. A. et al.; Strategic Planning of Sustainable Urban Water Management; ISBN: 1843391058, 2006

o Mitchell, G.; Applying Integrated Urban Water Management Concepts: A Review of Australian Experience; 2006

Treated sewage
- effluent in ponds, reservoirs and small dams

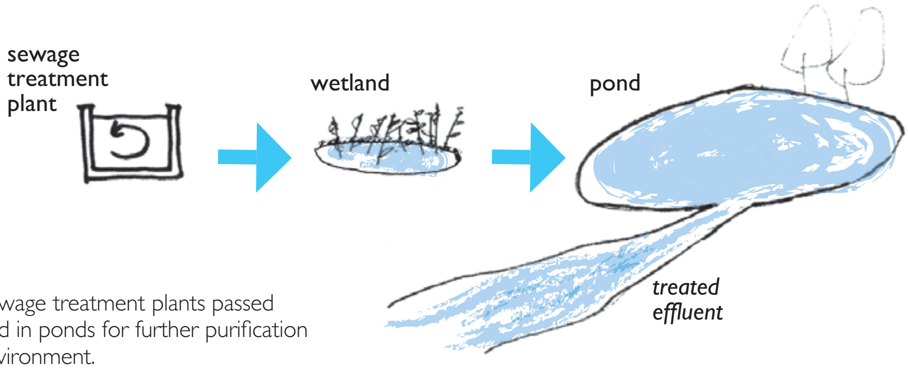


Illustration 18: Effluent of sewage treatment plants passed through wetlands and stored in ponds for further purification before discharged in the environment.

fact sheet 7 4.2.4

Technological description:

The purified effluent from sewage treatment plants can be used for the augmentation of surface water bodies, in which the effluent is diluted with freshwater and reused as a source for urban water supply. It is an efficient technological approach to avoid the over-exploitation of freshwater reservoirs in case of water extraction for water supply. Treatment, augmentation and storage are principally possible on all urban scales, from decentralized to centralized, depending on the specific basic conditions. The water quality of receiving water should be preserved to facilitate a safe water supply. The separation of storm water from domestic wastewater is generally recommended for the appropriate treatment of sewage. The protection from pathogens (bacteria, viruses, protozoa cysts and helminths ova) as well as nutrients (phosphorous and nitrogen) can be realised effectively by separating urine and faeces from the domestic sewage stream (e.g. by application of dry-toilets). Alternatively pathogens can be removed from wastewater by appropriate sewage treatment or by post-treatment of the sewage effluent, e.g. by constructed wetlands. The effective removal of pathogens in waste stabilisation ponds and reservoirs is dependent on many factors, like the specific system and the climate, which are influencing the required retention time (e.g. between 5 and 40 days). The decentralized treatment of sewage streams and its reuse may save infrastructure cost due to savings in sewer constructions (*see also sections 4.4 and 4.5*).

Construction, operation and maintenance:

- o Comparably high space demand for surface water bodies.
- o Comparably low effort for the construction discharge facilities.
- o Comparably low construction effort for the adaptation of existing open water bodies and high effort for the construction of new ponds and reservoirs.

Relative costs:

o Comparably low for drainage and discharge of effluent but dependent on pipeline length (decentralized treatment and augmentation can save infrastructure cost by the minimization of drainage systems).

o Comparably low for modification of existing water bodies.

o Comparably high for construction of ponds and reservoirs.

o Low for quality management in case of relatively unpolluted effluent.

o High for quality management in case of contamination by effluent.

Appropriate technological approach when:

o Surface water is used as a source for water supply.

o Surface water bodies are used for the post-treatment of sewage before it is used for the artificial recharge of groundwater.

o Surface water bodies are located physically near the sewage treatment facilities.

o Sufficient space for the construction of surface water bodies is available.

o Quantity and quality (pollution load) of sewage effluent does not exceed the cleaning capacity of a specific water body.

o Freshwater reservoirs are protected from pollution by treated sewage.

Advantages:

o Protects surface water bodies which are used for water supply from over exploitation.

o Facilitates small water cycles if surface water bodies are located near the sources of discharge and supply.

o Surface waters can be integrated in urban areas on different scales and different designs, from decentralised (e.g. on properties) to centralised (e.g. in parks).

o Visible and easily accessible EST facilitates with easy quality control and communication of water issues.

o Potential multifunctional use of freshwater bodies, e.g. for treatment, storage, nature conservation, recreation, etc.

DisadvantagesConstraints:

o Effluent with high pollution load can lead to declining water quality in the receiving water bodies.

o Contamination of freshwater reservoirs, e.g. with pathogens, nutrients and heavy metals originating from domestic but also from rural sewage as well as industry and agriculture.

Cultural acceptability:

o Critical in case of poor treatment of wastewater and polluted surface waters.

o Critical in case of limited capacity of receiving water bodies.

o Comparably high in case of appropriate pollution control and quality management.

Extent of use:

o Widespread use in cities which are located near lakes and rivers.

References, links and literature:

o Jiménez, B.; Helminth ova removal from wastewater for agriculture and aquaculture reuse; Water Science and Technology, Vol 55, No 1-2, Q IWA Publishing, 2007, pp 485-493

o UNEP, DANIDA U. Tanzania and Pharmacy University Denmark; Waste Stabilization Ponds and Constructed Wetlands; Design Manual, 2005.

o UNEP-IETC; Environmentally Sound Technologies for Wastewater and Stormwater Management - An International Sourcebook; UNEP-IETC Technical Publication Series 15, 2002.

Treated sewage
- effluent for the artificial recharge of groundwater

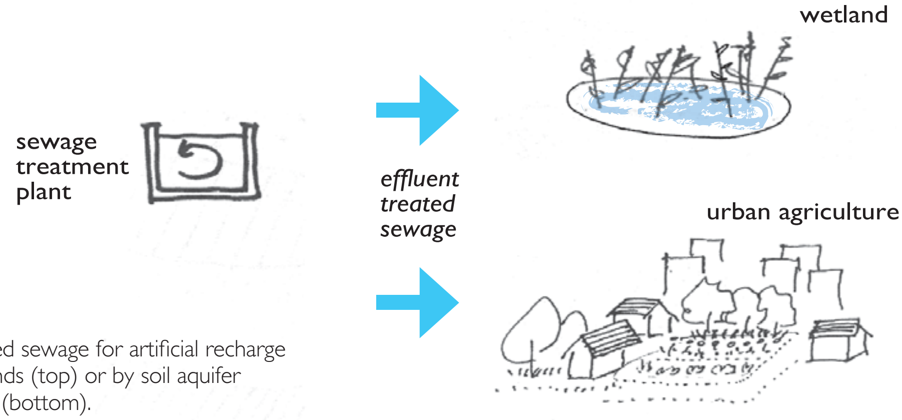


Illustration 19: Effluent of treated sewage for artificial recharge of groundwater through wetlands (top) or by soil aquifer treatment in urban agriculture (bottom).

fact sheet 8 4.2.4

Technological description:

The purified effluent from sewage treatment plants can be used for artificial groundwater recharge under certain circumstances. It may be an efficient technological approach to avoid depleting aquifers due to over exploitation. Due to the comparably high pollution load of treated mixed sewage effluent (compared with rainwater) the selection of appropriate recharge technologies is crucial to protect the aquifers from pollution with pathogens (bacteria, viruses, protozoa cysts and helminths ova) as well as nutrients (phosphorous and nitrogen).

The infiltration of wastewater by gravity through soil, Soil Aquifer Treatment (SAT), can significantly decrease contamination by treated sewage effluents and should therefore be preferred. The efficiency is dependent on various factors which will be discussed in more detail in section 4.5. The direct subsurface discharge in the framework of drip irrigation facilitates positive interdependencies with urban agriculture.

Construction, operation and maintenance:

o Low operation and maintenance effort.

o Varying effort for the construction of drainage systems, dependent on the distance between treatment and infiltration facilities and on the specific capacity.

o Varying effort for the construction of infiltration facilities. They are very low if pre-existing infiltration facilities for rainwater management or drip irrigation systems in urban agriculture can be used also for the infiltration of wastewater.

o Comparably high effort for the construction of underground infiltration facilities under traffic areas.

Relative costs:

o Low for operation and maintenance.

o Varying costs for the construction of drainage systems, dependent on capacity and pipeline length.

o Varying costs for the construction of infiltration facilities. Comparably high for new systems underground and low for systems on surface as well for the use of existing systems for rainwater infiltration and irrigation.

Appropriate technological approach when:

- o Water permeable soils with appropriate structure are available.
- o Sufficient freeboard between groundwater level and surface is present.
- o Urban green or agriculture requires irrigation.
- o Further treatment of effluent is required due to contamination with pathogens.
- o Surface water bodies are not available or are not suitable for the discharge of effluent.

Advantages:

- o High potential for purification of effluent by elimination of pathogens (in soil) and absorbance of nutrients (by plants).
- o Augmentation of groundwater.
- o Appropriately treated and infiltrated effluent can be compatible with native groundwater and can meet primary drinking water standards.
- o Protects surface water bodies from contaminations by effluents.
- o Systems can be integrated on different scales and different designs, from decentralised (e.g. building) to centralised (e.g. in parks) and from visible (e.g. ditches) to invisible (e.g. underground swales).
- o Decentralized groundwater recharge can save infrastructure cost by the minimization of drainage systems.

Disadvantages/Constraints:

- o Effluent with high pollution load may lead to contamination of ground water (dependent on infiltration method, quantity and quality of discharged sewage and soil quality).
- o Discharge of effluent on surface may lead to contamination of people and crops with pathogens as well as odour problems.
- o Area intensive because effluent may not be injected into aquifers without further treatment.
- o Excessively rising ground water tables.

Cultural acceptability:

- o Generally high in case of subsurface irrigation/ infiltration due to positive interactions with irrigation effects on purification and odour control.
- o Critical in case of odour problems and contamination of groundwater.

Reclamation of domestic sewage for drinking water purposes

Namibia is the most arid country in Southern Africa and continuously faces serious water challenges. The Goreangab Water Reclamation Plant in Windhoek, Namibia is internationally renowned as the first plant in the world to reclaim domestic sewage for drinking water purposes. The Water Reclamation Plant was built by the City of Windhoek in 1967 to reclaim water directly from domestic sewage effluent as a supplement to Windhoek's very scarce raw water resources. The Plant can be fed from two sources, these being the Gammams Sewage Treatment Plant and the Goreangab Dam. The Plant can be split into two streams, with one stream used for effluent from the sewage treatment plant and the other used for the treatment of Goreangab Dam water. Alternatively the raw waters can be blended and treated as a single stream. Due to pollution in the catchment area of the dam, the quality of the water had deteriorated to such an extent that conventional treatment methods could no longer be applied. The two sources had to be combined and treated in a single extended and upgraded new Goreangab Water Reclamation Plant which was completed in 2002. The old Plant was taken as a starting point for the new design. To enhance the purification and multiple barrier concept, the following additions to the original process (based on Dissolved Air Flotation (DAF) filtration and two chlorination steps were implemented: Powdered Activated Carbon (PAC), Ozone, Biological Activated Carbon (BAC) and membrane filtration. *(Water Reclamation, City of Windhoek, available at: http://www.windhoekcc.org.na/)*

Extent of use:

o Irrigation of agriculture with effluent is widespread in areas with water shortages, which have sewer systems and are equipped with sewage treatment plants. However untreated sewage is often used for irrigation due to lacking treatment facilities. The optimizations of these systems concerning the safe and appropriate use of effluent is contributing to health care preservation of freshwater resources (*see also section 4.5.4*)

References, links and literature:

o *Asano, T.; Artificial Recharge of Groundwater; Butterworth Publishers, Boston,1985*

o *Foster, S., Lawrence, A. and Morris, B.; Groundwater in urban development assessing management needs and formulating policy strategies; World Bank, Technical paper, No. 390, The World Bank, Washington, D.C. 1998. (In: Jiménez, B. Wastewater risks in the urban water cycle (in press), in Urban Water security: Managing Risks, Jimenez, B. And Rose J., Ed. UNESCO (in press))*

o *Marsalek, J., Jiménez-Cisneros, B. E., Malmquist, P.-A., Karamouz, M., Goldenfum, J. and Chocat, B.; Urban water cycle processes and interactions; IHP-4, Technical Documents in Hydrology, No. 78, UNESCO, Paris, 2006, pp. 45 - 46.*

o *Jiménez, B. and Chávez, A.; Quality assessment of an aquifer recharged with wastewater for its potential use as drinking source: El Mezquital Valley case; Water Science and Technology 50(2), pp. 269-276, 2004*

o *Rose, G. D.; Community-Based Technologies for Domestic Wastewater Treatment and Reuse: Options for urban agriculture; International Development Research Centre, Cities Feeding People Series, Report 27, Spring 1999*

o *World Health Organization, Aertgeerts, R., Angelakis, A. (editors); Health risks in aquifer recharge using reclaimed water - State of the art report; 2003. Available at: https://www.who.int/water_sanitation_health/wastewater/wsh0308/en/index.html*

4.3 WATER SUPPLY AND DISTRIBUTION ESTs

4.3.1 INTRODUCTION

Positioned between the storage and use aspects, *supply and distribution* is the section that discusses the issue of how to provide the users efficiently with enough and good water. The central questions concern the appropriate technologies and policies for construction and maintenance of supply networks.

The stepwise analysis of flows, areas and actors (4.3.2) may provide the required information for the discussion of the main arguments (4.3.3) for the selection and combination of specific ESTs presented in the last subsection (4.3.4).

The analysis of the existing situation should point out all available but also missing information. The aim of the analysis is a clear understanding of the facts and uncertainties as a basis for the decision making process. Selected ESTs should fit in this specific situation. After the analysis of the actual and potential storage situation (4.2.1) the demand side should be analysed in order to discuss the way supply ESTs can bridge the gap between the two.

4.3.2 ANALYSIS OF THE DECISION SITUATION

4.3.2.1 Analysis of flows: Quantity aspects

- o The first step is to make a *balance of water use* for different purposes. It is important also to consider higher and lower water use scenarios for the future.
- o The second step is an analysis of the rhythms or patterns. What are the high peak and low peak levels in water use and when do they occur.
- o Then a clear picture should be drawn of the present supply and distribution systems and the quantity problems (leakage, reliability, vulnerability) that go with them.

4.3.2.2 Analysis of flows: Quality aspects

- o The first step is to analyse the water quality available and the qualities required for different types of water use. This information should be identified and combined with the quantity analysis made for the present situation and for the future.
- o The second step analyzes the treatment of raw water resources already applied in the present situation.
- o Then, a general assessment should be carried out on the quality problems and opportunities encountered presently and in the future. This includes making an overview of the required treatment facilities to meet the water demand of different qualities.

4.3.2.3 Analysis of areas

- o The spatial analysis starts with mapping the surface water, rainwater (storm water) and groundwater pumps, reservoirs, canals, aqueducts or piped water networks that carry water from the storage areas to the users.
- o Special attention should be given to the location of access points.
- o It is important to know where the problems and opportunities for flow management (*regarding quantity and quality*) are located.

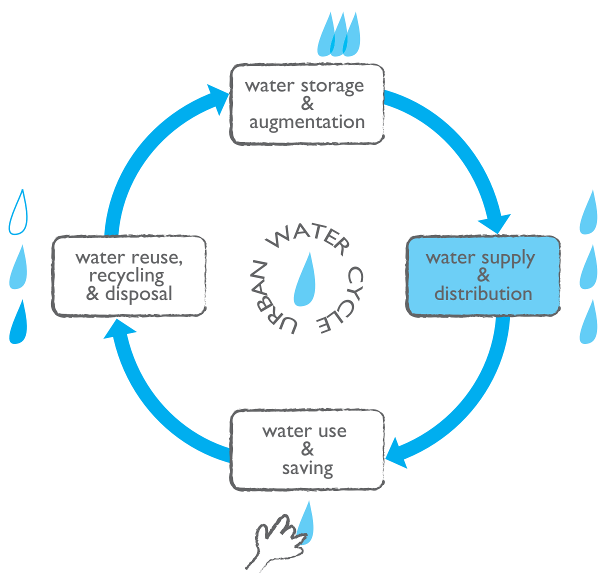


Illustration 20: Position of the section on water supply and distribution in the urban water cycle.

4.3.2.4 Analysis of actors

An analysis of the relevant actors, or stakeholders, should throw light on the role groups and individuals play in the funding, the legal permits and the operation of ESTs that belong to different supply and distribution options. Who has access? Who pays? This question, for example, may lead to a discussion about a trade-off between the reduction of leakage and the costs involved. But these discussions are linked to the answers to other questions such as: who is responsible for operating the systems, for quality control and for maintenance? If there are supply and distribution problems, now or in the future, for whom are they problematic? Many of these issues relate to the institutional framework in place: laws, rules, customs etc. Understanding the roles, the power of actors or the need for empowerment, is essential to decision making.

4.3.3 DISCUSSION OF ARGUMENTS FOR DECISIONS ABOUT ESTS FOR SUPPLY AND DISTRIBUTION

4.3.3.1 Piped water networks

From a quantity supply point of view, central treatment to produce drinking water quality and a *complete piped water network* seems to offer complete control over a system that provides full access to safe drinking water for everybody. The fact that most developed cities have such systems, however, does not necessarily imply that this is the most water-efficient system. Piped water networks are vulnerable and leakage rates of up to 50 % and even more are not exceptional. Apart from proper *maintenance*, *reliability* and *quality control* are crucial conditions. Urban systems that depend on one centralised supply network will be more vulnerable to droughts compared to cities with a diversity of water supply systems. If the urban water supply is dependant on one big source, for instance a central groundwater pumping station, it becomes more important to protect that source from polluting influences such as the central urban waste-dumping site. Quality control, however, remains extremely important in all supply options. The analysis of the decision situation will reveal the potential *actor* based and *area* based answers to these required conditions. Adequate institutional organisation and capacity building to create and maintain this organisation is conditional and so is spatial planning. The institutional conditions concern a solid and stable financial basis, but also the organisation of a labour force of skilled people that can monitor and maintain the piped network system and can learn from experiences. In case the potential for building this level of organisation is low, an essential requirement for piped network development is missing. It should be stressed, however, that also decentralised options require organisational capacity to support proper construction, operation, maintenance and quality control. Capacity building is a cornerstone of all solutions.

In case of leakage and other problems of an already existing piped water network, it seems logical to consider repair and improvements. The Water for African Cities Programme, for example, has published a Water Demand Managing Cookbook (*Rand Water and UN Habitat; Water Demand Management Cookbook; Johannesburg/Nairobi, 2003, available at: http://www.unhabitat.org/pmss/getPage.asp?page=bookView&book=1781*) that focuses on two strategies: First leakage control of the existing network and second reducing water use. The latter issue will be discussed in section 4.4.

4.3.3.2 Pressure management and metering

Improving existing single quality piped water networks requires, above all, a sound organisational basis or at least the potential and the will to improve that basis. Technical measures, however, may be helpful. *Pressure management*, for example, may considerably alleviate the problem of leakage. High pressure substantially increases the losses caused by leakage and an analysis of the flow pattern may reveal the timing and the difference between the night-flow (usually very low) and the peak flows during day-time. Lowering the night-time pressure may reduce losses without nuisance for the users. However 24-hour continuous pressure should be the first priority and if a system has intermittent supply, the first target should be to return to a fully pressurised system. In many countries the damage done by intermittent supply is so great that the remaining network will never be able to handle 24-hour pressure and it will be necessary to replace the whole system. Another technical measure that can be effective to reduce water use is metering and billing customers per m^3. After the installation of water meters per connection, individual users may develop more awareness and care. Experiences show that a regime of free water up to a certain basic level of use and payment above that level may provide basic needs to the poor and yet act as an incentive for saving water.

4.3.3.3 Dual quality supply networks

A dual quality pipe supply system has parallel networks for potable and non-potable water quality, for example for cleaning and watering gardens. They can either be installed on a centralized or decentralised scale. Dual networks can improve water efficiency by limiting the consumption of scarce drinking-quality water. The dual system limits the use of chemicals and energy to treat water to potable standards. Apart from the extra costs and material for the second network, quality control and the avoidance of false connections are critical issues. For this reason, drinking water companies in some countries often do not support the dual network idea. They are responsible for public health standards of drinking water and the risk of individual residents making false connections is beyond their control. The risks can be minimised, however, e.g. by clear labelling of "no drinking water" and the use of different pipe materials and colours. While decentralised dual supply networks are used in many cases worldwide (e.g. in case of rainwater harvesting for service water supply) there are only a few examples for centralised dual supply networks. In Tokyo and Melbourne, for example, the service water quality is not delivered by the drinking water company but by the wastewater treatment company.

4.3.3.4 On-site (house and street) service water ESTs

Piped water networks require a sophisticated organisation of control and maintenance. Some environmentally sound systems, however, are less vulnerable. One is a single quality central pipe network for drinking water distribution supplemented by on-site service water supply. At the level of houses and individual buildings, for example, rainwater from roofs can be caught and stored to be used for cleaning, watering plants and gardens or for toilet flushing. At the level of streets and green spaces, stormwater can be harvested and infiltrated near trees and shrubs. The result can save the drinking water that otherwise would be used for these purposes. The 'house system' requires a limited infrastructure inside buildings and the 'streets and green space systems' require water sensitive design of open spaces. Even in the 'house system' the risk for false connections is small and the central institution is not responsible. Awareness and care of the users, however, remains an essential condition.

4.3.3.5 Bottles and tanks

If a piped water network does not deliver reliable healthy drinking water, the individual users have to purify the water before using it for food and drinks, e.g. by boiling, filtration or the addition of chemical disinfectants and coagulants. Alternatively they have to use water from other sources for the production of drinking water. In such a case and if no other appropriate resources are available, residents may also be dependent on bottled water for drinking.

In the absence of a piped water network, bottled water is also a general water supply option. For the users, however, this risks to become a very expensive option that is only a profitable business for the vendors. This is not a desirable solution for the poor population of squatter areas. Instead, water supply by trucks with tanks is more suitable in such situations. Water quality can then be controlled by a central agency.

4.3.3.6 Wells

In neighbourhoods and small villages people often can go to a river or to a well to fill their buckets. Sometimes, they have to walk long distances to get water. A common strategy is to build new wells at the neighbourhood level. This can be a good solution, provided there is enough good quality groundwater. Depending on the local circumstances, building new wells and improving the quality of the existing ones may be an environmentally sound solution that is far less costly and much easier to organise than a piped water network. Sometimes, a system of neighbourhood taps is constructed as a part of a neighbourhood-upgrading scheme such as the Bissau case described in chapter 3. This system only misses the links of the network to individual houses, which makes it less costly and somewhat less vulnerable for leakage. But the conditions for reliability and quality are the same for the neighbourhood taps network as for a fully developed piped water network. If treatment is required, it should be centrally organised.

4.3.3.7 Priorities

Under an *Integrated Water Resource Management (IWRM)* perspective, the choice of supply and distribution options may result in a mix of ESTs. The priority sequence of options that may summarise the arguments is as follows:

- o In the situation of wells or a river, improving these supply sources and measures to limit the water demand (section 4.4) will have the first priority.
- o If that is difficult to realise, and there is an immediate need to provide healthy drinking water to many people, trucks with tanks may supply drinking water to static tanks for distribution.
- o A next step can be to consider installing on-site water supply systems e.g. with rainwater as a source.
- o Piped water networks may become feasible if the standard of life is developing. It is under these circumstances that investments and funding can be made available for public or private water supply firms and co-operations. Capacity building should lead to institutional strength and an organisation capable of maintenance and quality control of the network. Water use reduction and the combination with on-site service water systems based on water recycling and reuse may lead to environmentally sound and sustainable solutions.

4.3.4 FACT SHEETS ON WATER SUPPLY AND DISTRIBUTION ESTS

The ESTs Fact Sheets below enlisted for "water supply and distribution" are presented in the following Section 2:

4.3.4.1 Surface water abstraction
(Surface water as source for water supply)

4.3.4.2 Groundwater abstraction
(Groundwater as a source for water supply)

4.3.4.3 Water supply reservoirs

4.3.4.4 Transfer of water

4.3.4.5 Single pipeline systems
(supply with one type of water quality)

4.3.4.6 Dual pipeline systems
(supply with two types of water qualities)

4.3.4.7 Water containers
(bottles and tanks)

4.3.4.8 Centralised treatment systems

4.3.4.9 Point of use treatment systems

Surface water abstraction
(Surface water as source for water supply)

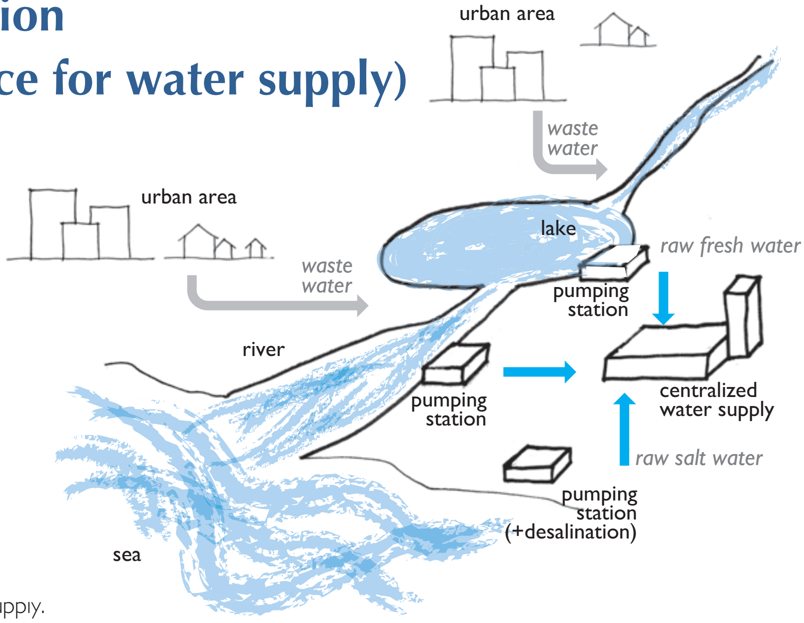


Illustration 21: Surface water as source for water supply.

Technological description:

Within the centralised water supply surface water abstraction is a very common form. The water can be abstracted from natural lakes, dams, rivers or the sea. In many cases it is an indirect form of wastewater reuse, because surface water is often used as a sink for urban sewage. Riverwater may go through several abstraction-treatment-use-treatment-discharge cycles before reaching the sea.

Construction, operation and maintenance:

- The water quality of surface waters can be significantly influenced by integrated urban water management and measures for the reduction of wastewater production. e.g. by reuse and recycling and appropriate treatment of the residues.
- An integrated policy for waste water and drinking water management is required.
- In case of surface water abstraction on collective or individual level water management needs to focus on collective and individual responsibility.
- In case of centralized surface water abstraction centralized water management policy and responsibility is required.
- Based on the specific contamination load, the treatment processes and the related effort for construction, operation and maintenance of the facilities for drinking water production from surface water differ significantly. They vary from quite simple sand filtration processes to mechanically and chemically enhanced treatment processes.
- For the treatment of seawater a desalination process is required. The two principal methods are thermal distillation and reverse osmosis.

Relative costs:

- For the treatment of surface water, more expensive monitoring and treatment technologies are often required for the production of drinking water (filtration technologies and/or chemically treatment) than for the production of drinking water from ground water.

- o The treatment of sea water is a more expensive process than the treatment of river water.
- o The treatment of surface water is generally more costly than the treatment of groundwater due to higher contamination load. Costs can be reduced by nature-orientated treatment methods, like bank filtration.

Appropriate technological approach when:

- o A water body where surface water can be abstracted is present.
- o The abstracted water is able to meet potable water standards after treatment if it is to supply drinking water.
- o Abstraction from the water system should not exceed the natural replenishment volume, in order to realize sustainable water supply.
- o The quality of the water bodies (natural lakes, dams, rivers, sea) can be maintained.
- o The extracted water quantity for water supply does not exceed the capacity of the water body.

Advantages:

- o The abstraction of surface water for drinking water use may stimulate pollution control and sound urban water management to avoid contamination and depletion of the drinking water source, e.g. by the reduction of wastewater production, by reuse and recycling and appropriate treatment of the residues.
- o The abstraction allows the use of nature-orientated technologies for the treatment of raw water, such as bank filtration.
- o In case that cities are located near rivers or lakes, surface water bodies are easy accessible for the abstraction of water but also for quality control.

Disadvantages/Constraints:

- o Available water quantity is dependent on natural basic conditions and anthropogenic factors. Water contaminations by uncontrolled discharge from industry, urban sewage, stormwater and agriculture often lead to poor surface water quality which does not meet drinking or even bathing water standards. Therefore the abstracted water usually needs to undergo treatment processes (like coagulation, filtration and disinfection) before it meets potable water standards.
- o The construction of large upstream water abstraction systems and large down-catchment wastewater treatment plants can lead to significant reductions in the surface water flow in between the two facilities. In addition it prevents sediments from flowing into the river. This may cause scouring and erosion of riverbeds.
- o The surface water quality is significantly influenced mostly by human activities (urban sewage management, industries and agriculture).

Cultural acceptability:

- o High regarding the demand of (drinking) water.
- o Critical when abstraction is influencing the surface water flow.

Extent of use:

- o Often used in urban and rural areas which are located near rivers or lakes and in areas where no appropriate groundwater resources are available. Abstracted surface water is also used for the large scale transport of water to areas where no other or sufficient water resources are available.

Groundwater abstraction (Groundwater as a source for water supply)

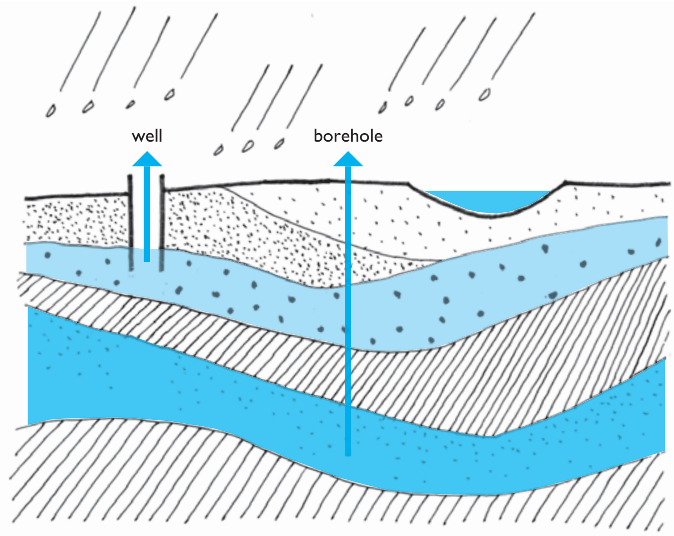


Illustration 22: Groundwater abstraction as source for water supply.

Technological description:

Groundwater abstraction from aquifers is a common and often vital form of raw water production for urban water supply and also for industry and agriculture, especially in areas where the availability of surface water with appropriate quantities and qualities are limited. Groundwater can be either abstracted by wells or boreholes. The water can be withdrawn using containers or by specifically designed borehole pumps.

Construction, operation and maintenance:

o Ground water can either be abstracted by wells or boreholes, depending on the depth of the used aquifer.

o From wells water is taken by lowering a container into it and withdrawing the water by hand or using a motor.

o From boreholes water is withdrawn by specifically designed borehole pumps.

o An integrated policy for domestic sewage and drinking water management is required.

o Water management policy focussing on collective and individual responsibility in case of groundwater abstraction on collective or individual level.

o Centralized water management policy and responsibility is required in case of centralized ground water abstraction.

o The central or municipal government should monitor and regulate the total volume of groundwater abstraction or introduce measures for groundwater recharge.

Relative costs:

o The costs of treatment and construction of infrastructure are relatively low. Groundwater does not require much treatment (with exception for the case of polluted groundwater; see box) and boreholes can be developed close to the destination of supply.

Appropriate technological approach when:

o An aquifer with appropriate water quality and quantity is present.

o Contamination of groundwater (e.g. by agriculture, industry, contaminated soils and leaking sewer systems) is avoided.

o Integrated water management for groundwater and the surrounding water systems is applied to avoid depletion of aquifers.

o No more water is extracted from the aquifer than is replenished on a yearly timescale.

o Abstracted quantity of ground water is balanced with the quantity for (artificial) recharge to avoid the depletion of the used aquifers and declining water tables (leading to environmental damage and limiting the available ground water also in other areas)

Advantages:

o It often has good quality that requires no or only simple treatment technologies (e.g. disinfection and taste control) to meet the requirements for safe drinking water, making it often a preferred water source for supply.

o Ground water generally requires less treatment than surface water because the water is filtered and protected by soil layers.

o The constructive and monetary effort for the development of groundwater-supplied systems may be lower than the development of new surface water resources, due to savings in treatment and construction of infrastructure.

o The ground water quality can significantly be influenced by human activities (urban sewage management, industries and agriculture), therefore the water quality of surface waters can be significantly influenced by IWRM.

Disadvantages/Constraints:

o The over-abstraction of groundwater may cause declining ground water tables and serious land subsidence as well as the destruction of ecosystems.

o Groundwater can be polluted by natural and anthropogenic sources.

o Available water quantity is dependent of natural basic conditions (capacity of aquifers) but also on quantity of the abstracted ground water.

o Depletion of aquifers can lead to low river flows and the drying up of wetlands, which is harmful to aquatic ecosystems and can reduce the effectiveness of rivers diluting pollution, e.g. from sewage treatment effluent.

Cultural acceptability:

o High when water quality can be ensured.

o High regarding the low costs.

o Low when the depletion of aquifers is leading to low river flows and the drying up of wetlands.

o Low when ground water abstraction causes declining ground water tables and serious land subsidence.

Extent of use:

o Widespread use in urban and domestic areas with sufficient groundwater resources.

o In areas where the groundwater table is either not sensitive to water abstraction or in areas where Aquifer Storage and Recovery (ASR) is practiced.

References, links and literature:

o *Ohgaki, S., Takizawa, S., Herath, G., Katoaka, Y., Keishiro, H., Kathiwada, N. R. and Moon, H.-J.; Sustainable Groundwater Management in Asian Cities, a summary report of Research on Sustainable Water Management in Asia; Institute for Global Environmental Strategies (IGES), Japan, 2006*

o *Chilton, J. (editor); Groundwater in the Urban Environment, Selected City Profiles; International Association of Hydrogeologists, International Contributions to Hydrogeology, 21, Routledge 1999*

Groundwater Contamination:

Worldwide millions of people are drinking heavily polluted groundwater. Arsenic in drinking water threatens 35 million people in Bangladesh, three million people in Nepal and many more in other countries like India, Peru, Ghana, Nicaragua, Vietnam, Argentina, Mexico, Chile, Taiwan, Hungary, Philippines, and Mongolia. Only in China around 63 million people drink water which is naturally contaminated by fluoride. *(Clayton, M.; Finding a filter for arsenic-tainted water; 18.02.2005, available at: http://www.scidev.net. Hepeng, J.; China maps massive problem of water contamination; 29.04.2005, http://www.scidev.net)*

Water supply reservoirs

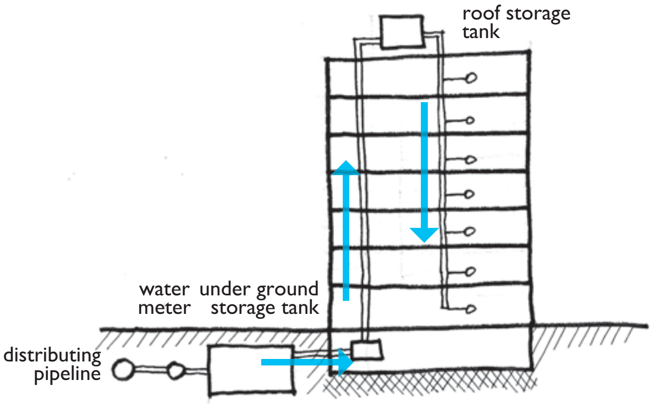


Illustration 23: Water supply reservoirs for buildings and properties using underground and roof reservoirs or water tanks.

Technological description:

Water supply reservoirs are generally defined as natural or constructed ponds or lakes. In this section of the Sourcebook, the focus is only on reservoirs or water tanks. The storing of gravity-driven inflow of water and the piping of the majority of the stored water directly into the water supply can be defined as direct supply storage. If the major part of the inflow of reservoirs is obtained by pumping, the reservoirs can be defined as pumped storage. Generally water reservoirs are designed in a way that they can provide water for a specific period even in absence of raw water input.

Construction, operation and maintenance:

- o Reservoirs work by storing and releasing water to a supply region depending on demand and reservoir rules that are governed by the type of reservoir.
- o The available water quantity is primarily dependent on the available raw water quantity.
- o Reservoirs can be sited across surface water (e.g. a river) and receive their water from that water body.
- o Reservoirs can be constructed underground (where it is comparably cool and dark) without limiting the use of buildings, real estates and traffic areas.
- o Reservoirs are often installed also on towers and rooftops to provide water supply and distribution by gravity (without pumping).
- o Reservoirs can be filled artificially by pumping or by a gravity feed from an independent water source (either surface water, ground water, rainfall or reclaimed waste water).
- o In most centralized as well as decentralized water supply systems pumped storages are used.
- o After the treatment of raw water (fresh water or recycled waste water) for meeting the required water quality (e.g. drinking water or service water quality), the water is stored temporarily before it is distributed either in a supply network by piping or by filling it in containers.
- o Storage should provide a dark and cool storage of water to avoid degradation of the original water quality.
- o Decentralized and semi-decentralized installations of water reservoirs can distribute for the security of water supply in urban areas.
- o Water losses from reservoirs should be avoided by watertight construction (leakage control) and an enclosure for the reduction of evaporation losses.
- o Water management policy focussed on collective and individual responsibility is required in case of reservoirs on collective or individual level.
- o Centralized water management policy and

responsibility are required in case of centralized reservoirs.

o Integrated Policy is required for adopted water supply and distribution systems under consideration of reuse and recycling measures on all scales, from decentralized to centralized.

Relative costs:

o Relatively high in comparison with natural storage solutions.

o Costs depend on the type of storage (construction).

o Centrally constructed supply reservoirs are resource intensive with their construction requiring large amounts of land and construction materials.

o In case of decentralized applications infrastructure costs can be saved for the construction of centralized pipeline systems.

Appropriate technological approach when:

o When natural storage solutions are limited.

o High fluctuations in water demand and supply occur in the system.

o There is enough raw water available.

o Water quality in the reservoirs can be ensured. Reservoirs for the storage of (purified) drinking water should be closed and protected against pollution (e.g. by infiltrating liquids, atmospheric pollution or animals).

o Water losses of reservoirs are avoided by watertight construction (leakage control) and an enclosure for the reduction of evaporation losses.

Advantages:

o Water supply reservoirs are suitable for different scales, from decentralized to centralized systems.

o Reservoirs for the storage of recycled waste water can contribute to significant savings in fresh water demand.

o During appropriate storage the water quality tends to improve as a result of settling suspended solids, the reduction of nitrate concentration and the decay of pathogenic bacteria.

o Centrally installed reservoirs can provide additional storage capacities for peak demands.

o In case of only temporarily available water supply or damages in a water supply network, decentralized reservoirs can provide distribution safety.

Disadvantages/Constraints:

o Open reservoirs are sensitive to atmospheric pollution and are a potential habitat for breeding mosquitoes.

o Reservoirs on towers and rooftops may limit the use of buildings and incur the risk of diminishing water quality.

o Water quality can deteriorate in cases where water with high nutrient content is stored or in case of stratification in deep open reservoirs during the summer.

o Adoption of water supply reservoirs is often hindered by planning issues and objections due to perceived environmental damages.

Cultural acceptability:

o High when the water quality can be ensured.

o High when positive interactions can be achieved by the construction of open supply reservoirs which can be integrated in urban areas and used as recreational facilities (e.g. for fishing) as well as areas for nature conservation and water treatment (e.g. by wetlands).

Extent of use:

o Widespread use in urban areas with scarce water resources, with high fluctuations in water demand and supply and where natural storage resources are limited.

References, links and literature:

o Neelakantan, T. R., Pundarikanthan N. V.; Hedging Rule Optimisation for Water Supply Reservoirs System; in: Water Resources Management, Volume 13, Number 6 / December 1999, pp. 409-426.

Transfer of water

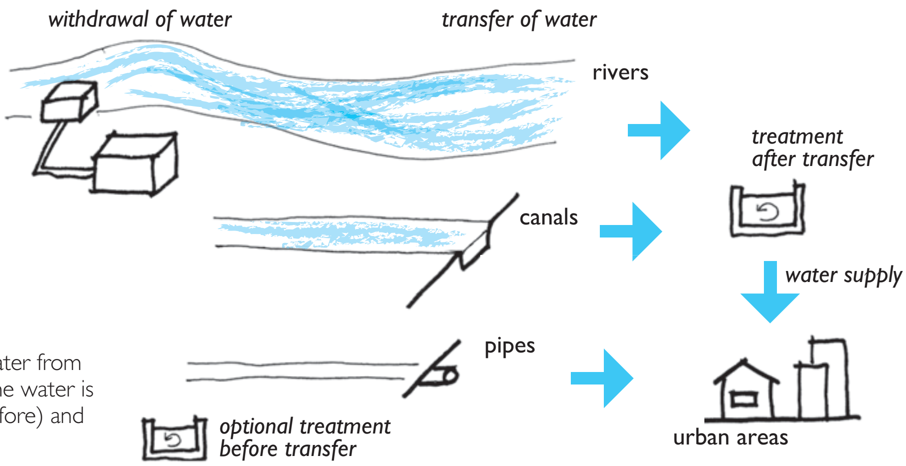


Illustration 24: Withdrawal of surface water from rivers for the transfer to urban areas. The water is treated after transfer (optionally also before) and distributed to properties and buildings.

Technological description:

Transfer of water resources over long distances between resource zones may be described as inter-regional or inter-basin water transfers from areas with abundant water to zones with relative water scarcity. The transfer can be achieved with technologies such as canals, rivers and pipelines. While canals and rivers are generally used to transport raw water, pipelines are used for the transfer of treated water.

Construction, operation and maintenance:

- o The available water quantity is primarily dependent on the available raw water quantity.
- o Purification at the destination of transfer may be required.
- o The transfer of water requires a centralized infrastructure for the distribution of water.
- o The transfer of water includes construction in the catchment of water at the source.
- o The construction of canals and rivers can be integrated in urban design because it offers the possibility of positive interactions between the transfer of water and other uses, such as transport, recreation and water management.
- o The construction of pipelines can be realised underground without affecting the urban design but also without possible positive interdependencies between water transfer and other uses.
- o High centralized water management policy and responsibility is required.

Relative costs:

- o The transport of huge water resources over long distances to serve urban areas centrally is technically feasible but costly.
- o The transfer over long distances includes potential high water losses by evaporation and/ or leakages (leakage control).
- o The construction of either canals or pipelines is expensive.

Appropriate technological approach when:

- o No alternative water resources can be made available (e.g. by leakage control, water-saving use or reuse and recycling of waste water).
- o There is a lack of sufficient and efficient urban water supply.
- o The environmental impact of water abstraction and its transfer need to be evaluated carefully.
- o The water quality can be preserved.

Advantages:

- o Water shortages can be diminished by the use of abundant water from another area.
- o Multifunctional use and combination with urban design is possible.

Disadvantages/Constraints:

- o The transport of huge water resources over long distances to serve urban areas centrally includes a lot of effort and also potential water losses by leakages and evaporation.
- o The transport of water over long distances includes high risk of degrading water quality.
- o The abstraction of huge amounts of water includes the risk for environmental damage at the source of abstraction (evaluation of environmental impact) and social resistance from residents of the source area.
- o For large inter-basin or inter-regional water transfers it is necessary to besides preserving the water quality, avoid impacting the ecosystem by undertaking the necessary precautions such as undertaking environmental impact and risk assessments and taking the necessary actions. The assessment should include studies at the source, destination as well as along the transfer route.
- o Before considering the transfer of water, other ESTs for the urban water cycle should be surveyed concerning their potential to provide sufficient and efficient urban water supply, as well as the positive interdependencies between urban and agricultural water demand (e.g. by the reuse of purified urban sewage for irrigation).

Cultural acceptability:

- o High when ecological damages can be avoided, a good water quality can be preserved and when integrated in urban design.
- o Critical in case of bad effects on the water quality and availability at the source of transfer and in case of high water losses and high costs.
- o Low when other ESTs can be applied.

Extent of use:

- o Used in many urban areas which are chronically short to water, either because they are situated and have mushroomed despite limited nearby water resources (e.g. Chennai, Mexico City, Las Vegas and Amman) or because the water consumption became so high, that it already exceeded the available natural water resources (São Paulo, Atlanta, Kuala Lumpur, Coimbatore and Hyderabad). Even though the application of ESTs for water use efficiency could avoid the necessity for the transfer of water significantly, in general, these measures are only applied limitedly so far.

References, links and literature:

- *o Molle, F., Berkoff, J.; Cities versus Agriculture: Revisiting Intersectoral Water Transfers, Potential Gains and Conflicts; Comprehensive Assessment Research Report 10. Colombo, Sri Lanka: Comprehensive Assessment Secretariat, 2006.*
- *o Ghassemi, F., White, I.; Inter-Basin Water Transfer: Case Studies from Australia, United States, Canada, China and India; International Hydrology Series, Cambridge University Press, 2007*

Single pipeline systems (supply with one type of water quality)

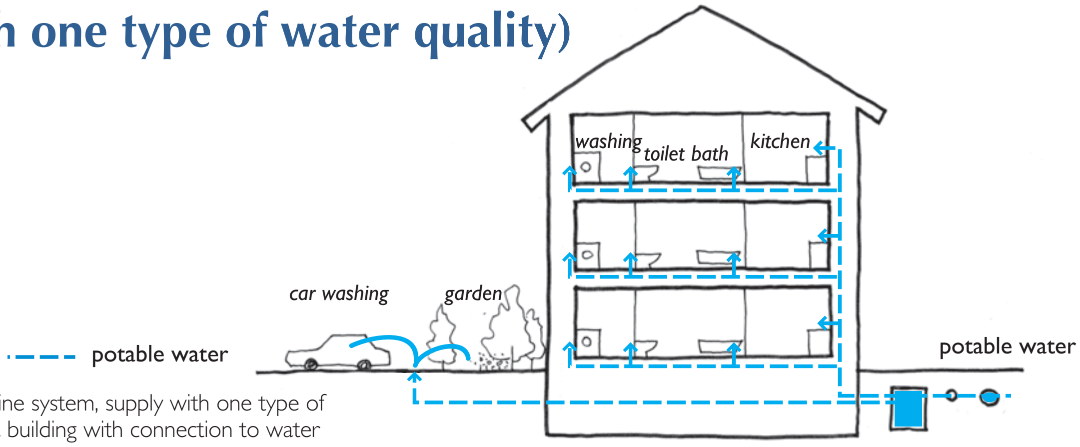


Illustration 25: Single pipeline system, supply with one type of water quality. Section of a building with connection to water storage tank and connection to centralised water supply.

Technological description:

Single pipeline systems are used for the supply of one water quality, generally potable water to the consumers. Single pipeline systems are used commonly for piped water supply in urban and domestic areas, in centralized systems but also in decentralized systems. The single pipeline systems can be principally differentiated in public systems (between source of supply and meter) and systems on properties and buildings (between meter and point of withdrawal). Public central water supplies with single pipeline systems allow the supply of urban and domestic areas with sufficient quantities of water and drinking water respectively.

Construction, operation and maintenance:

- o Centralized systems consist of a network of water transmission and reticulation mains, which are either distributing water from main reservoirs to smaller water tanks (acting as pressure break tanks) or directly to the consumers.
- o In public water supplies the water is generally supplied from the water mains to the customers by connection pipelines.
- o Public central water supply with single pipeline systems is generally installed invisible underground.
- o At the end of these pipelines meters are generally installed and form the transition from the public to an individual pipeline system.
- o The pipelines from the meters to the properties are defined as service pipelines.
- o Single pipeline systems on properties and in buildings are generally integrated in buildings and are managed individually or collectively.
- o The installation of individual meters for single households allows the individual billing of water consumption and may raise awareness and interest in water-saving measures.
- o Various materials are available for the construction of pipeline systems, metals (cast iron, copper and lead), plastics (PVC) but also compound materials. Metal pipes should not be used in situations were the water is acidic to prevent pollution of the supplied water and corrosion of pipelines.
- o Minimum leakage rates in well maintained centralized supply systems are approx. 5% of the supplied water quantity.
- o Leakage rates in poor maintained systems can easily be over 60% or even more.
- o Leakage can be managed and reduced through various leakage management interventions.

- o Leakage analysis (extent of leakage in a specific area and main source of leakage) is the basic condition for leakage control (repair or exchange of leaking pipelines and fittings).
- o Losses by leakages can be reduced also by the reduction of pipeline length.
- o The decision to make piped water supply good enough to be potable or to leave it as is and to introduce measures for the decentralized purification is primary dependent on the technical feasibility and the related technical and financial effort for the specific measures.
- o Public central water supply with single pipeline systems requires centralized infrastructure and management.
- o Water management policy focussing on collective and individual responsibility, in case of pipeline systems on collective or individual level.
- o Centralized water management policy and responsibility in case of substitution of centralized water supply.

Relative costs:

- o All water supply systems leak to some extent and system leakage can never be eliminated. Moreover, total leakage reduction would not make sense economically: beyond a specific point the costs for leakage reduction are exceeding the marginal cost of the water potentially saved.
- o Measures which are required to cope with the degradation of the water quality in a pipeline system or even contaminations may be difficult and costly.
- o Maintenance costs are high, because most pipe line systems are constructed underground. They are generally not accessible easily and for low cost.

Appropriate technological approach when:

- o Sufficient water resources are available.
- o A degradation of original water quality is allowed.
- o Losses of leakages are reduced to a minimum by appropriate installation, control and maintenance.
- o Extensive water consumption is avoided by the implementation of ESTs for water use efficiency.

Advantages:

- o Public central water supply with single pipeline systems allow the supply of urban and domestic areas with sufficient quantities of water and drinking water respectively
- o Positive effect on society and economy as well as gender issues (time for the transport of water by hand, which is often done by women, is available for other activities)
- o Appropriate for convenient water supply in centralized and decentralized systems.

Disadvantages/Constraints:

- o These systems can lead to inefficient water use of high quality water.
- o Leakages occurring in reservoirs, water mains, service pipelines and connections are leading to drinking water losses.
- o Leakages causing permanent water losses mainly occur outside of buildings where they are not easily noticed and can not easily be repaired.
- o The supply with drinking water quality implies the production and consumption of drinking water for uses which do not require drinking water quality, in public systems as well as on properties and in buildings.
- o The central supply of water to consumers facilitates the consumption of comparably high quantities of water (the water does not need to be carried over long distances but just flows out of the tap).

o Various factors influence the water quality during its way from the supply reservoir to the taps and are leading to a degradation of the water quality (e.g. by pipeline materials, long residence times or leakages).

o The supply of poor water quality, e.g. service water quality only (non-potable water), requires point of source treatment for the production of drinking water, or is depending on another supply of potable water (e.g. bottled water).

o In case of microbiological contamination it may sometimes be hard for the authorities to reach drinking water quality, even in developed countries.

Cultural acceptability:

o Very good in case of permanent supply with good water quality.

o Generally good also when used only as intermediate supply and limited water quality, due to non-available convenient alternatives.

o In many cases people do not drink tap water directly before it is further purified because they do not trust in public drinking water supply. Therefore it is important to make either piped water supply good enough to be potable or to develop supply concepts which are based on the point-of-use treatment of piped water for drinking water purpose.

o May be critical in case of high leakages.

Extent of use:

o In almost all urban but also rural areas which have installations of centralised water supply networks.

o In all public water supply systems (between source of supply and meter).

o In all systems on properties and buildings (between meter and point of withdrawal).

References, links and literature:

o *Habitat, Rand Water; Water Demand Management Cookbook; Nairobi/Johannesburg, 2003, available at: http://www.unhabitat.org/pmss/getPage.asp?page=bookView&book=1781*

Dual pipeline systems (supply with two types of water qualities)

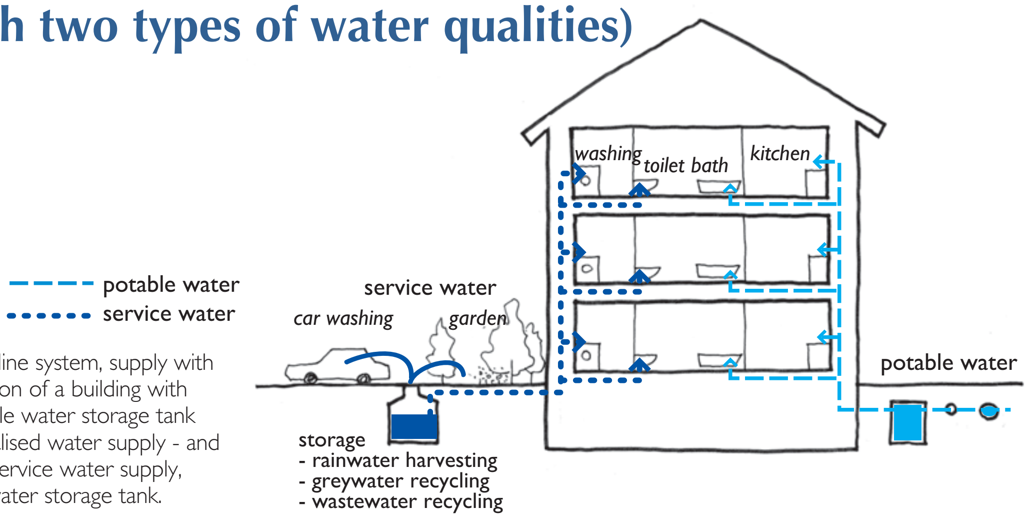


Illustration 26: Dual pipeline system, supply with two water qualities. Section of a building with one connection to potable water storage tank and connection to centralised water supply - and one pipeline system for service water supply, connected to a service water storage tank.

fact sheet 6 4.3.4

Technological description:

Dual pipeline systems are used for piped water supply of two different water qualities in urban and domestic areas. They are also known as dual reticulation systems. Additionally to the potable drinking water quality, which is mainly distributed in single pipeline systems, a lower non-potable water quality (so called service water) is supplied to substitute drinking water for non-potable uses and therefore to contribute to the saving of drinking water. Similar to single pipeline systems, various pipeline materials are available and the water is generally supplied from water mains to the customers by connection pipelines. Rainwater harvesting, grey water recycling facilities and wastewater recycling are typical water sources for service water in dual supply systems. The risk of wrong connection can be prevented by giving the second pipe a distinctly different colour. Furthermore, the inlet and outlet connection points of the water meter for recycled water should be different from those for potable water supply. Only certified plumbers should be allowed to construct the system and guidelines for installation and quality control should be made available.

Construction, operation and maintenance:

- o Dual pipeline systems are used in centralized systems and in decentralized systems.
- o The can be installed easily in buildings in the framework of new constructions or renovations of buildings.
- o In centralized systems they consist of two separated networks of water transmission and reticulation mains which are either distributing water from main reservoirs to smaller water tanks (acting as pressure break tanks) or directly to the consumers.
- o At the end of these pipelines meters are generally installed which form the transition from the public to the individual pipeline systems.
- o Leakage analysis (extent of leakage in a specific area and main source of leakage) is the basic condition for leakage control (repair or exchange of leaking pipelines and fittings).
- o Losses by leakages can be reduced also by the reduction of pipeline length, therefore decentralized installations of dual pipeline systems should be preferred (e.g. in addition to centralized single pipeline systems).

- o Public central water supply with dual pipeline systems are generally installed invisibly underground.
- o To avoid cross connections of the two pipeline systems and to provide drinking water security the two systems have to be tagged clearly throughout (e.g. by different materials or colours).
- o Dual pipeline systems on properties and in buildings are generally integrated in buildings and on properties and are managed individually or collective (for the source of the second water supply with service water, please refer to *section 4.5, water reuse, recycling & disposal*).
- o Public central water supply with dual pipeline systems requires centralized infrastructure and management.
- o Water management policy focussing on collective and individual responsibility in case of pipeline systems on collective or individual level.
- o Centralized water management policy and responsibility in case of substitution of centralized water supply.

Relative costs:

- o Installation costs for a dual pipeline system are higher compared to single pipeline systems, because a second pipeline network is required.
- o The installation in buildings in the framework of new constructions or renovations of buildings is comparably cheap.
- o The comparably low installations costs for a dual supply pipeline network can be paid back by savings in drinking water consumption.
- o Cost reduction can be achieved in the framework of water purification measures because the service water needs to meet lower quality standards than drinking water.

Appropriate technological approach when:

- o High savings in drinking water have to be achieved by the substitution and supply with service water.
- o The installation of dual pipe networks is done in the framework of new constructions or the renovation of infrastructures.
- o Alternative sources can be made available (e.g. by recycled greywater or harvested rainwater)

Advantages:

- o Dual pipeline systems often achieve savings in the overall consumption of freshwater resources by the recycling of sewage.
- o Can be used in centralized systems and in decentralized systems.
- o Public central water supply with dual pipeline systems allows the supply of urban and domestic areas with sufficient quantities of drinking water and service water.
- o For the service a degradation in water quality that does not matter.
- o The supply of two water qualities facilitates the protection of water with high quality due to savings in the production and consumption of drinking water, only for purposes which require drinking water quality, in public systems as well as on properties and in buildings.
- o Dual pipeline systems on properties and in buildings allow the convenient and efficient distribution of two water qualities without significant leakages and related water losses.
- o Installations of dual pipe networks in buildings can be realised for comparably low cost in the framework of new constructions or renovations.

Disadvantages/Constraints:

o In case of centralized dual pipeline systems the water losses by leakages occurring in reservoirs, water mains, service pipelines and connections, are twice as high as in single pipeline systems, due to the fact that all water supply systems are leaking to some extent and that the leaking is also dependent on the total pipeline length of a system.

o The occurrence of cross connections of the two pipeline systems may cause serious pollution to the drinking water supply.

o When constructing two networks, capital costs, and material use are higher compared to the one pipe system.

Cultural acceptability:

o High regarding the achievable savings in freshwater consumption and the related costs.

o High in case of correct installation and when the second water quality is meeting minimum quality standards for service water.

o High regarding the achievable savings of drinking water.

o Low in case of bad second water quality.

o Unacceptable in case of cross connections between service and drinking water pipelines.

Extent of use:

o Used with rising tendency in domestic, public and commercial areas with water scarcity.

o Non-centralized systems on properties and buildings are often combined with measures for the separation of sewage streams at the place of their origin, e.g. rainwater harvesting or the separated treatment and recycling of grey water.

o Public systems with centralized dual supply networks are generally based on the supply of service water which originates from further purified effluents from centralized sewage treatment plants.

References, links and literature:

o Coombes, P. and Mitchell, G.; Urban Water Harvesting and Reuse; in: Engineers Australia; Australian Runoff Quality, A Guide to Water Sensitive Urban Design; 2006. Available at: http://www.engaust.com.au/bookshop/arq.html

o DIN 1989-1:2002-04; Rainwater harvesting systems - Part 1: Planning, installation, operation and maintenance; Germany, 2002

o Fan, C. Y. and Field, R.; Beneficial use of urban stormwater; in : Field, R. and Sullivan, D.; Wet-Weather Flow in the Urban Watershed; Lewis publishers, New York, USA, 2003

o Furumai, H.; Reclaimed stormwater and wastewater and factors affecting their reuse; in: Novotny, V. and Brown, P.; Cities of the Future: Towards Integrated Sustainable Water and Landscape Management; 2007

o Koenig, K. W.; The Rainwater Technology Handbook; Dortmund, Germany, 2001

o Kwon, K-H. and Schuetze, T.; Sustainable water and sanitation systems in existing housing estates of international cities; Proceedings 2nd International Congress on Environmental Planning and Management, Technical University Berlin, Germany, 5.-10. 08.2007, pp. 205 - 208.

o Mitchell, G.; Applying Integrated Urban Water Management Concepts: A Review of Australian Experience, 2006

o Schuetze, T.; Ecological water and sanitation systems in remodelled urban housing estates in Europe and Asia; proceedings International Conference Sustainable Water Management - Meda Water,Tunis, Tunesia, 21.-24.03.2007, pp. 63 - 68

Water containers (bottles and tanks)

Illustration 27: Water containers, water distribution by bottles or tanks.

4.3.4 fact sheet 7

Technological description:

Water containers or bottles are an alternative way for delivering water without being dependent on a water distribution network based on pipelines. Basically there are two options for the water supply with containers: delivering just the potable fraction of supply in containers while the non-potable fraction is delivered by a single pipeline system, or delivering all required water in potable quality by containers. The consumption of water delivered by bottle in developed countries (which generally provide potable water supply by a centralized water supply network) is growing at a rapid rate.

Construction, operation and maintenance:

- o For the collective or semi-decentralized delivery of drinking water often comparably big tanks are used which function as a kind of small water supply reservoir in the framework of a delivery and filling station for the residents who carry the water in smaller containers to their homes (in bags, bottles, pots or canisters).
- o Canisters or bottles are generally delivered or collected by road vehicles.
- o Bottled water is widely available in retail outlets and used for drinking and some cooking applications.
- o The average amount of water supplied and distributes by containers is primary dependent on the related transport effort.
- o Generally the average water consumption of people living in areas supplied by containers only, is significant lower than of people supplied by a central water supply.
- o The average water consumption of people living in areas with central water supply and using containers for the supply with potable water only is similar to people which only have central water supply available.
- o The delivered water quality is primarily dependent on the quality of the water used for the filling of the containers.
- o Water management policy focussing on collective and individual responsibility.
- o Centralized water management policy and responsibility in case of substitution of centralized water supply.

Relative costs:

o Costs for the production of bottled water are significantly dependent on the raw water quality. While no or only low cost for additional treatment of pure groundwater is required, the purification of contaminated water sources may be quite costly.

o The production, but also the reuse and recycling of bottles, creates additional costs.

o Costs for the transport of the water via existing infrastructure (roads) are generally low.

Appropriate technological approach when:

o There is a non-availability of drinking water, an overall water shortage or contamination of centralized water supply.

o If appropriate infrastructures and systems for the transport and delivery as well as for the collection, reuse or recycling of the containers, respectively bottles are available.

Advantages:

o The supply of potable water by containers is an appropriate kind of water supply in case of non-availability of drinking water, in case of overall water shortage or contamination of centralized water supply.

o Water containers are suitable for the safe supply with potable water in small quantities.

o Containers can be distributed easily by vehicles if road infrastructures are available.

o Small containers can be carried by hand over short distances.

o For the water supply by containers only, no pipeline network is required (see also effects on water reuse, recycling and disposal).

Disadvantages/Constraints:

o Due to the often high costs of bottled water, it is not affordable for many people in developing countries for all uses for which drinking water quality is required. Therefore contaminated water from other sources is often consumed. However bottled water may be an interesting option for some peri-urban areas, particularly in countries (e.g. Mexico) where bottled water is available in big bottles (~20-30 litres) and is sold at a reasonable price e.g. by several local mini-enterprises.

o Not very environmentally sound, in some case it is more appropriate to look for alternative technologies to provide potable water, e.g. by the "point of use" treatment of water, even if the raw water is contaminated.

o The containers must be microbiological clean.

o The material of the containers should be appropriate for the storage of potable-water and may not lead to contamination by chemicals or metals.

o The water must be stored in a cool and dark place.

Cultural acceptability:

o Potable water delivered in bottles is very user acceptable in societies which can afford the comparably high costs when it doesn't have to be carried long distances.

o Increasing consumption because of fashion, habit and convenience as well as the growing awareness and interest of people in health issues (fuelled by advertising, bottled water is perceived by the public to be a healthy drink).

Extent of use:

o Used with rising tendency in areas with high income due to health and fashion issues.

o In areas where there is a non-availability of drinking water, in case of overall water shortage or contamination of centralized water supply.

Centralised treatment systems

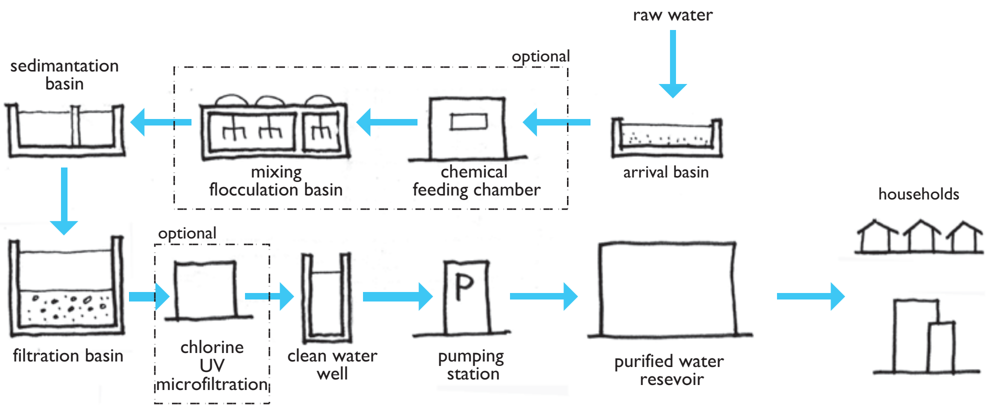


Illustration 28: Centralized treatment system for the purification of surface water for potable water supply. The process for the purification of groundwater is generally simpler and requires less treatment steps due to its generally lower pollutant load.

Technological description:

Centralised treatment systems for water supply and distribution are designed to provide non-potable or potable water, either for centralised water supply systems or for the distribution of drinking water by containers. According to the raw water quality and the desired quality of the treated water, different technologies can be applied. Common technologies for the elimination of solids in raw water are sedimentation and filtration methods like sand filtration. Aeration is used for the oxidation of iron and manganese. A common method for the centralised disinfection of water is chlorination. However there are doubts concerning the effects of chlorine on the human health and the environment. An alternative when disinfection of potable-water is required is radiation with ultraviolet rays (using UV-lamps) or micro-filtration.

In case of dissolved contaminations in raw water (e.g. chemicals), degradation can be provided by additional treatment methods, e.g. the filtration with activated carbon, treatment with ozone or other enhanced purification methods. The distillation method provides the production of almost pure water even from non-potable seawater. In centralized systems, thermal distillation is common. Alternatively, filtration technologies using membranes are used for the production of pure potable water. The reverse osmosis technology provides also the production of distilled water and is often used as an alternative for thermal distillation, because it is more energy efficient and requires less space. Other filtration technologies, using also membranes but with wider pore sizes (nano- ultra- and micro-filtration) can be adapted to the specific degree of water pollution. Technically even the production of drinking water from polluted sewage or seawater is possible (*see Box: Reclamation of domestic sewage for drinking water purposes under section 4.2.4.8 Treated Sewage - effluent for the artificial recharge of groundwater*).

Construction, operation and maintenance:

o For a sustainable and efficient water treatment and efficient water use, the protection of raw water quantity and quality has first priority.

o Water quantity is primarily dependent on the available quantity of raw water and the capacity of the treatment facility.

- o Almost all water qualities can be produced by centralised treatment, depending on the raw water quality and the specific technology used for the treatment.
- o Depending on the technology maintenance is regularly required to avoid quality degradation of the treated water.
- o Centralised treatment systems should be located near the raw water source as well as the destination for water supply to minimise the effort for the transportation of water.
- o Nature-orientated treatment technologies, like sedimentation and sand filtration generally require less energy but more space than technical solutions.
- o Centralized water management policy and responsibility is required.

Relative costs:

- o The effort and the related costs for construction, operation and maintenance differ significantly between the treatment methods.
- o They are comparably low for simple sand filtration and aeration technologies
- o They are very high for thermal distillation and reverse osmosis technologies.

Appropriate technological approach when:

- o Sufficient quantity of raw water is available.
- o The treatment of raw water is required at the point of supply to meet the required water standard.

Advantages:

- o Treatment systems can provide safe potable-water for centralized supply systems.
- o Treatment technology can be adjusted to the raw water quality and the desired water quality.
- o Enables the purification of even contaminated water to drinking water.
- o The design of nature-orientated treatment technologies, like bank filtration, can be combined with other uses, like recreation and the protection of raw water resources.

Disadvantages/Constraints:

- o Treatment methods have to be always well adapted to the specific basic conditions.
- o The produced water quality is degrading on its way from the point of supply to the point of use.
- o However drinking water is distributed, the use of bottled water and point of use treatment systems is widespread, with rising tendency.
- o The centralized production and distribution of only drinking water does not contribute to an efficient drinking water use.

Contamination of central water supply

The water supply of the third biggest city of Ireland, Galway, was hit by an outbreak of the parasite cryptosporidium. The residents were not allowed to drink the water any more without further treatment for months. "... A sewage treatment plant in a small town north of Galway has come under suspicion as a possible source of the pollution. The plant, originally designed to service 250 households, is now receiving sewage from 800 residences. Critics claim that this is typical of many areas across Ireland where rapid expansion of housing developments has not been matched by infrastructure upgrades. Concerns have also been expressed over the impact of farming practices on water quality, and it was reported that heavy rain prior to the outbreak may have washed manure slurry from surrounding farmland into Lake Corrib..." *(Cooperative Research Centre for Water Quality and Treatment, Health Stream Newsletter; Galway Cryptosporidium Outbreak; Health Stream Article - Issue 46 - June 2007)* Lake Corrib provides the raw water for Galway's drinking water production.

Cultural acceptability:

o Generally high when the supplied water reaches the points of use in drinking water quality.

o Critical in case of supply with contaminated water with bad taste, odour and not clear.

Extent of use:

o Practiced in almost all areas with centralised water supply.

References, links and literature:

o Schuetze, T.; Decentralized water systems in housing estates of international big cities considering as example the cities Hamburg in Germany and Seoul in South Korea (Dezentrale Wassersysteme im Wohnungsbau internationaler Großstaedte am Beispiel der Staedte Hamburg in Deutschland und Seoul in Sued-Korea; (Dissertation), Books on Demand, Norderstedt, Germany, October 2005

Point of use treatment systems

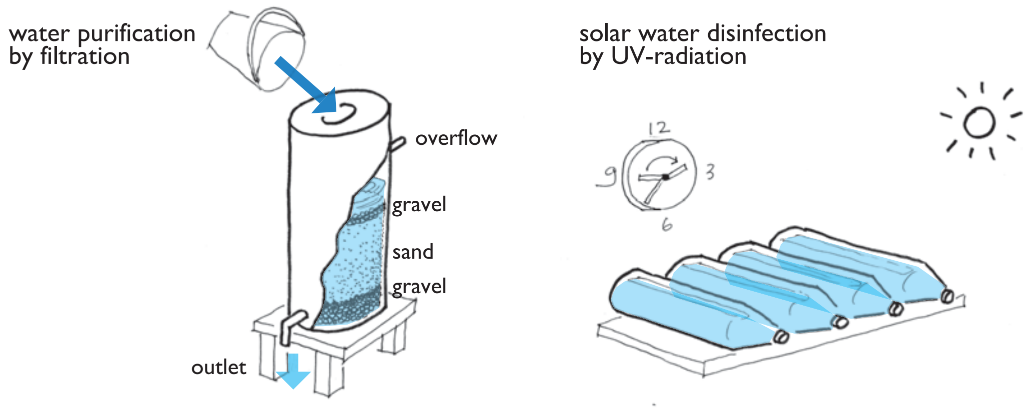


Illustration 29: Point of use treatment systems. Displayed are low-cost options for individual level.

Technological description:

Point of use treatment systems are designed to provide water for non-potable or potable applications at the point of use. These points can be either totally decentralised systems for single taps on properties or in apartments, but also semi-decentralised systems for the treatment of water e.g. for the supply of filling station or the distribution in comparably small collective systems. Similar to centralised systems, different technologies can be applied, depending on the raw water quality and the desired quality of the treated water. For point of use treatment systems, it is common for smaller and more compact systems to be used. Therefore filter systems are generally preferred to sedimentation systems.

Generally two different filter systems are available: Filters which are connected to a piped water supply and do allow the enhancement of the water quality of centrally supplied water and stand-alone filter systems which are filled manually either with raw water or water from public supply. Filters which are connected to piped water supply are generally equipped with different filter modules, containing ion-exchangers, activated carbon and even membrane filtration modules with pore sizes up to reverse osmosis. Depending on the system and the desired filtration effect, different media are used for the filter. For the separation of solids and disinfection and so on, filters out of burned clay equipped with silver ions are available. Other filters contain different layers of minerals (working as ion exchangers) and activated carbon for the elimination of chemical pollution and the enhancement of taste. Special forms of stand-alone filters which can provide even the desalination of water are small distillation facilities based on evaporation and condensation of water, driven by solar radiation, either for personal or collective use.

Construction, operation and maintenance:

- The systems are available in different sizes from semi-decentralised collective, e.g. for bigger buildings or housing estates, but also for single houses, apartments or even for single taps (e.g. to provide drinking water quality in the kitchen alone).
- Stand-alone filters are available in different sizes depending on the application (e.g. private household or filling stations) and have to be filled manually.

o Stand-alone filters consist of two pots (one located above the other) separated from each other through a filter module.

o Water quantity is primary dependent on the available quantity of raw water and the capacity of the treatment facility.

o Depending on the technology, maintenance is regularly required to avoid quality degradation of the treated water.

o Semi-decentralised and decentralised treatment systems should be located near the raw water source as well as the destination for water supply to minimise the effort for the transportation of water.

Relative costs:

o The effort and the related costs differ significantly between the treatment methods.

o Compared with the costs for the supply with bottled water the costs are comparably low.

Appropriate technological approach when:

o Only contaminated water sources, which are not meeting drinking water standards, are available at the point of use.

o Centralised water supply is not meeting drinking water standards.

o The system is well adapted to the specific basic conditions and requirements of the specific point of use.

o Individuals or collectives are able to operate and maintain the systems appropriately.

Advantages:

o May be more effective and cost-effective means of preventing diarrhoeal disease than conventional treatment at the source (Clasen, 2005).

o These systems are principally usable for the production of safe potable water out of non-potable water at the point of use.

o Almost all water qualities can be produced by semi-decentralised or decentralised treatment, depending on the raw water quality and the specific technology used for the treatment.

o Low-tech and nature-orientated treatment technologies, like filtration and solar distillation require more space than high-tech solutions (such as membrane filtration or reverse osmosis).

Disadvantages/Constraints:

o Individuals or collectives are responsible for the correct operation and maintenance of the systems (e.g. regularly cleaning and exchange of filters).

o When filter systems are not maintained they will either not work properly or produce contaminated water.

Cultural acceptability:

o High when operated properly and a safe potable water quality can be ensured.

o High when the taste and colour of raw water is enhanced.

Extent of use:

o Widespread use in areas without centralised water supply and with very limited as well as contaminated raw water resources.

o Systems are also applied in areas where the centrally supplied water is supposed to be safe to enhance the taste but also to avoid risks from unexpected contaminations in centrally supplied water

References, links and literature:

o Biosandfilter.org, available at: http://www.biosandfilter.org/biosandfilter/index.php/

o Clearinghouse, Jal Mandir (overview low-cost household water treatment, based on biological, chemical, mechanical and thermal treatment as well as radiation), available at: http://www.jalmandir.com/

o HelioTec (solar distillation for individual and collective use), available at: http://www.heliotech.net

- o *IFH report on household water storage, handling, and POU treatment, available at: http://www.ifh-homehygiene.org/2003/2library/low_res_water_paper.pdf*
- o *IRC FAQ sheet on options for household water treatment, available at: http://www.irc.nl/content/view/full/8028*
- o *Lase, T.; Well Factsheet on Household Water Treatment, 2005, available at: http://www.lboro.ac.uk/well/resources/fact-sheets/fact-sheets-htm/hwt.htm*
- o *MIT Civil and Environmental Engineering web portal on HWTS, available at: http://web.mit.edu/watsan/*
- o *Potters for Peace (Ceramic Filters), available at: http://www.pottersforpeace.org/*
- o *Safe Water International survey of HWTS systems, available at: http://www.safewaterintl.org*
- o *SODIS (Solar Water Disinfection), available at: http://www.sodis.ch*
- o *Water Cone (solar distillation for personal use), available at: http://www.watercone.com/*
- o *Waterpyramid (solar distillation for collective use), available at: http://www.waterpyramid.nl/*
- o *WHO, Household Water Treatment and Safe Storage, Information Network, available at: http://www.who.int/household_water/en/*
- o *Wilson Center report on HWTS options: a review of current implementation practices, available at: http://www.wilsoncenter.org/waterstories/Household_Water_Treatment.pdf*

4.4 Water use and saving ESTs

4.4.1 INTRODUCTION

This section focuses on *demand side* issues. The central questions concern the environmentally sound technologies for efficient use of water as a limited resource.

The stepwise analysis of flows, areas and actors (4.4.2) may provide the required information for the discussion of the main arguments (4.4.3) for the selection and combination of specific ESTs presented in the last subsection (4.4.4).

The analysis of the existing situation should point out all available but also missing information. The aim of the analysis is a clear understanding of the facts and uncertainties as a basis for the decision making process. Selected ESTs should fit in this specific situation. Given the analysis of the sustainable supply options, the demand side should be brought into balance. Saving water is a key issue.

4.4.2 ANALYSIS OF THE DECISION SITUATION

4.4.2.1 Analysis of flows: Quantity aspects

o The first step is to reconsider the *balance of water use* for different purposes (4.3.2). A domestic level analysis is displayed in *Illustration 31*, using as an example the quantities (in litres) used per person per day in The Netherlands in 1990. They happen to be approximately the same as the quantities (in m^3) used per family per year. The 136 litres becomes 127 due to water losses caused by pipeline leakages. The quantity of piped water with drinking water quality metered on building level as well as the outflow of sewage are 127 litre per person and day. Water use is categorised as: kitchen, cleaning, bathroom, washing and toilet flushing. An extra potential input and outflow is the rainfall of average 30 litres per person and day that falls on the roof and leaves the building by drains. This analysis reveals the relative importance of the different domestic water flows and thus demonstrates where ESTs and water-saving policies may be most effective. It must be stressed that this is just an example. A similar graph for a developing country will show a completely different picture. Quantities, but also categories may vary considerably in different cultures and in different technological situations

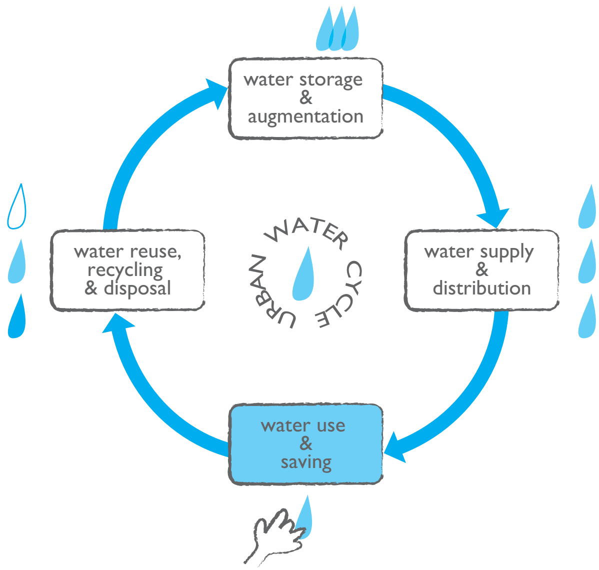


Illustration 30: Position of the section on water use and saving in the urban water cycle.

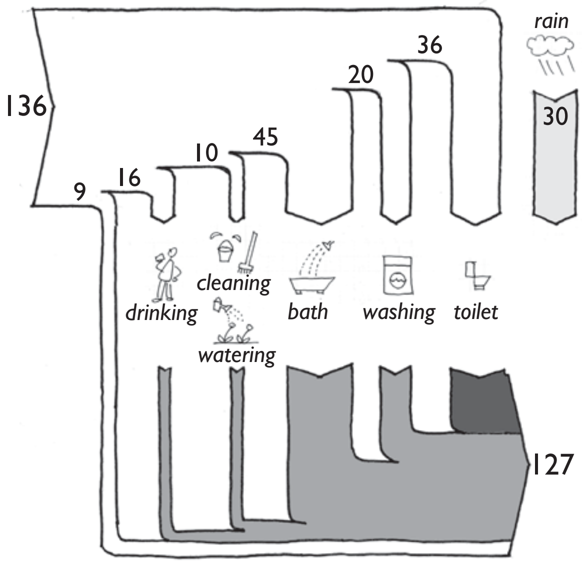


Illustration 31: Example for the average water consumption of a domestic household in litres per person and day, separated in different uses. Display of resulting sewage streams and average amount of rainfall, also per person and day.

as well as climates and urban settings (regarding the average rainfall). A similar analysis can be used to visualize different categories of water use on urban level. In the over all analysis it is important to consider also future scenarios with higher and lower water use.

o The second step is an analysis of the *rhythms*, the temporal patterns. What are the high peak and low peak levels in water use and when do they occur. The confrontation of supply and use rhythms allows for a further elaboration of the potential saving strategies.

o The third step is to make an inventory of the reported problems in the existing situation and of possible solutions that do already exist in individual situations.

4.4.2.2 Analysis of flows: Quality aspects

o The qualities of supply and demand should now be investigated. This analysis can be combined with the results of the quantity analysis for the present situation and for the future.

o The second step is exploring the potential for improving the relationship between supply and demand qualities.

o Then follows an analysis of the present and future problems and opportunities.

4.4.2.3 Analysis of areas

o The spatial analysis focuses on questions about

- the house design types in different parts of the city
- the categories of water use and their place within the house in the different types
- the average building and population densities
- the location of public parks and green spaces and the way they can they be provided with enough water in dry periods
- income levels in different areas

o Analysis of the location of access points, such as taps, wells or rivers.

o A spatial; analysis of the problems and opportunities for flow management (*regarding quantity and quality*).

4.4.2.4 Analysis of actors

An analysis of the relevant actors, or stakeholders, should throw light on the role groups and individuals play in the funding, the legal permits and the operation of ESTs that belong to different use and saving options. Who has access? Who pays? Who is responsible for operating the systems, for quality control and for maintenance? If there are problems, now or in the future, for whom are they problematic? Understanding these roles, the power of actors or the need for empowerment, is essential to decision making about water policies, strategies for technological innovation or financial incentives for efficient water use.

4.4.3 DISCUSSION OF ARGUMENTS FOR DECISIONS ABOUT ESTS FOR USE AND SAVING

4.4.3.1 EST combinations

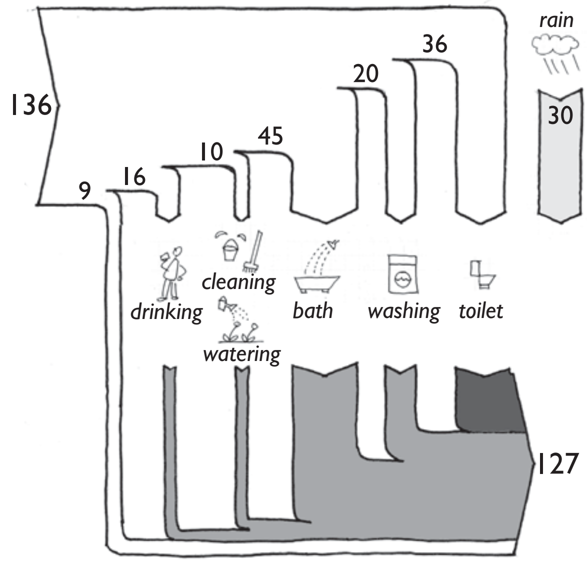
Decisions about the choice of ESTs for water use and saving partly depend on the efficiency of the individual EST. It is important, however, to design a feasible new system where the ESTs fit together. Take, for example, a typical townhouse in a modern city situated in a humid temperate climate, the case discussed in the flow analysis above.

Illustration 32 shows how the analysis of an existing system may lead to a specific combination of ESTs that fit together to make a new system that fits to the decision situation. The figures in this example, again, represent the water consumption in litres per person per day. *Water-saving taps* and *water-saving showerheads* are responsible for water-saving in the kitchen and in the bathroom. The *rainwater butt* in the garden stores water that is used for cleaning and for watering the garden and in this way reduces the piped water consumption. The example illustrates further saving by *using grey water from the bathroom and the washing* *machine* (*see section 4.5*) for the *water-saving toilets*. Generally speaking, the used water from bathing and showering alone would be sufficient and can be reused after minor treatment. In this case the arguments for this specific combination of ESTs are primarily technical: the ESTs are relatively low cost and low tech if compared with a centralised system for water supply and wastewater treatment. At the household level, however, introducing these ESTs is more expensive than the traditional solutions. The differences between ESTs make a difference. Taps and showerheads are cheap and do not take any extra space but the grey water technology does and so do rainwater containers. For the grey water ESTs, climate does not make much difference, but climates with long dry periods and shorter rainy seasons require sizable containers, especially if they should contain enough water for a lush garden. If water efficiency and the reduction of water use is the starting basis of a design process, the required effort and related costs for an optimal system, including reuse and recycling measures can be minimized effectively (water which is not required has to be neither purified, distributed nor stored).

4.4.3.2 Water efficiency: innovation at the urban level

The example in *Illustration 32* focuses on a typical singe family house, but, of course, there are different types of houses in different densities. Water efficiency can be optimised for each type, but generally in the existing built environment houses have not been designed for water efficiency. Therefore the introduction of new technology will either require comparatively high effort and related cost (in case of replacement of building service engineering which is still in good order) or take comparatively much time (in case of introduction of new technology in the framework of conventional renovation cycles of buildings). Increasing water efficiency at city level depends on the time innovations need to penetrate in both new and existing urban areas.

This asks for a planning strategy that explores the potential for change in different parts of the city



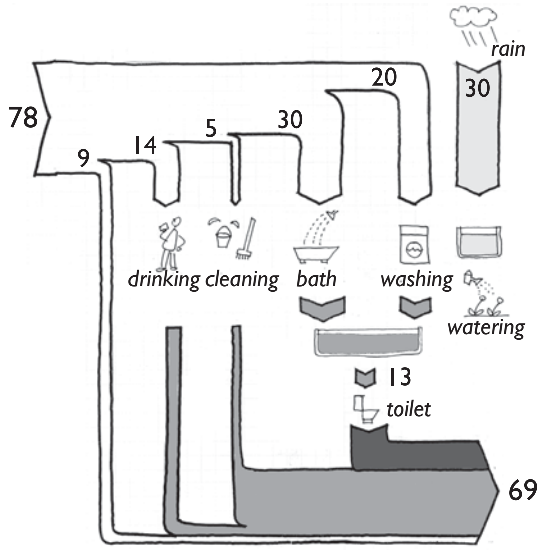


Illustration 32: Examples for an existing domestic water household with high water consumption (top) and a water-saving household, with applied ESTs for water use and savings (bottom) in litres per person and day.

and the conditions that can be created. Institutional conditions are crucial. If, for example, the city sets a water-saving standard for taps in new developments and in renovation projects, there is no more discussion about non-water-saving taps that can possibly be a bit cheaper. This, however, requires an institutional strength to set such standards and to impose and enforce them. In a *carrot and stick* perspective of governance instruments, this is the *stick* approach. On the *carrot* end of the spectrum there may be stimulating tax incentives or fashionable demonstration projects that may accelerate the voluntary process of change towards a water efficient city. The public parks department, for example, may choose plant species adapted to the local climate and apply rainwater harvesting for irrigation public green spaces. Thus, the government sets an example that may stimulate private water efficient behaviour. Efficient is what works. And what works may vary from place to place. It is important to conceive strategies that fit to the decision situation, strategies that explore the most efficient policies and are followed by operational plans that set them in motion.

4.4.3.3 Water use and development

The example in *Illustration 32* shows how water saving can be realised in a modern 'industrial' household and this is the situation in an increasing number of cities all over the world. It is the process of modernisation that often goes hand in hand with a huge increase of water consumption. The ESTs in this Sourcebook have to fit in with strategies that seek to connect economic and welfare growth to growing water efficiency. They aim at "meeting increasing service demands, without increasing water supplies". *(UN-Habitat; Water and Sanitation in the World's Cities: Local Action for Global Goals; Earthscan, London, 2003, p.193)*

This is not only a technical issue, however. The lifestyles of the cities in humid temperate climates are often exported to developing countries even in the arid zones: lush English gardens with lawns in desert environments. This may lead to a culture of squandering water in situations of scarcity. Generally, governments cannot prescribe individual citizens how to use water in their private garden. But there are other options. One is metering and pricing water based on the real volumes used. Another option for the local government is giving a good example in public parks and green spaces by demonstrating the use of native vegetation, adapted to dry conditions and rainwater harvesting. The use of water in daily life of affluent societies also influences the water consumption significantly. The unmindful washing of dishes and vegetables under running water, bathing, taking long showers is related to comparatively high water consumptions even if water efficient technology is installed. Public education and awareness raising can be efficient tools to change a society's habit, as demonstrated by the campaigns to save water in order to avoid restrictions in water's supply by the official authority in Bogotá, Colombia, in 1997.

In poor housing areas and slums, minimum water quantity and quality for survival and basic health are the key issues. This implies that supply ESTs become more important than most of the water-use ESTs discussed here. On the demand side it is crucial to improve the access of deprived groups to water. For a successful introduction of water-use ESTs, such as *waterless toilets*, the acceptance by the users is pivotal. Experiences in pilot projects show that the interaction with the users, especially with women, is essential for the acceptance of new appliances. The use of waterless toilets implies a big potential regarding water savings and pollution control. However, there are doubts concerning the social acceptance, especially in comparatively prospering societies. The application of appropriate technologies, careful planning and demonstration projects could pave the way for an interactive process of learning about change. While enhanced composting toilets may be relatively costly to construct and require skills for proper installation and maintenance, simpler dry toilets, which are based on the working principles of pre-composting or dehydration offer promising low cost alternatives, as demonstrated by projects that will be discussed in chapter 5.

4.4.3.4 Priorities

Under *an Integrated Water Resource Management (IWRM)* perspective, the choice of use and saving options may result in a situation specific combination of ESTs. The priority sequence of options that may summarise the arguments is as follows:

- o In new developments water use efficiency should become part of the design and planning strategy from the beginning. This implies utilising the full potential of water-saving appliances, wastewater reuse and rainwater use options. Planning and budgeting of the water systems' maintenance should be a vital part of the development plan.

o In existing urban areas the innovation process for increasing water efficiency should be promoted by creating conditions: financial incentives, technical support, training of skilled labour, legal support and new standards.

o Public and collective buildings, parks, streets and squares could demonstrate water-saving options. Local agencies, universities and NGOs should co-operate in a process of learning about technology, spatial design, maintenance and public acceptance of new environmentally sound technologies for water use.

4.4.4 FACT SHEETS ON WATER USE AND SAVING ESTS

The ESTs Fact Sheets below enlisted for "water use and saving" are presented in the following Section 3:

4.4.4.1 Waterless toilets

4.4.4.2 Water-saving toilets

4.4.4.3 Water-saving urinals

4.4.4.4 Waterless urinals

4.4.4.5 Water-saving taps

4.4.4.6 Water-saving shower heads

4.4.4.7 Pressure reducers

4.4.4.8 Water-saving household appliances

4.4.4.9 Economised water use for personal hygiene

4.4.4.10 Economised water use for cleaning and watering

Waterless toilets

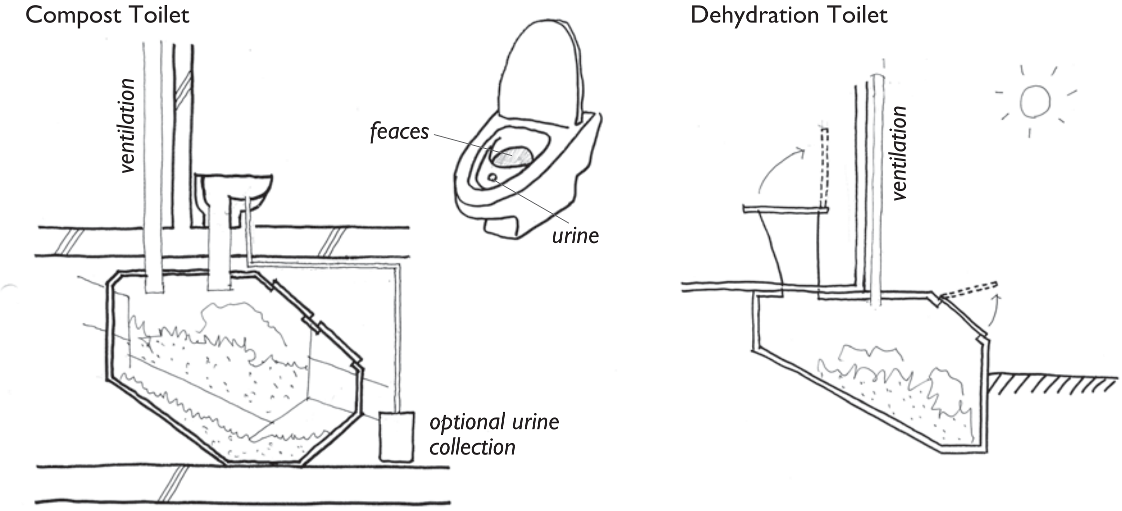


Illustration 33: Principle sections of two different dry toilets, a compost toilet (left) and dehydration toilet (right).

fact sheet 1 4.4.4

<u>Technological description:</u>

Waterless toilets use no water for flushing and require only small amounts of water for cleaning. Therefore waterless toilets are an effective sanitation technology for the saving of water resources in the urban and domestic environment. The most common types are pre-composting, composting and dehydration toilets, based on dehydration and composting processes (Incinerator toilets are a special kind of toilet which is not environmental sound because they are energy intensive. They use electricity or gas to produce high temperatures for the burning of the faecal matter. Furthermore the faecal matter can not be reused. Therefore only dry toilets based on dehydration and composting processes will be further discussed). These toilet systems provide the ideal environment for pathogen destruction in human waste through dehydration and/or decomposition. The resulting inoffensive compost-like material can be applied to the soil to increase the organic matter content, improve water-holding capacity and increase the availability of nutrients.

The available systems vary from simple toilets with temporarily storage of excreta to enhanced toilet systems with on site treatment. The human waste is stored in watertight-sealed and well-ventilated containers and is converted in a compost-like material. The final product should be odour free and have a soil-like consistency if the process has been correctly managed. In some systems only a pre-composting process takes place in the sealed chamber of the toilet. In these cases the matter is transported for the finalisation of the composting process to an adequate facility. Crucial for an appropriate dehydration and composting process is the right degree of humidity. Therefore dry toilet systems often provide also the possibility of urine separation. For the Indian market dry toilets have also been developed to allow the separation of faeces as well as the separated draining of urine and anal cleansing water to allow an enhanced treatment process of the faeces.

Construction, operation and maintenance:

o Dry toilets are available as industrial pre-fabricated products but can also be constructed in local workshops. For the construction and operation of composting toilets a lot of know how and good maintenance is required. Due to large size of the storage and composting chambers, these toilets require a comparably big space under the toilet. The direct discharge of faeces limits the connection of multiple dry toilets to one compost chamber. Hence compost toilets are only limitedly useful for buildings with up to 4 storeys.

o The installation of small dry toilets for temporarily storage of faeces and urine directly in or under the toilet is comparably easy and cheap. The systems are also adaptable to multi-storey buildings and in existing housing estates. Due to the comparably low storage volume, it is necessary to empty the storage regularly (e.g. once a week) and transport it to a facility for further treatment (composting).

o Installation of a vertical ventilation pipe for ventilation of the storage chamber is required to guarantee an odour free operation of all dry toilet types. In case of substitution of flush toilets in existing buildings, existing ventilation ducts can in some situations be used.

Relative costs:

o Investment, construction or installation costs vary significantly and depend on the specific system and design. They vary from low cost for simple dry toilets to comparably high costs for industrialized composting toilets. If dry toilets are constructed in local workshops, investment costs can be substituted by labour costs. Used bins and cans can be recycled for the storage of dry and wet matter.

o Different toilet designs which vary considerably in complexity and application potential result in a wide range of prices. Urine diversion waterless toilets and squatting plates cost from 8 to 750 EUR.

o Comparably low cost for management (effort for maintenance and transport). The required costs can be either full or partly covered by the profit, which can be generated by the use of compost as fertilizer.

Appropriate technological approach when:

o Water resources are scarce.

o Income is very low

o No centralised water supply is available.

o Sewers and sewage treatment facilities are not present.

o Areas for the use of faeces and urine are applicable (urban farming or gardening).

o Acceptance by the users as well as appropriate maintenance and service can be guaranteed.

o Citizens are used to dry toilets already.

o Appropriate individual and community-based operation and maintenance exists.

Advantages:

o Suitable for almost all urban and domestic areas also in areas without sewer systems and without centralised water supply.

o Dry toilets are not only contributing significantly to the saving of water resources but do protect also surface water and ground water resources from pollution with pathogens, nutrients and pharmaceuticals due to the separation of human excreta and urine from urban sewage.

o The service does not require the use chemicals and requires nor or only a low energy demand.

o Operating in a closed system and emitting no odour or flies if properly designed.

o No sewage treatment plant or sewer network is required.

Disadvantages/Constraints:

- o For the operation of simple dry toilets, the regularly transport of wet and dry matter is required, compared with the transport of household waste.
- o For the installation of enhanced compost toilets, a lot of space in the basements of buildings is required. Due to the high space demand for the discharge chutes, the maximum building height is limited to 4 storeys so far.
- o Integrated management of human waste and land management, including agriculture, is required to facilitate profitable use of compost.
- o Composting toilets require careful selection, installation and ongoing maintenance to operate reliably and safely. Hence policy for public awareness building and training (proper construction and management) is crucial for successful implementation.
- o Legal and institutional regulations are limiting the use of compost from human excreta in some countries.

Cultural acceptability:

- o User acceptance is dependent on cultural background and awareness. Generally people who are using flush toilets already do not switch easily to dry toilets because the image of dry toilets is less attractive than the image of flush toilets.
- o Individual or collective maintenance and handling of urine and faeces might not be acceptable for all people. However in almost all societies, groups can be found for proper maintenance.

Extent of use:

- o Widespread use in areas without water supply all over the world, indoors and outdoors, for private as well as communal or public use, especially in areas without sewer systems and water supply and in environmental sensible areas.
- o For example, in East Asia (China, Japan and Korea), urine diverting dry toilets and composting toilets were used traditionally for thousand of years.

References, links and literature:

- o *Black, M. and Fawcett, B.; The Last Taboo Opening the Door on the Global Sanitation Crisis; Earthscan, 2008*
- o *Composting Toilet World, available at: http://www.compostingtoilet.org/*
- o *Eawag: Swiss Federal Institute of Aquatic Science and Technology; Household-Centred Environmental Sanitation, Implementing the Bellagio Principles in Urban Environmental Sanitation; Provisional Guideline for Decision Makers, 2005*
- o *Ecological Sanitation, available at: http://www.ecosanres.org*
- o *GTZ-Ecosan, available at: http://www2.gtz.de/ecosan/english/*
- o *IRC International Water and Sanitation Centre, available at: http://www.irc.nl/*

Arborloo and Fossa Altera

Arborloo are pit latrine systems where the latrine slab and superstructure is portable, the contents of the pits remain and trees are planted in the pits that remain. They are topped up with soil and vegetable matter. The end result after years of use is a series of trees which may form an orchard. A slightly different concept is known as *Fossa Alterna* (from the Latin - alternating pit). Two more permanently sited pits are used alternately. In this case, the pit which has become full is not planted with a tree but left so that the contents are allowed to turn into compost over a period of 6 to 12 months. After this period the humus like material is withdrawn from the pit, which is then put back into use. The advantage of this concept is that just two pits are used and these can occupy a very small area and thus this method becomes suitable for peri-urban settlements where space is limited. The slab and structure simply move back and forth from one pit to another. *(Morgan, P.; The Fossa Alterna alternating pit, a method for recycling human waste; 1999, available at: http://aquamor.tripod.com/page2.html)*

- *IWA Specialist Group "Ecological Sanitation", available at: http://www.ecosan.org/*
- *Jenkins, J.C.; The Humanure Handbook, A Guide to Composting Human Manure, Third Edition, 2005, available at: http://www.josephjenkins.com/books_humanure.html*
- *Habitat, Rand Water; Water Demand Management Cookbook; Nairobi/Johannesburg, 2003, available at: http://www.unhabitat.org/pmss/getPage.asp?page=bookView&book=1781*
- *Schuetze, T.; Decentralized water systems in housing estates of international big cities considering as example the cities Hamburg in Germany and Seoul in South Korea (Dezentrale Wassersysteme im Wohnungsbau internationaler Großstaedte am Beispiel der Staedte Hamburg in Deutschland und Seoul in Sued-Korea; (Dissertation) Books on Demand, Norderstedt, Germany, October 2005*
- *Sustainable Sanitation Alliance (SuSanA), available at: http://www.sustainable-sanitation-alliance.org/*
- *The EcoSan Market Place, available at: http://www.ecosan.nl*
- *UNESCO, International Hydrological Programme (IHP), Deutsche Gesellschaft fuer Technische Zusammnearbeit (GTZ) GmbH; Capacity Building for Ecological Sanitation; 2006*

An overview of commercially available dry toilets is available at: *http://www.gtz.de/de/dokumente/en-ecosan-tds-03-c-manufacturers-composting-toilets-2006.pdf*

Water-saving toilets

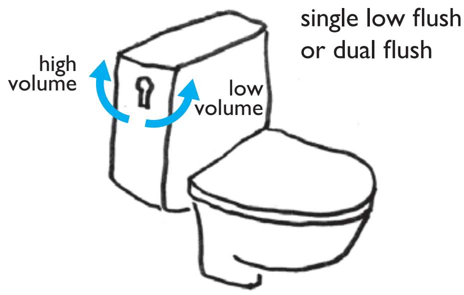


Illustration 34: Water-saving toilet, options for design and operation.

fact sheet 2 4.4.4

Technological description:

Water-saving toilets are based on the same working principles as common flush toilets, but they require a comparably low flush volume. Some of these toilets are also available with separated drainage for urine to reduce the impacts of nutrients and pharmaceuticals on the sewage-receiving environment and to facilitate the reuse of the urine as a fertilizer. However, most water-saving toilets available on the markets are designed for the combined drainage of urine and faeces. They can be differentiated in toilets with low volume cisterns (including vacuum toilets), dual-flush cisterns and cisterns with water-saving retrofit devices.

Low-volume toilets typically use 6 litres of water per flush, but there are also toilets available which require only 4 litres or even only 1 litre per flush. They are available in designs which look similar as high-volume toilets which require approximately 10 litres per flush or even more.

There are three types of low flush toilets: gravity tank toilets, flushometer toilets and vacuum toilets. While gravity tank toilets flush based on the gravity flow of water, flushometer toilets require a minimum water pressure for the flush (provided by pressure in piped water supply). The transport of faeces in both systems is provided by gravity flow in sewer pipelines after flushing. Vacuum toilets require only a very small amount of water which is actually not used as transport media but as a slip additive. After flushing the transport of faeces is provided by a vacuum which is created by a vacuum station connected to a collection tank at the end of the sewer pipeline.

Toilet retrofit devices, such as *displacement devices, dual flush devices* or *early closure devices* can be used in the urban and domestic environment to lower the water consumption of existing high volume toilets with either single or dual flush to the level of low-volume toilets.

Construction, operation and maintenance:

- The installation of gravity tank based low volume and dual flush toilets are compatible with most sanitary installations. Hence they are suitable for the replacement of toilets with high water demand. Construction operation and maintenance is comparable to high volume toilets.
- The installation of toilets with urine separation requires the installation of a second drainage pipeline and a collection tank for the diverted urine.
- Dual flush toilets operate in the same manner as the normal gravity toilets but allow the user to select either a full flush (with 4, 6, or 9 litres depending on the model) for solids or a half flush (2 to 4.5 litres) for liquids.
- Drainage pipelines for water-saving toilets can be installed with a smaller diameter and less slope than for high-volume toilets (e.g. 8 cm instead of 10 cm).
- The flushometer technology requires a relatively constant and comparably high water pressure from piped water supply for operation.
- For vacuum toilets generally a vacuum pipeline system has to be installed, consisting out of a

central vacuum pumping station with a collection tank The toilets require less than 1 litre per flush.

- o Displacement devices, such as bottles or bricks can be easily installed after opening the cover of the gravity tank. They save water by occupying a part of the toilet tank that would otherwise be filled by water. Thereby they are reducing the amount of water held in the tank and released for each flush. They are easy to install, requiring no plumbing experience.
- o Low volume toilets with single flush devices can be adjusted with dual flush devices. The installation requires plumbing experience.
- o Early closure devices are available in various styles and are used for the replacement of the original flush valve or mechanism. When the toilet is flushed, the devices force closure of the valve earlier than the original valve, releasing only a reduced amount of water. The installation requires plumbing experience.

Relative costs:

- o The investment cost for low volume toilets are comparable to high volume toilets. However, dual flush toilets may cost more than common cisterns. In South Africa, for instance, double flush toilets cost approx. double that of normal flush toilets.
- o The investment costs for water-saving urine diversion flush toilet prices are comparably high to non-diverting standard toilets.
- o The investment and operation costs for vacuum toilets and the required technology are high compared with gravity flow toilets. Therefore the gravity tank toilet is the most common form of low-volume toilet for most developing countries so far. However, in case of higher production rates of urine, diverting toilets it might be expected that the prices for these toilets would be comparably with common toilets.
- o Displacement devices can be realised for low or even no cost in case of reuse of old bottles or bricks.
- o Toilet retrofit devices are available for relatively low prices, but the installation requires skilled personal.
- o Depending on the water price, the savings of displacement and saving devices often provide payback on the installation costs within a matter of months to years.

Appropriate technological approach when:

- o Central water supply and a connection to a sewage treatment facility are available.
- o The installation of dry toilets is not feasible.
- o New installations of water-saving toilets are feasible if new toilet installations or if the replacement of old toilets is required.
- o The flushometer technology can only be applied in areas where a relatively constant and comparably high water pressure from piped water supply is available, which can not be guaranteed in many developing countries.
- o The installation of retrofit devices is appropriate if existing high-volume toilets have to be optimised for low cost and in short term.
- o Water-saving is simultaneously stimulated by education (e.g. in form of campaigns to rise awareness concerning water-saving issues), water metering and pricing.

Advantages:

- o Reduced water consumption for the flushing of toilets compared with standard toilets. The replacement of standard toilets which require 10 litres per flush (~60 litres per person and day) with dual flush toilets which require 4 and 6 litres per flush (~26 litre per person and day) results already in a reduction of 50%. (The daily water consumption for toilet flush is calculated on the basis of 6 flushes per person and day. In case of toilets with high and low flush volume, the amount is calculated based on 5 small flushes and 1 big flush per person and day.)
- o The use of displacement devices saves water with

each flush; approximately 1 to 2 litres depending on the volume of the object inserted.

- o Lower flush volumes can contribute significantly to an appropriate treatment of toilet water (black water) if it is treated separately from other waste water.
- o Generally the drainage pipelines for toilets with low flush volume can have smaller diameters which result in space and cost savings.

Disadvantages/Constraints:

- o The saved water demand is dependent on the specific toilet type and may vary significantly.
- o The overall saved water is dependent on the portion of water used for toilet flushing in relation to the water demand of other uses (shower, bath, cleaning, etc.).
- o The hydraulic design of the toilet bowl influences the required minimum flush volume for an appropriate cleaning of the toilet bowl with one flush. Therefore the retrofitting of toilets may result in a poor cleaning of the toilet bowl which requires double flush and results finally in higher water consumption.
- o The saved water is significantly dependent on the functionality of the flush procedure (If a water-saving toilet has to be flushed two times to empty the bowl, no water-saving is achieved).
- o Leakage control of flush devices is crucial for achievable water-savings (leaking retrofit devices may waste more water by permanent water losses than they save).
- o The drainage system has to be hydrological adjusted to the flush volume of toilets to avoid clogging.
- o The separated discharge of toilet paper (e.g. newspapers) might be advised to allow good flush properties and avoid clogging.

Cultural acceptability:

- o Generally well accepted and principally no difference with toilets with high flush volumes.
- o User must be educated to avoid flushing rubble and other refuse down the toilets.

Extent of use:

- o The installation has been part of residential and non-residential water conservation programmes and campaigns in many countries.
- o Low flush toilets as well as retrofit devices are already widespread and are installed with rising tendency. Therefore toilets with flush volumes of 6 litres for a big flush and 4 litres for a small flush can already be defined as standard water-saving toilets.
- o The installation of very low flush toilets from 6 litres for a full flush downwards, is not widespread, due to an only limited availability of models on the market.

References, links and literature:

- o *Habitat, Rand Water; Water Demand Management Cookbook; Nairobi/Johannesburg, 2003, available at: http://www.unhabitat.org/pmss/getPage.asp?page=bookView&book=1781*
- o *Schuetze, T.; Decentralized water systems in housing estates of international big cities considering as example the cities Hamburg in Germany and Seoul in South Korea (Dezentrale Wassersysteme im Wohnungsbau internationaler Großstaedte am Beispiel der Staedte Hamburg in Deutschland und Seoul in Sued-Korea; (Dissertation) Books on Demand, Norderstedt, Germany, October 2005*
- o *World Toilet Association, available at: http://www.worldtoilet.org*
- o *International Water and Sanitation Centre (IRC): http://www.irc.nl*

Toilets (selection):

- o *Wost Man Ecology AB: http://www.wost-man-ecology.se/*
- o *Flushmate retrofitting device: http://www.flushmate.com*
- o *Gustavsberg Toilets: http://www.gustavsberg.com*
- o *Adjustable flush unit: http://www.sanit.de*
- o *http://www.dubbletten.nu*
- o *http://www.roevac.com*
- o *http://www.meilongco.com*

Water-saving urinals

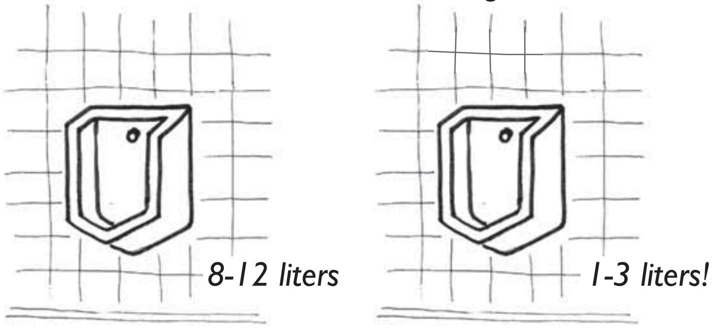


Illustration 35: Water consumption of a conventional urinal with high water consumption(left) and a water-saving urinal(right).

Technological description:

Water-saving urinals need water for flushing but require a comparably low flush volume. Even though urinals are more used in public buildings but not domestically, they are mentioned here to give a comprehensive overview about available water-saving sanitation technologies. Low volume urinals use approx. 3 litres per flush but are also available with less than 1 litre per flush (e.g. keramag centaurus) while common high-volume urinals use 8 to 12 litres. Furthermore the adjustment of flush-valves may save 3 litres per flush.

Construction, operation and maintenance:

o High volume flushometer-valve urinals can be replaced with low-flush units, generally without modifications to the bowl or to wall-floor-wall connections.

o Urinals based on different technologies (e.g. siphonic, washout and washdown urinals) require the replacement of flushing apparatus and valve.

o The adjustment of existing flush valves does not require any change in construction.

Relative costs:

o The investment costs differ among producers and technologies. However water-saving urinals are generally available in the same price range as urinals with high flush volume.

o The use of timers is comparably expensive.

o The adjustment of existing flush valves is possible at low cost.

o Dependent on water price and saved water quantity, the payback on the installation costs is provided within a matter of months.

Appropriate technological approach when:

o In case the existing urinals with high flush volume have to be retrofitted but not replaced.

o In the framework of replacements or new installations, and in case that waterless urinals are not used, water-saving urinals are an environmental sound alternative.

o Installed in addition to a toilet (due to higher water-saving potential).

o Installed in combination with separate urine treatment facilities.

o The users do not try to dispose of rubbish down the urinal.

Advantages:

o Reduced water consumption for the flushing of urinals compared with standard urinals and (standard) toilets.

o Standard urinals with high flush volumes can be equipped with water-saving devices.

Disadvantages/Constraints:

o Water-saving urinals are still consuming water.

o The dilution of urine with water causes odour, therefore a too small flush volume might cause odour problems and the occurrence of urinal cake (occurs when urine is mixed with water).

o The separated collection and treatment of urine is nearly impossible due to dilution with water and comparably high volume from water born urinals (please refer to waterless urinals).

o It is more economically (and at least water) efficient to replace water-saving urinals with waterless urinals.

Cultural acceptability:

o Well accepted due to same performance as urinals with high flush volumes.

Extent of use:

o Widespread use in public and commercial buildings.

References, links and literature:

o Habitat, Rand Water; Water Demand Management Cookbook; Nairobi/Johannesburg, 2003, available at: http://www.unhabitat.org/pmss/getPage.asp?page=bookView&book=1781

Urinals (selection):

o Keramag: http://pro.keramag.com

o Caroma: http://www.caroma.com.au

o Eviro-fresh: http://www.enviro-fresh.com.au

Waterless urinals

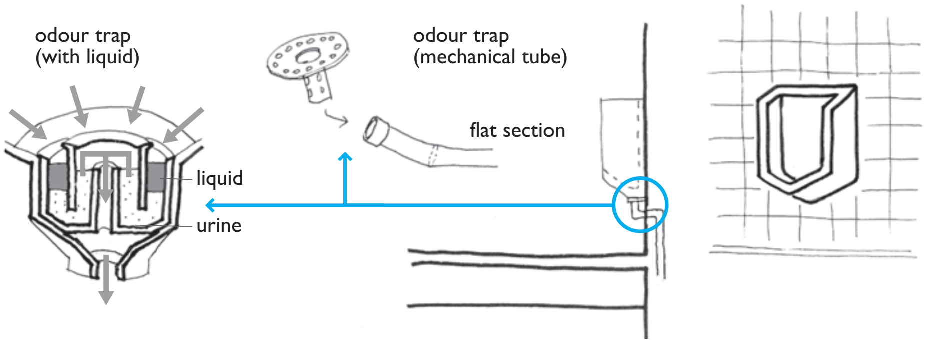


Illustration 36: Waterless urinals, working principles of different waterless u-traps, with oil barrier (left) and mechanical u-trap (middle).

Technological description:

Waterless urinals need no water for flushing and are therefore contributing significantly to water use efficiency. They can replace a conventional fixture connected to standard 50 mm drain lines. For the control of odour without siphons filled with water, different technologies from different companies are available which all have specific requirements for installation and maintenance as well as advantages and disadvantages. The available technologies can be differentiated in three main designs, oil barriers (either with refillable or replaceable cartridge), mechanical designs (one way valves), or microbial blocks. Microbial blocks are appropriate for the retrofitting of existing urinals with flush devices and are based on water-soluble blocks which are placed in a urinal. On contact with urine, the blocks break down and release odour-masking agents and bacteria which inhibit scale and odour. However a small amount of water is required each day to keep the bacteria active. Oil barriers or oil seal traps are a variation of the standard plumbing 'S' trap. The oil in the trap floats on urine entering the system, and the oil layer prevents odours escaping the sewer pipeline through the trap. One-way valves enable urine to pass into the sewer system, but stop odours from escaping the system. They are the newest and smartest type of waterless urinals because no chemical additives are required for operation.

Construction, operation and maintenance:

- o Can be installed easier than waterborne urinals because no connection to water supply is required.
- o Sewer pipes may not be made of copper or a copper alloy because the ammonia in urine is corrosive to the copper.
- o Sufficient fall of sewer pipes of at least two degrees is required to avoid the build up of scale and sludge in the pipes.

Relative costs:

- o Low tech urinals are inexpensive. Self-built urinals can be made from a simple plastic container, which should be thoroughly washed before use to ensure high quality of collected urine.
- o Prefabricated plastic urinals produced in South Africa cost around 30 Euro per bowl without a stench trap.
- o High tech urinals are more expensive, the investment costs are comparable with waterborne urinals.

o Service cost savings compared with waterborne urinals can be significant but are primarily dependent on water pricing and saved water quantity.

o Maintenance costs are similar to waterborne urinals (regular cleaning is sufficient) in case of urinals which require no chemical replacement of odour trap.

o Higher maintenance costs for urinals which require chemical replacement of odour trap.

o Dependent on water price and saved water quantity the payback on the installation costs is provided within a matter of months to years.

Appropriate technological approach when:

o Generally appropriate in any cases because there are no rational disadvantages but only advantages compared with waterborne urinals.

o Water savings in urinal installations want to be achieved to the greatest possible degree (especially in public toilets).

o The separated collection of undiluted urine is desired.

o Integrated management of human waste and land management, including agriculture, is desired.

Advantages:

o Waterless urinals produce fewer odours than urinals with water flush and also have no problems with urinal cakes (odour and urinal cakes occur when urine is mixed with water).

o Require no water consumption for the service (except regularly cleaning) and contribute to water saving at the greatest possible degree.

o Contribute to the protection of water resources to the greatest possible degree.

o Allow the pure and undiluted collection of urine for reuse, e.g. as fertilizer in urban farming (after appropriate treatment, e.g. storage and dilution) and can contribute to closed loop economy, or for effective anaerobic treatment by e.g. an anaerobic ammonium oxidation (anamox) reactor.

o Surface water and aquifers are protected from nutrients and pharmaceuticals if the urine is collected separately.

o They are touch free.

o No water pressure required.

Disadvantages/Constraints:

o In case of replacement of odour trap seal, the maintenance personnel needs to be instructed how to replace the seal when necessary and how to wash the fixture. However no skilled personnel are required.

o Correct installation and regularly cleaning is required for an odour free operation.

o The use of microbial blocks may cause pollution problems in case of reuse of urine in agriculture and is therefore not recommended.

Cultural acceptability:

o First time users can be confused by the absence of a flush valve or water pipes. A display with educational information about the technology and environmental issues like the saved amount of fresh water can easily clarify confusion.

o User acceptance is practically proven in case of correct installation and odour free operation.

o Users may become negative about waterless urinals if they are confronted with poorly maintained urinals and exposed to unacceptable odour or hygiene issues.

Extent of use:

- o Suitable for urban and domestic areas without sewer systems and without centralised water supply.
- o Applicable in environmental sensible areas.
- o Widespread use in public and commercial buildings in countries with comparably high water price.
- o Water-saving urinals and waterless urinals with chemical odour traps are often replaced with waterless urinals which require no chemicals.

Links and Literature:

- *o Gtz; technical data sheets for ecosan components; available at: http://www.gtz.de/en/themen/umwelt-infrastruktur/wasser/9397.htm*
- *o Hegger, D.; Greening sanitary systems: an end-user perspective; (PhD thesis), Wageningen University, 2007. Available at: http://library.wur.nl/WebQuery/catalog/abstract/1860131*
- *o Sydney water, fact sheet about waterless urinals, available at: http://www.sydneywater.com.au/Publications/FactSheets/WaterlessUrinalsFactSheet.pdf*
- *o Wilsenach, J. A.; Treatment of source separated urine and its effects on wastewater systems; (PhD thesis), Delft University of Technology, 2006, available at: http://www.library.tudelft.nl/ws/search/publications/search/metadata/index.htm?docname=202108*

Waterless Urinals (selection):

- *o Britex, available at: http://www.britex.com.au/index.html*
- *o Urimat, Switzerland, available at: http://www.urimat.com (from 400 Euro + odour trap))*
- *o F. Ernst Ingenieur AG, Germany, available at: http://www.ernstsystems.com (from 420 Euro + odour trap)*
- *o Keramag, Germany, available at: http://www.keramag.com (from 490 Euro)*
- *o Franke GesmbH, Austria, available at: http://www.franke-wss.com (from 465 Euro)*
- *o Waterless, available at: http://www.waterless.com*
- *o Caroma, avilable at: http://www.caroma.com.au, http://www.caromausa.com*
- *o Addicom, South Africa, available at: http://www.addicom.co.za (from 30 Euro)*
- *o Falcon waterfree, available at: http://www.falconwaterfree.com/how/index.htm*
- *o Uridan, available at: http://www.uridan.com/*

Water-saving taps

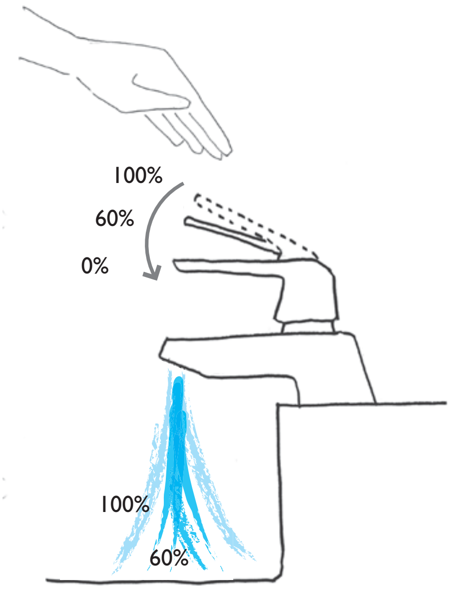


Illustration 37: Working principle of a water-saving tap with two flowrates. Convenient and efficient for uses which require two flow volumes (e.g. in kitchen)

fact sheet 5 4.4.4

Technological description:

Water-saving taps offer the possibility to significantly reduce water consumption compared to conventional taps. The actual water quantity that can be saved is dependent on various factors, like the water pressure, the type and flow rate of standard taps, as well as the purpose of consumption. As a rule of thumb a conventional tap can have a flow rate of approx. 14 litres per minute. However, a basic measure to enhance the efficiency of taps is the repair of leaking or drippy taps. They are one of the most common sources of water wastage in many households. They should be checked regularly for leaks at the tap head, and for seepage at the base and the connections.

Low-volume taps for different applications (e.g. kitchen and bathroom) are available in manifold designs and different technologies. For uses which require two scenarios, e.g. the withdraw of a lot of water in a short period of time (e.g. for cooking) but also water-saving (e.g. the washing of vegetable under a steady stream of water) taps with a so called water brake are available, allowing the selection between high-volume and low-volume flow by easy handling with one hand. In these taps the water flow is regulated by closing devices inside the tap. Alternatively tap *(retrofit) devices* can be screwed on the head of taps with suitable threads to decrease flows. Conventional *aeration or spray devices* reduce the water flow by mixing air with water or reducing the diameter of a taps water outlet, but can not be adjusted to specific flow rates, because the actual flow is dependent also on the specific water pressure. In opposed to that so called flow rate delimiters (or flow-control devices) are reducing the flow rate independent on the specific water pressure. Small mechanical devices in these small tap heads (looking similar to sprayers and aerators) regulate the flow to a specific maximum flow rate. They are available for flow rates from 1.7 litres upwards in steps of 0.5 to 1 litres.

Alternative water-saving devices which are mainly applied in public buildings to avoid water losses are metered-valve taps, delivering a preset amount of water before shutting automatically off. Self-closing spring-loaded taps feature a knob that automatically shuts off the water when the user releases the knob. *Sensor-activated taps* contain light and motion sensing devices causing a tap to shut on once the sensor detects motion direct in front of them and to turn off when the user steps away. Sensor-activated taps require a power supply to drive the sensors.

Construction, operation and maintenance:

o Leaking taps can be repaired by the quick, easy and inexpensive replacement of worn washers, which are a common cause for dripping taps or the loss of a steady stream of water. Leaks at the tap stem or the base can be also quick, easy and inexpensively repaired by the tightening of fixtures or the placement of new packing in the packing nut.

o Installation of water-saving retrofit devices is easy, no plumbing experience is required and they require no maintenance.

o Installation and maintenance of water-saving taps is not different to high-volume taps.

o Periodic cleaning sensor-activated taps is required to minimise malfunctions caused by sediment obstructions.

Relative costs:

o Tap retrofit devices like aeration or spray devices are relatively inexpensive.

o In case of already existing taps, retrofitting high-volume taps is less expensive than replacing the entire unit. However, in the kitchen the installation of entire water-saving taps which allow the selection between two volume flows (high and low) are more effective than only water-saving devices. For the filling of pots a high flow rate can be chosen, while for washing purposes a low flow rate is sufficient.

o Dependent on water price and saved water quantity the payback on the installation costs is provided within a matter of months to years.

Appropriate technological approach when:

o The specific flow rate should be adapted to the specific use of taps. While in bathrooms low-volumes might be sufficient, for other purposes (e.g. in kitchens) low as well as high volumes are required.

Advantages:

o Significant reduction of water consumption compared with conventional taps is possible without loss of comfort and at low cost.

o No negative influence on the delivered water quality.

Disadvantages/Constraints:

o Sensor-activated taps require a power supply for operation.

o In case of pressure dependent hot water production (either electric or gas continuous flow heaters) a minimum flow rate is required for operation. The achievable savings in water consumption are in this case dependent on the minimum required flow rate of the installed technology.

o Flow rate delimiter with a low flow rate installed in taps which require the consumption of specific quantities of water (e.g. for cooking and drinking) may be uncomfortable. In these cases water-saving taps which allow switching between high and low volume flows are appropriate.

Cultural acceptability:

o User acceptance is practically proven if flow rates are adapted to the specific use and the required volume flows.

Extent of use:

o Widespread use in new and existing private households as well as in public and commercial buildings especially in countries with water scarcity or high water prices.

References, links and literature:

o *Habitat, Rand Water; Water Demand Management Cookbook; Nairobi/Johannesburg, 2003, available at: http://www.unhabitat.org/pmss/getPage.asp?page=bookView&book=1781*

o *Schuetze, T.; Decentralized water systems in housing estates of international big cities considering as example the cities Hamburg in Germany and Seoul in South Korea (Dezentrale Wassersysteme im Wohnungsbau internationaler Großstaedte am Beispiel der Staedte Hamburg in Deutschland und Seoul in Sued-Korea; (Dissertation), Books on Demand, Norderstedt, Germany, October 2005*

Water-saving taps and retrofit devices (selection):

o *Neoperl, available at: http://www.neoperl.net*

o *Aquaclic, available at: http://www.aquaclic.ch*

o *Microplast, available at: http://www.microplast.de*

Water-saving shower heads

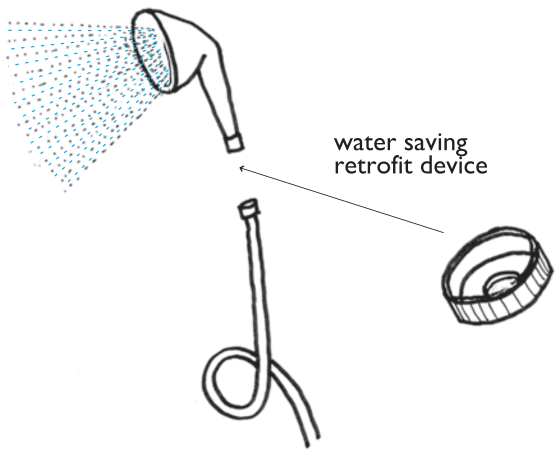


Illustration 38: Water-saving showerhead. Example for a retrofitting device which is simply inserted in the fitting between showerhead and hose.

4.4.4 fact sheet 6

Technological description:

Water-saving shower heads, or low-volume showerheads, improve water use efficiency compared with high-volume shower heads by mixing water with air, improving the spray patterns or by creating a narrower spray that simulates the feeling of much water with low-volume flows. A variety of spray and other design options are available for new low-volume showerheads. For the retrofitting of conventional high-volume showerheads flow restrictors can be installed. These are inexpensive plastic or metal disks with a small whole in the middle. They are inserted in the coupling between shower arm and hose and fit to standard connections. However the flow rate can not be adjusted exactly with these devices because the specific flow rate also depends on the water pressure. Shower heads using flow control devices (or flow rate delimiters) can be adjusted to a specific flow rate, independent of the specific water pressure. The function is generally based on a disc containing an elastic O-ring that is controlled by pressure. Under high pressure the O-ring flattens and reduces the water flow while it relaxes and allows higher flow under lower pressure. Additional water-saving devices, mainly applied in public buildings to avoid water losses, are metered-valve taps, delivering a preset amount of water before shutting automatically off. Self-closing spring-loaded taps feature a knob that automatically shuts off the water when the user releases the knob.

Construction, operation and maintenance:

- o Installation of water-saving retrofit devices is easy, no plumbing experience is required and they require no maintenance.
- o The measures used in water-saving shower heads to reduce the flow are comparable with the ones used in water-saving taps.

Relative costs:

- o Shower retrofit devices which reduce the volume flow of existing showers are relatively inexpensive.
- o Water-saving shower heads are available from low to high cost, depending on the model and the features (comparable with costs for high -volume shower heads).
- o Dependent on the specific water price, the cost of a water-saving shower head and the amount of saved water, the payback on the installation costs is provided within a matter of months to years.

Appropriate technological approach when:

- o The installed shower heads are meeting the comfort criteria of the users.
- o Water wants to be saved without changing behaviour pattern and without loss of comfort.

Advantages:

o Significant reduction of water consumption compared with conventional shower heads.

o No negative influence on the delivered water quality.

o Design and use is similar to conventional shower heads.

o Positive interaction can be achieved in case of greywater recycling from bathrooms for service water supply. Treatment facilities can be designed smaller and can operate more efficiently.

Disadvantages/Constraints:

o In case that water-saving shower heads are not satisfying the users expectation for a shower experience (e.g. to soft a shower), the user might be motivated to switch back to high volume shower heads. However, water-saving shower heads are available for different user profiles, with soft water flow and hard spray.

o Retrofitting devices are only reducing the volume flow and may therefore create a too soft a water flow, which might not satisfy the user.

o In case of pressure dependent hot water production (either electric of gas continuous flow heaters) a minimum flow rate is required for operation. The achievable savings in water consumption are in this case dependent on the minimum required flow rate of the installed technology.

Cultural acceptability:

o User acceptance is practically proven if spray patterns are comfortable and satisfying, in public and commercial as well as private installations.

Extent of use:

o Widespread use in commercial or public baths as well as in private households, especially in countries with water shortage or high water prices.

References, links and literature:

o Habitat, Rand Water; Water Demand Management Cookbook; Nairobi/Johannesburg, 2003, available at: http://www.unhabitat.org/pmss/getPage.asp?page=bookView&book=1781

o Schuetze, T., Decentralized water systems in housing estates of international big cities considering as example the cities Hamburg in Germany and Seoul in South Korea (Dezentrale Wassersysteme im Wohnungsbau internationaler Großstaedte am Beispiel der Staedte Hamburg in Deutschland und Seoul in Sued-Korea, Dissertation, Books on Demand, Norderstedt, Germany, October 2005

Water-saving taps and retrofit devices (selection):

o Neoperl, available at: http://www.neoperl.net

o Microplast, available at: http://www.microplast.de

o Neco, available at: http://www.neco.com.au/product.asp?pID=150&c=35926

o Rippleproducts, available at: http://www.rippleproducts.com/shop/productdetail.asp?id=23&catid=2

Pressure reducers

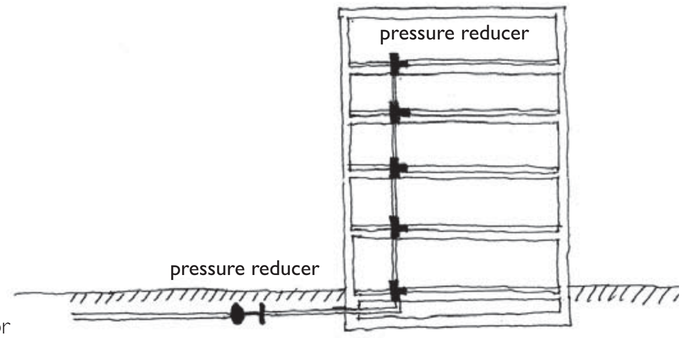


Illustration 39: Section of a building with optional locations for installations of pressure reducers.

4.4.4 fact sheet 7

Technological description:

Pressure reducers can be installed either at the supply point of a building or at certain points inside a building in case of larger or higher buildings. Pressure reducers are installed between pipeline joints to reduce the water pressure and to reduce the flow to taps and other fixtures (within flow requirements for each floor and water supply connection).

Construction, operation and maintenance:

o Comparably easy to install for skilled plumbers. No maintenance for the operation is required.

Relative costs:

o Comparably low cost.

Appropriate technological approach when:

o Buildings are equipped with a centralized water supply.

o The water pressure in the whole building or in building parts is high (above 3 bar).

Advantages:

o They can contribute to water-savings without requiring a change of taps or showerheads inside flats or apartments.

o A positive side effect is that fittings generally last longer when operated at lower pressures.

Disadvantages/Constraints:

o Water pressure may be too low and limit the comfortable use of water.

Cultural acceptability:

o Generally well accepted if water pressure is not below comfort level or limiting the use of continuous flow heaters.

Extent of use:

o Used successfully in areas with high water pressure and where water-savings are desired but measure on individual level are difficult to implement

References, links and literature:

o *Habitat, Rand Water; Water Demand Management Cookbook; Nairobi/Johannesburg, 2003, available at: http://www.unhabitat.org/pmss/getPage.asp?page=bookView&book=1781*

Water-saving household appliances

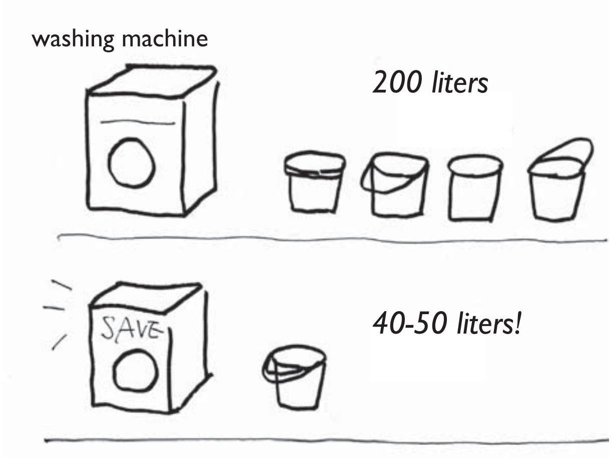


Illustration 40: Water consumption of water-saving household appliances (bottom) compared to consumption of conventional appliances (top)

Technological description:

Water-saving household appliances in the urban and domestic environment are generally washing machines and dishwaters. The water consumption between different technologies and models differ significantly. Old average top-loading washing machines use 200 litres of water per wash while new water-saving models use only between 40 and 50 litres per wash. Dishwashers are used in restaurants and in domestic kitchens. Modern and properly used dishwashers which use less than 23 litres per load are generally more water-efficient and wash more effectively than manual washing-up. Modern machines use less than 15 litres per wash.

Construction, operation and maintenance:

- Comparably with common household appliances. No additional effort is required.

Relative costs:

- Investment costs are comparably with common household appliances.
- Water and energy savings of new efficient technology can result in significant savings.

Appropriate technological approach when:

- In case new appliances are bought, only water-saving technology should be chosen.

Advantages:

- Appliances are convenient to use and save water compared with inefficient technology and manual washing.
- Detergents used for washing machines can be phosphate free and biodegradable and therefore not more harmful to the environment as detergents for washing by hand.

Disadvantages/Constraints:

o Compared to manual washing the appliances require high investment costs and electric energy for the service.

o For dishwaters often strong detergents are used. They often contain a high portion of phosphates which are a potential contaminant for receiving water bodies. It is highly recommended to avoid the use of such detergents particularly in areas were no or only limited wastewater treatment facilities are available.

Cultural acceptability:

o They are well accepted by the users, because they offer the same convenient service as conventional appliances but save a lot of water.

Extent of use:

o Widespread in family households of middle and high income groups, due to the comparably high investment costs.

References, links and literature:

o Habitat, Rand Water; Water Demand Management Cookbook; Nairobi/Johannesburg, 2003, available at: http://www.unhabitat.org/pmss/getPage.asp?page=bookView&book=1781

o Schuetze, T.; Decentralized water systems in housing estates of international big cities considering as example the cities Hamburg in Germany and Seoul in South Korea (Dezentrale Wassersysteme im Wohnungsbau internationaler Großstaedte am Beispiel der Staedte Hamburg in Deutschland und Seoul in Sued-Korea; (Dissertation), Books on Demand, Norderstedt, Germany, October 2005

Economised water use for personal hygiene

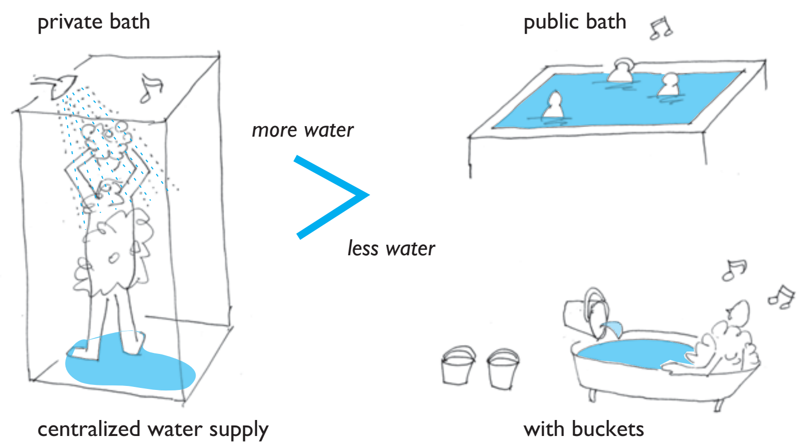


Illustration 41: Economised water use for personal hygiene.

fact sheet 9 4.4.4

Technological description:

Personal Hygiene includes the washing of the human body as well as showering or bathing. The required water quality for personal hygiene in case of centrally water supply is generally potable. The amount of water required and used for personal hygiene is not only primarily dependent on technologies for the withdrawal of water, like the mentioned taps and showerheads, but also on cultural and religious traditions as well as on the available water quantity and available appliances. Centralized water supply and bathrooms are generally motivated to use more water because the water withdrawal is more convenient compared to washing or showering using buckets which have to be carried by hand, even though the flow rate per time unit can be limited with water-saving devices. Furthermore private bathrooms may motivate the users to shower and bath more often compared to the necessity to visit public baths for personal hygiene. Potable water quality is not necessary for showering and bathing if water is not consumed orally (bathing water standards) and is even not supplied in many cases, even though it is generally required. Hence the use of non-potable water for personal hygiene should be tolerable if public health is not at risk. If the absence of pathogens can be guaranteed, the use of non-potable water for personal hygiene can contribute to the saving of potable water resources for drinking and the preparation of food.

Construction, operation and maintenance:

o No specific technology is required for changing human habit and behaviour.

o For the separate supply of bathing water and drinking water two water supply pipeline networks are required inside the building. This bathing water is general used as service water, for irrigation, toilet flushing, cleaning, and so on.

Relative costs:

o It only requires awareness and action to economise water.

o In areas with drinking water scarcity, water with bathing water quality is generally cheaper and easier available than drinking water.

Appropriate technological approach when:

o Water resources are scarce, specifically drinking water.

o Only bathing water quality is supplied and drinking water is either purified at the point of use or supplied bottled.

o Two water qualities, bathing/service water and drinking water, are supplied by two separate networks.

Advantages:

o Economising water saves scarce resources and the use of water with bathing water saves drinking water.

Disadvantages/Constraints:

o It is hard to change people's habits to use water less luxuriously if they are used to it.

o The use of water with bathing water quality for bathing and showering is often not allowed. According to regulations in most developed countries drinking water quality has to be provided also for shower and bath.

Cultural acceptability:

o In many areas worldwide economising water use is essential for saving scarce drinking water resources. In many cases the centrally supplied water quality is not meeting drinking water standards, but it is used and well accepted for personal hygiene and, with further purification, used for drinking and the preparation of food.

Extent of use:

o Necessarily wide spread use in many places worldwide, particularly in areas with water scarcity.

References, links and literature:

o See chapter 5.3.6 Case 6: Water-saving by communication and public awareness in Bogotá Colombia:, on page181

Economised water use for cleaning and watering

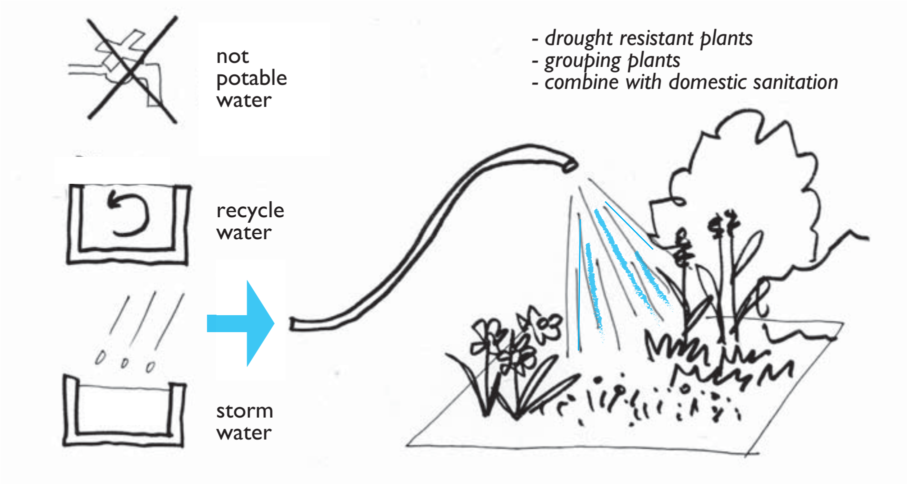


Illustration 42: Economised water use for watering.

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Technological description:

Cleaning includes the washing of cloth and cleaning of the urban and domestic environment (household and building parts). The supplied water quality for personal cleaning in case of a water supply based on single pipeline systems is generally potable. The amount of water required and used for cleaning is dependent on cultural and religious traditions and also on the available water quantity. Potable water quality is neither necessary nor required. Therefore the use of non-potable service water (fulfilling the quality requirements for bathing water) for cleaning can contribute significantly to the saving of potable water resources.

Watering includes the use of water for potted plants, green roofs, gardening, irrigation of parks and other public green areas and the growing of plants for food (urban farming). Potable water quality is neither necessary nor required for the watering of plants. The proportion of water used for watering can differ significantly and is primarily dependent on the basic conditions (e.g. climate and evaporation rate) and the use at a location. For watering potted plants, the water demand is much smaller than in case of gardening or even urban farming, especially in warm and dry climates. Consequently, reductions in water for gardening and farming can make a significant contribution to the saving of water resources. Water conservative gardens and farms are designed to reduce the amount of water used through measures such as drought resistant planting, grouping of plants, trenching, mulching, adjustments to design of watering tools (e.g. timing, duration and frequency of watering and dripping irrigation to reduce evaporation and percolation losses, the use of soil moisture activated controllers) and use of non-potable service water (e.g. recycled domestic waste water or rain water). Experience in South Africa shows that garden watering is a massive problem in areas where water is not paid for based on metered consumption. In some areas the monthly water consumption was reduced by 80% after the control of garden watering by proper billing and enforcement.

Positive interactions between watering and urban and domestic sanitation can be especially achieved by the safe reuse of recycled waste water (mixed sewage or greywater). Nutrients can be absorbed by plants and hindered from entering either aquifers or surface waters. Contaminants are degraded by microorganisms in the soil. In case of decentralized or semi-decentralized waste water recycling measures, savings in discharge and supply infrastructure can be achieved.

Construction, operation and maintenance:

- o No specific technology is required for economising water use although the amount can be reduced, e.g. by water saving fittings and dripping irrigation systems. However, awareness is required which can be raised and spread by public education and campaigns.
- o For the use of service water for cleaning and watering, please *see section 4.5, "Water reuse, recycling & safe disposal"*, and "*dual pipeline system*" *under section 4.3*.
- o The requirements for the use of treated sewage for irrigation are also described in section 4.5.

Relative costs:

- o Compared with possible savings by economised water use, the costs for education and awareness rising are comparably low.
- o The costs for the use of waste water for irrigation are primary dependent on the location of treatment facilities and irrigated areas, see also section 4.5.

Appropriate technological approach when:

- o Water resources are scarce, specifically drinking water.
- o Alternative water sources in addition to piped potable water supply are available.

Advantages:

- o Less water of drinking water quality is needed.
- o Decrease of nutrient load to receiving waterways.

Disadvantages/Constraints:

- o The practicing of water-saving cleaning and watering requires action from citizens.

Cultural acceptability:

- o High in case of awareness concerning economised water use.
- o High if costs can be saved and water availability is better after introduction of measures.

Extent of use:

- o Increasingly important and practiced in areas that suffer from permanent or temporary water shortages.
- o Service water or purified waste water use is particularly important in areas with water scarcity and gardens, parks and urban farming.

Links and Literature:

- *o Campos, C., Oron, G., Salgot, M., Gillerman, L., and Casals, G.; Attenuation of microorganisms in the soil during drip irrigation with waste stabilization pond effluent; Water Science and Technology, Vol 42, Nos 10-11, 2000, pp. 387-392.*
- *o Rose, G. D.; Community-Based Technologies for Domestic Wastewater Treatment and Reuse: Options for urban agriculture; International Development Research Centre, Cities Feeding People Series, Report 27, Spring 1999*
- *o Schuetze, T.; Decentralized water systems in housing estates of international big cities considering as example the cities Hamburg in Germany and Seoul in South Korea (Dezentrale Wassersysteme im Wohnungsbau internationaler Großstaedte am Beispiel der Staedte Hamburg in Deutschland und Seoul in Sued-Korea; (Dissertation), Books on Demand, Norderstedt, Germany, October 2005*

4.5 Water reuse, recycling and safe disposal ESTs

4.5.1 INTRODUCTION

This section focuses on the ESTs for water flows that have been used earlier or, as in the case of rainwater run-off, have passed through the urban system and are now treated for reuse or for safe disposal. The central questions concern the environmentally sound technologies for treatment of polluted water.

The stepwise analysis of flows, areas and actors (4.5.2) may provide the required information for the discussion of the main arguments (4.5.3) for the selection and combination of specific ESTs presented in the last subsection (4.5.4).

The analysis of the existing situation should point out all available but also missing information. The aim of the analysis is a clear understanding of the facts and uncertainties as a basis for the decision making process. Selected ESTs should fit in this specific decision situation. Given the analysis of the sustainable supply and use options, increasing the opportunities for reuse is the key issue.

4.5.2 ANALYSIS OF THE DECISION SITUATION

4.5.2.1 Analysis of flows: Quantity aspects

How big is the volume of wastewater and polluted water flows? Their quantity can be compared with the volume of the demand flows. A schematic diagram as the one that is given in 4.4.2 may be helpful for this purpose.

4.5.2.2 Analysis of flows: Quality aspects

o Pollution quality is the central issue and many questions arise concerning the potential of this situation for reuse and safe disposal. This leads to questions about:

- the nature of the pollutants,
- the way pollution can be prevented; for domestic wastewater the options are limited but for other sources, such as pollution resulting from industrial and commercial activities and solid waste dumping sites, an ounce of prevention is worth a pound of cure,
- the ways polluted water is purified already,
- the natural purification processes at work, e.g. in wetlands or in dry road verges,
- the contaminants accumulating in soils or vegetation,
- the knowledge available about the ecological impacts of water and soil pollution,
- the possibility to use natural processes for further treatment of polluted water, for example in constructed wetlands.

o The analysis of pollution can now be confronted with the analysis of quantity and quality of water demand that results from the use and saving analysis in section 4.4.

o The analysis should generate a frame of knowledge about the systems at work that can be used for the selection of alternative EST strategies that fit to this specific situation.

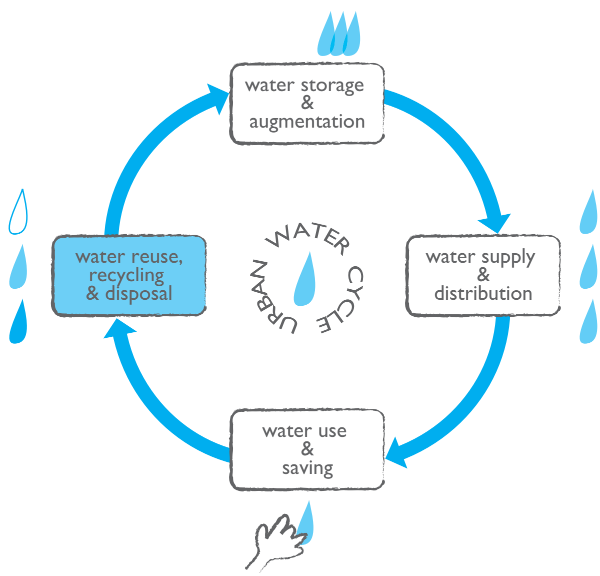

Illustration 43: Position of the section on water reuse, recycling and safe disposal in the urban water cycle.

4.5.2.3 Analysis of areas

The spatial analysis should further contribute to the design of alternative solutions, both at the level of houses and buildings and at the urban and urban periphery level.

4.5.2.4 Analysis of actors

The recycle, reuse and safe disposal issues are closely related to human behaviour and to the social and economic organisation of responsibilities and risks. It is important to start any process of change with the existing organisation, including the initiatives for improvement that are already there. A stakeholder analysis should throw light on the role groups and individuals play in the funding, the legal permits and the operation of ESTs that belong to different reuse and safe disposal options. Who pays? Who is responsible for operating the systems, for quality control and for maintenance? If there are problems, now or in the future, for whom are they problematic? Understanding these roles, the power of actors or the need for empowerment, is essential to decision making.

4.5.3 DISCUSSION OF ARGUMENTS FOR DECISIONS ABOUT ESTS FOR REUSE, RECYCLE AND DISPOSAL

4.5.3.1 Rainwater quality control

Issues concerning storage, supply and the use of rainwater have been already discussed in the previous sections. The relevant question here is whether rainwater run-off needs to be treated for (re)use or for safe disposal. Generally speaking the contamination will be low and certainly does not justify carrying the rainwater to an advanced sewage treatment plant, as it happens in the traditional combined sewer systems of many old cities. ESTs for *separating rainwater from sewer systems* already play an important role in many urban areas with existing combined sewer systems. In new developments, of course, these practices are easier to realise. Less rainwater to a *central sewage treatment plant* contributes to a more constant and more concentrated wastewater flow and this significantly increases the efficiency of the purification process in these plants. In these situations rainwater-harvesting ESTs, at any level, will increase the quality of the purified effluent. In climates with an annual precipitation of 800 mm, disconnecting rainwater from combined sewers will approximately halve the volume of water that goes to the central treatment plants. In that case, the separated rainfall equals the average domestic water demand per year.

Only minor treatment is required for *quality control of domestic rainwater use* if this implies roof-top rainwater use. Most important is quality control by preventive measures in construction and in the stage of use and maintenance. If rainwater is used for drinking, quality control should be strict, and for non-drinking purposes, such as cleaning, washing, watering gardens at the domestic level, quality control is also required. At the urban level, street run-off is more contaminated. But, generally speaking, it will be sufficient for purification to create some infiltration swales or detention and retention ponds, lined up with some wetland vegetation. The spatial design of new or renewed urban districts should create conditions for these ESTs that combine storage with some purification. In doing so, the rainwater serves the water supply of urban parks and green spaces. Run-off from busy roads will be more contaminated. In these or similar cases, depending on the nature of the pollutants, sedimentation ponds and constructed wetlands may provide sufficient treatment to use the water for watering urban green spaces, urban agriculture or for safe disposal in a river. Treatment of storm water in soils may also create conditions for aquifer storage, an important issue for areas with high evaporation. This practice is known as Soil Aquifer Treatment (SAT, not to be confused with the SAT methodology discussed in chapter 3).

4.5.3.2 Decentralised ESTs for grey water and black water treatment

Many urban areas have separated sewer systems leading to central sewage treatment plants. Although these systems are more environmentally sound than the combined sewers and although central control of the operation and quality of the purification process is advantageous, there are also a number of serious disadvantages. One of them is the huge investment required for the sewer network and the treatment plants that make it very difficult for poor cities to set up a central system. Secondly, from a recycle and reuse point of view, the central treatment makes it almost impossible to reuse wastewater at the domestic level. Thus, the central system misses great opportunities to be more water efficient. Home-based decentralised system options, therefore, deserve more attention. They can offer an attractive alternative for urban areas that do not have a central sewer system. In those cities that do already have central sewers, the decentralised ESTs may create conditions for gradually improving water efficiency at the household level. At this level it is both sensible and feasible to separate different qualities of wastewater: grey water, black water and urine.

Even in urban situations with high density and very limited available space a number of ESTs are applicable. They generally operate on the basis of small-scale on-site technical sewage treatment technology. Generally the technical and financial effort is comparatively low for the purification of less polluted sewage. Less polluted grey water from bathrooms and washing laundry is relatively easy to purify to service water quality. ESTs for *on-site treatment of grey water from kitchens* do provide this. As a rule, grey water from kitchens requires more treatment. This can be realised by technical *kitchen grey water treatment ESTs.* Heavier purification tasks are performed by ESTs for *on-site and near-site black water treatment.* The higher performance systems naturally are more costly and usually take more space. If more space is available, as in houses with gardens or in public buildings with special technical spaces, it may become feasible to install aerobic treatment facilities, such as retting containers, producing compost. Another option is to install anaerobic treatment facilities, for instance by combining vacuum toilets with vacuum sewers and bio-digesters that produce methane gas and a fertile slurry. Urban agriculture may benefit from the compost or digested slurry (mitre residues). In case of even more available space also *constructed wetlands* may become feasible, either for full treatment or for post treatment of effluent. Different combinations of these technologies may be interesting in specific situations. Some of these systems may also partly rely on the central sewer connection.

4.5.3.3 Improving existing centralised systems

A step-by-step transition process of introducing more on-site technologies may also improve the functioning of existing centralised treatment facilities, as clearly demonstrated by the disconnecting of rainwater from sewer systems. The discussion about decentralised and centralised approaches is crucial but should not be seen in an either-or but in a both-and perspective. The same holds true for the debate of technical sewage treatment versus nature-oriented sewage treatment, also known as Phytotechnology (UNEP). Paying more attention to the natural processes of the area is vital and may lead to appropriate technology. Equally important is paying attention to institutional and organisational differences of decision situations. How to organise efficient water use and effective quality control as a basis for health is a question that may lead to different answers in different situations. One interesting option for some existing centralised treatment plants to pay attention to the fact that in many developing countries wastewater is less polluted by heavy metals and other toxicants but relatively more contaminated by pathogen microorganisms (bacteria, viruses or the eggs of parasitic worms). If such a situation occurs in an arid or semi-arid region, there is a great need to be water efficient and to reuse urban wastewater for irrigation in agriculture. In such cases it might be appropriate to reconsider existing centralised treatment practices and discuss the option of introducing an advanced primary sewage treatment with additional filtering systems: an option that is more water efficient and less costly.

4.5.3.4 Change and learning

Apart from the technical aspects and the cost and space considerations, the introduction of new technologies necessarily implies the need for special care, both in construction and in the stage of use and maintenance. The implementation of new technology at the domestic level requires guidance and assistance even if it is relatively simple. This means there is a need for an organisation to take up responsibility for the quality of the technical performance through customer advice and assistance, through training of professional technicians and, if necessary, through financial support or loans to stimulate the innovative process. The basis of change is an interactive process of learning by doing. As in any innovative development, the introduction of new water use and reuse technologies requires a committed *change agent* who assumes the responsibility for making progress and who can cope with the risks related to construction and maintenance. Without risks, there is no innovation. The crucial question is who will play the role of *change agent*? In new development schemes or in redevelopment projects it could be the developer or the housing corporation or a municipal agency, but it seems wise, depending on the situation to set up a public-private organisation with active participation of the users themselves.

4.5.3.5 Priorities

Under an *Integrated Water Resource Management (IWRM)* perspective, the choice of recycle, reuse and disposal options may result in a situation specific combination of ESTs. The general priority sequence of options that may summarise the arguments is as follows:

- o In developing countries that have sufficient rainwater or snow-melt water, roof-top rainwater collection for drinking water purpose is the first choice. Quality control is essential.
- o In more developed urban situations with an existing drinking water network, treatment of grey water and run-off rainwater to service water quality is a first option to be considered because it is low-cost, relatively simple and less risky. At the domestic level this leads to a priority for ESTs treating grey water from bathrooms and washing laundry for reuse in cleaning, watering gardens or toilet flushing. At the urban level, run-off rainwater can be (re)used easily for watering green spaces and vegetable gardens and, if necessary, for cleaning roads. Simple constructed wetlands that can be part of urban green spaces may perform well.
- o If sufficient professional guidance can be organised for construction and maintenance, more advanced decentralised ESTs can be introduced for the treatment of sewage inside or near houses. There are aerobic and anaerobic options, producing compost or methane gas and fertile sludge that can be used in urban agriculture. The treated water can be reused at the domestic or urban level.

In densely populated urban areas centralised sewer systems may exist already. To improve these systems, rainwater should be separated from the system. Depending on the nature of wastewater pollution the treatment process can be adapted to the situation. Creating conditions for the reuse of effluent in irrigation for agriculture is a priority.

4.5.4 FACT SHEETS ON WATER REUSE, RECYCLING AND SAFE DISPOSAL ESTS

The ESTs Fact Sheets below enlisted for "water reuse, recycling and safe disposal" are presented in the following Section 4:

4.5.4.1 Domestic rainwater use

4.5.4.2 On-site treatment of grey water

4.5.4.3 Constructed wetlands

4.5.4.4 On-site and near-site treatment of black water and mixed sewage

4.5.4.5 Separating rainwater from sewer systems

4.5.4.6 Environmentally sound centralised sewage treatment in developing countries for reuse

Domestic rainwater use

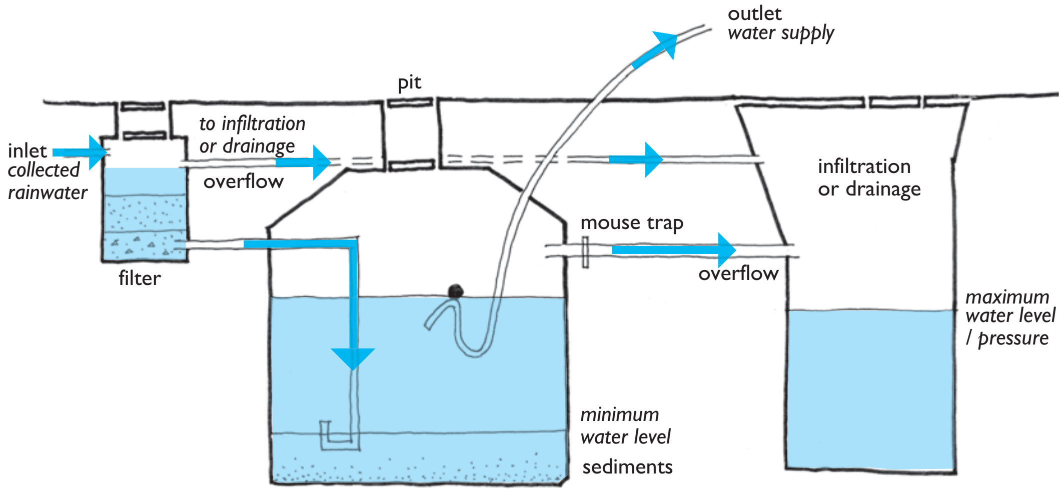

Illustration 44: Section of an underground storage tank for domestic rainwater harvesting, collection and storage. Well visible are the main components of the system.

Technological description:

While the quantitative aspects of domestic rainwater use have been already discussed in "Rainwater harvesting - runoff in tanks", in section 4.2, the focus in this section will be on qualitative aspects. The safe use of collected rainwater for domestic use requires a quality system. Air quality, dust, faeces from animals, organic matter and chemical substances may pollute rainwater runoff from streets and, to a lesser extent, also from roofs. For high quality use of rainwater in households, it is therefore generally advised only to use rainwater runoff from roofs due to its smaller pollution load. Additionally, the collection of rainwater from relatively polluted surfaces is feasible, but the runoff will require enhanced purification to meet service water standards (e.g. by sedimentation, filtration and disinfection) in addition to the relatively simple purification steps which are required for roof runoff.

The design of rainwater harvesting systems for the collection of water from roofs with gutters, down pipes, tanks for storage and a (service) water supply system enables the storage of rainwater with good quality to prevent the water supply system from pollution and the users from health risks. Beside the already mentioned quality aspects of the catchment area, the rainwater has to undergo a specific treatment before it is supplied. As a rule, filtration of the runoff (to ensure that small debris do not enter the tank), a calmed inlet of the rainwater in the tank (to avoid turbulence of sediments) and sedimentation processes in the tank are sufficient treatment processes to meet service water quality in the tank. However, in case that rainwater is used as potable water, quality control and further treatment steps (e.g. filtration and disinfection) are strongly advised.

For the design of the tanks it is important that no light enters the reservoir. All openings should be covered to avoid contamination by dust. Required openings (e.g. overflow) should be equipped with barriers for small animals like mice and should be covered with a fine and durable mesh material to holds back mosquito adults and larvae. In particular in climates and situations where malaria or dengue fever is a problem, mosquito control remains of vital importance.

Construction, operation and maintenance:

o The catchment area should be prevented from pollution load.

o The installation of mechanical filters (with mesh sizes of smaller than 0.5 mm) to filter the runoff before it enters the storage tank are a sufficient pre-treatment. The filter is crucial for a proper operation and has to be easily accessible for regular maintenance and cleaning (depending on pollution load).

o Construction of storage tanks preferably in a dark place, e.g. underground or in the basement of buildings. For maintenance purpose the tanks must be equipped with a manhole.

o Inflow of the filtered runoff into the tank should be via a calmed inlet to avoid turbulence (sedimentation processes in the storage tank are important for purification and keeping good water quality).

o Installations for the extraction of surface water should also avoid turbulence at the bottom of the reservoir. Hence a minimum constant water level should be provided in the tank.

o Construction and repair requires some skills from local craftsmen, but individual users may take care of maintenance and cleaning, particularly the regularly inspecting and cleaning of the filters.

o They will need the help, however, of their local sanitary inspector for testing samples for microbiological and chemical quality and for vector control, particularly if rainwater is considered as a source for portable water supply.

o Installation and proper operation and maintenance of additional filters or alternative point of use treatment facilities are advised to use additional barriers for potential chemical and microbiological contamination of rainwater, especially in urban areas.

Relative costs:

o In urban areas with abundant rainfall, rainwater collection on individual or collective level may be possible at comparably low cost.

o Compared to community tub wells, however, individual rainwater systems generally require more investments.

o In case of contaminated groundwater or centrally-piped water, individual rainwater collection can be turned into a source for drinking water (compared to bottled water) if rainwater quality and quantity are sufficient and if additional point of use treatment ESTs can be provided in order to protect public health.

o Costs may be recovered from the consumer's perspective if the substituted water is relatively expensive and therefore high savings can be achieved (e.g. in case of substitution of bottled potable water by purified rainwater).

o In cities with existing piped drinking water systems, the introduction or reintroduction of rainwater collection also will be more expensive than the standard house technology.

o In new developments or in the framework of remodelling measures, however, rainwater use can be part of the standard and water efficiency can be achieved at relatively low cost.

Appropriate technological approach when:

o In humid climates with sufficient precipitation, the domestic use of rainwater is an attractive option if the required water demand can be covered to a notable degree, collection pipelines can be installed and the required storage tanks can be located in or near the building.

o In arid conditions it might be generally more effective to harvest rainwater for artificial recharge of groundwater and use aquifers for seasonal storage.

o If a quality control system can be organized through sanitary inspections and improvements, rainwater systems can be appropriate even as a supplementary source in areas where water is scarce. This may also be the case in urban situations with an existing piped water network and centrally produced drinking water.

Advantages:

o Appropriate collected filtered and stored rainwater meets the quality requirements of service water and can be used without further treatment for service purposes like washing laundry, cleaning, irrigation and toilet flush.

o The advantage of rainwater use with prevention of quality problems is the optimal use of a source of quality water.

o Personal commitment to the home technology may prevent indifference and the squandering of water.

o Rainwater systems may offer a low cost alternative or a supplementary solution for water scarcity problems.

Disadvantages/Constraints:

o In some cases, rainwater-harvesting schemes have failed, due to poor planning and construction which were resulting in operation failures, but also due to low available rainwater quantity and poor rainwater quality caused by air pollution in combination with too high ambitions regarding the potential functionality of the collected rainwater.

o The organization of quality control is crucial.

Cultural acceptability:

o Rainwater systems have a long history and are part of many traditional water supply systems.

o Abandoning these systems can be part of modernization processes.

o Reintroducing rainwater systems is sometimes perceived as moving backward.

A Study of Gastroenteritis and Tank Rainwater Consumption in Young Children in South Australia

In South Australia more households (42%) use tank rainwater as their main source of drinking water compared with those using public mains (40%) (Heyworth et al. 1998). An earlier prevalence study of 9,500 children indicated that there was a slight but not significant increase in risk of gastroenteritis associated with consumption tank rainwater in South Australia. To investigate the temporal relationship between risk of gastroenteritis and the levels of exposure to tank rainwater, a longitudinal study was undertaken with 964 children which were mainly either drinking tank rainwater without further treatment or chlorinated and filtered water from public mains. The study found that young children in Australia drinking tank rainwater were not at greater risk of gastroenteritis compared with children drinking treated public mains water but that the children drinking treated public mains water were at greater risk. The implication of the findings with regard to tank rainwater beyond South Australia depends upon local conditions such as maintenance and construction of rainwater tanks and catchments, as well as the carriage of pathogens by local fauna.

(Heyworth J, Maynard E, Cunliffe D, Who drinks what?: Potable Water use in South Australia. Water 1998;25(1):9-13; in: Heyworth J, A Dairy Study of Gastroenteritis and Tank Rainwater Consumption in Young Children in South Australia, 10th International Rainwater Catchment Systems Conference, Mannheim, Germany, September 10-14. 2001, Proceedings of the Conference, P 141 - 148)

Extent of use:

- o Rainwater use including preventive quality control is widely practiced in the less developed urban areas in all parts of the world.
- o In some cases it is successfully reintroduced in new developments of more developed urban areas.
- o Successful applications in semi-arid and arid areas are widely available.

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- o *UNEP DTIE IETC Sumida City Government/People for Promoting Rainwater Utilisation; Rainwater Harvesting and Utilisation, An Environmentally Sound Approach for Sustainable Urban Water Management; An Introductory Guide for Decision-makers, 2001.*
- o *UNEP DTIE ETC Phytotechnology; A Technical Approach in Environmental Management; Freshwater Management Series, Number 7, 2003.*
- o *World Health Organization, Environmental Health Indicators for the WHO European Region, Update of methodology, May 2002, available at: http://www.euro.who.int/document/e76979.pdf*

On-site treatment of grey water

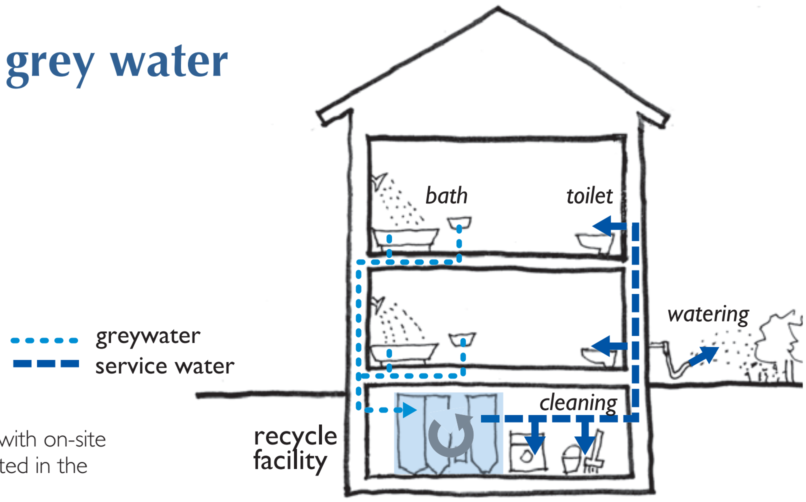

Illustration 45: Section of a residential building with on-site treatment of greywater with a SBR facility, located in the basement, and with service water supply.

Technological description:

Grey water is domestic waste water without black water from toilets. Typical sources are bathing, laundry, dishwashing and food preparation. Due to its comparably low and easy degradable contamination, it can be relatively easy purified for reuse. Hence purification for reuse as service water is an option to save water. It requires separate collection and storage of grey water and storage of service water. If necessary, environmentally sound hygienisation can be achieved by, for instance, micro filtration or uv-light radiation. Due to the short period required for the recycling process (less than one day), the storage tank capacities may be quite small, covering in average the grey water supply and service water demand of one day. The technology can also be applied at a collective management level for groups of houses or larger buildings. Treated grey water may also be used for watering of plants and for the safe augmentation of ground- or surface water.

Grey water can be differentiated in two fractions: in grey water from bathing and laundry and in grey water from the kitchen. The two fractions can be either purified separately or combined. Principally the treatment processes for both options are equal, but for the treatment of gray water from the kitchen an additional primary treatment step is required due to its higher pollution load. It should be investigated in each case if separate or combined treatment of grey water is more appropriate. If the required service water demand is exceeding the available quantity of grey water from bathing and laundry, grey water should be treated combined. This is also true if dry toilets are installed or black water is treated separately. The combined treatment of grey water from the kitchen, which is not purified to service water for reuse, and black water will be discussed in the fact sheets about black water treatment and constructed wetlands.

This fact sheet discusses the on-site treatment technology for separated and combined treatment of all grey water inside the house. Feasible options are *Trickling filters, Activated sludge facilities* (both followed by an additional hygienisation process, e.g. by uv-radiation) and *Membrane Bio Reactors*. Nature-orientated treatment options which require more space demand will be subsequently discussed under the EST "Constructed wetland". Typically these technologies can be integrated in the basements of buildings. The space demand is independent from the local climate, but dependent on the amount and the pollutant load of the grey water and the required service water quality; it may vary between 0.1 to 0.3 m^3 per person. For the membrane technology this is 0.05 to 0.3 m^3. The energy demand, including the supply of service water, is approx. 2 kWh/m^3.

Construction, operation and maintenance:

o Construction requires plumbing expertise and skilled labour.

o Once installed, operation does not require much maintenance. However the system should be permanently monitored to avoid water quantity problems in case of system failure.

o For proper monitoring of the operation, maintenance and repair as well as for quality control, experienced and skilled professional guidance is required. However, monitoring can be realised comfortably by remote operation monitoring, e.g. provided by the system provider.

Relative costs:

o The investment costs for facilities in domestic buildings with service water supply are in the range of facilities for domestic rainwater harvesting and service water supply. While the treatment facilities for the components are more expensive, savings can be achieved by shorter pipeline length and smaller storage tanks.

o The costs for the investment and installation of SBR and MBR facilities are dependent on the number of connected households and the quantity of greywater which is treated.

o The investment costs for properties with several hundred inhabitants and collective facilities are in the range from 50 Euros to 100 Euros per person; the operation and maintenance costs are approx. 1 to 2 Euros per person and year (Schuetze, 2005).

o The investment costs for single buildings and individual facilities are more expensive and are in the range of 600 - 800 Euros per person; the operation and maintenance costs are approx. 10 Euro per person and year (Schuetze, 2005).

o Compared to facilities for rainwater utilisation the service costs are higher, primary due to a higher electricity demand of approx. 1 kWh/m^3 for the purification process (while the electricity demand for service water supply of 0.5 - 1 kWh/m^3 is the same in both systems).

o To keep the effort and related cost for the installation of the drainage and service water supply network low, the grey water is collected and treated preferably on decentralized/ individual or semi-decentralized/ collective basis.

o Costs may be recovered from the consumer's perspective if the substituted water is relative expensive and therefore high savings can be achieved. In some countries, authorities are providing grants to encourage the introduction of grey water systems.

Appropriate technological approach when:

o Significant water-savings want to be achieved by the substitution of drinking water with service water on property or building level.

o Separating grey water which is originating from bathing and washing from other waste water streams is an appropriate option if a separated drainage pipeline can be installed and the treatment facilities can be located in or near the building.

o If a high degree of drinking water savings has to be achieved by the substitution with service water for non-drinkable purposes this technology saves generally more water than the domestic use of rainwater. While greywater recycling can cover 100% of the service water demand (independent from climate conditions and population density), domestic rainwater harvesting in urban areas with high densities is very limited and can generally only cover approx. 25 % of the domestic service water demand (Schuetze, T., 2005). *See also training module "WiseWater".*

o Installation is relatively easy in the framework of new construction and during renovation of old buildings which have to be equipped with new pipelines.

Advantages:

o In most households which are connected to centralised water supply, the quantity of greywater from bathrooms only is already similar or even exceeds the demand of service water with non-potable quality (e.g. for washing laundry, toilet flushing and cleaning). Therefore the recycling of grey water from bathing can contribute to the saving of potable water resources.

- o The separated treatment of grey water leads to a concentration of the remaining waste water streams and improves therefore the performance of sewage treatment facilities.
- o Sufficiently and specified purified grey water is hygienically and chemically safe and meets bathing water standards.
- o It also provides a constant supply of water for gardening and irrigation in urban agriculture with no restrictions during drought periods.
- o The energy demand and technical effort for the treatment is less than the requirements for the treatment of more polluted sewage streams.

Disadvantages/Constraints:

- o Concerns regarding the feasibility and costs because it is a relative new technology.
- o Proper construction, monitoring and maintenance are crucial for proper operation.
- o Extra costs can be kept relatively low if the technology is made part of the standard for new houses in new development schemes.
- o In case of only small demand of service water with high quality (e.g. in case of dry toilets which require no flush), the separated treatment and reuse of grey water from bathrooms for reuse in households might not be financially attractive and may therefore ask for the combined treatment of sewage.
- o In case of low water prices users are generally not interested in the installation and service due the investment and service costs.

Cultural acceptability:

- o In general, users do not find it difficult to accept these systems because the difference between drinking water and the canonical purified service water is imperceptible, is hygienically clean and has sufficient quality for the functions it has to serve.

Extent of use:

- o After a number of pilot projects in the 1990s, the technologies for grey water recycling have improved significantly. Today treatment and recycling facilities from serial production are available which are already installed in numerous buildings in more developed urban areas in all parts of the world, e.g. in Africa, Australia, Europe, and America.

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- o *World Health Organization; WHO Guidelines for the safe use of wastewater excreta and greywater; Volume 1, Policy and regulatory aspects; Volume 2, Wastewater use in agriculture; Volume 3, Wastewater and excreta use in aquaculture; Volume 4, Excreta and greywater use in agriculture; World Health Organisation, 2006. Available at: http://www.who.int/water_sanitation_health/wastewater/gsuww/en/*

Constructed wetlands

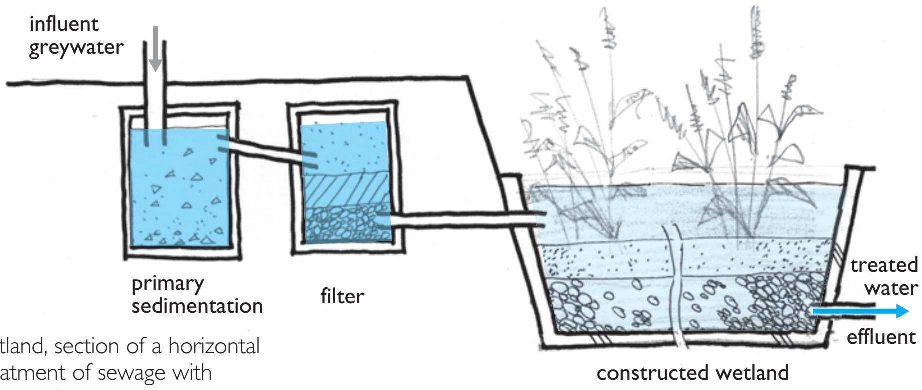

Illustration 46: Constructed wetland, section of a horizontal flow type wetland with pre-treatment of sewage with sedimentation tank and gravel/ sand filter.

Technological description:

At the neighbourhood or community level, between the individual household and the city, constructed wetlands (defined as Phytotechnology by UNEP) are an environmentally sound technology for the treatment of grey water and stormwater run-off from polluted catchment areas like streets, paved surfaces and roofs. In some urban areas constructed wetlands are even used for sewage treatment, either with combined or separated black and grey water. At a centralized level constructed wetlands can be used for the treatment of domestic wastewater instead of technically sound sewage treatment or they can be used for the enhanced purification of runoff from such plants.

There are different types of constructed wetlands available, which can be part of the green structure of the city or of the urban fringe: *stabilisation ponds, duckweed ponds* and *bulrush or reed beds and wetlands* have permanent water. Constructed *Reed beds* can have permanent surface water flow (*Horizontal Flow Wetlands*) but they can also be dry on the surface and only intermittently flooded with polluted water that percolates intermittently through the soil (*Vertical Flow Wetlands*) or the water can flow horizontally through the root zone of the wetland plants (*Horizontal Flow Wetlands*).

These wetlands can be located near buildings, in courtyards or on flat roofs. Purification processes for pathogens, nutrients and other contaminants through sedimentation, plant uptake, adsorption and biological degradation can be very effective. The quality of the effluent and the space required depends on various factors, like the design of the specific wetland (including combinations of different wetlands), the inflow water quantity and pollutant load as well as the climate and the plant species. Favourable species depend on the local climate conditions, the material and the construction of the filter. As a rule of thumb for the treatment of grey water, an area of 0.5 to 2.5 m^2 per person and for the treatment of combined domestic sewage (black- and grey water) a surface area of 1 to 3 m^2 per person is required.

Construction operation and maintenance:

o Construction requires expertise and skilled labour.

o Once installed, operation is relatively easy.

o For proper maintenance and repair and for quality control, experienced and skilled professional guidance is indispensable. The wetland plants, duckweed and helophytes (reed, bulrush, typha) need to be harvested to remove the nutrients taken up by the leaves and stems from the system.

o To improve the removal of phosphorous, calcareous gravel of certain size and porosity is used as a substrate in some wetlands systems. Concrete debris can also be used for the same purpose.

Relative costs:

o Constructed wetlands are not energy and capital intensive and are relatively cheap compared with centralised treatment plants.

o Electric energy for pumping, labour for regularly removing of sediments (in ponds), and removal of reed or bulrush are responsible for the main service costs.

Appropriate technological approach when:

o Stabilisation ponds are a good solution for wastewater treatment in developing countries, especially in semi-arid climates. They provide an immediate irrigation source.

o For arid regions the dry reed beds offer a solution with less evaporation losses. Also in hot climates there are many possibilities.

o Constructed wetlands require an appropriate design that makes them fit to the purification task and to the local urban landscape.

o Stormwater runoff can pass from the streets through wetland banks along canals and rivers to discharge safely into surface waters.

o As good design and maintenance is vital, a monitoring system of quality control is essential with feed back and improvement of the system if necessary.

Advantages:

o Stabilisation ponds and wetlands are an appropriate low-cost solution for the treatment of domestic wastewater. They provide water for irrigation and for watering public green spaces and, thus, may contribute to water efficiency at the urban level. For instance, an organization in Bangladesh has successfully developed a duckweed cropping system, combined with the cultivation of fish.

o In some countries like China and Bangladesh wetlands are part of wider integrated systems where fish and ducks are included having the wetlands more than one function to play.

Disadvantages/Constraints:

o It is crucial to organise skilful design and construction and to care for continuity in the maintenance regime (cleaning, cropping and harvesting) and quality control. Pathogen risks and mosquito prevention deserve special attention. Depending on the design, mosquito problems can be avoided which is of particular importance in areas where waterborne diseases like malaria and dengue are endemic.

o Availability of space.

Cultural acceptability:

o If designed well, there will no problems with the acceptance of wetland systems.

Extent of use:

o Widely implemented and further developed and differentiated in many countries.

o While it is not yet a mainstream practice, but it is implemented with rising tendency in developing as well as in developed countries also for the retrofitting of cities without domestic waste water treatment.

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On-site and near-site treatment of black water and mixed sewage

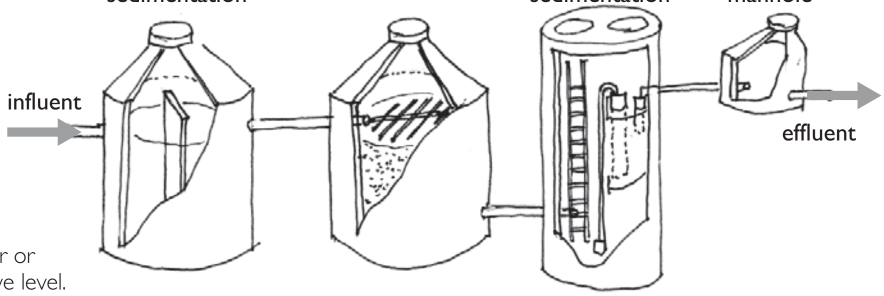

Illustration 47: Treatment of blackwater or mixed sewage on individual or collective level. Example for a stepwise decentralised treatment.

Technological description:

In a water efficiency perspective, a first step in the search for alternatives to the centralised sewage transport and treatment system is to save on potable water. Waterless toilets, which have been discussed already in the section about water use, allow the avoidance of black water and the composting of human waste to manure. The application of water-saving toilets which have been discussed already in the section about water use can be applied in situations where waterless toilets do not fit. The occurring black water can be differentiated in a brown water fraction which originates from faeces and a yellow water fraction which origins from urine. The technologies discussed here are applicable for the treatment of black- and brown water but generally also for the combined treatment of concentrated domestic sewage.

From the perspectives of public health and water quality it is important to purify the sewage as well as possible. The separated treatment of black water is helpful in this perspective, because it allows the specified treatment of a very small fraction of domestic sewage, which is responsible for the bigger part of the domestic pollution of domestic sewage. It contains approximately 60% of the COD, 90% of the phosphorous, more than 60% of the potassium, almost 100% of nitrogen load and the total contamination by micro-organisms and pharmaceuticals. (Lange, Otterpohl, 2000)

At the level of households and neighbourhoods it is important to search for treatment alternatives that are both water efficient and minimize health risks. Septic tanks for instance are widespread but are often responsible for environmental pollution due to poor purification effects and leakages. Therefore they should be either optimized (e.g. by leakage control) or replaced with environmentally sound alternatives like *retting containers.* They are a filter and pre-composting system for the pre-treatment of black- or brown water but also sludge from sewage treatment of mixed domestic sewage. Existing septic tanks can be even remodelled to retting containers because they require a smaller space demand. (Gajurel, 2003) In both cases it may be necessary to add a further treatment step, for instance a soil filtration or wetland system, for the treatment of the effluent to make sure pathogens and pollutants are really removed or below the risk level. This may require space outside of buildings. From on-site the system expands to near-site. An up-scaling of the system requires a collective form of management.

Further options for the treatment of black water or the combined treatment of blackwater and greywater are based on technologies which are discussed in the fact sheets *grey water treatment* (*Trickling filters, Activated sludge facilities* and *Membrane Bio Reactors*) and *constructed wetlands*. Due to the high pollutant load of black water, the effluent of the treatment facilities may still be rich in nutrients and microbiological contaminated. A lower grade effluent is not appropriate for reuse in domestic households and for discharge in fresh water reservoirs, but it can be used for irrigation. The high nutrient load of purified black water can be used as liquid fertilizer for plants. However, it is necessary to avoid the contamination of food or water resources by insufficiently sanitised effluent. The infiltration of sewage by gravity through soil, Soil-Aquifer Treatment (SAT), can significant decrease contamination in treated sewage effluents and should therefore be preferred. The direct subsurface discharge in the framework of drip irrigation facilitates the avoidance of health risks and of positive interdependencies with urban agriculture.

The *anaerobic digestion* of concentrated black water is an appropriate method to produce fertilizer. If black water is collected in a very concentrated form, e.g. by low flush vacuum toilets and is fermented together with biomass, methane gas and a residing slurry are produced. While the gas can be used as a renewable energy source, the remaining sludge can be used in peri-urban agriculture. The microbiological safety of the digestion residues can only be guaranteed if the slurry is sanitised, e.g. by thermal treatment, i.e. keeping it for a minimum period of 1 hour at a minimum temperature of 70°C.

Construction operation and maintenance:

- o The construction, operation and maintenance of improved anaerobic technology such as biogas installations requires a lot of expertise and skilled labour.
- o Construction, operation and maintenance of aerobic technologies such as septic tanks and retting containers require experience and some expertise and skilled labour.
- o Once installed, operation is relatively easy. For proper maintenance and repair and for quality control, experienced and skilled professional guidance is indispensable.

Relative costs:

- o Comparably low cost for nature-orientated systems like Constructed Wetlands and for low technology systems like optimised septic tanks and Retting Containers.
- o Comparably high cost for technical systems like trickling filters, Sequencing Batch Reactors and Membrane Bio Reactors. Compared to traditional sewer systems and centralised treatment plants the costs for decentralised facilities may be lower but also higher, dependent on the specific basic conditions.
- o Cost are acceptable in case they are used as an alternative to centralised sewer and sewage treatment facilities, either in absence of sewer systems and sewage treatment plants or in the framework of deconstruction of existing sewers and sewage treatment systems.
- o High investment costs for vacuum sewer systems and anaerobic digestion facilities for biogas production. These systems become economically feasible if designed also for the fermentation of biomass from urban agriculture and the production of fertilizer and renewable energy.

Appropriate technological approach when:

- o In the situation of collective projects at the neighbourhood level or for projects such as schools or hotels, these systems might be appropriate, particularly in case of absence of centralised sewers and sewage treatment facilities.
- o For poor areas in less developed urban areas, it may not be the appropriate solution, except retting containers and constructed wetlands, but once the capacity to manage these technical systems has developed, it may become an option.
- o Effluent can be use for irrigation and works as fertilizer.
- o Nature orientated treatment systems and anaerobic digestion facilities with biogas

production require much space which has to be made available.

- o Anaerobic digestion with biogas production requires significant amounts of biomass and agricultural land for the application of residues.

Advantages:

- o Instead of expanding a non-water-efficient centralised sewage system other alternatives, aerobic or anaerobic, may become attractive.
- o By saving significantly on canalization, the construction of non-centralised systems only incurs capital lockup for relatively short periods (<30 years), while centralised sewer systems and sewage treatment plants incur high costs and the lockup of capital for long periods of time - even decades (Schuetze, 2005).

Disadvantages/Constraints:

- o The crucial factor is the organisation that takes responsibility for managing the facilities.
- o The discharge of purified black water in surface water requires appropriate treatment.
- o Leaking treatment facilities may contaminate groundwater resources.

Cultural acceptability:

- o If designed and managed well there will be no acceptance problems.

Extent of use:

- o Aerobic solutions are widely applied all over the world.
- o Anaerobic technologies have been successfully applied in several pilot projects in different countries.

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Separating rainwater from sewer systems

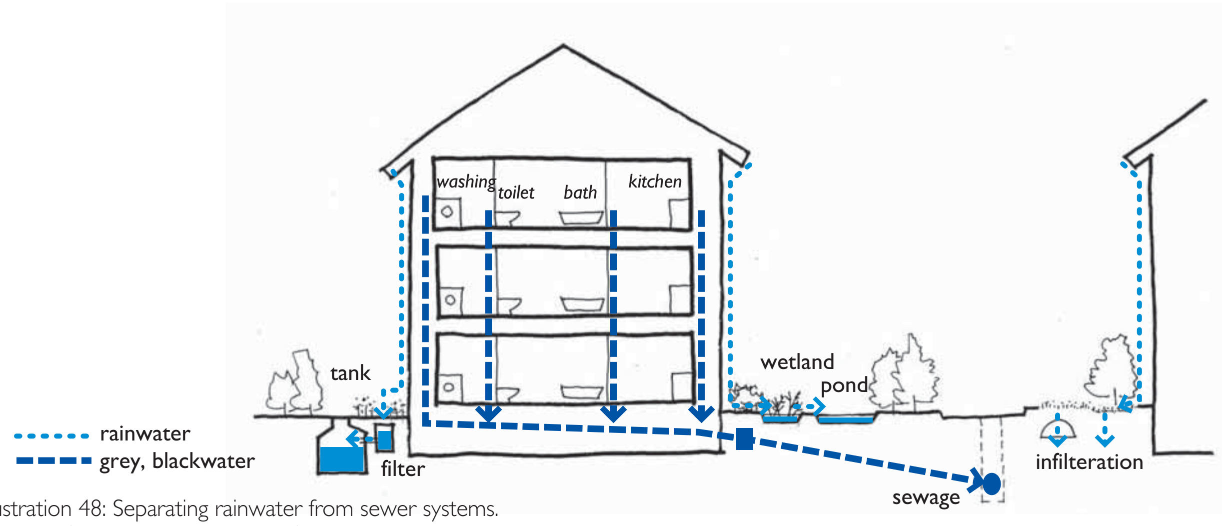

Illustration 48: Separating rainwater from sewer systems. Section of the working principle of separating rainwater on building and property level.

fact sheet 5 4.5.4

Technological description:

Many existing cities have combined sewer systems which are designed for the discharge of domestic sewage and storm water (surface water runoff) in one pipe. Improving these systems can make a significant contribution to water efficiency. In heavy rainfall events the system cannot cope with the accumulating water quantity. In such moments combined sewer overflows (CSOs) occur which result in the discharge of sewage into surface waters. In the case of high groundwater levels, leakages in the sewers lead, to increased drainage. During storm water events huge wastewater quantities and dilution disturb the proper functioning of the sewage treatment plants, often resulting in limited purification and discharge of more polluted, or even untreated effluent. The traditional answer is constructing underground storage systems, retention basins or additional 'super sewers' to store sewage and storm water in case of heavy rainfall. A more environmentally sound answer is *separating rainwater* from the combined sewer systems. In some densely built urban centres a separate network of rainwater drains is necessary, but in most cases there are many opportunities to separate rainwater from domestic sewage. After sufficient treatment, e.g. in sedimentation ponds and by bio-filter technologies, such as sand-filters or constructed wetlands, according to the degree of pollution, the stormwater can be used for the augmentation of nearby surface waters or aquifers by infiltration. Additionally rainwater can also be used inside buildings (*see fact sheets "Rainwater harvesting - runoff in tanks", section 4.2, and "Domestic rainwater use", first EST in this chapter*).

Construction operation and maintenance:

- The approach of rainwater retention in surface water includes the construction of wetlands or wetland zones alongside the banks of natural waters or canals (see special fact sheet).
- The approach of rainwater infiltration includes the construction of swales with sand filtration or more elaborate soil aquifer treatment (SAT) combined with aquifer storage recover systems (ASR), a promising option for arid regions.

o Disconnecting rainwater from streets and other more or less polluted surfaces requires specific design expertise and skilled labour but can be part of already planned urban upgrading projects. The appropriate treatment of severely polluted runoff is crucial for the protection of water qualities in receiving water bodies.

o Once installed operation is relatively easy.

o For proper maintenance and repair and for quality control, experienced and skilled professional guidance is indispensable.

o Wetland plants along the banks of surface waters and infiltration swales can be integrated in the urban design of new developments or the redesign of existing areas.

Relative costs:

o Compared to the construction and maintenance of combined sewer systems, this alternative is very cost-effective. (The construction of sewer systems incurs high costs and the lockup of capital for long periods of time, even decades.) If combined with urban renewal projects and reconstruction works of roads, the extra costs are limited. There are big savings on the costs of treatment plants.

o Costs for implementation can be assigned to owners of buildings and properties by the introduction of separated fees for the discharge of rainwater in (mixed) sewer systems. (In case of total separation, the fee is not applied).

Appropriate technological approach when:

o Receiving water bodies (ground or surface) with sufficient capacity are available.

o Facilities for purification of runoff and/ or infiltration can be integrated in the urban environment, either on private properties or public areas.

o Sewer systems and/ or sewage treatment plants are suffering from hydraulic overload in case of (extreme) precipitation events.

o When it comes to reconstruction of combined sewer systems it is appropriate to combine reconstruction works with the disconnection of rainwater.

o In the design of public and private open spaces, storm water catchment and storage (retention or infiltration) can be an integrated part of the plan that does not require extra space.

Advantages:

o Disconnecting measures on building and property level are easy and can be delegated to owners of properties, e.g. by the regulations and the introduction of fees for the discharge of rainwater in (mixed) sewer systems.

o Disconnecting rainwater creates opportunities to use this source for freshwater augmentation, watering (e.g. for gardens and public green spaces) and for cleaning purposes (e.g. streets) as well as domestic use.

o Facilitates the use of rainwater for the augmentation of freshwater resources.

o Allows the appropriate treatment of domestic sewage in non-centralised as well as in centralised systems and protects the environment from combined sewer overflows and urban floods.

Disadvantages/Constraints:

o Changing existing technical systems is not easy.

o The stepwise realization of disconnecting projects makes it difficult to predict the results and therefore it is also difficult to plan the capacity of the treatment plants. Also here a stepwise approach might be feasible.

o Limited space in urban areas with very high density

o Limited availability of surface water or limited basic conditions for groundwater augmentation (e.g. high freeboard or watertight ground).

Cultural acceptability:

- o Building owners can be motivated to introduce separation measures, e.g. by regulations and the introduction of separated fees for the discharge of rainwater in sewer systems.
- o In a proper design of open spaces, people will accept and appreciate the visible role of rainwater during and after rainstorms.

Extent of use:

- o Separated systems are common practice in many countries.
- o Implementation is realised with rising tendency in new urban developments and in areas with existing combined sewer systems.
- o Disconnecting rainwater from existing combined systems is practiced in numerous countries.

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Environmentally sound centralised sewage treatment in developing countries for reuse

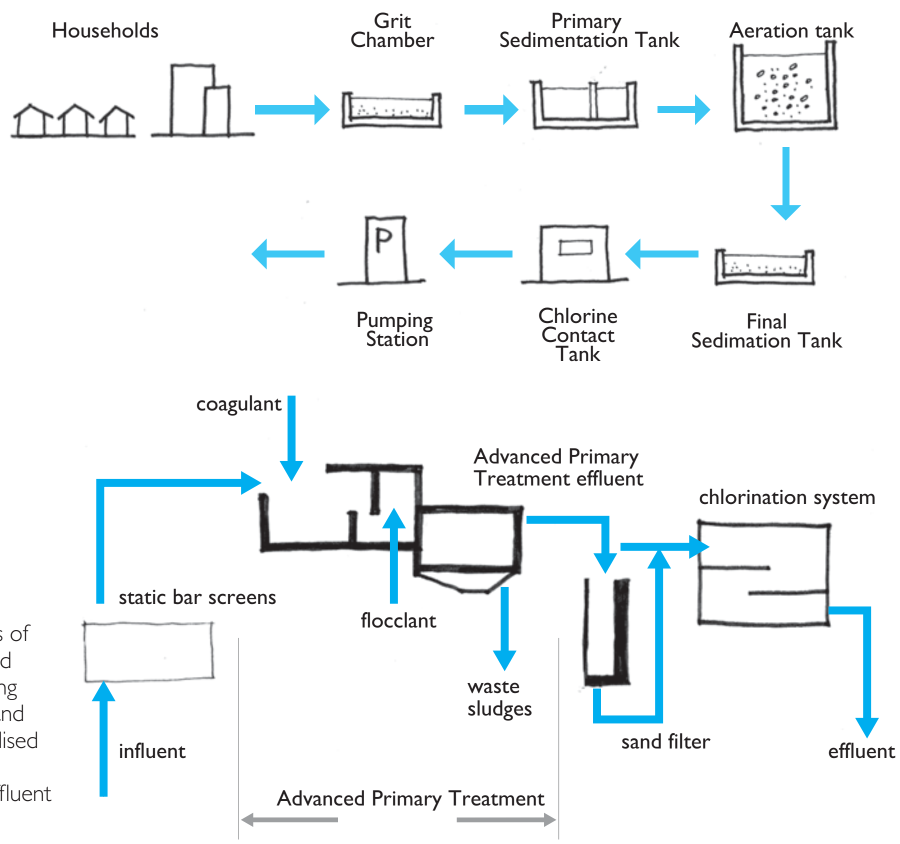

Illustration 49: Working principles of conventional centralized advanced sewage treatment plants according to international standards (top) and the concept of alternative centralised sewage treatment in developing countries for safe reuse of the effluent for irrigation (bottom).

Technological description:

The preceding fact sheets discussed sewage treatment technologies with an emphasis on on-site, individual and small collective options that, depending on the situation, may offer good, and in many cases, more environmentally friendly, alternatives to the centralised treatment plants. However, they will not replace the big treatment plants in the short term. Therefore it makes sense to discuss the options for making traditional treatment plants more sustainable. This Sourcebook does not discuss details of treatment technology innovations in the developed world (like e.g. the reuse of effluent of wastewater treatment plants for service water and for irrigation purposes in Tokyo (Japan) and in Melbourne (Australia) but pays attention to the specific situation in developing countries. The traditional approach in developed countries has a sequence of treatment steps: primary (mechanical removal of suspended solids), secondary (biological removal of organic matter) and tertiary treatment (chemical removal of nutrients and other contaminants). Increasingly strict standards, mainly derived from the situation in developed countries and supported by the international scientific community, have made it almost impossible to reuse effluent and sewage sludge in peri-urban agriculture. For agriculture this is often not a major problem, as in many cases there are other water sources. This does not reflect the situation in many developing countries where water scarcity leads to massive reuse of wastewater in agriculture, treated or untreated. At the same time the effluent in these countries usually contains more pathogens and less heavy metal and other toxic substances. This has led to the innovative development of a new treatment technology called Advanced Primary Treatment (APT) followed by filtration and, if necessary further disinfection, e.g. by uv-radiation or chlorination.

Construction, operation and maintenance:

- o Construction, operation and maintenance can be part of treatment-plant upgrading projects.
- o Operation and maintenance are the work of the treatment plant staff.
- o For the construction and operation of irrigation systems skilled workers.

Relative costs:

- o The investments can be combined with upgrading existing treatment plants, thus using the existing infrastructure of these plants. The new technology is very low cost if compared to the traditional high level treatment practices.

Appropriate technological approach when:

- o The new approach is appropriate in situations where pathogen contaminants are the main problem and treated wastewater is used for irrigation in (peri-urban) agriculture.

Advantages:

- o Optimal reuse of centralised treated wastewater for irrigation is highly water use efficient and can be part of integrated water management, especially in semi-arid and arid regions.

Disadvantages/Constraints:

- o Existing national and international standards for wastewater treatment can pose a serious constraint to this approach, because the described sewage treatment process does not confirm to these standards.
- o If necessary, the standards should be reconsidered in the context of relevant regional conditions.

Cultural acceptability:

- o The technical nature of these innovations does not make them a social acceptability issue for local residents.

Extent of use:

- o Implemented on pilot-project scale. Since 2001 there is an example in Mexico City in operation.

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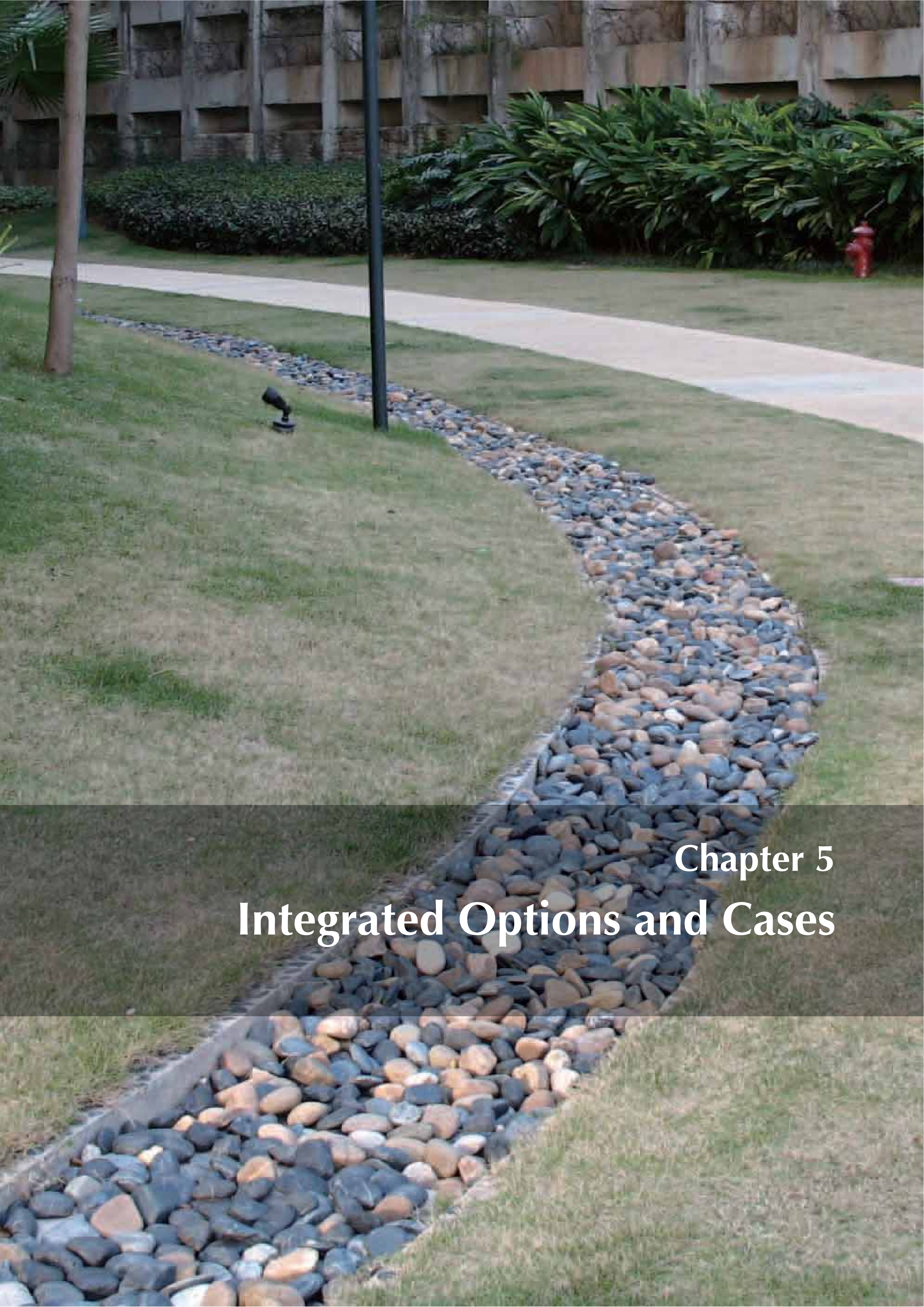
Chapter 5
Integrated Options and Cases



5.1 Introduction

The previous chapter discussed Environmentally Sound Technologies grouped in sections according to stages in the water cycle: storage, supply, use and reuse. This is useful for getting information about the properties of different ESTs and for discussing and comparing different groups of ESTs. Chapter 4, however, did not discuss how to combine ESTs from different sections. In reality it is the promising combination of ESTs from all four sections that should become the building stone of an integrated strategy for an environmentally sound system. This chapter will look at such combinations.

Preferred EST combinations may vary from place to place. This chapter addresses this variety by first discussing some general principles for combining ESTs and policies (5.2) and then presenting some interesting realized projects that can be considered as demonstration projects of good practice that can show the way to environmentally sound systems for efficient and sustainable water use. The cases can be used as benchmarks (5.3).

5.2 Promising combinations

A preference for an appropriate EST combination basically stems from a comparison of the general criteria for flows, areas and actors with the local situation at the time of decision making. Chapter 3 discussed the general criteria related to *efficiency* and *fit* under the umbrella of *flows, areas* and *actors*.

- o For flows, the priority principle is summarised as: *reduce, reuse and recycle*.
- o For areas, the general principle may be summarised as: *use local nature to create a human habitat.*
- o For actors, the general principle is: *create a participative learning process.*

Chapter 4 used questions for flows, areas and actors to analyse and assess the local potential. The confrontation of the criteria with the local answers to the questions is the basis for a fruitful discussion about promising combinations of strategy and tools, policies and ESTs. It is the confrontation of the wish to use water efficiently and sustainable with the local knowledge that leads to the know-how of the promising combinations of ESTs. Discussions about promising combinations may have different starting points. Climate and local geography provide essential information but perhaps the most convenient and relevant point of departure is a typology of urban settlements that belong to different stages of development and have different institutional capacity.

5.2.1 CLIMATE

If a discussion of promising combinations starts with the flows, climatic conditions will be decisive about the role of the rain.

- o *Humid climates* (tropical or temperate with an equal distribution of rainfall over the year) have, in principle, good conditions for the direct use of rainwater as a freshwater source, supplied by nature in a decentralised way. This does not mean that rainwater can meet the full water demand - certainly not in densely built urban areas - but the role of the rain may significantly reduce the dependence on precious groundwater resources. Quality control is crucial. The scarcity of drinking water quality may call for reduced use and improved reuse technologies.
- o *Seasonal climates* in the temperate zone require seasonal storage. Decentralised storage may be a feasible option employing, for instance, rainwater butts or cisterns for watering gardens and other domestic use. However, the volume of the required storage for drinking water may lead to a preference for additional collective or centralised solutions that can be combined with quality control.
- o *Arid climates* with limited rainfall during a short period of the year are not favourable conditions for direct rainwater use for domestic purposes. However, collecting, storing and using rainwater from roofs, streets and other open spaces may significantly reduce the water demand for

watering gardens and green spaces especially if native plant species are used that are adapted to arid climates. Thus, also in these climates, rainwater should play an important role in the EST combination.

5.2.2 LOCAL CONDITIONS

The local hydrology is an important factor. The presence of groundwater aquifers and proximity to mountains that feed groundwater, springs and rivers may significantly increase the water quantity that is available for sustained use. However, actual water use can also exceed the carrying capacity of these favourable conditions. Increased water efficiency may then create conditions for further and yet sustainable urban development. Other local conditions may relate to the position of the area in an upstream-downstream perspective. Promising combinations, of course, are also highly dependent on the existing local systems of water storage, supply, use and reuse and the existing infrastructure and technology.

5.2.3 URBAN SETTLEMENTS, DEVELOPMENT AND INSTITUTIONAL CAPACITY

Change towards more efficient water use realistically has to start from the stage of development of a settlement and its institutional capacity. Taking these as a starting point is a good way to generate promising combinations. They may be listed as five 'guiding models', typical models that may be used to guide the planning process. Possibly a given decision situation is close to one of these models. In larger urban areas, however, it is more probable that the models can be used as a guide for a zoning model of the city. In that case, the models may lead to define and locate within the area of that city different zones that require different guiding models of strategies and EST combinations.

Village model

The village model is characterised by long-term simple systems based on self organisation with only minor role for central government. Promising EST combinations are:

- *Storage:* Preferably ESTs based on groundwater as a source, support of traditional rainwater based practices.
- *Supply:* First option is water supply by wells. Residents take water home in small containers. Generally low level of water supply (< 30 litres per person and day).
- *Use:* First sanitation options are dry toilets and improved pit latrines to avoid groundwater contamination. In case of urban agricultural areas, anaerobic digestion and biogas production might be a second option. No specific water use ESTs.
- *Reuse,disposal*: Reuse of compost for vegetable gardens or residues from anaerobic digestion for urban agriculture. Grey-water gardens or soil aquifer treatment for waste water discharge.

Squatter area model

The squatter area model is characterised by many new arrivals, short-term urgency and possible roles of central relief organisations for setting up primarily collective services for water and sanitation for a limited period. For an environmentally sound long-term development, the model should be modifiable to the urban village model. Promising EST combinations are:

- *Storage*: Preferably ESTs based on groundwater as a source, river-based ESTs as a second option.
- *Supply*: Preferably by central supply, e.g. by tanks to collective tanks and to individual small containers. Generally low water supply level (< 30 litres per person and day)
- *Use:* First sanitation system with trench latrines.
- *Reuse, disposal*: Simple soakaways for waste water.

Urban village model

The urban village model is characterised by squatter areas, favelas, bidonvilles, slums etc. on a more permanent basis and increasing roles of central governments or NGOs to improve sustainable water use. Promising EST combinations are:

o *Storage*: Groundwater, if feasible: small dams in rivers. Promotion of decentralised rainwater-harvesting ESTs.

o *Supply*: Piped water network that supplies collective tap stands and centralised quality control.

o *Use*: First sanitation options are dry toilets and compost collection systems. Centralised technical support for rainwater use in households.

o *Reuse, disposal*: Use of compost for urban agriculture. Grey water gardens, irrigation with soil aquifer treatment or improved soakaways with filters for waste water.

City model

The city model is characterised by existing medium to large cities, important roles for central government agencies, only few collective services and individual consumer based systems. Promising EST combinations are:

o *Storage*: Groundwater, if feasible: small dams in rivers. If big dams exist, their role should be reduced by alternative measures. Strong promotion of decentralised rainwater-harvesting ESTs.

o *Supply*: Piped networks to individual households. Leakage control programmes.

o *Use*: Sanitation: promotion of waterless or water-saving toilets and introduction of water-saving appliances. Central government and collective organisations should encourage water sensitive urban design. Rainwater run-off should be used for public and private open spaces (gardens, parks, streets).

o *Reuse, disposal*: Centralised or collective treatment of wastewater with wetland treatment. Reuse of sludge in agriculture. Reuse of safe effluent for surface water, watering urban green spaces and for cleaning purposes.

New-town model

The new-town model is characterised by leading roles for central organisations like government agencies, NGOs and developers. In the stage of use and maintenance, an increasing role is encouraged for collective organisations and individuals. Central actors retreat to a basic level of support and quality control. Promising EST combinations are:

o *Storage*: Groundwater or surface water based systems, supplemented by small dams in rivers if necessary. Design of buildings as well as the legal and institutional framework creates physical conditions for optimal rainwater harvesting.

o *Supply*: Centralised piped water network for drinking water quality. Collective and individual systems for service water quality supply.

o *Use*: Sanitation with waterless and water-saving toilets, water-saving appliances. Water sensitive urban design. Use of service water for non-drinking purposes at the level of buildings and for open spaces.

o *Reuse,disposal*: Central and collective treatment of wastewater (black water). At the building level: grey water treatment for reuse as service water. At the urban level wetlands for treatment of wastewater and run-off rainwater should be made part of the urban green space design.

The guiding models described here of course do not cover the full range of endless variety, but the five EST combinations may create some order in the discussions about decisions. A local zoning plan on the basis of these models may be more specific and may also contain locally specific models that are not listed here. Obviously the first three models struggle primarily with the minimum water quantity and quality required for health, whereas the fourth and fifth models focus on the maximum quantity that can be tolerated in the framework of sustainable water use. If the rich are not efficient, the poor will not have sufficient.

The guiding models are characterised by EST combinations. As a rule, the first option for storage and augmentation is to take groundwater. If it is available, usually the quality is good and this may be the best basis for the supply of healthy water. If the basic conditions are not appropriate, there is not enough quantity or the quality is bad, other options may be recommended, e.g. the use of surface or rain water. The first two models do not have a centralised water supply network but the others do have such a system. It must be stressed that these networks can only operate properly if supported by good maintenance. In a specific case, the institutional capacity for proper maintenance might be the decisive argument for recommending certain options. In the discussions about use and reuse, health conditions and water efficiency are two sides

	VILLAGE MODEL	SQUATTER AREA MODEL	URBAN VILLAGE MODEL	CITY MODEL	NEW-TOWN MODEL
character of model	Long term simple systems based on self organisation with only minor role for central government.	Many new arrivals, short-term urgency and possible roles of central relief organisations for setting up primarily collective services for water and sanitation for a limited period.	Squatter areas, favelas, bidonvilles, slums etc. on a more permanent basis. Increasing role of central governments or NGOs to improve sustainable water use.	Existing medium to large cities, important roles for central government agencies, only few collective services and individual consumer based systems..	Leading roles for central organi-sations like government agencies, NGOs and developers. In the stage of use and maintenance, an increasing role is encouraged for collective organisations and individuals. Central actors retreat to a basic level of support and quality control.
storage	Groundwater.	Groundwater.	Groundwater.	Groundwater.	Groundwater or surface water based systems.
	Support of traditional rainwater based practices.	River based ESTs as a second option	If feasible: small dams in rivers.	If feasible: small dams in rivers. (If big dams exist, their role should be reduced by alternative measures.)	If necessary supplemented by small dams in rivers.
			Promotion of decentralised rainwater-harvesting ESTs.	Strong promotion of decentralised rainwater-harvesting ESTs.	Design of buildings as well as the legal and institutional framework creates physical conditions for optimal rainwater harvesting.
supply	Wells: Residents take water home in small containers.	Central supply e.g. by tanks to collective tanks and to individual small containers.	Piped water network that supplies collective tap stands.	Piped water networks to individual households.	Centralised piped water network for drinking water quality.
	cf: Low level of water supply (< 30 l.p.p.p.d.)	cf: Low level of water supply (< 30 l.p.p.p.d.)	Centralised quality control.	Leakage control programmes.	Collective and individual systems for service water quality supply.
use	1st: Dry toilets and improving pit latrines.	1st: Sanitation system with trench latrines.	1st: Dry toilets and a compost collection systems.	Promotion of waterless or water-saving toilets.	Waterless and water-saving toilets.
	2nd: In case of urban agricultural areas, anaerobic digestion and biogas production.		Centralised technical support for rainwater use in households.	Introduction of water-saving appliances.	Water saving appliances.
	No specific water use ESTs .			Water sensitive urban design (central government and collective organizations)	Water sensitive urban design.
				Use of run-off rainwater for public and private open spaces.	Use of service water for non-drinking purposes at the level of buildings and open spaces.
reuse & disposal	Reuse of compost for vegetable gardens.	Simple soakaways for waste water.	Use of compost for urban agriculture.	Centralised or collective treatment of wastewater with wetland treatment.	Central and collective treatment of wastewater (black water).
	Residues from anaerobic digestion for urban agriculture.		Grey water gardens, irrigation with soil aquifer treatment	Reuse of sludge in agriculture.	At the building level: grey water treatment for reuse as service water.
	Grey-water gardens or soil aquifer treatment for waste water discharge.		Improved soakaways with filters for waste water.	Reuse of safe effluent for surface water, watering urban green spaces and for cleaning purposes.	At the urban level: wetlands for treatment of wastewater and run-off rainwater should be made part of the urban green space design.

Table 5: Promising combinations of ESTs and their position according to the different sections in the urban water cycle.

of one coin. The decision abut ESTs should produce the best combination of these two issues.

5.3 Cases

In the previous chapter promising combinations of ESTs have been assigned to different settlement types and differentiated in 5 different guiding models (*Table 5*). However each urban and domestic area has different conditions, which require an individual analysis, evaluation and discussion of feasible ESTs and finally the selection and combination of specific ESTs which fit to the specific case.

In this section two case studies in Mali and Mexico are described which include combinations of ESTs for all 4 sections of the urban water cycle. The combinations in these cases demonstrate the need to find solutions that fit to the specific climate and culture and to the existing infrastructure and institutional capacities. The cases were not chosen to illustrate the general guiding models. These general models may guide the discussions but should not be seen as blueprints.

In addition to these two comprehensive examples, case studies which focus only on specific ESTs and single sections of the urban water cycle are also described in this chapter. An overview of the case studies with a mapping of specific ESTs to the four sections of the urban water cycle is displayed in *Table 6*. The structure is similar to the matrix in *Table 5*.

Project name	**Ecosan pilot installations**	**Topez Eco urban ecosan pilot project**	**Rainwater harvesting**	**Munsieville private property leak repair project**	**Water saving through pressure management**	**Water saving by communica-tion and public awareness**
City	**Koulikoro**	**Tepoztlán**	**Delhi, Noida, Gurgaon**	**Mogale**	**Sebokeng, Evaton**	**Bogotá**
Area	Mali, Africa	Mexico, Latin America	India, Asia	South Africa, Africa	South Africa, Africa	Columbia, Latin America
Model	Urban Village Model	Urban Village and City Model	City model	City model	City model	City model
Climate	Semi Arid	Humid	Arid	Temperate	Temperate	Temperate
Storage & augmenta-tion	grondwater	groundwater	groundwater	groundwater	groundwater	groundwater
		rainwater harvesting	rainwater harvesting			surface water
Supply & distribution	grondwater abstruction	grondwater abstruction (well)	grondwater abstruction	grondwater abstruction	grondwater abstruction	grandwater abstruction
	central water supply	central water supply	central water supply	central water supply	central water supply	central water supply
		dual water supply for drinking and service water	decentral water supply	pipe leakage control	pressure control	pressure control
			supply with one type of water quality	supply with one type of water quality	supply with one type of water quality	supply with one type of water quality
Use & saving	waterless toilet	waterless toilet	drinking water	plumbing fixture (citerns, taps, pipes)		washing and cleaning behavior
	waterless urinals	waterless urinals		replace and retrofitting of taps and cisterns		personal hygiene
	watering plants	watering plants				retrofitting of cisterns
Reuse, recycling & disposal	greywater treatment	greywater treatment			centralised sewage treatment	
	blackwater treatment	blackwater treatment				
	separated sewer system	separated sewer system				
	greywater garden	reed bed				

Table 6: Overview of the case studies, applied ESTs and their position according to the different sections in the urban water cycle.

Ecological Sanitation pilot installations in Koulikoro, Mali

Main ESTs

Water supply and distribution:	Groundwater abstraction and centralized water supply
Water use and saving:	Water less urine diverting dry toilets
Water reuse, recycling and disposal:	Grey water treatment and reuse for urban agriculture in greywater gardens

case 1

Planning institution:	*Otterwasser GmbH*
Executing institution:	*BOATA GmbH, Mali, Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) GmbH, Germany*
Start of planning:	*April 2000*
Start of operation:	*July to December 2001*
Project Scale:	*11 decentralised installations, each for groups of approx. 10 to 25 inhabitants*
Type of settlement:	*Urban area with low population density in the city Koulikoro (26,000 inhabitants)*
Climate:	*Semi-Arid, high average temperature, long dry season & short rainy season*
Topography:	*The settlement is located in a sandy river valley with high groundwater level and stretches up to a neighbouring plateau with hard and rocky ground.*

Object of project

o Establishment of appropriate locally adopted environmental sound low-tech and low-cost sanitation system, which are easy to apply and to maintain at the individual household level by the inhabitants.

o Reduction of environmental pollution and health risks and improvement of water efficiency.

o Safe and controlled use of human manure for soil improvement, reduction of erosion and crop fertilisation.

o Extension of the centralised water supply system.

Background of project

At the beginning of the project, the initial situation in the project area was investigated. The houses in Koulikoro are partly connected to a central water supply but not connected to a functioning wastewater management system. Waste water from approximately one quarter of the households is discharged to soakaways, so called "puisards", generally designed as a hole in the street or a collection basin. However waste water sometimes flows directly onto street. Only about 3% of the households are equipped with water flush toilets and poorly designed septic tanks. The effluent is discharged uncontrolled. Due to a high groundwater table in the river valley and a rocky underground in the higher areas, the infiltration of waste water is difficult.

Nearly all households are equipped with traditional pit latrines and a showering area. Faeces and water used for anal cleansing are collected in a pit while the urine and the shower water usually flow over the latrine floor and then, running either into a soakaway outside the compound, into open storm

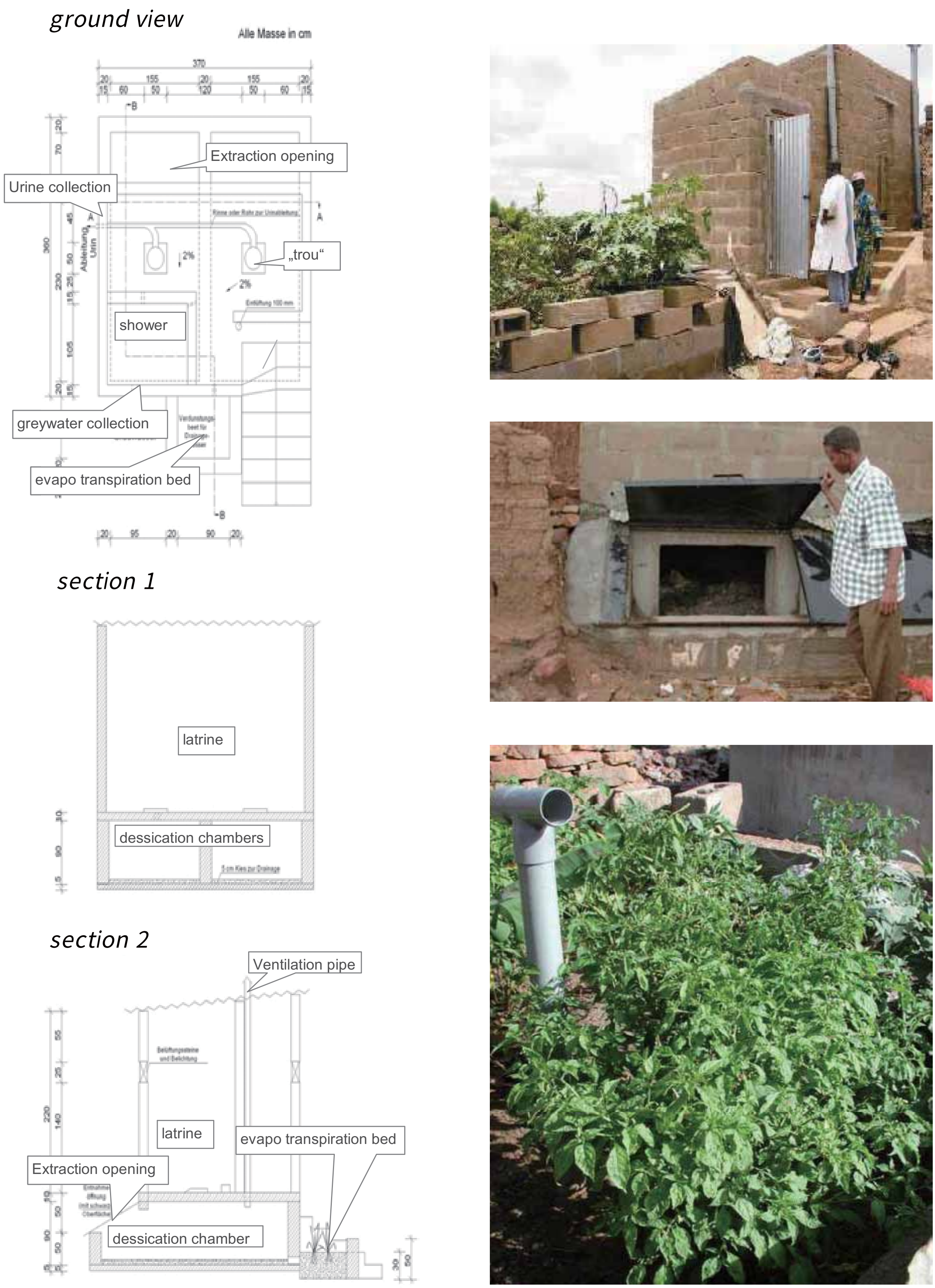


Illustration 50: Dry toilet with greywater gardens; layout, sections and photos.

water drains or directly onto the street. The income levels of most people in Koulikoro are very low. An agriculture area is located near the domestic areas. The soil is sandy and poor in nutrients and is affected by severe erosion during the rainy season. Traditionally, untreated faeces from latrine pits are used for affordable soil improvement and fertilization of the farmland.

Technical description

Use: Waterless Toilet and Urinals (urine-diverting dry toilets) with separation of faeces and urine at the source by special latrine slabs/squatting toilets.

- o Faeces: Two-chamber dehydration toilets for the drying, storage and hygienisation (for later safe use in agriculture) with a controlled drainage of seepage water.
- o Urine: A separate collection and storage from faeces and shower water (for later safe use in agriculture) by simple gutter/trench on floor (*see sections 4.4.4.1 - 4 Waterless and saving toilets, Waterless and saving urinals*)

Reuse & disposal: Nature Orientated Waster Water Treatment

- o Greywater treatment by mechanical and biological means. The grey water is first purified by sedimentation and filtration and afterwards drained in a greywater garden for further aerobic treatment and the irrigation of plants. (*see section 4.5.4.3 Constructed wetland*)

Reasons for the application of the specific technologies

Based on the local climatic conditions as well as the geological circumstances a two-chamber desiccation latrine with both chambers above ground seemed to be the most safe, simple and cost effective EST by contributing to water-savings, the safe collection and drying of the faeces as well as the protection of groundwater resources. The separated collection of urine contributes to an appropriate aerobic treatment, storage and transportation of the faeces. Furthermore it protects groundwater and facilitates the specified use of urine in the nearby located agricultural area, as fertiliser for the nutrient poor sandy soil. The greywater garden is the preferred treatment solution, due to the available space and the comparably high irrigation demand for fruits and vegetables in hot climates. It can be directly reused for irrigation purposes without requiring a complex drainage system. Due to the low contamination and the protective measures the reuse can be regarded as safe. Furthermore positive interactions can be achieved by saving drinking water for irrigation

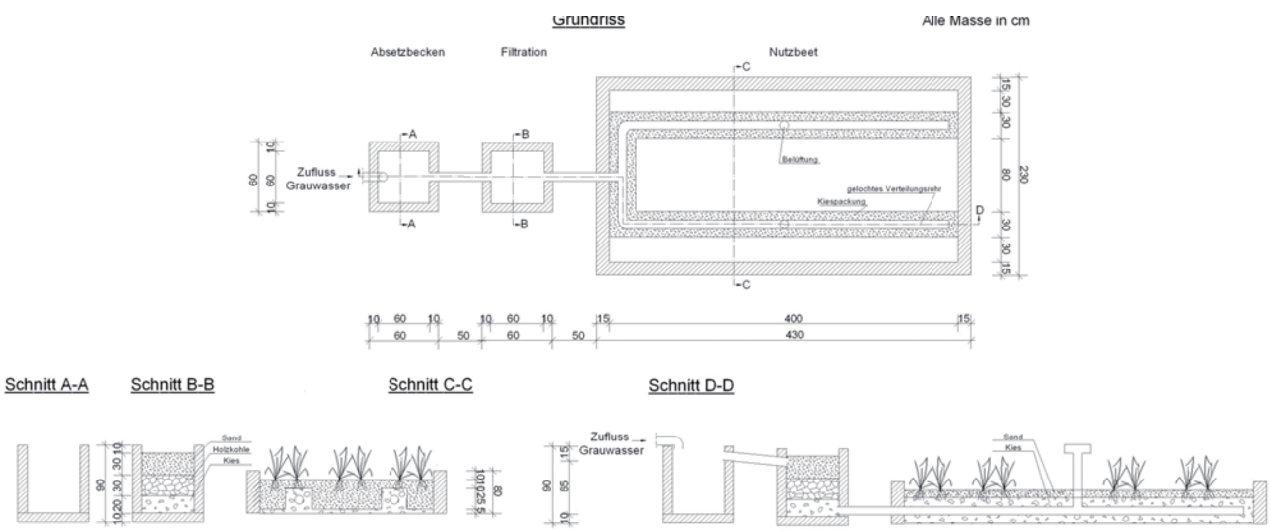


Illustration 51: Layout and sections of the greywater garden.

purpose, the consumption of nutrients by plants and the elimination of pollutants by soil treatment. The extension of the already existing central water supply was regarded as appropriate EST due to the already existing and functioning network and sufficient water resources.

Technical specifications

The function principle of the two latrine chambers of each dry toilet installation is based on the complete drying and hygienisation of their content by solar radiation. However this process was hampered during the first operation phase by the amount of water used for anal cleansing that drained into the latrine chamber. This problem was minimised several modifications of the first design:

- o Sloping of the bottom of the toilets desiccation chamber and covering it with a layer of gravel (functioning as a drainage layer). From the water-tight sealed bottom of the desiccation chamber, all liquids are drained directly into the soil of an evapo-transpiration bed, located outside of the chamber and filled with gravel, earth and plants with high water consumption (functioning principle of a small constructed wetland for blackwater treatment).
- o Equipping the desiccation chambers with aeration pipes and south facing black iron access doors to increase the temperature in the chambers and to stimulate the drying process.
- o Redesign of the toilet floor to allow the urine and greywater from showering to be separately discharged, without entering the desiccation chambers.

The grey gardens were designed to encourage effective aerobic processes and the reuse of nutrients in the greywater. This was achieved by the design of gardens with an area of approximately 8 m^2 enclosed by a wall with a height of 50 cm. The dimensions were selected based on the pollution load and the volume of water to be treated and the climate. The enclosed area was filled with 3 layers, consisting (from bottom to top) out of gravel, sand and soil. The greywater for irrigation of the garden is distributed by perforated pipes underground. To avoid a clogging of the pipes it is essential to remove all solid particles. Therefore the greywater is led through a small sedimentation basin and afterwards through a filter filled with sand, charcoal and gravel before entering the horizontal irrigation pipes. For an efficient aerobic treatment process, these are equipped with vertical ventilation pipes. The planting of the greywater garden with plants such as okra, bananas, baobab, pepper and papayas has produced good results.

Construction, operation and maintenance

The successful construction and operation of decentralised EST with reuse of solids and effluents requires a high degree of motivation and awareness raising as well as a steady and efficient external support in form of experienced manpower and financial resources on site, at least for a initial period, as well as a great interest in either recovering fertilisers and food production or in an improvement of the hygienic situation.

The subject was discussed intensively with all stakeholders and the installations were developed in close cooperation with the future users and all concerned parties. Nevertheless these factors were underestimated or insufficiently considered in Koulikoro for several reasons and the long-term user commitment was rather low. This led to a steady deterioration of the majority of the pilot facilities.

Artisans have to receive intensive training before they are able to construct the new facilities on their own. However in the long run their practical work experience can be combined with effective training to enable them to consult their clients and run an autonomous service business. Parallel to the training of artisans, possibilities for a service business to empty and collect the recyclates should be investigated to serve users who do not have the possibility to reuse and to create sources of income. Entrepreneurial possibilities were investigated and discussed with the stakeholders.

Careful management following certain utilisation rules is required for the system and will be discussed later. Following these rules users can operate and maintain the system themselves. The procedure includes the evacuation of hygienised faeces after one year of natural drying in the two desiccation chambers. After this period the content is collected manually without any health risk and utilised for agricultural soil improvement. An effective treatment process is supported by the regular adding of ash by the users.

For the proper operation of the grey garden it is required to maintain the filter, decanter and greywater garden, and remove solids and foreign material; to maintain and harvest the plants; to monitor and control if necessary the volume of water in the greywater garden; and to clean the garden. Furthermore, the regularly monitoring and cleaning of the filter is required to prevent clogging and overflowing. The fencing of the garden is essential to prevent damage by domestic animals.

Cost

Based on the geographic (rocky ground) and economic (low income) conditions of the inhabitants as well as the expected construction costs, a centralised sewer and waste water treatment system was not considered. Furthermore the operational costs for such a system were estimated to be twice as high as the whole town councils budget.

Construction costs of the double chamber were approximately 270 - 414 Euros in the 2001. This cost is double that of a conventional latrine. However, its operation creates saving and gains. The cost for the evacuation of faeces can be saved because users can operate it easily themselves. Drinking water can be also saved by the substitution of drinking water with service water. The recycled faeces can be reused as fertiliser for additional food production. The savings per household are in the range of approximately 25 Euros.

Cultural acceptance

The use of dry toilets and the drying of faeces and their reuse in agriculture are well accepted in areas without waterborne flush toilets and where there is a need for affordable fertilizers and where fertilising with faeces is already practised. The problem of cultural specific sanitation practice, like the occurrence of anal cleansing water can be solved through an appropriate construction, which incorporates a direct drainage system.

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TepozEco urban ecological sanitation pilot program in Tepoztlán, Morelos, Mexico

Main ESTs

Water storage and augmentation:	Rainwater harvesting for direct use as service water
Water supply:	Dual water supply for drinking water and service water
Water use and saving:	Water-saving use, urine-diverting dry toilets, low-cost composting toilets, waterless urinals
Water reuse, recycling and disposal:	Domestic rainwater use, nature oriented grey water filters (reedbeds, mulch), reuse of purified greywater for irrigation. Recycling of nutrients in faeces and urine

case 2

Planning Institution:	*Sarar Transformación SC / EcoSanRes.*
Executing Institution:	*Sarar Transformación SC.*
Start of planning:	*January 2002.*
Start of operation:	*January 2003.*
Project Scale:	*30 household-centered ecological sanitation systems (additional 100 toilets in 2006) public toilets, reed bed, communal composting centre.*
Type of settlement:	*Peri-urban water scare community with 2000 inhabitants, in a municipality with 35,000 inhabitants.*
Climate:	*Tropical humid, seasonal with dry winters.*
Topography:	*The settlement is located at the foot of mountains within a national park and does not receive waters from upstream villages.*

Object of project

o Establishing a fully functioning 'closed-loop' system of water efficiency and ecological sanitation, within 4 years.

o Giving a household-centered approach to sustainable management of separate domestic residue flows (urine, faeces, greywater, organic and non-organic solid waste).

o Providing an example for implementing sustainable water and waste management systems within a Latin American municipal context.

o 'Closing loops' at the household level as much as possible, then moving up to a neighbourhood level and lastly if required, at the municipal level.

o 'Retrofitting a small town' as a process of change in an existing urban environment.

Background of project

Tepoztlán shows wide variation of settlement types from poor villages to rich weekend homes, which is a typical contrast in Mexico and Latin America. Water is polluted by poor maintenance of waste and sewage. Upstream settlements drain grey and black water and dump garbage into clean water from mountains. An estimated 70% of urban population uses waterborne toilet systems, which are emptied into septic tanks. The systems are not maintained at acceptable standards and improperly treated effluent is drained into the ground. The aquifers supply water to most of the population, however recent quality tests show contamination by nitrates and detectable levels of faecal and total coliforms.

Technical description

The ecological sanitation (*ecosan*) vision seeks to develop integrated water management systems, including rainwater harvesting, an integrated washbasin, greywater treatment in mulch beds, and urine collection for later application in agriculture.

- o *Storage:* Rainwater harvesting and pre-treatment by sedimentation and volcanic gravel filtration. The local rainwater harvesting potential: over 1 m^3 per m^2 of roof surface. At a higher level, other components of the integrated project include watershed conservation (streams and ravines). (*see section 4.2.4.4 - 6 Rainwater harvesting*)
- o *Supply:* The project does not directly address supply but creates better conditions for the quality of the main water source: an aquifer supplying public and private wells. (*see 4.3.4.2 Groundwater abstraction*)
- o *Use:* Urine-diverting dry toilets constructed with passive solar design and built with natural or traditional materials. Water saving is also achieved by public, institutional and domestic waterless (male and female) urinals with a yearly collection goal of 6,000 litres. (*see section 4.4.4.1 - 4 Waterless and saving toilets, Waterless and saving urinals*)
- o *Reuse & disposal*: Reed-bed or mulch greywater filtering systems for physical and biological treatment. (*see section 4.5.4.2 On-site treatment of greywater and section 4.5.4.3 Constructed wetland*)

The water-saving ESTs fit in with an integrated strategy for recycling nutrients that includes the development of low-cost shallow pit composting sanitation systems like *fossa alterna* and *arborloo* (*see: box in section 4.4.4.1 Waterless toilets*) for poor peri-urban and rural populations. At the municipal level, the project seeks to consolidate the Municipal Composting Centre to receive and process a range of organic solid residues as well as promotion of neighbourhood and domestic composting.

Reasons for the application of the specific technologies

At a general level the reason for this approach is the understanding that in developing countries conventional waterborne systems are simply too expensive and unsustainable to cater to most of the population.

As mentioned, recent water quality tests indicate that faecal coliform and nitrate levels exceed national standards. No effective enforcement exists, although legislation sets clear guidelines for regulating waterborne sanitation. Groundwater contamination risk is high because septic tanks are often connected to fissures in volcanic soil. Septic tanks are poorly maintained and sludge is not regularly emptied. 70% in urban core and 30% of peri-urban and rural areas are using septic tanks with infiltration pits; the rest uses latrines, dry toilets or open defecation. The conditions in Tepoztlán reflect the national situation. Treatment plants are rare, while those that exist are either non-functional or operate below design efficiency, although municipalities are requested to treat wastewater by law. Therefore the *ecosan* approach is applied as decentralized, low-tech and sustainable sanitation options. With *ecosan* it is possible to recycle a significant amount of greywater, increase soil fertility (through application of sanitized products as organic fertilizers), and close the loop to urban agriculture. Also domestic water consumption can be cut by approximately half. *Ecosan* addresses water scarcity, improves health and food security, and diminishes reliance on non-renewable fertilizers, such as phosphates.

Since its outset, the TepozEco project has pioneered the links between sanitation and urban agriculture. Decreasing soil fertility, escalating prices of chemical fertilizers, and contamination of water bodies due to leaching and runoff of agrochemicals highlight the need to develop alternatives that recover the valuable nutrients found in human excreta for agricultural purposes. Adequately stored urine is sterile and most nutrients in human excreta are found there in forms ideal for plant uptake. Aside from its direct use in agriculture, urine can improve composting processes, both as an activator and accelerator. Compost may then be used as a soil conditioner.

Technical specifications

The dry toilets have one dehydrating chamber with 2 large-capacity plastic containers (on wheels) for faeces collection, storage and pre-treatment. Urine harvesting takes place in 20 litre plastic containers. South facing ventilation pipes and fly-traps are

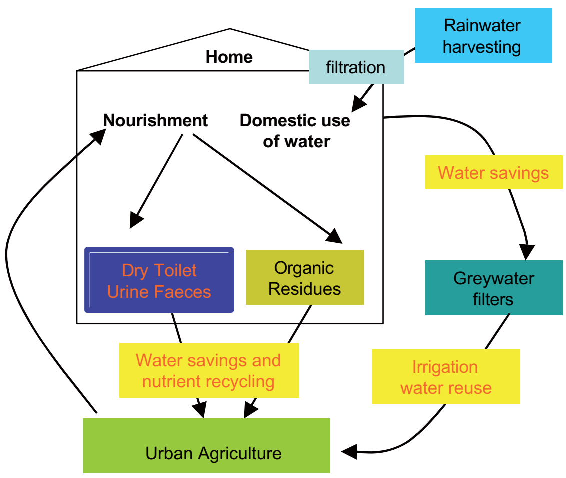
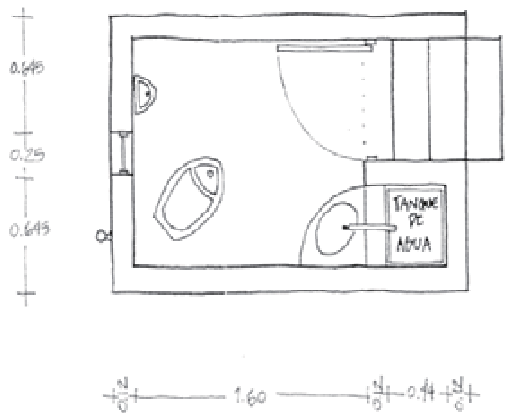
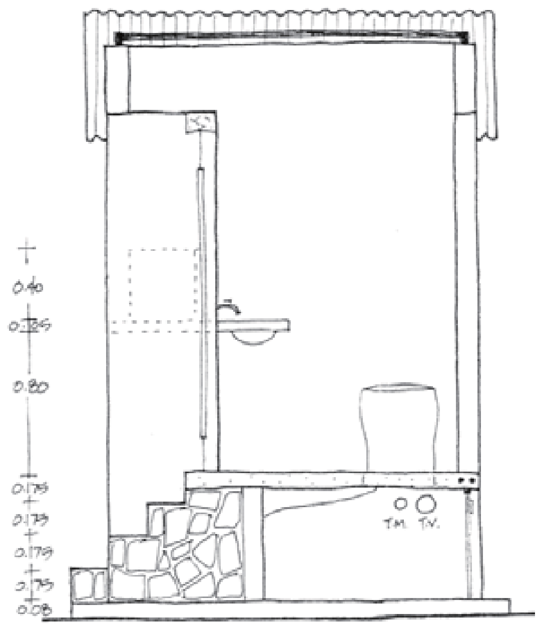


Diagram of 'Closing loops' household centred approach

Municipal Composting Center

Illustration 52: ESTs applied in Mexico





Sketches (above) / Picture (left) of *ecosan* toilets important details that make these systems work properly and avoid health risks.

Construction, operation and maintenance

Users are responsible for normal operation and maintenance. TepozEco provides operation and maintenance workshops for owners to ensure their proper use. Those who cannot or do not want to reuse their urine and faeces in their own gardens can bring their product to the Demonstration Centre or to the Composting Centre. TepozEco provides operation and maintenance workshops for ecosan system owners to ensure their proper use. Partially, these issues are of a technical nature, but the project is also confronted with the more difficult task of establishing an appropriate framework for ecosan to be considered in policy, planning and budget allotments, while most government decisions and programs are geared towards often unsustainable waterborne solutions.

The lessons of this project have underscored the need to put more attention on design elements to stimulate demand, financial and credit mechanisms to increase access, and improved service delivery and maintenance support to assure user satisfaction and sustainability. All of these, together with an appropriate regulatory and institutional environment, will be critical for institutionalizing ecosan in Tepoztlán and beyond.

Costs

Typically a urine-diverting dry toilet including urinal and wash basin costs $1,000 USD, a shallow pit composting sanitation system costs $25 - 300 USD. Grey water filters can be constructed for $150 USD. All costs are including building material, accessories and labour.

Funding is used for realization, research, outreach and capacity building. The Swedish EcoSanRes Project has provided core funds for a multidisciplinary team of ecosan experts (part-time and full-time) and local counterpart staff (e.g. architect, biologists, agronomists, environmental and water management engineers and social scientist).

For research and international outreach, another major source of funding has been the United Nations Development Program (UNDP/BDP/EEG). Recent research has focused on groundwater quality for strategic assessment of water and sanitation; vulnerability and risk analysis as a baseline for sanitation regulations; and development of guidelines for urine application and faecal composting. In addition, WASTE (Netherlands) supported regional outreach, networking and capacity building. Other funds for capacity building are NCCR-NS and EAWAG (Switzerland) for activities that will help ensure sustainability in the San Juan subproject that includes assisting a youth group to construct the eco-station as a support mechanism to the 30 domestic ecosan systems. International donor funds have been used to leverage local and national resources to support ecological sanitation initiatives, including among others input from local families, the municipal government, the farmers association, CEAMA, Fundación Comunidad AC (with sponsorship from a large private enterprise), and INDESOL.

Cultural acceptance

The urine diversion dry toilet has been demonstrated to be versatile and adaptable in many regions: East Asia, Latin America, Scandinavia, and Africa. Waterborne urine diversion toilets with two flush volumes, pioneered in Sweden, offer an alternative for those who have resistance to dry sanitation. Earth composting toilets, such as the *fossa alterna* and *arborloo*, (*see: box in section 4.4.4.1 Waterless toilets*) are low-cost alternatives - and major improvement - to pit latrines and open-air defecation.

Through participatory and social marketing approaches and a range of products catering to distinct socio-cultural tastes and habits, In TepozEco, it is demonstrated that ecosan solutions are suitable for different socio-economic population segments. The project has also demonstrated that by providing an aesthetically appealing, functional and affordable *ecotoilet system*, it is possible to overcome the stigma of the dry toilet as the inferior, temporary solution only until sewerage becomes available. The Demonstration Center displays working ecosan systems; provides information, training and support to the general public; and develops new prototypes or upgrades existing technologies. So far, the Project has held 12 workshops, advised 139 families, and designed 22 systems for institutions and private households. The project has deliberately addressed the sociocultural issues that are vital for acceptance, commitment and care. The range of tools used for community education and mobilization are drawn for the SARAR methodology, which has been used in a wide range of ecosan and social development programs:

Self-esteem, **A**ssociative strengths, **R**esourcefulness (creativity), **A**ction-oriented planning, **R**esponsibility for follow-through (commitment).

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World Health Organization; WHO Guidelines for the safe use of wastewater excreta and greywater; Volume 4, Excreta and Greywater use in Agriculture, Chapter 11, Planning and implementation; World Health Organisation, 2006. Available at: http://www.who.int/water_sanitation_health/wastewater/wwuvol4_chap11.pdf

Rainwater harvesting projects in Noida, Gurgaon, and Delhi, India

Main ESTs

Water storage and augmentation: Rainwater harvesting for the artificial recharge of groundwater

Water supply and distribution: Varying from total decentralised ground water supply by bore wells to partly centralised supply with drinking water and additional supply by borewells

Planning institution: *Centre for Science and Environment (CSE)*

Executing institution: *Enterprising citizens*

Start of planning: *2001 - 2002*

Start of operation: *2001 - 2004*

Project Scale: *Different project scales, with varying total rooftop and surface areas:*

- *BPCL HOUSING COMPLEX (Noida):*

  Total rooftop and surface area = 13,910 m², 85 % of the total water harvesting potential is harvested

- *GARDEN ESTATE (Gurgaon):*

  Total rooftop and surface area = 89,012 m², 46 % of the total water harvesting potential is harvested

- *SURYA VIHAR (Gurgaon):*

  Total rooftop and surface area = 44,029 m², 85 % of the total water harvesting potential is harvested

- *NIZAMUDDIN EAST COLONY (Delhi):*

  Total rooftop and surface area = 200,916 m², 40% of the total water harvesting potential is harvested

Harvested water from: *Rooftop rainwater and surface runoff harvesting*

Type of settlement: *Housing estates in urban centres*

Climate: *Continental arid climate with unequal distribution of rainfall over the year. The majority of rain falls during the summer monsoon from July to September. The annual average rainfall is 792 mm in Noida, 578 mm in Gurgaon and 611 mm in Delhi.*

Topography: *Varying, from sedimentary to hilly terrain*

Object of projects

- Prevention of groundwater exploitation
- Stabilisation of groundwater tables
- Recharge and rehabilitation of groundwater tables
- Sustainable water supply

Background of projects

Delhi is facing a temporary water shortage crisis which is worst during the dry season. During that time the extraction and overexploitation of groundwater exceeds the available resource and leads to a significant subsidence of the groundwater tables. Water supply of the municipality is provided by the abstraction of ground water (aapproximately 11 %) and for the rest of surface water from the Yamuna River. However the total quantity of abstracted groundwater is difficult to quantify because groundwater is abstracted by a large number of unregistered tube wells which are owned by individuals, industries and companies producing bottled water. Water supply is unstable. For example in Delhi approximately 13% households do not receive water every day, and in Rajkot, Gujarat, water availability in April 2000 was only for 30 minutes every alternate day *(Zerah., M.- H.; Water - Unreliable Supply in Delhi; French Research Institute of India, 2000).*

For promotion of successfully community based rainwater harvesting in urban centres the Centre of Science and Environment (CSE) in Delhi has planned and monitored 16 rainwater harvesting model projects. The models and the evaluation results are providing answers to queries from people who are concerned about the prevailing water crisis, are keen to play an active role in managing water and are looking for a way to fulfil their own water needs.

Technical description

The system's aim is to collect as much rainwater as possible from the properties and use it for the artificial recharge of groundwater which is the main available source of water in Delhi during the dry season. Different variations of collection, purification and recharge facilities are used in the specific model projects. Also in specific projects different ESTs have been applied.

- o The rainwater from rooftops is drained through stormwater drains to a recharge structures. For the facilitation of recharge bore wells are provided inside the recharge wells, trenches or percolation pits.

	BPCL housing complex	Garden Estate	Surya Vihar	Nizamuddin East colony
completed year	2002	2001	2002	2004
city	Noida	Gurgaon	Gurgaon	Delhi
average rainfall (mm/year)	792.4	577.8	577.8	611
total rooftop and surface area (square meter)	13,910	89,012	44,029	200,916
harvested water (cubic meter)	4,446	23,549	18,207	48,531
rate of harvested water	85%	45.8%	85%	39.6%
water supply	bore well	bore well	tube well	bore well
	+ municipal supply		+ municipal supply	+ municipal supply
rooftop rainwater	route 1 > collection chambers	> collection chambers	> strom drain	> strom drain
	> recharge wells	> recharge well	> percolation pit	> collection chambers
	> recharge bores	> recharge bores	> recharge well	> recharge well
	route 2 > strom drain		> recharge bores	> recharge bores
	> percolation pits			
	> recharge bores			
surface run off water	> recharge trenchs	> collection chambers	> recharge trenchs	
	> recharge bores	> percolation pits	> recharge bores	
		> recharge bores		
cost (lakhs)	Rs 4.5	Rs 5.9	Rs 0.65	Rs 1.74
ground water level (meter below ground water level)	17 (Feb 2004) 16.7 (Feb 2004) 18.4 (Feb 2006)	39.6 (Apr 2003) 37.9 (Jul 2003) 48.7 (Feb 2006)	48.3 (Feb 2004) 54.5 (Feb 2005) 55.0 (Feb 2006)	7.3 (Jan 2005) 7.6 (Jan 2006)

Table 7: Overview and data exemplary rainwater harvesting projects in India.

o Rainwater runoff from roofs and paved surface areas is intercepted in drains that are connected to desilting chambers. The purified water is drained from the chambers in a recharge structure. To facilitate recharge, borewells are provided inside the recharge wells. Layers of pebbles and sand or bricks inside the recharge wells act as filtering media, for further purification of runoff that is being recharged.

(*See also: section 4.2.4.2 Artificial recharge of groundwater and section 4.2.4.4 - 6 Rainwater harvesting*)

Reasons for the application of specific technologies

The specific technologies which are applied for the collection and infiltration of rainwater are primary dependent on the specific basic conditions. The comparably clean rainwater from roofs is used directly, after passing the recharge well and without further purification used for the recharge of groundwater. Borewells are used to facilitate the recharge of large amounts of water during a short period of time without the need to percolate the infiltrating rainwater through the ground. The comparably highly contaminated rainwater runoff from paved surface areas is purified by desilting chambers as well as by gravel and sand filtration to avoid the contamination of groundwater.

Technical specifications

The four selected cases are representing successful rainwater harvesting projects in housing estates with comparably high urban density. The installations for the drainage, collection, purification and recharge of groundwater are based on simple technologies which are designed and located adapted to the local basic conditions.

Recharge wells:

The sizes of the recharge wells which are used in the projects have sizes which are in the range of approx. 3 m x 2 m x 3.5 m per well.

Recharge borewells:

The recharge bores used in these projects have diameters of 100 - 160 mm and depths of 10 - 20 m, depending on the location of the aquifers which have to be recharged. Some of recharge bores are filled with filtering material such as boulders, peddles and coarse sand, from 10 - 100 mm width for the filtration and purification rainwater runoff.

Recharge trenches:

The sizes of trenches vary from 3 to 4.5 m length, 0.5 - 1 m width and 1 - 2 m depth. A recharge trench is a continuous trench excavated in the ground and refilled with porous media like pebbles, boulders or broken bricks. The length of the recharge trench is based on the amount of runoff expected. In terms of recharge rates, recharge trenches are relatively less effective since the soil strata at a depth of about 1.5 metres is generally less permeable. For recharging through recharge trenches, fewer precautions have to be taken to maintain the quality of the rainfall runoff. Runoff from both paved and unpaved catchments is tapped.

Percolation pits:

The sizes of the percolation pits used in the projects are designed on the basis of expected runoff and are filled with pebbles or brick jelly and river sand. They are covered with perforated concrete slabs where necessary. The pits have sizes of approx. 0.6 x 0.6 x 0.6 m.

Operation and maintenance

The construction of the rainwater harvesting systems based on an appropriate planning is comparably easy. The proper maintenance of the described rainwater harvesting systems is easy but crucial for a proper operation. Regular inspection and cleaning of catchment, gutters and filters is generally sufficient. For example, recharge trenches have to be periodically cleaned. Accumulated debris is removed to maintain the intake capacity.

Cost

The costs of a rainwater harvesting system for the recharge of groundwater are site specific and hence it is difficult to specify general cost. A big portion of the investment costs is required for the construction of drainage systems. The additional costs are significantly dependent on the availability of existing structures like wells and swales which can be modified and used for water harvesting and the construction of collection and infiltration facilities. Investment costs for the construction of ESTs for rainwater harvesting which are used in the described cases are varying from Rs 0.65 lakh to Rs 5.9 lakh.

Result

In order to study the impact of rainwater harvesting on the groundwater table in the 11 model projects, the water level in the existing borewells was measured every month. The impact of rainwater harvesting on the quality and quantity of groundwater in the location has been remarkably positive and proved therefore that rainwater harvesting is one of the most effective tools for the recovery of rapidly depleting groundwater reserves.

Cultural acceptance

The acceptance of the facilities ESTs for rainwater harvesting for the artificial recharge of groundwater as well as for the decentralised groundwater supply by bore wells are very positive. The main reasons are the awareness of the users and the enhanced water availability and quantity.

Source:

Centre for Science and Environment; Urban Model Projects; New Delhi, India, 2008, available at: http://www.rainwaterharvesting.org

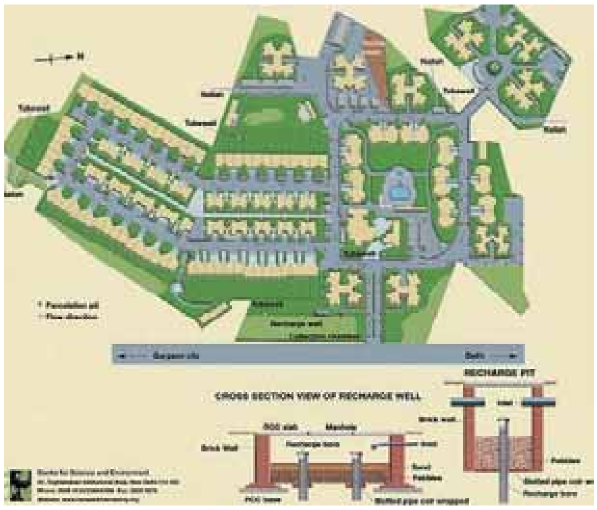

Illustration 53: Surya Vihar Rainwater Harvesting Systems, isometric view and cross sections percolation pit and recharge trench (top), Nizzamuddin East Colony's Rainwater Harvesting Systems, site plan and cross section recharge well (middle), Garden Estate Rainwater Harvesting System, site plan and cross sections of rainwater harvesting well and recharge pit (bottom).

"We fix the leaks"
Munsieville private property leak repair project in Mogale City, South Africa

Main ESTs

Water supply and distribution:	Leakage control of centralized water supply pipelines on properties
Water use and saving:	Retrofitting and replacement of plumbing fixtures like cisterns, taps, pipes, etc.

case 4

Planning Institution:	*Alliance to Save Energy*
Executing Institutions:	*Alliance to Save Energy, Plumbing Institute of South Africa (IOPSA), Construction, Education and Training Authority (CETA)*
Start of planning:	*2005*
Start of operation:	*July 2006*
Project Scale:	*1,371 households and approximately more than 13,000 persons benefited from the project.*
Climate:	*Temperate with dry winters*
Topography:	*Plain at an altitude of 1,700 meters above sea level*

Object of project:

The aim of the Project was the development of a water efficient water supply by retrofitting and replacement of plumbing fixtures (cisterns, taps, pipes, etc.) on private properties in a previously disadvantaged community with high levels of water wastage. Simultaneously municipal cost recovery had to be addressed for the provision of the basic services. Furthermore the objectives which were set by the project included the creation of jobs, the training of skills, and the empowerment of local community members for a sustainable future, community awareness and upliftment, water-savings through repair of pipeline leakages as well as energy savings by the reduction of water losses.

Background of project:

The township of Munsieville is a very old part of Mogale City. The water consumption in the project area before project start was on average 1024 litres per household per day. This was approximately five times more than the amount of 200 litres water which is distributed by Mogale City per household free of charge (6,000 litres per month).

Illustration 54: Overview site plan project area.

At the beginning of the project, a Project Steering Committee (PSC) was established for overseeing the work which had to be carried out for the implementation of the project. It was made up of local Councillors, the South African National Civic Organisation (SANCO), the Mogale City Local Municipality, the Plumbing Auditor, the Plumbing Contractor, the Project Community Liaison Officer (CLO) and the Project Manager on behalf of the implementing agent, the Alliance to Save Energy. Every second week meetings were held in Munsieville to monitor the progress of the project and to evaluate whether the project was meeting its objectives. Minutes of these meetings were distributed to all stakeholders. Based on interviews with previously disadvantaged persons, six learner plumbers and one community liaison officer were appointed for the duration of the Project and started with their training in 2006.

A pre-audit inspection of every property in the project area, in order to assess the extent of the plumbing repairs required, was carried out by a qualified plumber. Each house was inspected and evaluated according to a very detailed checklist; a job card as well as a list with required materials was also compiled. Every household owner was required to sign off on the pre-audit checklist, showing agreement with the findings and the repairs that would be carried out. The vast majority of leakages were found to be through the toilet cisterns. The worst cistern inspected had a continual flow of water through its flow valve, which when measured, had a measured flow of 1 litre every 23 seconds, or an equivalent of 112 m^3 per month. This is more than 18 times the allocated minimum supply of free basic water (6 m^3 per month) supplied by the municipality and is similar to a water quantity of 3.6 m^3 per day. The existing infrastructure is comprised mostly of old galvanized pipe which was found to be in a much corroded state before the project started. Once the pre-audit of the properties had been completed, the actual plumbing repairs were started by a local plumbing contractor with qualified, registered plumbers.

Illustration 55: Measure for fixing the leaks. Retrofitting and exchange of containers (top) and of leaking pipelines on properties (bottom).

Technical description

The repair or replacement in the framework of the project included complete new toilet cisterns or cistern components, complete new taps or tap components and water pipes. Where cisterns could not be repaired, complete new cisterns were installed. Water-saving behaviour and leakage control by citizens was communicated by the executing institutions.

Reasons for the application of specific technologies

The specific standard technologies were repaired or replaced to achieve an effective leakage control and related water-savings on property level.

Technical specifications

Cisterns:

As part of the project, a "leak-free" cistern was also installed. This cistern stands empty for the majority of the time, and only fills when the flush button is activated. In case of cistern failure, the leakage rate is drastically reduced because the failure occurs in the empty position. Originally it was intended to install this cistern throughout the project, but due to low pressure being experienced in the area, the cistern took a long time to fill up. This proved to be a point of concern to the residents. Therefore normal cisterns were utilised for the remainder of the project implementation.

Taps:

Wherever possible, washers only were replaced at leaking taps. If a tap was beyond repair, new taps were installed.

Water pipes:

The existing old galvanized water pipes were mostly and in a much corroded state and leaking. Therefore it was required to install new sections of water pipes in many houses.

Operation and maintenance:

The plumbing repairs and replacement of cisterns and taps were realised by qualified, registered plumbers. After the finalisation of the plumbing work a post-audit of the work was done on the properties. All properties had to be signed off by the home-owner once repairs had been completed. Each property was checked by the plumbing auditor for quality of repairs completed. A total of 1,075 properties had plumbing repairs carried out on their premises.

In order to communicate the general water savings and awareness message and objectives of the project, every household received a visit and an information brochure with water-saving tips, handy pointers for fixing leaks, general awareness of water and the environment and relevant telephone contact details in the municipality. To inform about the project, a project awareness day was held, not only to raise awareness among the citizens but also

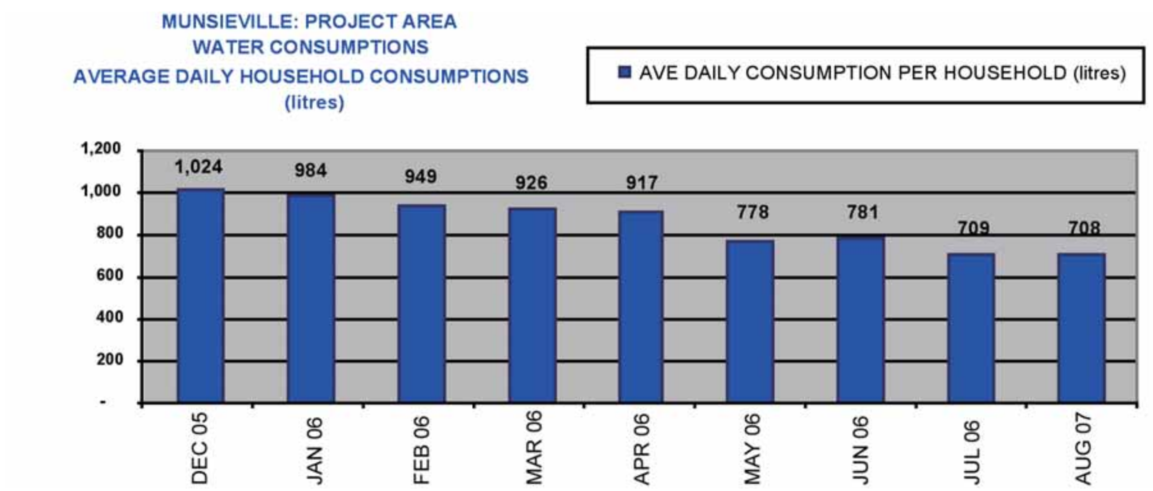

Illustration 56: Declining average water consumption per household and day in the framework of the described project.

to motivate the proper operation and maintenance of cisterns and taps.

Cost

The total costs of the project were project cost R 1,062,000. The savings in the cost of water supplied due to this Project implementation are at average 316 litres per house per day. This is resulting in savings of 432.7 m^3 per day in the project area of 1,371 h/holds, in 12,982 m^3 saving per month in savings of 155,784 m^3 per year. At a Rand Water tariff of R2.94 per m^3, annual saving in water purchases of R 351,962 are achieved for Mogale City Local Municipality. The pay-back period is therefore 2.32 years.

Result

For the measurement of the technical success of the project, the water-savings had to be determined. In order to measure the water used in the project area, 2 bulk meters were installed which allowed the measurement of the whole water quantity supplied to the project area and leaving the project area. Every week, the bulk meters were read to measure the water flowing into and out of the project area. Additionally the 2 bulk supply meters were logged before and after the project to determine the Minimum Night Flows (MNF) in the area. After the completion of the project in July 2006 the water-savings compared to the water consumption at the beginning of the project in 2005 are 45%. The average water consumption was reduced from 1,024 litres per household and day to 708 litres per household and day.

Cultural acceptance

The acceptance of the project is very high because the life quality was enhanced for the Munsieville residents by improvement of service. Furthermore the project provided water infrastructure to some residents who had never had a water pipe from their meter to their homes before. Due to affordability reasons they were not able to pay the installations of the required pipeline.

Source

Ross, D. and Alliance to Save Energy; Munsieville Private Property Leak Repair Project, "Rea Thiba Marothodi" (We fix the leaks); Mogale City, South Africa, 2007

Water-saving through pressure management in Sebokeng and Evaton, South Africa

Main ESTs

Water supply and distribution:	Centralized water supply, leakage control through pressure management
Water reuse, recycle & disposal:	Centralized sewage treatment

case 5

In many South African residential suburbs night flows are extremely high. In Sebokeng and Evaton for an example, an area south of Johannesburg, the minimum night flow recorded in July 2003 represented 75% of the average daily flow. According to investigations the majority of the night flow was occurring in private households, e.g. by leaking plumbing or taps. The areas are predominantly low-income residential areas with approximately 70,000 household connections, each of which is supplied with an individual water supply as well as water borne sewage. The combination of low income coupled with high unemployment has resulted in a general deterioration of the internal plumbing fittings over a period of many years causing high levels of leakage.

The purpose of the project was through pressure management, to reduce this leakage in one of the worst areas. It was estimated that the yearly payments of the municipality to the bulk water supplier could be reduced by the order of two-thirds through pressure management. The situation is similar to that in Khayelitsha, in Cape Town, where the first large pressure management installation in South Africa was commissioned in 2001. This is still operating to its full potential, and continues to give the savings estimated when it was designed, thus demonstrating that such measures are sustainable.

The project undertaken in Sebokeng and Evaton is the first of its type in South Africa where a public-private partnership, a partnership between a firm of consulting engineers and the municipal water entity, was formed to undertake the work. The firm and its private sector funding partners funded the full cost of the installation to manage water pressures. The installation became immediately the property of the municipality.

For a period of five years after commissioning of the installation (in 2005), a proportion of the savings ("savings" in terms of reduced purchases

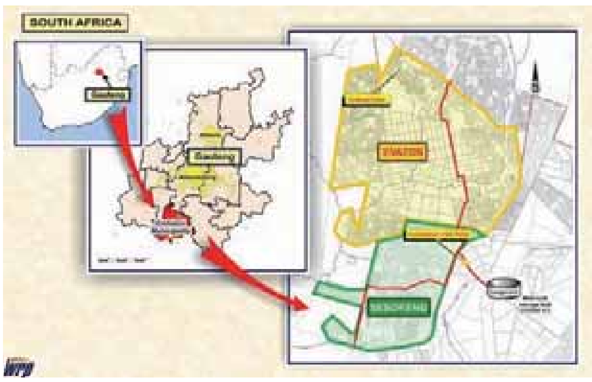

Illustration 57: Location of the project areas.

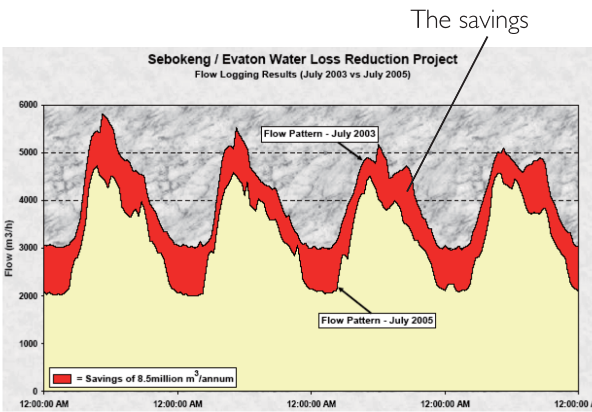

Illustration 58: Curves representing the daily water consumption in the project area before and after implementation of pressure control.

from the bulk supplier) accrues to the firm and its funding partners, with the remainder going to the municipality. If there are no savings, then the firm and its partners receive no return on their investment. Thus far the savings (which are independently audited) have been so large that, as predicted, the installation paid for itself in the first four months.

The installation is thought to be one of the largest pressure management installations in the world and it is clearly one of the most successful small scale Public Private Partnerships to be completed in South Africa. The real benefits of the project were only materialised two years after the project was commissioned. The savings achieved in the first two years of operation of the installation exceeded all expectations of both the Project Team as well as the Municipality and are the most obvious benefits to accrue from the project. After operating and managing the installation for two years, several other benefits also became apparent which were not initially anticipated. In particular the subsequently described benefits have been achieved.

Defer upgrading of infrastructure

The reduced water demand by implementation of the advanced pressure management system also had a significant impact on the sewer flows entering the treatment plant. As a result of the project the client has gained a reprieve of at least ten years on the upgrading of the water supply and sanitation infrastructure. The reduced pressures have also resulted in a significant reduction in the number of bursts experienced in the area which in turn will prolong the life of the infrastructure.

Identification of bottlenecks in the system

Unexpected low water pressures in some areas were caused by poor maintenance or inappropriate operation of various boundary valves and/or control valves. In each case the project team had to cease all further pressure reduction activities and undertake a full investigation to identify and correct all problem valves and/or sections of pipeline in a particular area. Following the corrective measures, it was normally found that the overall level of service to the specific community improved significantly when the system was reinstated to its original configuration.

Identification of problem infrastructure

Serious problems were found in the basic reticulation infrastructure. One of the most common problems identified was that of "missing" pipes or connections. In several cases it was found that connections from smaller pipes had not been made to the bulk mains running through a particular area. In one case, it was found that of the 4 connections shown on the "as-built" plans, only one had in fact been commissioned. In this instance, the community of approximately 3,000 residents had been experiencing intermittent supply (water available only during the night-time periods) for almost 9 years and had stopped complaining many years ago since nothing was ever done to alleviate the problem. On excavating the three mystery connections and adding the necessary T-pieces the area was restored to full system pressure on a 24-hour basis for the first time. Although the additional connections actually increased the water use in the one problem area, it allowed the pressure to the whole of Sebokeng and Evaton to be lowered during the off-peak periods which more than made up for any small local increase in use during the remaining periods.

The other key problem identified with the infrastructure was the identification of "missing" valves which were not shown on any reticulation drawings but were thought to exist by the project team due to the manner in which the system was responding to the water pressure. The valve chamber had been buried with rubble and rubbish for approximately 30 years and when the valve was eventually unearthed, it had seized completely. In many cases, the valves are more than 60 years old and must be removed completely and refurbished in order to restore the reticulation system to its normal operating condition. This type of problem has been a common occurrence and it is anticipated that more than 100 large valves will have to be refurbished. It is difficult to replace such valves with new valves due to the different flange drilling patterns and dimensions since all new valves use the metric specifications while those in the system are all based on the older imperial system. Refurbishing the valves results in very significant cost savings compared to a normal replacement policy.

Identification of bulk meter errors

The water supplied into Sebokeng and Evaton is measured by two 600mm diameter mechanical meters - one on each supply pipe. After the new installation had been commissioned, it became clear that there was a discrepancy between the bulk water meter readings and the meter readings in the installation. Unfortunately the magnitude of the discrepancy was around 4% in the favour of the bulk water provider. The acceptable accuracy range of the meters was in the order of 3% and thus it was technically possible to record a 6% difference and still be within the acceptable accuracy limits for both sets of meters. The new installation is clearly a very valuable asset to the Municipality since it now provides some form of verification of the bulk water meters which had previously always accepted as accurate with no form of check.

Catalyst for funding

Prior to the implementation of the project, the Municipality was unable to access any funding for WDM activities of any nature and even the various "development" banks were unwilling to provide funding for the project. Once the project had been completed, however, and the results were published, the situation changed dramatically and suddenly there were several organisations (including the bulk water provider) wishing to invest funding into Sebokeng and Evaton. One of the main supporters of the project is now the Department of Water Affairs and Forestry (DWAF) which is the national custodian of all raw water in the country and also fulfils the role of regulator countrywide. After assessing the savings from the Sebokeng/ Evaton pressure management initiatives, DWAF realised the value of such projects and created a new budget to help overcome the funding difficulties that originally threatened to halt the project.

Improved municipality status

The publicity surrounding the project has created awareness at the highest levels in government and the project has been acknowledged in Parliament by the Water Portfolio Committee as a model which should be repeated throughout South Africa wherever conditions permit. The positive exposure from the project has also created a general atmosphere of success within the Municipality and the municipal managers who supported the project have also been able to promote their own personnel through various radio and television interviews on the project. In effect, the project has created a turning point within the Municipality and the general perception of the Municipality has changed from negative to positive.

Creation of national WDM fund

Perhaps one of the most important benefits to arise from the project is the fact that it has demonstrated what can be achieved with relatively little funding and combined support from both the private and public sectors. Following the successful completion of the project, the Municipal managers have since been able to motivate for and gain approval for several additional technical and social WDM interventions.

Sustainability of savings

One of the key problems to many WDM interventions is the problem of maintaining the initial savings after the project has been completed and the project team has been paid for its efforts. In the case of the described case, the Project Team is responsible for all maintenance and operation for a period of at least 5 years. Since the Project Team receives payment in accordance with the savings generated it is essential that the project continues to operate properly until such time that the Municipality takes over or extends the period of the contract. The percentage of the overall savings retained by the Project Team is approximately 15% based on the first two years of operation and is sufficient motivation for the team to ensure that the project is fully functional at all times. This is one of relatively few WDM projects where the savings are audited carefully on a continuous basis and this is considered one of the key elements of a successful WDM project.

The principal best practice or innovation point of this project is that under certain circumstances public-private partnerships can be profitable for the private sector, even though income may not come from sales of a product or service, but may come from savings, on a risk-sharing basis with the water services authority. Both the Project Team and the Municipality are very happy with the outcome of the project and are continuing to work together to build on the initial success.

<u>Sources</u>

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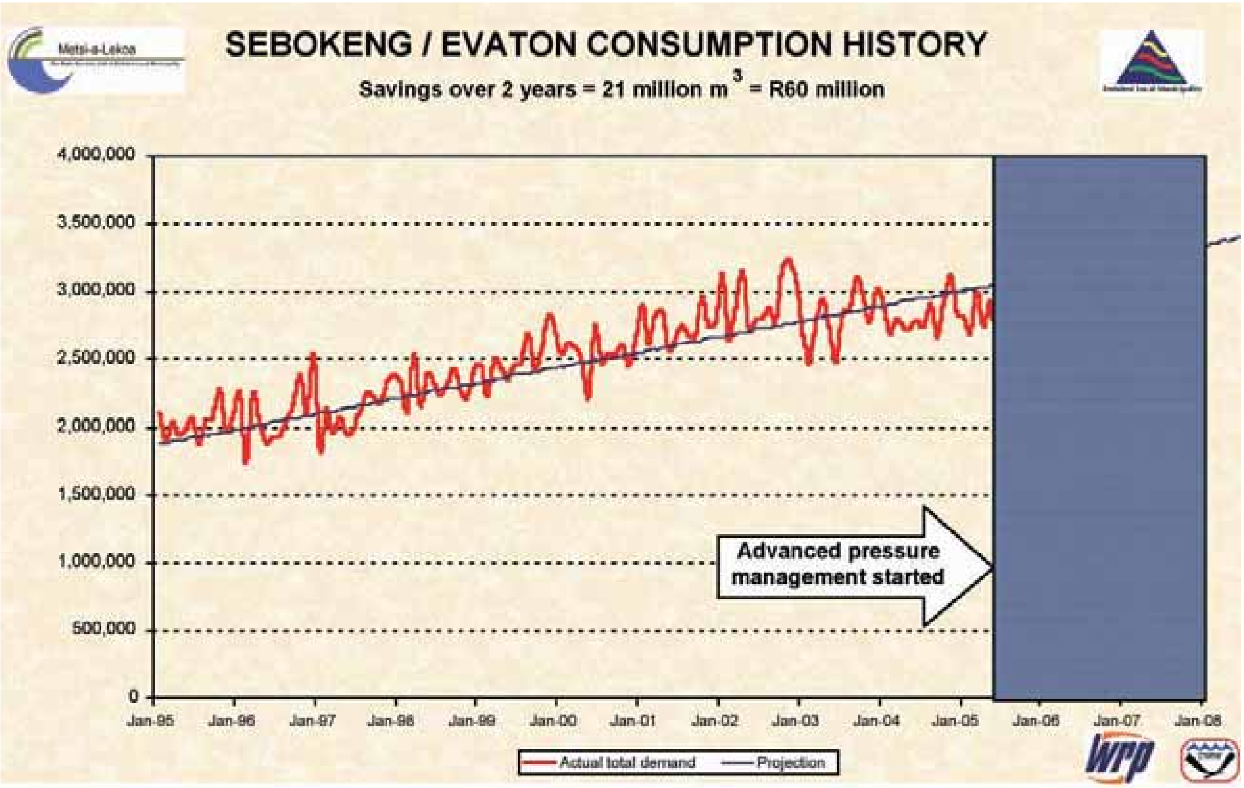

Illustration 59: Historical water consumption in Sebokeng and Evaton areas.

Water-saving by communication and public awareness in Bogotá, Colombia

Main ESTs

Water supply and distribution:	Pressure control, centralized water supply
Water use and saving:	Personal hygiene, rerofitting of cisterns, water-saving by economized water use

A successful example for water use efficiency introduced by communication are the campaigns to save water in order to avoid restrictions in water's supply by the official authority in Bogotá, Columbia. In 1997 malfunctioning of a tunnel carrying water to Bogotá made it imperative to save water. Thanks to a communication campaign by the mayor Mockus, the per capita consumption of water fell from 26 m^3 to 20 m^3 per year and the need for new investment for the development of new water resources was delayed. The resources freed from this measure went to the poor. An intensive communication was the key to its success. The basic messages of the campaign were:

- o Shower: use half the water pressure during half the time;
- o Toilet flush: flush the water only when necessary;
- o Dish wash: turn off the water while putting the soap in the dishes;
- o Laundry: use half the amount of water for washing clothes.

Each week the mayor told the users how much they saved. At the end of the first week, however, water consumption raised again by 2%. The importance of two-way communication was demonstrated in the need to enquire for the reasons for the increase. When asked in a survey, users mentioned that they have been saving water to avoid an interruption of the water supply. The communication campaign of the mayor restored the confidence in water-saving measures and the level of consumption diminished again. Mockus appeared on TV programs taking a shower and turning off the water as he soaped, asking his fellow citizens to do the same. In just two months, people were using 14 percent less water. The savings increased when people realized how much money they were also saving because of economic incentives approved by Mockus campaign. The result in the long term was that the water use in 2004 still was 40 percent less than before the shortage in 1997.

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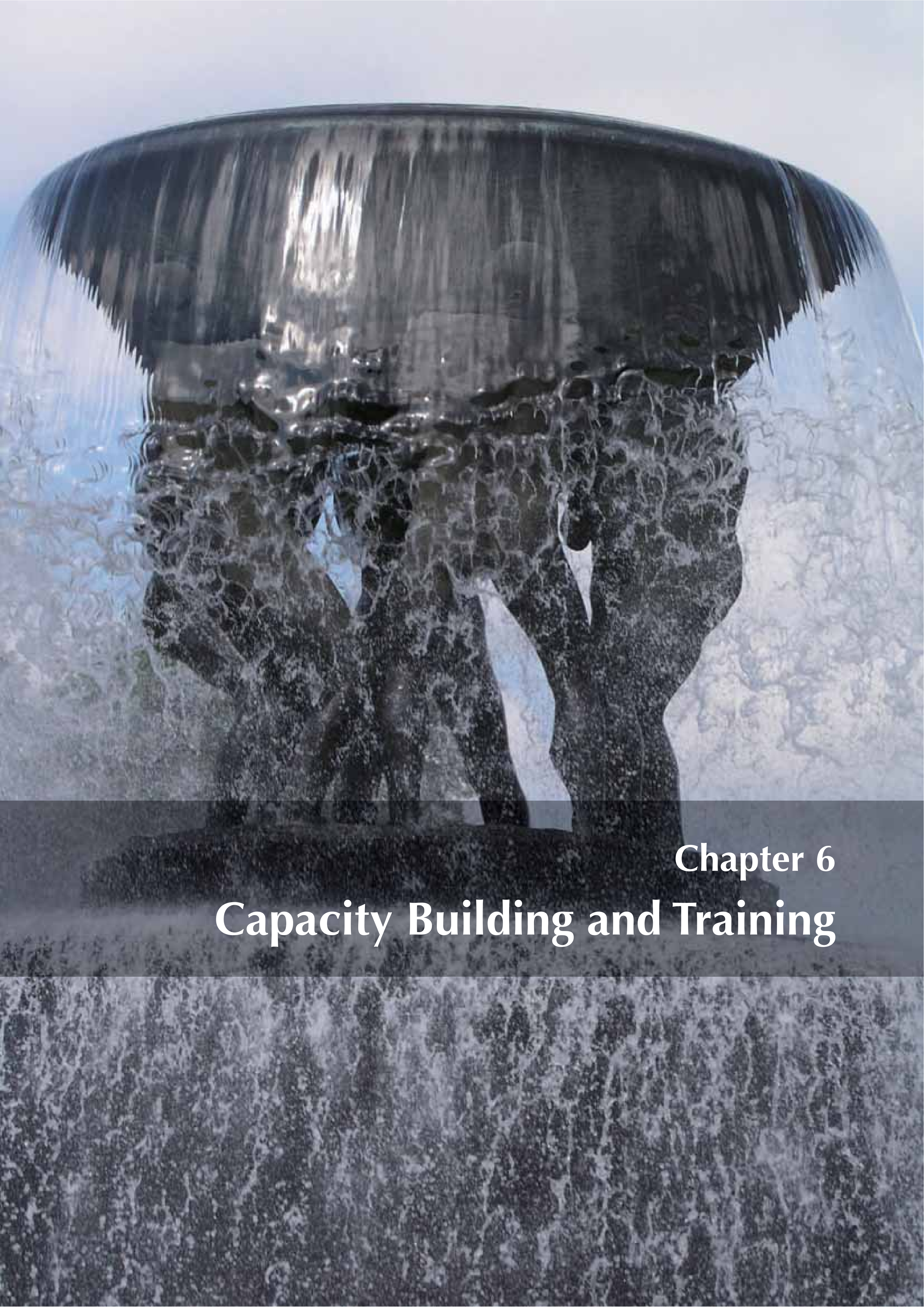

Chapter 6
Capacity Building and Training

For the facilitating of the decision making process of stakeholders, the Sustainability Assessment of Technologies (SAT) methodology has been developed. This Sourcebook has added an approach for choosing Technologies in Sustainable Strategies (TISS). The selections of specific ESTs which are appropriate for the specific basic conditions of each case as well as the appropriate combination of different ESTs for the sections of the urban water cycle are very complex task. This book wants to facilitate decision makers in finding sustainable solutions for water use efficiency in the urban and domestic environment in the framework of IWRM, based on TISS and relevant information about the properties of different ESTs and interactions with each other. For capacity building, training material in electronic format on a CD ROM is added to this Sourcebook.

- o A Microsoft PowerPoint presentation includes the main content of the Sourcebook in form of text and illustrations. The focus is on the selection and combination of appropriate ESTs for water use efficiency in the framework of Sustainable Strategies.
- o The tool WiseWater is based on a Microsoft Excel based spreadsheet model and allows the exemplary modelling the managing of water across a domestic property. Based on the specific basic conditions of a city area, which can be defined by the user, the model allows the selection and combination of different feasible ESTs. The model can only a give rough idea about the potential saving which can be achieved due to the many specific influencing factors of each case, which can not be considered in the framework of this overall model. However, in the model, various technologies and infrastructure models are included like water use reduction, water recycling and water source augmentation as well as the supply with drinking and service water. The model is described more detailed subsequently.

6.1 WiseWater

6.1.1 WHY WISEWATER

It is important that every effort is made to understand the impact of our lifestyles on the consumption of water at the individual household as well as property levels. Once understood, especially in the context of limited water resources, it becomes necessary to change our lifestyle and make use of ESTs to reduce the water consumption. The WiseWater tool is developed to help compute existing water consumption, make changes by adopting a range of ESTs and estimate possible water use reduction.

WiseWater is developed for the purposes of building awareness as well as skills towards water use reduction. WiseWater draws its technical information from this Sourcebook and in this sense serves as training complement to "Every Drop Counts".

6.1.2 WHAT CAN WISEWATER DO?

WiseWater is currently developed for domestic water use. The User can define existing domestic water use for drinking and service purposes (e.g. washing, sanitation).

WiseWater accounts for domestic water consumption at individual and property levels. Property level water consumption is derived from individual household water use. Thus it is possible to estimate water consumption of all water uses at both individual as well as property levels. These computations are automated and graphical representation is provided for better appreciation.

City level computations of water consumption are currently not possible in WiseWater as commercial and industrial water uses are not addressed. However, WiseWater provides a simple model that can be used to assess rainwater harvesting potential across the city. Using this simple model, it is possible to determine how much rainwater can be stored or used for recharging groundwater. Such information could be used in overall city level water resource planning as well as to stimulate rainwater harvesting at property level.

6.1.3 ENVIRONMENTALLY SOUND TECHNOLOGIES CONSIDERED

WiseWater provides for four types of ESTs. ESTs that

o Reduce water leakages,

o Reduce water use at source,

o Allow recycling and reuse of used water, and

o Complement or augment water resource.

WiseWater uses EST like pressure reducers for reduction of leakage losses. ESTs that lead to water use reduction consist of retrofitting/adding fixtures. WiseWater provides these options specific to water use so that user can make different choices to understand effectiveness of an EST. ESTs for recycling use principles of segregation and deploy wastewater treatment technologies. EST for augmenting water resource primarily consists of rainwater harvesting. For each EST, WiseWater maintains a database in the form of a "fact sheet". These sheets make it possible to view as well as edit to a limited extent. The limited editing is provided to allow user to "customize" ESTs as well as reflect local experience. At present, it is not possible to add new ESTs to the EST database.

6.1.4 STRUCTURE OF WISEWATER

WiseWater is menu driven. User has four key options, to

o Provide Water Consumption Data,

o Apply ESTs towards Reduction of Water Consumption,

o View Reports, and to

o Estimate City level Rainwater Harvesting Potential.

WiseWater has accordingly various "worksheets". A brief description of each of the above four options is provided below. More detailed information is included in the user manual.

6.1.5 PROVIDING WATER CONSUMPTION DATA

To start with, the User needs to define existing water use details at individual as well as property levels as well as the target for reduction in water consumption. The water use data is to be entered in the Inputs worksheet following the units indicated. Default values where applicable are provided. For better appreciation, summaries and pie charts are generated as data is entered. Appropriate data validation checks are built in to eliminate possible data entry errors.

6.1.6 APPLICATION OF ESTS

After entering the water use data, user should make a choice of ESTs. This is done in the worksheet - Apply ESTs. For each water use, a drop box is provided to allow the user a choice of applicable ESTs. Information on the EST can be accessed for better decision making. New patterns of water consumption are instantly computed and revised totals and graphs are shown to the user. The user can make new or different choices to test effectiveness of various ESTs and try to meet the target. If the target is not met, then the user is informed accordingly so that the scheme of application of ESTs could be revised or target can be reduced Thus a number of scenarios can be generated and tested by the user.

6.1.7 VIEWING REPORTS

In this option, user gets an opportunity to view a summary of results and understand the changes in the water consumption pattern - both at individual and property levels. A histogram based comparative assessment is provided for better appreciation. The user can also obtain a report complete with relevant description of the ESTs applied. This information consists of experience on implementation of ESTs, operation and acceptability as well as pointers for additional references or reading if any.

6.1.8 ESTIMATING CITY WIDE RAINWATER HARVESTING POTENTIAL

In this option, the user provides rainfall data for the city and specifies total roof, sealed and unsealed areas. Based on this information, calculations are done to show rainwater that can be stored and rainwater that can be used to recharge the groundwater. Accordingly plans could be evolved for promoting and implementing rainwater harvesting.

6.1.9 EDITING OF THE EST DATABASE

In addition to the above four options, there is an option to edit the EST database. The EST database provided in WiseWater has been developed based on information from literature and drawing experience of several water experts. This database is used as a basis for computing water use reduction. It is possible for the User however to edit the EST-related information based on new data or to factor site specific considerations. WiseWater allows users to make such changes within "limits" and customize application. At any time the user can revert to the original or default EST database, by clicking on the Restore Default option.

6.1.10 SOFTWARE REQUIREMENTS

WiseWater is a Microsoft Excel application and uses Microsoft Word for producing reports. It will run on any system with Microsoft Office version 1997-2003 and beyond.

It is hoped that WiseWater serves as an awareness and training tool to stimulate reduction in domestic water consumption and promote the theme - "Every Drop Counts".

Chapter 7
Abbreviations and References

7.1 Abbreviations

Anamox	anaerobic ammonium oxidation
ASR	Aquifer Storage and Recovery
BAC	Biological Activated Carbon
BMP	Best Management Practice
CETA	Construction, Education and Training Authority
CLO	Community Liaison Officer
CSE	Centre for Science and Environment, Delhi, India
CSO	combined sewer overflows
DAF	Dissolved Air Flotation
DHI	Danish Hydraulic Institute
DIN	Deutsche Industrie Norm (German Industrial Standard)
DSM	Demand-side management or demand management is a complementary approach that aims to avoid many of the problems of excessive water use by reducing or capping water demand
DSM	Demand-side measures
DTIE	Division of Technology, Industry and Economics (UNEP)
Eawag	Eidgenoessische Anstalt für Wasserversorgung, Abwasserreinigung und Gewaesserschutz (Swiss Federal Institute of Aquatic Science and Technology)
ESA	Environmental Services Association
ESTs	Environmental Sound Technologies
GEC	Global Environment Centre
Hardtech	Technical infrastructure for IWRM, such as appliances, installations, equipment, machines and their accessories
IDRC	International Development Research Centre
IEIA	Institute for Ecology of Industrial Areas
IETC	International Environmental Technology Centre (UNEP-DTIE)
IHP	International Hydrological Programme
IOPSA	Alliance to Save Energy, Plumbing Institute of South Africa
IRC	International Water and Sanitation Centre
IWRM	Integrated Water Resource Management
MBR	Membrane Bio Reactors
MNF	Minimum Night Flows
NGO	Non Governmental Organization
PAC	Powdered Activated Carbon
PPP	People, Planet and Prosperity (in the framework of this publication not "Public-Private Partnership" or "Poor People Pricing"
PSC	Project Steering Committee
PURE	Planning for Urban-rural River Environments
SANCO	South African National Civic Organisation
SARAR	Self-esteem, Associative strengths, Resourcefulness (creativity), Action-oriented planning, Responsibility for follow-through (commitment)
SAT	"Sustainability Assessment of Technologies" or "Soil Aquifer Treatment"
SBR	Sequencing Batch Reactor

Softtech	Overall policies, regulations, economic instruments and management strategies which are required for the implementation of the technical infrastructure for IWRM, such as appliances, installations, equipment, machines and their accessories
SSM	Supply-side water measures or water management treats fresh water as a virtually limitless resource, resulting in a regime of water policy and practice concerned primarily with securing sufficient quantities of water to meet forecast demand. This supply-side orientation rarely takes full account of environmental or economic impacts of municipal water services
SuSanA	Sustainable Sanitation Alliance
TISS	Technologies in Sustainable Strategies
UD	Urine Diversion
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Scientific and Cultural Organisation
UN-HABITAT	United Nations Human Settlements Programme
UPE	Urban Poverty and Environment
WDM	Water Demand Management
WHO	World Health Organisation
WMS	Water management System
WSSD	World Summit on Sustainable Development

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About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

> sustainable consumption and production,
> the efficient use of renewable energy,
> adequate management of chemicals,
> the integration of environmental costs in development policies.

The Office of the Director, located in Paris, coordinates activities through:

- **The International Environmental Technology Centre** - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- **Chemicals** (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- **Energy** (Paris), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

For more information,
see **www.unep.fr**

Water use efficiency within the context of sustainable water balance in the urban and domestic sector means optimizing safe and sufficient supply and water demand while also closing the life cycle. As Environmentally Sound Technologies (ESTs) play a crucial role in this process technologies and best practices for storage, supply and distribution as well as water related policies need to be identified.

Although not an exhaustive compendium, this source book is expected to assist policy makers and water managers in identifying those most commonly used ESTs. This will also familiarize them with water related policies within the realm of water use efficiency in the urban and domestic sector considering integrated water resource management and the urban water cycle.

To facilitate computing the existing water consumption, make changes by adopting a range of ESTs and estimate possible water use reduction the Sourcebook presents "WiseWater". "WiseWater" is a tool developed in Microsoft Excel based spreadsheet which basically considers four types of ESTs approaches to reduce water leakages, reduce water use at source, allow recycling and reuse of used water, and complement or augment water resources at a property level. "WiseWater" together with information for capacity building purposes is included in the CD-ROM as part of this publication.

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