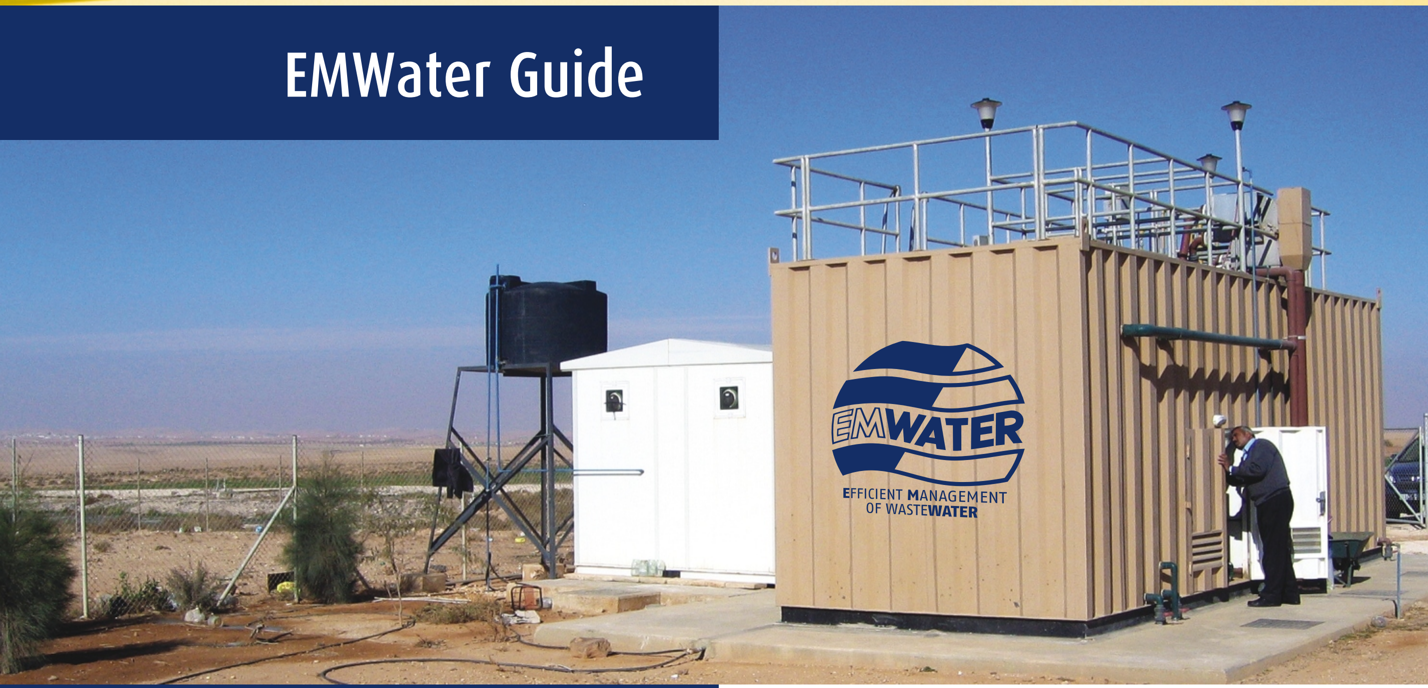

EMWater Guide

A Practical Guide for Decision-Makers

Improving wastewater treatment and reuse practices in the Mediterranean Countries

MEDA Water
inWent
Capacity Building International Germany

About the EMWater Project

Water shortage is currently one of the biggest concerns worldwide; it is becoming a global problem seriously affecting the lives of a high percentage of the world population. The Mediterranean region belongs to the most affected areas in the world. However, the situation varies significantly between different countries: while, for example, Jordan and Palestine are already seriously affected by water scarcity today, Turkey and Lebanon, on the other hand, are not likely to face water shortage for several decades. The factor common to all countries is that, in most cases, wastewater is not adequately treated, leading to deterioration both of existing freshwater resources and the Mediterranean Sea.

The different framework conditions call for different approaches to water and wastewater management - but also allow for mutual learning. The EMWater partners aim to increase awareness and the exchange of experience on innovative solutions in wastewater treatment and reuse as well as to support the installation of new technologies. Experts from the field, decision-makers, interested citizens and civil organisations are to be involved in order to sustainably prevent water shortages and water deterioration in the Mediterranean region.

Improving security and the safety of water supply in the Mediterranean countries is one of the most important factors in social, economic and political stability in the region and is, thus, the overall goal of the project.

Given the fact of water shortage in many Mediterranean countries, on the one hand, and increasing pollution of existing water resources, on the other, the EMWater project aims to improve water management in the Mediterranean partner countries through highlighting innovative solutions in wastewater treatment and promoting the reuse of reclaimed water.

With this aim in mind, awareness raising activities will sensitise experts from the field, decision-makers, interested citizens and civil organisations to these issues.

A more specific goal is the strengthening of regional co-operation both by creating networks among experts and encouraging cross-border knowledge transfer.

Additionally, the project aims to strengthen capacity through local, regional and e–learning training programmes as well as through developing draft regional policy guidelines for wastewater treatment and reuse.

While the project, which started in 2003 and ends in 2008, is limited to 60 months, its measures are designed to create long-term, positive effects in the region. The primary result of the project will be an increase in efficiency and effectiveness of wastewater management, wastewater treatment and reuse in Turkey, Jordan, Lebanon and Palestine.

The EMWater Project

EMWater – "Efficient Management of Wastewater, its Treatment and Reuse in the Mediterranean Countries" – is a mainly EU-funded project that encourages reuse-oriented wastewater management. The EMWater project promotes innovative wastewater treatment and reuse solutions in its four partner countries Jordan, Palestine, Lebanon and Turkey through:

- Trainings of staff involved in water resources management,
- Development of a guide for decision-makers and water resources planning engineers,
- Applied research and demonstration of innovative solutions by the implementation and operation of pilot plants, and
- Dissemination and awareness raising activities.

Experts from the field, decision-makers, interested citizens, and civil organisations are involved in all stages of project implementation.

Project Partners

InWEnt - Capacity Building International, Germany, an international foundation for capacity building, is the leading institution in the project consortium and contributes with its strong experience in human resources development by designing and implementing training programmes and dialogue throughout the world.

The **Birzeit University in West Bank/Palestine** has a range of institutes, centres and programmes that carry out community-oriented activities, aiming at a sustainable development of Palestine and the preparation of the younger Palestinian generation to become responsible leaders and citizens.

The **Al Al-Bayt University of Al Mafraq in Jordan** serves the local community and helps the country in solving problems of national and international concern by applying their expert knowledge in improving environmental protection.

The two Lebanese partners the **University of Balamand** near Tripoli and the **Lebanese American University** in Byblos are private, non-profit, independent Lebanese institutions of higher learning. One of key aims of both universities is to provide an intellectual, moral and cultural antidote to the long years of internal war in Lebanon.

The **YILDIZ Technical University of Istanbul** in Turkey is a Government University which defines and continues to update methods of engineering and architecture. It has a modern educational environment and a strong academic staff.

The **Hamburg University of Technology** is a young university in Germany highly regarded for the interdisciplinary and industrial orientation of its research.

ENEA, the **Italian National Agency for New Technologies, Energy and the Environment**, is one of the largest scientific and technological state-owned Italian institutions with a specific mission in applied research activities, technology transfer and dissemination of innovation to companies.

Adelphi Research, an independent, non-profit research institute, develops and implements innovative sustainable development strategies. Adelphi Research increases awareness and understanding of the political, economic and technological forces driving global change, and provides expert knowledge and advice to decision-makers at all levels of policy-making.

For more information on the initiative and its partner organisations please refer to www.emwater.org.

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🕮 This icon points you to literature and other sources with more detailed information on the respective issue.

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Title	**EMWater Guide** **Improving wastewater treatment and reuse practices in the Mediterranean countries - A practical guide for decision-makers**
Objective	**The overall objective of the EMWater Guide is to provide easy-to-understand guidance on taking decisions in wastewater management.** **Specific aims of the EMWater Guide** · Enabling decision-makers to **pre-select appropriate technologies** for wastewater treatment and reuse, while · Considering all **relevant framework conditions** and alternative solutions Taking an **integrated and sustainable** approach to water and wastewater management and planning The reader is **referred to existing literature and research results for detailed information.** The EMWater Guide will **NOT replace in depth analyses** of specific conditions and consultation of experts, once the decision to start a wastewater project has been taken.
Target groups	· **Officials and decision-makers** mainly at municipal level, including those without an engineering background · **NGOs and consultants** active in the field of wastewater management
Structure	· **Introduction** · **Part I: Guide for Wastewater Collection & Treatment** · **Part II: Guide for Water Reuse** · **Annex**
Focus	**Part I focuses on:** · small communities · small centralised systems and · small decentralised systems **Part II focuses on:** · small communities · reuse of treated municipal wastewater · water reuse for irrigation in agriculture
Methods and resources	· **Know-how and experience of EMWater project partners** · **Literature and internet research** · **Background paper on water reuse guidelines by Adelphi Research** · **Questionnaire survey on guide contents:** · 50 questionnaires filled in the MEDA partner countries · Respondents included staff at municipalities, authorities, ministries, universities, utilities, user groups, etc.

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EMWater Guide

Introduction

Introduction

Water is an essential resource for human life, for the economy and for ecosystems. However, more than 1.2 billion people still do not have access to safe drinking water and over 2.4 billion lack basic sanitation. The need to focus on this issue has been strongly affirmed by the World Summit on Sustainable Development in Johannesburg (2002) that fixed clear targets for halving this dramatic situation by 2015.

The Mediterranean region is one of the areas in the world most affected by water shortage. The Mediterranean demand for water is increasing due to continuing population growth, rising standards of living, ongoing urbanisation, increasing economic activities and the expansion of irrigated agriculture. This urgently requires significant improvements in water demand management and the substantial development of new water resources.

Furthermore, the wastewater is often not adequately treated in the MEDA (Euro-Mediterranean Partnership Programme) countries, which leads to further deterioration in the quality of the freshwater resources and in the Mediterranean Sea. This situation calls for integrated water and wastewater management systems to be particularly established in regions affected by water shortage. Such integrated systems would see the use, treatment and reuse of water as part of the same management cycle. This will help to protect the availability and quality of the freshwater resources.

Objectives and target groups

The EMWater Guide seeks to support decision-making in environment protection, wastewater management and planning of relevant projects. They consist of two parts:

Part I, "Wastewater Treatment", introduces **small-scale, centralised and decentralised treatment systems suitable for rural and suburban areas**.

Part II, "Water Reuse", focuses on **the use of reclaimed water for irrigation in agriculture and for landscaping.**

The EMWater Guide is especially meant for officials at municipal level who do not necessarily have an engineering or scientific background. Hence, the followed approach is not only about eliciting knowledge on technological or biological aspects, or the design and costs of wastewater management systems. It rather provides key criteria as a basis for decision-making processes in a condensed form and easy to understand. This will enable decision-makers to take into account all relevant framework conditions, consider alternative solutions for, and costs of, their projects, and to select the appropriate technologies for wastewater treatment and reuse.

The EMWater Guide also provides lists of references and other sources of information that may support the successful development, implementation and operation of wastewater projects. Hence, this publication will also be useful for other stakeholders, such as NGOs, consultants active in the field, or authorities at national level.

It should be noted that the EMWater Guide does not replace in-depth analyses of existing framework conditions, feasibility studies, tariff-setting and other surveys. Moreover, it remains crucial to involve experts and consultants active in the relevant fields to ensure a successful development and implementation of the wastewater projects.

The Guide draws on the results and know-how accumulated under the EMWater project in the four Mediterranean partner countries Jordan, Palestine, Lebanon and Turkey.

EMWater recommendations on wastewater treatment and reuse

Based on research, studies and project work, the EMWater project team has developed the following basic recommendations regarding the implementation of wastewater treatment and reuse systems:

- Local water management should take a long-term perspective giving preference to the protection of scarce water resources and develop sustainable wastewater treatment and reuse projects accordingly.
- Decentralised wastewater treatment systems should always be given preferential consideration, since sewerage networks costs account for up to 80% of total wastewater treatment costs.
- Operation and maintenance costs, including energy costs, should be calculated with care when selecting a wastewater treatment technology.
- Setting up a schedule of treated wastewater/reclaimed water charges may serve to recover the costs of operating and maintaining the wastewater treatment system.
- Consider appropriate technology for wastewater treatment. High technology does not always represent the best option. Make sure to have the financial and human capacities necessary to properly operate and maintain the facilities.
- Consider the options of source separation: domestic versus industrial wastewater, rainwater runoff versus greywater versus blackwater.
- Water reuse has major benefits, since it means protected freshwater resources, lower costs for wastewater treatment and fertilisers, and possibly an increase in agricultural production (see Chapter II.2).
- Effluent quality objectives: Nutrient (nitrogen, phosphorus) removal is not always necessary, when the treated wastewater is meant for reuse in agriculture or aquaculture. However, pathogens and suspended solids removal as well as biodegradation of organic matter are prerequisite for the reuse of water in agriculture.
- Ensure that groundwater aquifers are not contaminated through seepage of reclaimed water. This includes taking into account seasonal fluctuations in nutrient requirements of crop plants.
- Market assessments are needed as to whether the usage of reclaimed water and the farm-goods produced are accepted and economically feasible (see Chapter II.3).
- Additional expenditures for transfer, storage, distribution and drainage need to be considered when planning a water reuse project.
- Microbiological water quality standards are only one way to prevent health risks. Other measures such as crop restriction and human exposure control should also be taken into account (see Chapter II.4).
- Regulations for water reuse should not be too strict in order to promote sustainable reuse practices (see Chapter II.4).
- Any legal standards to regulate water reuse need to be adapted to local conditions: They should be affordable, achievable and enforceable (see Chapter II.4)
- Awareness raising is a major issue in water reuse projects. Campaigns for farmers and consumers should be included already at project planning stage (Chapter II.5)
- Water reuse can be demonstrated and promoted by subsidising pilot projects that can be visited by local farmers, decision-makers and the interested public.

Short review of the current situation in Jordan, Palestine, Lebanon and Turkey

Fresh water availability differs significantly between the four countries: While Jordan and Palestine are already seriously affected by water scarcity, Turkey and Lebanon do not face water shortages in general today. In Jordan, water shortage is currently one of the biggest concerns of the water authorities. Many groundwater resources are overexploited and are expected to be exhausted within a few decades. In Palestine, groundwater is the only substantial and most used – partly renewable – water resource. In contrast, Lebanon and Turkey are still classified as water-rich countries, but are likely to face water scarcity within the next decades. In Turkey, the water availability and quality varies strongly from region to region.

Agriculture is by far the largest consumer of water in the region, accounting for around 70 percent of water usage, followed by domestic and industrial usage. While the demand for irrigation water continues to grow, irrigation also offers the highest potential for water reuse applications. In fact, in a number of arid and semiarid countries worldwide reclaimed water already provides the greatest share of irrigation water (Kanarek and Michail 1996).

Wastewater treatment

In Lebanon and Palestine, the wastewater is largely discharged into the environment with little or without treatment, which seriously endangers existing and future irrigation and potable water sources. Conversely, wastewater treatment has been given priority in Jordan for many years. Today more than 60 percent of the Jordanian population is connected to sewage systems. In Turkey, wastewater treatment has improved considerably in recent years. Many modern treatment plants have been built and further plants are under construction. In all four countries, several decentralised, small-scale wastewater treatment systems have been installed in rural areas in recent years. Most of them provide secondary treatment resulting in a water quality suitable for irrigation or other reuse applications.

Water reuse

Jordan's desperate need for water has necessitated the reuse of treated wastewater in agriculture for many years. In the other three countries the application of direct water reuse is very limited to date. In Palestine, the authorities recognise the high potential of water reuse highlighting its role as a valuable resource that must be authorised and utilised, but until today only a few demonstration projects exist. In Turkey, numerous bureaucratic formalities restrict water reuse application in agriculture, while cheap irrigation water with limited quality control is offered to farmers. However, due to the rapidly developing tourism sector, water reuse for landscape irrigation and other purposes is gaining more and more importance.

The failure to promote water reuse in the region is mainly due to socio-cultural, technical and financial particulars. Moreover, insufficient planning of projects, inadequate laws and regulations and their poor enforcement most likely entail opposition to water reuse systems.

Legislation on wastewater treatment and reuse in Jordan, Palestine, Lebanon and Turkey

While Turkey and Jordan have adopted quality standards for wastewater treatment and reuse, Palestine and Lebanon are still awaiting the enforcement of wastewater treatment standards and the adoption of reuse standards. In the following details regarding the legal situation in each country are given:

Wastewater treatment regulations

Country	Regulation
Jordan	Standards exist that specify the conditions for discharge of domestic and industrial wastewater effluents: The Jordanian Standard JS 893 of 2006 specifies the conditions that domestic wastewater discharged from wastewater treatment plants should meet. The Jordanian Standard JS 202 of 1991 specifies the standard requirements and conditions that industrial wastewater effluents should meet for discharge.
Palestine	Minimum effluent quality standards (Environmental Limit Values – ELV) have been recommended by the Environment Quality Authority (EQA) and have been adopted by the Institute of Palestinian Standards: The standard for industrial wastewater discharge into the municipal sewage system relates to the pre-treatment targets for industrial wastewater to protect the sewage system infrastructure and the receiving natural environment. The standard for the discharge of domestic effluents into the sea within national waters relates to the maximum allowable limits of discharge into the sea. However, the standards are yet to be enforced.
Lebanon	Minimum standards to regulate the discharge of wastewater exist, but are not fully enforced. As to the discharge of industrial wastewater, Article 11of Decree No. 2761 (of 1933) rules that “industrial wastewater should not be discharged in sewer lines without the permission of the Directorate of Health, and after it is adequately treated”.
Turkey	In the process of Turkey joining the EU, a lot of efforts are made to prepare the adoption of EU standards and specifications in water and wastewater works: The Environmental Law (1983) and the Water Pollution Control Regulation (1988) set minimum effluent standards for industrial and domestic wastewater to be discharged depending on the size of the settlement and the sensitivity of the receiving waters. The Water Pollution Control Regulation Technical Instructions (1991) contain wastewater quality standards for effluents to be discharged into the sea.

Water reuse regulations

Country	Regulation
Jordan	The Jordanian Standard JS 202-1991 from 1991 deals with "Industrial Wastewater Effluent Standards". It is purposely set to specify the standard requirements and conditions that the industrial wastewater effluent should meet in order to be discharged into surface water or into naturally recharged groundwater aquifers, or to be reused for irrigation purposes. The Jordanian Standard JS 893/2006 from 2006 deals with "Reclaimed Domestic Wastewater". It specifies the conditions that effluents from wastewater treatment plants should meet in order to be discharged into streams, wadis or water bodies or to be used for artificial groundwater recharge and for irrigation purposes. The JS 893/2006 does not stipulate the water quality of streams or wadis after the reclaimed water is discharged and blended with the receiving water. Therefore, the Reclaimed Water Project (RWP) initiated a national interdisciplinary working group that elaborated a proposal for irrigation water quality guidelines based mainly on the guidelines of the FAO (Ayers and Westcot 1985) and the WHO (1989). The proposal was approved by all relevant national authorities in 2004 and distributed and applied during 2005. Meanwhile, the proposal was reviewed and amended.
Palestine	There are a standard for water reuse for restricted and unrestricted irrigation and a standard for water reuse for groundwater recharge (by infiltration). However, the standards are yet to be enforced.
Lebanon	Guidelines for water reuse do not exist.
Turkey	The "Water Pollution Control Regulation (WPCR)" (1988) encourages the use of treated wastewater for irrigation purposes in areas where water shortage is of concern and wastewater is an economic asset. Consumers need to obtain a written permission from the relevant government organisations and are obliged to comply with the standards published in the "Technical Aspects Bulletin (WPCR-TAB)" of 1991.

➔ For further details and selected limit values for water reuse in Jordan, Palestine and Turkey please refer to Annex I: Information on existing legal frameworks.

📖 A detailed review of the water policies and the institutional framework in Jordan, Palestine, Lebanon and Turkey can be found in the country profiles of the MEDA Water project MEDAWARE.

Further reading

📖 From Wastewater Reuse to Water Reclamation: Progression of Water Reuse Standards in Jordan (McCornick P.G., Hijazi A., Sheikh B. 2004)

📖 Standards, Regulations & Legislation for Water Reuse in Jordan. Water Reuse Component, Water Policy Support Project (Sheikh, B. 2001)

📖 European Standards dealing with water, wastewater and reuse, e.g. CEN TC 164: Water Supply; CEN TC 165 Wastewater Engineering; CEN TC 230 Water Analysis; EN 1085: Wastewater Treatment Vocabulary; EN 12255 Wastewater Treatment Plants.

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EMWater Guide

Part I: Wastewater Collection and Treatment

Index:

I.1 Introduction - Wastewater collection and treatment

Wastewater treatment systems for small communities are a matter of concern to every country. They represent the majority of the existing treatment plants subjected to high seasonal and even daily variations in wastewater flow and load on the one hand and on the other need to be easy to manage and to operate.

Both wastewater collection and treatment should be considered within a regional planning process to ensure long-term sustainability under various conditions (see ➔ textbox "Regional Planning for Efficient Wastewater Management"). Especially in rural/agricultural areas, treated wastewater that is provided in reliable quality and quantitiy is valued as a precious resource (agricultural reuse).

The following criteria are considered to be most important to achieve sustainability in wastewater collection and treatment in suburban and rural areas of the MEDA countries (Wendland et al. 2007):

- Affordability: especially low construction and operation costs;
- Operability: by use of local operational know-how;
- Reliability: producing an effluent suitable for safe water reuse
- Environmental soundness: e.g. little sludge production and low energy consumption
- Suitability in Mediterranean climate (the average wastewater temperature e.g. in Istanbul varies from 23°C in July to 15°C in January)

There is not an adequate classification to discern suburban and rural areas, as the threshold population usually varies from 2,000 up to 5,000 or even 10,000 PE. However, such formal classification will not affect the possible wastewater treatment options to be addressed in the EMWater Guide, which will focus on small communities obliged to develop appropriate treatment and water reuse strategies (see e.g. Article 7 of the EU Council Directive 91/271/EEC of 21 May 1991 on urban wastewater treatment).

They will assess the most relevant options as to their feasibility in small-scale wastewater treatment systems, with a view to achieve sustainable sanitation in both centralised and decentralised wastewater management systems. The main objective is to provide an overview of different wastewater collection and treatment systems, as well as to discuss their strenghts and weaknesses with a special reference to low-cost and easy-to-manage treatment techniques.

It is important to note that efficient wastewater management should be incorporated in rural, urban, and settlement planning to ensure that adequate technologies for wastewater supply, sanitation, stormwater drainage, rainwater harvesting and flood control are selected. Furthermore, modern planning and implementation processes demand to encourage public participation and acceptance of, e.g., the systems and tariffs.

The first section of this part of the EMWater Guide provides guidance for the decision "decentralised versus centralised", as this is the first step for town-planners and decision-makers to take. Then, a general overview of the most feasible technology options for the different possible scenarios is provided. A brief description of the wastewater treatment options will be given, with emphasis on aspects and parameters affecting the selection of the appropriate treatment system and most relevant framework conditions to be considered (e.g. as to quality of effluents). In the final part, the process of selecting and implementing an appropriate small wastewater treatment system is discussed.

Regional planning steps for efficient wastewater management

1. Reducing wastewater flows through demand management measures and efficient water usage policy (raising public awareness for water efficient household installations, water saving toilets, etc.)

2. Keeping rainwater and wastewater separate, unless the runoff is contaminated (e.g., if received from first flush systems, roads with heavy traffic, industrial sites); rainwater infiltration through the top soil with groundwater aquifer recharge and reuse where possible (rainwater harvesting)

3. Considering separate treatment of industrial effluents where appropriate

4. Comparing central, communal or decentral solutions through dynamic cost comparison

   - Types of sewers: gravity, simplified, solids free, pressure, vacuum

   - Pre-treatment options: sedimentation units, Imhoff tanks, UASBs (if temperatures above 20° C all year), pre-composting tanks

   - Aerobic treatment options: activated sludge systems, trickling filters, rotating biological contactors, membrane bioreactors (good for ww-reuse), constructed wetlands, ponds (mosquito control)

   - For better effluent standards: post treatment with bio-filters, membrane-filtration, constructed wetlands

5. Checking local or regional water reuse options: agriculture (adjust for nutrients), industry, aquifer recharge where appropriate

6. Managing construction and operation, building capacity, verifying quality at any step

7. Assuring finance through water charges and reinvestment according to life expectancy and actual technical state, including verification of cost recovery into management cycle

I.2 Wastewater collection

The planning work should take a holistic approach to wastewater discharge, treatment and reuse. Any decision in favour of a specific technical option in the early planning phase will strongly influence the amount of both investment and operating costs. In this regard it is interesting to know that wastewater collection conventionally accounts for 50 – 80% of the total costs for wastewater disposal or reuse (see Figure 1 and Bode and Grünebaum 2000). Additional treatment steps to meet irrigation standards, such as a disinfection system, have to be calculated separately.

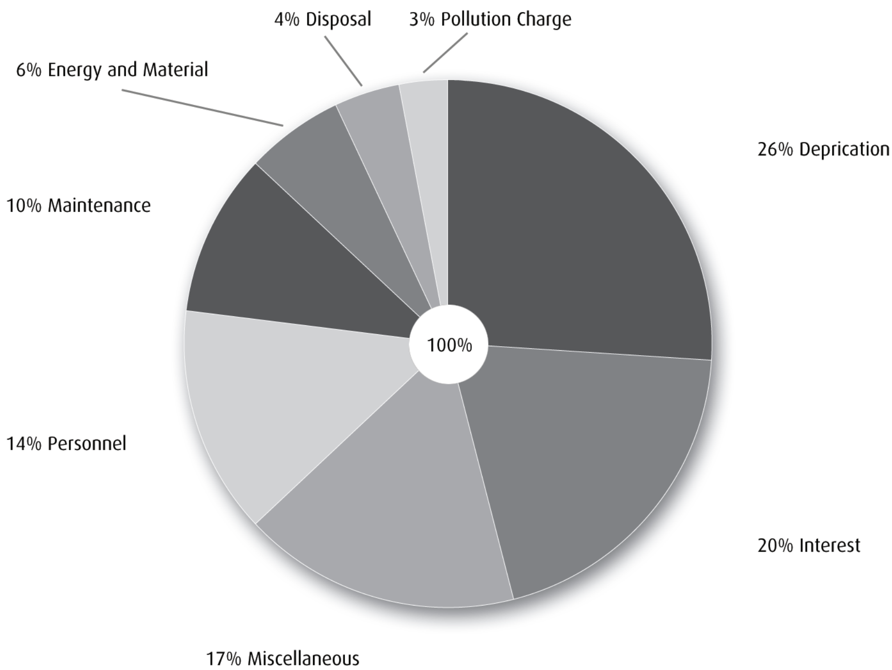

Figure 1 - Composition of total annual costs for conventional centralised wastewater collection and treatment systems in Germany. Source: Bode and Grünebaum 2000

Centralised wastewater management represents the conventional approach in many countries. It is characterised by the collection and removal of sewage and stormwater by means of sewers to a central advanced and intensive treatment plant where the wastewater and sludge are treated and disposed of under controlled conditions.

The **advantage** of this management concept is assumed to be lower investment and operational costs incurred by a single large treatment plant as compared to several small-scale plants as well as a more effective control of quality standards and plant operation procedures.

However, a number of **disadvantages** entailed with this management concept are speaking against a centralised wastewater management option as the universally applicable solution:

- The costs/benefits ratio of central systems may be less favourable if construction and maintenance costs of the collection system are taken into account.
- An extensive sewerage pipe system may leak and cause contamination of soil and groundwater, if not adequately maintained.
- Central treatment systems will most likely require (multiple) pumping stations.
- Central treatment systems usually require intensive aeration which may increase operation costs in exceedance of the local financial resources capacity.
- Central municipal treatment plants reduce opportunities for water reuse and sludge reclamation, due to their high load of harmful substances, such as chemicals, pharmaceuticals, heavy metals, and pathogens (especially when also industrial wastewater is collected).
- Effluent reuse from centralized treatment plants will most likely necessitate the realisation of an extensive centralised pipe system to distribute the reclaimed water. This means tremendous investment costs and/or a limited accessibility for potential beneficiaries (farmers).

This given, the choice of the suitable public sewerage and treatment system is an important task, especially since there is a variety of alternative systems available (see Table 1).

Table 1 – Types of sewerage systems and their characteristics

Type of system	Characteristics
On site system (no sewerage system)	• sparsely populated and/or difficult site conditions for sewerage • rainwater infiltration locally • cost efficient as no central sewerage is required • operation and maintenance to be done on site by, e.g., public services • requires public and private rights and obligations properly identified
Wastewater sewer	• rainwater infiltration locally • surface runoff
Separate sewerage (wastewater and rainwater sewers)	• in principle more suitable than combined sewerage but more costly • entails a non-negligible risk of wrong connections
Combined sewerage	• entails risks of pollution in case of rainwater flushes

Type of sewerage	Advantages	Disadvantages
Free water level sewerage		• exfiltration possible
Pressurised sewerage	• small diameter pipework • narrow trenching, shallow excavations	• technically complex • high energy consumption • exfiltration possible
Vacuum sewerage	• small diameter pipework • narrow trenching, shallow excavations • no exfiltration	• technically most complex • high energy consumption
Simplified sewerage	• minimum pipe length • minimum gradients • small diameter pipework • less inspection manholes • less trenching and excavations	• exfiltration possible
Settled (or solids free / small bore) sewerage	• a possible option where septic tanks exist • minimum gradients • small diameter pipework	• require septic tanks to be emptied and cleaned on a regular basis

In recent years, increasing attention has been given to decentralised wastewater management (DWM) concepts that are already applied in many countries, particularly in rural areas. By definition, DWM employs collection, treatment and disposal/reuse of wastewater from small communities (from individual homes to portions of existing communities) integrated in village/town development projects. Such approaches consist of many small wastewater treatment facilities designed and built locally, usually applying low-tech solutions (septic tanks or natural systems like ponds or constructed wetlands) and only rarely adopting advanced technical solutions.

Decentralised systems maintain both the solid and liquid fractions of the wastewater at or near the point of origin and, hence, minimise the wastewater collection network. In development situations, this approach offers a high degree of flexibility, allowing modifying the design and operation of the DWM system to suit various site conditions and scenarios.

Decentralised systems offer many advantages in that they

- save money in terms of investment costs and operation and maintenance costs regarding the sewage system,
- entail protection of water resources and less polluted wastewater runoffs and, hence, improve watershed management options,
- offer an appropriate solution for low density communities and
- provide effective solutions for environmentally sensitive areas.

The main arguments against decentralisation of wastewater management are based on financial concerns and issues of treatment efficiency.

Concerns against the decentralised approach are based on issues of treatment efficiency, such as low effluent quality (rarely allowing for safe water reuse), inadequate plant operation and the risk of groundwater pollution. In order to overcome these problems, **new concepts** have been introduced in recent years, based on

- an *integrated view* of the whole water cycle from water consumption to treatment and reuse of wastewater with focus on a local scale and a long-term perspective;
- the *separate collection* and treatment of different wastewater streams;
- the *recovery* of valuable substances for reuse by private or public beneficiaries.

This approach may represent a valuable option to minimise the demand for fresh water, which is of particular concern in water-scarce areas where local groundwater is not used as a source for drinking water.

With respect to municipal applications, four categories of wastewater streams are classified:

- Black water: wastewater containing faeces (the outlet from flushing toilets) or from kitchen sinks
- Yellow water: wastewater containing mainly urine (the outlet from separation toilets and urinals)
- Grey water: wash water from bathrooms and washing machines
- Rain water: water collected on impermeable surfaces

Black water and kitchen refuse contain much organic matter and conversion into biogas via anaerobic treatment appears to be attractive. Black water is of major concern with respect to health risks (pathogens and pharmaceutical residuals). Yellow water contains high amounts of nitrogen and phosphorus and could be used as a source for fertilizer production. Grey water can be purified relatively easily and used for reuse purposes, such as flushing toilets, cleaning, and irrigation.

The available wastewater systems offer different methods of separate wastewater collection and subsequent treatment: For example, separation or not of black and yellow water; harvesting or not of stormwater from roofs and driveways for subsequent reuse.

Developing sustainable water management concepts means to optimise and integrate water supply and sewage/wastewater disposal and reuse. Water service providers and communities have to coordinate their efforts to the benefit of the consumers.

I.3 Small treatment systems serving rural centers and peri-urban areas

Small wastewater treatment systems are particularly designed to cope with small-scale wastewater flows. Such systems typically rely on biological processes to degrade and remove organic matter. Many of the small systems are cost-effective because they utilise natural processes, rather than mechanical or chemical treatment processes.

Technologies (for secondary treatment) described below are intended to be applied in small communities. All the systems will be briefly characterised to provide basic information about their treatment principles as well as the typical features and requirements.

A review of tertiary treatment options (with focus on effluent reuse) is provided in the end of this chapter.

In Table 11, the most relevant characteristics of each treatment option are qualitatively evaluated as a basis for decision-makers.

🕮 Further details on treatment techniques and costs are given in Bode and Grünebaum 2000, Lens et al.2001.

I.3.1 Extensive systems

Extensive systems are characterised by lower surface loads than other (so-called intensive) systems. They carry out the wastewater treatment using fixed film microbiological cultures on small media or suspended growth cultures which use solar energy to produce oxygen by photosynthesis.

Consequently, it is possible to operate this type of facility without electricity, except for aerated lagooning for which an energy supply is required in order to power the aerators or air blowers.

In the following, the most widespread fixed film cultures (Constructed Wetlands, Land Based Treatment Systems) and suspended growth cultures (Waste Stabilisation Ponds, Aerated Lagoons) will be described.

I.3.1.1 Constructed wetlands

Constructed Wetlands (CWs) can be classified as extensive or lower-intensity techniques, although there are system configurations (Sub-Surface Flow Systems) where higher surface loads can be applied. In any case, if enough ground space is available, CWs can be also applied in large communities.

CWs are artificial areas similar to natural wetlands that are flooded or saturated by surface or sub-surface flow systems at a frequency and duration sufficient to maintain water-saturated conditions. The purification process relies upon bacteria for the degradation of organic substances and upon plants for uptake of nutrients. Adsorption on the substrate, according to the characteristics of the media, or by plants is also an important treatment mechanism with regard to removal of nutrients, heavy metals and organic compounds.

If properly designed and operated, effluents of CWs can reach a treatment quality comparable to those of secondary or tertiary effluents, making them suitable for discharge into surface water bodies or for water reuse applications. An efficient pre-treatment facility (e.g. Imhoff tank) is needed to remove the bulk of suspended solids to avoid clogging problems.

Two CW systems are distinguished:

- **Free Water Surface (FWS) Systems**, typically consisting of basins, trenches or channels, provided with a natural or artificial subsurface barrier to prevent wastewater seepage, soil or another suitable medium to support the vegetation, and water at relatively shallow depth flowing over the soil surface. Effective pre-treatment and a continuous influent distribution system are required to reduce total organic loading and prevent mosquito problems.
- **Sub-Surface (SS) Flow Systems** with the water to be purified flowing below the ground surface through sand or gravel.

  Depending on the flow direction, the following types of systems can be found:

  - **Horizontal Flow (SS-HF) Systems** typically consist of a trench or a bed underlain by impermeable material and containing a medium (rock or crushed stone, d = 10-15cm) to support the vegetation. The wastewater flows in a more or less horizontal direction through the medium and is purified during the contact with the surfaces of the medium and the root zone of the vegetation.

  When applied as secondary treatment, nitrification is limited with this type of applica tion but denitrification is very effective.

  - **Vertical Flow (SS-VF) Systems** in which the wastewater to be treated is distributed vertically over the surface via pumps or siphons, and is subject to a physical (filtration), chemical (adsorption, complexing, etc.) and biological (biomass attached to small media) treatment. Oxygen is supplied by convection and diffusion.

    Discontinuous and uniform distribution has to be provided, thus requiring the filtering surface to be separated into several units which makes it possible to establish batch conditions in each plant. Filter media is made up of several layers of gravel or sand with a variable grading.

    When applied to larger capacities (> 2000 PE) SS-VF systems require a very delicate control of hydraulics and a more regular operation and maintenance (reeds cutting, manual weeding before reeds predominate).

    According to treatment needs, different configurations of HF and VF in series or parallel can be used.

The main operational parameters of each type of CW are summarised in Table 2.

SS-HF systems, for incoming concentrations of 50-200 mgBOD_5/l, and for a sizing of 3-5 m^2/PE, can result in a reduction of 70-90% in terms of BOD_5. For incoming wastewater with 300-600 mgBOD_5/l, systems sized with 10 m^2/PE can remove approx. 86% of BOD_5 and SS, 37% of TKN and 27% of P_{TOT}.

SS-VF systems can ensure the following effluent standards: BOD_5 < 25 mg/l; COD < 90 mg/l; TKN < 10 mg/l; pathogens reduction 10 to 100 fold.

Table 2 – Operational Parameters of Constructed Wetlands (own compilation from Bode and Grünebaum 2000, International Office for Water 2001, Reed et al. 1995)

	Free Water Surface (FWS) CWs	Sub Superficial – HF	Sub Superficial – VF
Water depth [cm]	< 10 (in warm climates) < 45 (in cold climates)	> 50-80 cm for root penetration	> 80 cm (at least 40 cm for drainage)
Media Depth [cm]		> 50-80cm for root penetration	> 80cm (at least 40 cm for drainage)
Organic Load [$gBOD_5/m^3d$]	< 11		Total: 20 – 25 (1^{st} stage 60% - 2^{nd} stage 40%)
Hydraulic Load [mm/d]	14-47	< 50	< 30-60 (each filling < 10 litres/m^2 d)
Required surface for solids and organics removal [m^2/PE]	> 20	5 (input 150-300 mg BOD_5/l) 10 (input 300-600 mg BOD_5/l) 0.5 (storm sewage overflows)	2 – 2.5 depending on the type of wastewater (1^{st} stage 1.2-1.5 – 2^{nd} stage 0.8)
Actual detention time [d]	2-5 (BOD_5) 7-14 (N)	3-4 (BOD_5) 6-10 (N)	
Water Surface/ Plant Surface ratio	0.3 for organics removal (0.4-0.6 for nutrient removal)		
Aspect ratio L/W	3:1 needed to approach plug flow conditions	from 0.5:1 to 3:1	

Main Advantages	Main Drawbacks
• site location flexibility • absence of noise pollution • no alteration of natural wetlands • process stability under varying conditions • simple O&M (no highly qualified personnel needed, limited sludge management) • lower construction and operating costs (low energy consumptions, according to topography)	• much ground space needed • risk of mosquitos growth • possible start-up problems in establishing the desired plant species

📖 More information can be obtained at the following websites:
http://www.epa.gov/owow/wetlands/watersheds/cwetlands.html and
http://www.bodenfilter.de/engdef.htm

I.3.1.2 Waste stabilisation ponds (natural lagoons)

In waste stabilisation ponds (WSP), wastewater treatment is ensured thanks to a long retention time in several watertight basins placed in series. The use of WSPs is effective at removing BOD_5 and SS as would occur in traditional mechanical systems. Residence time is longer (in the order of days) than in other treatment systems (in the order of hours for activated sludge) allowing for the natural reduction in pathogenic organisms.

Lagoons are shallow excavations of around 1 to 1.5 m in depth. They are commonly arranged in a series (of at least three ponds) in which wastewater flows from one pond to the next by gravity. The pond base should be impermeable with a soil permeability of 10^{-7} m/s or less, accomplished by the sediment on the pond base (after a certain time) or by a plastic liner or clay barrier.

WSPs are characterised by high daytime dissolved oxygen concentrations (produced by algal growth) which allows the development and maintenance of aerobic bacteria. These bacteria are responsible for the decomposition of the organic matter and the rapid reduction in pathogens. Hydraulic retention times basically depend on the seasonal temperature, varying from 25-40 days when the temperature is higher than 15° C to more than 80 days when the temperature is close to 0° C. Consequently, much ground space is required (about 4-12 m^2/PE of total surface area), corresponding to a daily surface load of 2.0-4.5 $gBOD_5/m^2$ d. Precipitation and evaporative losses have to be taken into account when planning the design and size of the lagoon and calculating performance targets.

Removal efficiency obtained with WSPs is 65-85% for COD and 75-85% for BOD_5; systems combined with polishing ponds can eliminate 65% of nitrogen.

There are three main types of WSPs:

- Anaerobic ponds, usually classified as *first treatment stage*, removing BOD_5 and SS. Water depth (2-5 m) and high organic loads (200 – 400 $gBOD_5/m^3$ d) ensure anaerobic conditions. In temperate climates septic or Imhoff tanks or UASB reactors can be used for the same purpose.
- Facultative ponds, usually classified as *second treatment stage*, with a water depth of 1.5 - 1.8 m, aerobic conditions exist in the upper layers (maintained by algal growth) and anaerobic conditions in the deeper layers.
- Maturation ponds, usually classified as *tertiary treatment stage,* aerobic conditions are maintained throughout the entire water column, usually used to reduce pathogen levels. Typically used as the final stage located downstream from the anaerobic and facultative ponds.

Engineers should always consider waste stabilisation ponds as a treatment option by virtue of their low construction and operating costs, good process reliability and simple operation and maintenance, excellent performance results, especially with respect to the elimination of pathogens.

Main Advantages	Main Drawbacks
• low cost • simple construction • good removal of COD and nutrients • excellent pathogens elimination • ability to treat a variety of wastes • low O&M requirements • low sludge production • simple land reclamation	• much ground space needed • capital costs depend on the type of substratum • discharge quality varies according to season

📖 More information can be found at the website:
http://www.personal.leeds.ac.uk/%7Ecen6ddm/MProdIndex.html

I.3.1.3 Aerated lagoons

Suspended growth aerated lagoons consist of completely mixed and suspended growth activated sludge systems, made of relatively shallow earthen basins varying in depth from 2 to 5m, provided with mechanical aerators on floats or fixed platforms.

Roughly, a surface area between 1.5 to 3 m^2/PE must be planned for.

The principal types of suspended growth lagoon processes can be classified as follows:

- facultative partially mixed (50-200 mgTSS/l, SRT more than 100 d, HRT = 4-10 d)
- aerobic flow-through with partial mixing (100-400 mgTSS/l, SRT = 3-6 d, HRT = 3-6 d)
- aerobic with solids recycle and nominal complete mixing (1500-3000 mgTSS/l, SRT = 15-30 d depending on climate, HRT = 0.25-2.0 d)

Usually, one or more separate settling lagoons are required (two basins allow to be by-passed separately for cleaning operations). For the settling stage, a surface area of 0.6-1 m^3/PE and depth of 2-3 m must be planned for. Aerated lagoons can be placed after the anaerobic stage with recirculation to ensure denitrification or at the first stage of treatment after the screening and grit removal units.

Main Advantages	Main Drawbacks
• simple O&M consisting of regular overall cleaning • very good removal of COD, nutrients and pathogenic organisms • low sensitivity to hydraulic and/or organic fluctuations • production of stabilised sludge	• much ground space needed • high energy consumption • capital costs depending on the type of ground • lower performance than other intensive systems

Anaerobic lagoons have been used for high-strength industrial wastewater. HRT varies from 20 to 50 d with lagoon depths of 5-10 m. Reactors usually have a floating geomembrane cover sealed to the reactor perimeter, thereby allowing for biogas collection and odour control. Anaerobic lagoons are an option for primary treatment.

I.3.2 Intensive systems

In the following, basic information regarding the building technical characteristics, design parameters of, and technical-operational notes on, intensive systems are provided.

I.3.2.1 Imhoff tanks

Imhoff tanks are septic tanks suitable for the sedimentation of solids as well as for digestion by anaerobic or facultative bacteria.

Imhoff tanks consist of a two-stage septic system where the sludge is digested in a separate compartment. This avoids mixing digested sludge with incoming sewage. The shape of the tank must be designed to maximize the detention time of the wastewater. Wide and shallow tanks, made of concrete, polyethylene or fiberglass, are preferable for the process, for tank installation and safe operation.

The tank design must include provisions for adequate storage. Biological treatment efficiency is linked to detention time, ranging from 36 to 48 hours.

To avoid leach field failures it is recommended to inspect the tank at least once a year, and to pump out the sludge that might have accumulated at the bottom of the tank.

I.3.2.2 Biofilm systems

Biofilm systems – also known as fixed film or attached growth systems – use thin films of bacteria being attached to a solid surface. The most common biofilm systems are Biofilters and Rotating Biological Contactors (RBCs).

I.3.2.2.1 Biofilters

Biofilters should be preceded by primary clarifiers equipped with scum and grease collecting devices or other suitable pre-treatment facilities, in order to avoid clogging media problems. The operating principle of a biofilter consist in running pre-treated wastewater through a bed of porous stone or open plastic material (variable size 10/50 mm to 20/60 mm) that provides a support for purifying microorganisms.

Biofilters can be operated under anaerobic or aerobic conditions. Anaerobic biofilters are efficient in reducing up to 75% of BOD_5, especially if preceded by a settling unit (septic tank) upstream. In aerated filters, aeration is carried out by natural or by forced ventilation. Wastewater is fed in by rotary distributors or fixed-nozzle systems to ensure a uniform flow distribution over the entire surface of the filter media. The floor of the filter has to support the underdrainage system (> 30 cm high), the filter media, and the water load. Filter bed thickness of about 80 cm is sufficient. Sludge recycling is usually not needed.

Biofilters are designed according to a systematic approach and experiences from existing plants. The treatment efficiency depends exclusively on the organic volumetric loading rate and the hydraulic surface loading rate, as shown by the design criteria for trickling filters applied in Germany (see Table 3).

Table 3 – Design criteria for trickling filters used in Germany (Reed at al. 1995)

Load category	Low	Moderate	Normal	High
Organic Loading Rate [$gBOD_5/m^3d$]	200	200 – 450	450 – 750	> 750
Hydraulic Loading Rate [m/h]	Approx 0.2	0.4 – 0.8	0.6 – 1.2	> 1.2
Treatment Efficiency [%]	92 ± 8	88 ± 12	83 ± 15	75 ± 20
Effluent Concentration [$g\ BOD_5/m^3$]	< 20	< 25	20 – 40	30 – 80

Since no mechanical devices are installed (possibly except a loading pump), the system is easy to operate. All distribution devices, underdrains, channels and pipes should be installed in a way to facilitate easy maintenance, flushing or draining.

Main Advantages	Main Drawbacks
• high removal efficiency for BOD_5 (<25 mg/l) and SS (<30 mg/l) • surface area needed is much less than in natural lagooning	• effective primary settling is required • high sensitivity to hydraulic fluctuations • filter media must be carefully defined to avoid clogging problems

I.3.2.2.2 Rotating biological contactors

Rotating Biological Contactors (RBCs) consist of a biological attached growth treatment system made of a semicircular section basin (not exceeding 3.5 m in diameter) in which a cylindrical rotating media is submerged (at least 40% of the total media surface area). Media materials are usually plastics, suitably corrugated for stiffness and spacing to make them suitable and durable for the growth of attached biofilm on media surface.

During RBC operation, microorganisms develop on the media surface to form a film of 1-5 mm thickness. Biofilm stripping occurs naturally, due to the media rotation, but can also be promoted by aeration systems.

Staging of RBC media (at least two stages per flow path) is recommended to maximize removal of BOD_5 and ammonia nitrogen (NH_3-N). For a discharge objective of 35 mg BOD_5/l, an organic load of approximately 9 gBOD_5/m^2 d has to be applied after primary settlement. Other parameters that can be taken into account for RBCs design are the following (Bode and Grünebaum 2000):

m^2/PE	3	2	1	0.5
BOD_5 removed [%]	95	90	80	<80

The process is simpler to operate than activated sludge, since recycling of effluent or sludge is not required. Special consideration must be given to recycling supernatant from the sludge digestion process to the RBC's.

Preliminary treatment ahead of RBC units has to include primary sedimentation and oils and grease removal in order to ensure the continuous effectiveness of RBCs treatment.

Main Advantages	Main Drawbacks
• low energy consumption • simple operation requiring less O&M and monitoring than activated sludge • lower sensitivity to load variations	• capital costs higher than activated sludge • sensitivity to clogging • lower performance than activated sludge

I.3.2.3 Activated sludge systems

Activated sludge systems consist of the following basic components: a biological reactor, where microorganisms are mixed and aerated; a liquid-solid separation, usually in the form of a clarifier; a recycle system for returning solids (i.e. biomass) into the biological reactor. Numerous process configurations of conventional activated sludge processes have been introduced. Besides aerated lagoons or waste stabilisation ponds the following are commonly applied in small communities:

- Extended Aeration systems
- Sequencing Batch Reactor (SBR) systems

Activated sludge systems can achieve high removal efficiency: up to 90% of COD and 95% of BOD_5. However, a serious drawback of conventional activated sludge systems is the high production of sludge that must be thickened and eventually stabilised. This entails high cost for disposal and risks for the environments.

I.3.2.3.1 Extended aeration systems

Extended aeration systems are a process variant to the activated sludge technology that is operated at a low organic load and at a corresponding high sludge age which allows for the production of only small amounts of stabilised excess sludge.

Typical process parameters are:

- Organic Load: < 0.1 $kgBOD_5/kgSSV$ per day
- Volumetric Load: < 0.35 $kgBOD_5/m^3d$
- Sludge Concentration: 4-5 g SSV/l
- Retention Time (HRT): approximately 24 hours
- All other design criteria and parameters have to be defined according to the typical methods used for activated sludge systems.

Operational and maintenance costs are high, due to high energy consumptions and specialised manpower required. In case of high hydraulic load fluctuation, an ustream equalisation tank could be required.

Main Advantages	Main Drawbacks
• good performances for COD and nutrients removal • sludge stabilisation • adaptable to many sizes of community	• high energy consumption • requires skilled personnel and regular monitoring • sensitivity to hydraulic overloads

As for any activated sludge process producing a flocculent settleable sludge, a **secondary settlement tank** for liquid-solid separation is required where part of the sludge is recycled and returned to the reactor.

Different types of settlers can be realised that vary in their shapes, flow direction, and technologies applied to remove the settled solids. The choice is going to be made according to the parameters: detention time, overflow rates, solids loading rates, flow distribution and withdrawal devices.

I.3.2.3.2 Sequencing batch reactor

Sequencing Batch Reactors (SBRs) are a process variant to the activated sludge treatment system where all biological treatments and settlement processes take place in the same tank. The flow rate is fed and discharged in a sequencing mode on a batch treatment principle that can be modified according to the treatment requirements (usually, nutrient removal is achieved during alternating aerobic and anaerobic conditions within the reactor) and according to the variation of input parameters. Each batch treatment cycle comprises the processing steps of: fill and mixing, reaction, settling, decanting, and idle (in order to give flexibility to the whole system). Each phase and, consequently, each cycle can have a different duration according to the type of wastewater to be treated and to specific operator's needs.

It is preferable to operate at least two reactors in parallel in order to feed the continuously incoming flow rate alternately into the reactors. An equalisation tank should also be considered to avoid hydraulic overloading. No sludge recycling is needed; the excess sludge is usually removed near the end of reaction or during the settling stage.

Main design parameters are: number of tanks in parallel (>2), duration of a batch treatment cycle and of each process stage, FTR (Fill Time Ratio in relation to the total time- of a batch treatment cycle), VER (Volumetric Exchange Ratio, which is the ratio of the wastewater volume fed in during a cycle and the total reactor volume), HRT and SRT.

SBRs are highly-equipped electro-mechanical devices. Sensors and computer-aided control devices are usually installed in order to operate the process sequence in a viable manner to keep the biological treatment performance optimum while managing all flow variations.

Main Advantages	Main Drawbacks
• flexibility and regulation of the cycle duration related to the wastewater characteristics and pollutant load • high process reliability with respect to load fluctuations and to unsteady conditions • little ground space needed as all the treatment stages take place within a single reactor • no sludge recycling (means less energy and O&M costs) • higher settling phase efficiency due to static conditions • process automation	• experienced and skilled personnel is required for O&M • presence of specific electro-mechanical equipment requiring maintenance by specialised agents • best performance under low hydraulic load and high organic load

I.3.2.4 Hybrid technology

Hybrid systems represent a new technology that combine both biofilm and activated sludge systems. Hybrid systems are commonly employed to enhance treatment efficiency where the individual processes (biofilm or activated sludge) are less effective.

Such systems are usually incorporated into packaged plants. The most common applications consist of filter media that improve both flocculation and biomass concentration during the activated sludge process. This is to maintain a large floc size within the bioreactor in order to enhance both biodegradation performance of organic compounds and settling in secondary clarifiers.

Operational parameters of hybrid systems depend on the type of patented technology and are usually provided by the manufacturer.

A major drawback of this technology is the higher costs for maintaining the filter media.

I.3.2.5 Anaerobic systems (UASB reactors)

Interest in anaerobic systems has been greatly enhanced because of the necessity to decrease O&M costs required for aerobic treatment systems, which are mainly due to sludge production and electricity consumptions (in the order of 50-100 Euro / PE yr).

High-rate anaerobic treatment systems allow to halve these costs and to overcome the main drawback of completely mixed anaerobic reactors which is linked to long retention times. The high-rate reactors developed over the last two decades are a promising option for the anaerobic (pre)treatment of sewage even at low temperature (below 25°C).

The Upflow Anaerobic Sludge Blanket (UASB) reactors, that have found the widest application in full-scale systems over the last fifteen years, represent the best known high-rate anaerobic system. The operating principle consists of the following steps: The influent wastewater to be treated is fed in and distributed at the bottom of the reactor, where it comes in contact with the settled sludge blanket. The anaerobic degradation of the organic compounds occurs in the granular sludge bed, where biogas is produced. The combined upflow of the wastewater and the biogas causes natural mixing which again contributes to a better contact between wastewater and sludge. Effluent recycling can be employed to promote mixing and sludge bed expansion, or to dilute incoming substrate concentrations in highly concentrated effluents.

The sludge bed in UASB reactors consists of granular or flocculent sludge. Flocculent sludge will develop during the treatment of domestic sewage with a high content of suspended solids. Only in two-step systems where the majority of the SS is removed in the first step, methanogenic granules develop in the second step.

A gas-liquid-solids separator (GLS, three-phase-separator) placed at the top of the reactor causes separation of biogas, water and sludge. Biogas is collected under the gas-collector by means of a baffle and led out from the top of the reactor.

In Table 4 the various types of anaerobic reactors are compared based on the organic loading rate and performance:

Table 4 – Typical operational parameters of anaerobic treatment variants (compiled from Metcalf & Eddy 1991, Masotti and Verlicchi 2005)

Type of reactor	Organic Loading Rate [kg COD/m^{3}d]	HRT [d]	COD removal [%]
Anaerobic Lagoon	0.1 – 0.5	1 – 20	35 – 75
Imhoff Tank (10°C)	0.3	20 – 50	35 – 65
Upflow Anaerobic Filters	1 – 10	0.4 – 18	70 – 90
Anaerobic Fluidised Bed Reactors	1 – 20	< 1	80 – 85
UASB – low strenght – high strenght	< 5 5 – 20	0.3 – 0.5 2 – 10	85 – 80 70 – 85

Main Advantages	Main Drawbacks
• high treatment efficiency with high organic loading rates • short retention times • low energy consumption • simple reactor design without the need of support media • extensive full-scale experience in practice	• difficult control of granulation (depending on wastewater characteristics) • sensitivity to organic/hydraulic shock loads • application restricted to low-solids wastewater

I.3.2.5.1 Integrated systems

Anaerobic systems guarantee a fairly good removal of carbonaceous matter, but are markedly inadequate to remove nitrogen and phosphorus compounds. Consequently, in compliance with legal standards, anaerobic biological systems can be an attractive option especially for pre-treatment of highly concentrated wastewater.

The so-called integrated systems typically combine anaerobic and aerobic biological treatment units.

The first stage is for anaerobic treatment even of intensive and high-loaded wastewater and is designed to remove biodegradable dissolved organic compounds. Full-scale systems that have been widely applied are based on the UASB technology.

The second stage is for nitrogen and phosphorus removal and usually consists of an aerobic (low-cost) biological treatment system (e.g. RBCs). Alternative options for high-rate anaerobic pre-treatments are natural systems (constructed wetlands, algal ponds) or sand filters.

The integrated systems developed over the last few years differ as to their treatment design and the substances removed. Whatever configuration is applied, integrated systems represent a cost-effective option also for a decentralised approach and for reclaiming domestic wastewater for reuse in agriculture.

I.4 Tertiary treatments

Tertiary treatments (including advanced treatments) consist of specific combinations of chemical or physical processes for removing residual colloidal and dissolved solids and pathogens (disinfection) that are not adequately removed in conventional secondary treatments. Tertiary treatment becomes necessary to achieve a treatment level of high quality for effluent reuse (see also ➔ Part II of the EMWater Guide).

There are several types of treatments and functions available with the purpose of residual solids removal. The most widely applied are:

- Membrane techniques
- Chemical treatments
- Carbon adsorption
- Ion Exchange

The treatment options for disinfection will not be introduced here, but their major advantages and drawbacks are summarized in Table 5. For more details see Metcalf & Eddy (1991).

Table 5 – Main advantages and drawbacks of the most applied disinfection systems. Ponds and constructed wetlands are omitted (Metcalf & Eddy 1991)

Unit Process	Pathogen Removal [log units]	Main Advantages	Main Drawbacks
Chlorine compounds	Viruses: 1 - 3 Bacteria (or faecal coliforms as indicator): 2 – 6 Protozoan cysts: 0 – 1,5	• established and effective technology • chlorine residual can be monitored and maintained • relatively cost-effective	• hazardous chemical requiring safety measures • residual toxicity of treated effluent requires dechlorination • oxidises also organic and inorganic compounds • formation of DBPs • TDS in treated effluent is increased
Chlorine dioxide	Helminth eggs: 0 - <1	• effective disinfectant • biocidal properties not affected by pH • provides residuals	• unstable, must be produced on site • oxidises also organic and inorganic compounds • formation of DBPs • decomposes in sunlight • high operating costs
Ozone	Viruses: 3 - 6 Bacteria (or faecal coliforms as indicator): 2 – 6 Protozoan cysts: 1 – 2 Helminth eggs: 0 - 2	• effective disinfectant • more effective than chlorine respect viruses, spores, cysts • biocidal properties not affected by pH • little ground space required	• no residual effect • less effective at low dosages • oxidises a variety of organic and inorganic compounds • safety concerns (corrosive and toxic) • energy intensive • relatively expensive (much O&M required)

Unit Process	Pathogen Removal [log units]	Main Advantages	Main Drawbacks
UV radiation	Viruses: 1 - >3 Bacteria (or faecal coliforms as indicator): 2 – >4 Protozoan cysts: >3 Helminth eggs: 0	• effective disinfectant • no residual toxicity • more effective than chlorine in activating viruses, spores • improved safety compared to chemical agents • little ground space required	• no residual effect • hydraulic design of UV systems is critical • energy intensive and relatively expensive

I.5 Sludge production and management

Wastewater sludge from moderately industrialised countries is characterised by lower metal and toxic contents and higher microbiological concentrations. Furthermore, sludge production is usually less than compared to similar plants in industrialised countries, although sludge production data are rarely reported.

Sludge production amounts depend on the type of treatment applied, as shown in Table 6. Primary and physico-chemical treatments produce greater quantities than biological techniques, along with a lower mineralisation of organic compounds matter. Wastewater composition, solids from rainwater runoff and wash down as well as the prevailing operation conditions will also affect the sludge production.

Table 6 – Sludge production in different wastewater treatment processes (Metcalf & Eddy 1991)

Process	Sludge Generation [kgST 10^{-3} m^{-3}]		% TS
	Range	Typical	
Primary Settling	108-168	150	4.0-10.0
Advanced Primary Treatment	185-315	depending on the amount of chemical coagulant added	0.4-10.8
Activated Sludge	72-96	84	0.5-1.5
Trickling Filter	60-96	72	1.0-3.0
Anaerobic treatment	6-20	10	1-8

Sludge treatment aims at sludge stabilisation (decomposition and mineralisation of organic compounds, namely the VSS content in the sludge) and inertisation (the process of reducing pathogens in the sludge).

Sludge treatment processes can be classified according to complementary treatments (degritting, thickening, conditioning and dewatering) and stabilisation treatments (chemical stabilisation, composting, aerobic or anaerobic digestion). Dewatering can be achieved by variety of methods. Most commonly applied in small plants are sludge drying beds, mechanical dewatering (filter press, belt filter press, and centrifuges), reed beds and lagoons. Aerobic digestion is commonly used in small communities prior to land application and is performed in open tanks provided with continuous or intermittent aeration. Major advantages and drawbacks of selected stabilisation techniques are summarised in Table 7, even though advantages may be reduced or outweighted by the operation practices employed in the different countries.

Table 7 – Advantages and drawbacks of sludge stabilisation processes (WEF/ASCE 1992)

Process	Advantages	Drawbacks
Lime Stabilisation	• low cost and easy to operate • good as an emergent stabilisation method • good pathogen control (6-8 log of coliforms, 5-7 log of Salmonella, >98% helminth eggs)	• sludge production higher than compared to other treatments • bad odours from ammonia
Composting	• low cost and easy to operate • good VS reduction (20-30%) • sludge well accepted in agriculture • good pathogen inactivation (5-7 log of faecal coliforms, >95% helminth eggs)	• demands a bulking material • much ground space required • risk of odour problems
Drying beds	• low cost and easy to operate • particular suitable in hot climates	• much ground space needed • limited application in humid climates

The enactment of an appropriate legislation is crucial to ensuring an adequate sludge management, especially with regard to financial aspects and cost covering options.

The use of sludges as a fertilizer source can be an interesting option for agriculture, forestry and restoration purposes. Nevertheless, when assessing sludge disposal options, the issue of sludge-borne metals has to be taken into account. In this regard, distinctions should be made between potentially hazardous metals (e.g. cadmium, chromium, etc.) and micronutrients (e.g. iron, zinc, manganese, copper).

I.6 Selection of appropriate small wastewater treatment system

The appropriateness of techniques and their practical implications in municipal wastewater treatment depends on technical considerations, but is also linked to numerous non-technical factors and issues in the local context, such as regulatory, economic and environmental requirements as well as socio-cultural particularities that may lead to the acceptance and sustainability of a treatment system in the long term.

📖 More information about the effectiveness of urban wastewater treatment policies in selected countries can be found at http://reports.eea.europa.eu/eea_report_2005_2/en

Important elements for consideration and assessment in the selection process of wastewater treatment technology are:

- Population served
- Wastewater quality

- Water availability (per capita)
- Type of final wastewater destination
- Effluent quality standards and national laws and regulations
- Financial aspects: construction and O&M costs
- Charges, willingness and ability to pay
- Land availability and topography
- Site characteristics and distance from residential and agricultural areas
- Energy availability and requirements
- Local climate
- Sludge production and disposal management
- Operator expertise
- Simplicity in technology and structure (no sophisticated electro-mechanical equipment) and easy availability of construction materials and spare parts
- Management model to be applied
- Public and private obligations
- Demand and selling opportunities for reclaimed wastewater

The **choice between decentralised and centralised treatment systems** has implications beyond the issue of environmental sustainability, since economical aspects and financial soundness are the most relevant criteria to be considered: In general, a **detailed cost-benefit analysis** – along with the assessment of the capital needed, the presumed O&M expenditures and expected cost-defraying charges – is always necessary in order to select the appropriate treatment technology. In fact, failure to set up a proper schedule of cost recovery is the most common problem in planning treatment plants.

On-site or small systems will be chosen as a cost-effective solution primarily in remote and / or low-income areas as well as in regions affected by water shortage (where advanced methods of self-cleansing should also be considered). Conversely, larger treatment systems will be given preference where enough funds and water resources are available. In urban regions where the population and economic activities are sufficiently concentrated, a sewer network connected to a central wastewater treatment plant may be a feasible option. For agglomerations with more than 5,000 inhabitants, alternative solutions with a view to environmental sustainability should be evaluated using a phased development towards intermediate and long-term solutions in wastewater management, and, hence, to achieve the overall least-cost solution.

Indeed, decentralisation allows for reducing capital and O&M costs and for ensuring a higher flexibility in treatment capacity allocation for future growth. However, given the high quality standards for water reuse, costs and management efforts related to reclaimed-water utilisation can become a serious constraint to decentralised wastewater management at large. Thus, a detailed assessment of existing on-site reuse potentials and possible benefits is absolutely necessary. According to a win-win strategy an **appropriate long-term management model developed for the authorities responsible for wastewater treatment and reuse** will serve to coordinate the systems for effective water and sludge reuse in agriculture in line with environmental protection objectives.

Many arid and semi-arid areas of the world would benefit from **efficient large-scale water reuse** due to risks of water shortage entailing population growth and increasing water demands from agricultural. This has brought to the fore the importance of issuing clear, appropriate and feasible hygenic and microbiological quality standards to minimise health risks associated with water reuse practices (see ➔ Part II of the EMWater Guide for further details).

With reference to criteria from existing legal regulations (e.g. Italian legislation regarding treatment plants not exceeding 10,000 PE), the choice of the adequate wastewater treatment system – with the objective of a good ecological status of the water bodies – has to consider the following elements:

- Population served/population equivalents (PE) according to the projections
- Final destination (soil, groundwater via soil, rivers, lakes, sea, transitional waters, reuse)
- Quality level of the final destination

The range of population served allows to choose the final discharge media, and to select the relevant effluent standards to be achieved.

With all options known, the best solution can be chosen after a thorough audit of the wastewater flow characteristics (e.g., through groundwater pollution risk analysis, environmental impact analysis for surface water bodies etc.). The design of a treatment plant can then be developed or upgraded in a phased development.

From a technical point of view, first of all a good knowledge and understanding of the available and adequate technologies for wastewater treatment and reuse is needed. Furthermore, the design of a treatment plant has to **consider the local context**, (e.g., local climate, expertise and skills of local operators), as well as compliance to government and water service providers' policies.

Finally, all efforts should be made to closely monitor costs of construction, operation and maintenance **in order to achieve economic feasibility** of a project (see below).

Another concern is the **effective management and control of effluent treatment**, and of the removal of organic compounds and suspended solids. When effluent reuse in irrigation of edible crops is an objective, elimination of heavy metals, faecal coliforms and helminths eggs is an additional parameter of treatment performance. The same applies to nutrients such as ammonia, nitrate and phosphate in the case where the effluent is discharged into a water course sensitive to eutrophication.

The treatment process to be applied will be defined according to these and the following criteria and parameters that have to be equally balanced (see ➔ Chapter I.6.).

Ground space availability is the major factor determining the choice between an intensive or extensive centralised treatment system. The following practice rules will be helpful:

- If ground space is available at less than $1m^2$/PE intensive systems will be chosen;
- If available ground space is larger (up to $5m^2$/PE) mixed systems (biological secondary treatment plus finishing lagooning, drained vertical sand filters, etc) can be considered;
- If ground space needed of more than $6m^2$/PE is acceptable, extensive systems can be applied.

As a general rule, as a treatment process becomes more complex (intensive systems), the amount of ground space needed will be reduced, whereas total costs and sludge production will increase.

Financial aspects indeed introduce the strongest constraint for the process of wastewater treatment system selection. **Capital and O&M costs clearly depend on the local particularities** which renders fairly impossible to obtain assessment data for overall use. Long-term sustainability can only be achieved by:

- conducting feasibility studies to identify the economically most feasible solution
- developing a (binding but flexible) process design with a proper timing and defined requirements of resources
- ensuring building up of adequate institutional and human capacity

Operating extensive systems will commonly allow for reducing investment and operation costs, especially due to lower energy consumption and reduced sludge treatment and disposal. Furthermore, these techniques require a lower amount of manpower and less-specialised manpower than intensive processes. Compared to conventional intensive purification systems identical in performance capacities extensive plants should allow, to save an average of 20 to 30% on capital costs, and 40 to 50% on O&M costs.

Further insight comes from a French study (International Office for Water 2001) reporting on the capital and operation costs (including energy costs) of small wastewater treatment plants designed for 1,000 PE in France (see Table 8).

Table 8 - Capital and annual operation costs (€/PE year) of French small wastewater treatment plants sized at 1,000 PE (International Office for Water 2001)

Treatment Process	Capital Costs	Operation Costs
Activated Sludge	230 (±30%)	11.5
RBCs	220 (±45%)	7
Imhoff Tank + CW	190 ±35%)	5.5
Biofilters	180 (±50%)	7
Aerated Lagoons	130 (±50%)	6.5
Waste Stabilisation Ponds	120 (±60%)	4.5

In Tables 9 and 10, relative construction and operational costs (per PE) from an Italian survey are given. Compared are various types of wastewater treatment systems sized at 100 to 10,000 PE. The lowest cost values per unit are set to 100 (Oxydation Pond for 10,000 PE) expressing other costs as a percentage of that. Reported data include sewer system costs.

Table 9 – Construction costs (per PE) of some wastewater treatment systems (Masotti and Verlicchi 2005)

Type of System	Population served (PE)						
	100	200	500	1,000	2,000	5,000	10,000
Aerated Lagoon	1,600	1,050	610	400	265	150	100
Primary Settling	1,350	1,100	810	650	515	380	310
	1,250	1,030	785	650	525	400	330
Activated Sludge	2,025	1,600	1,230	1,000	800	600	490
	1,350	1,175	970	850	725	600	520
Biofilters	2,100	1,675	1,250	1,020	820	615	500
	1,150	1,015	850	750	640	530	460
Sewer Systems	6,300	5,350	4,300	3,650	3,120	1,030	2,130

Table 10 – Operation costs (per PE) of some wastewater treatment systems (Masotti and Verlicchi 2005)

Type of System	Population served (PE)						
	100	**200**	**500**	**1,000**	**2,000**	**5,000**	**10,000**
Aerated Lagoon	3,680	2,700	1,900	1,400	1,050	750	100
Primary Settling	10,800	8,950	7,100	6,000	5,000	4,000	3,250
	5,300	4,800	4,100	3,550	3,200	2,800	2,400
Activated Sludge	13,900	11,700	9,450	7,950	6,700	5,300	4,500
	14,000	11,950	9,550	8,100	6,900	5,500	4,700
Biofilters	15,300	11,900	8,600	6,700	5,250	3,800	3,000
	15,800	12,550	9,100	7,250	5,700	4,100	3,350
Sewer Systems	2,100	1,850	1,500	1,350	1,200	975	850

In Table 11 the most relevant parameters to be considered in the decision process are qualitatively evaluated in order to facilitate comparison of site-specific information.

Table 11 – Qualitative evaluation of decision criteria of importance for selecting an adequate sanitation system

Treatment system	Compliance with standards for discharge	Ground space needed	Sludge Production	Energy requirements	Construction costs	O&M costs	Main Advantages	Main Drawbacks
Constructed Wetlands	Good [combination SS-VF + SS-HF]	Moderate to much	Low	Low (inlet/outlet pumps)	Low	Low	Natural and simple low-cost system	Much ground space needed
Stabilisation Ponds	Good [also for nutrient and pathogens removal]	Much	Low	Low (inlet/outlet pumps)	Low (according to topography)	Low (solids disposal is the more expensive item)	Simple and low-cost system	Much ground space (and high capital costs) needed
Aerated Lagoons	Good [also for nutrient and pathogens removal]	Moderate	Low	Medium (inlet/outlet pumps, aeration)	Low-Medium (according to topography)	Medium	Simple O&M and good efficiency	High capital costs
Biofilters	Medium [low denitrification efficiency]	Little	Medium	Medium to High	Medium to High	Medium to High	Little ground space needed	Effective primary treatments required
				High-load biofilters require backwash system				
RBCs	Medium [low denitrification efficiency]	Little	Medium	Medium	High	Medium	Simple O&M and low energy consumption	High capital costs
Extended Aeration	Very Good [with denitrification stage]	Little	Hig	Very Hig	Medium-High	High	Good treatment efficiency	High O&M costs
SBRs	Very Good	Little	High	Very High	High	High	ittle ground space needed, flexibility and automation	High capital and O&M costs
UASB Systems	Post-treatment needed	Little	Medium	Low	Medium	Low	Low construction and O&M costs	Process sensitivity

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EMWater Guide

Part II: Guide for Water Reuse

Index:

II.1 Introduction - Water reuse

The reuse of treated wastewater can be a valuable alternative to freshwater resources, especially in water-scarce countries. Today, various technically proven wastewater treatment and purification processes exist to produce water of almost any quality desired. In the planning and implementation process, the intended water reuse applications dictate the extent of wastewater treatment required or – in other words – the quality of the available wastewater limits the possible reuse options.

Definitions

Water reuse: Use of reclaimed water for beneficial purposes.

Water reclamation: Treatment or processing of wastewater to make it reusable.

Water recycling: Use of wastewater that is captured and redirected back to the water-use scheme from which it originates. This technique is applied particularly in industry.

Direct reuse: Use of reclaimed wastewater without intervening discharge to a natural body of water.

Indirect reuse: Use of reclaimed wastewater with intervening discharge to a natural body of water.

Planned reuse: Direct or indirect use of reclaimed wastewater without losing control over the water during delivery through specifically designed projects to treat, store, convey and distribute treated wastewater.

Unplanned reuse: Use of wastewater after surrendering control of the water after discharge. A common example of unplanned wastewater reuse occurs when water from rivers that receive wastewater discharges upstream is used downstream for urban water supplies and/or irrigation.

Potential reuse applications:

- → Irrigation in agriculture or for landscaping
- → Reuse in aquacultures
- → Groundwater recharge
- → Industrial recycling and reuse
- → Other reuse options

General benefits of water reuse

The reuse of treated wastewater reduces the demand on conventional water resources and, thus, may allow for postponing or reducing investments in developing new drinking water supplies. Furthermore, water reuse reduces the volume of wastewater disposal which will positively affect the fresh water resources (surface and groundwater), the environment and public health by reducing pollution to receiving areas. Conversely, constituents harmful to water quality and aquatic communities can serve as a valuable source of nutrients in agriculture.

Risks and potential constraints

There are several constraints to water reuse: Health problems, such as water-borne diseases and skin irritations, may arise where people come into contact with reclaimed water or produce that was grown under reclaimed water treatment. In some cases, water reuse is not economically feasible because of the requirement for an additional distribution system. Water reuse may be rejected for cultural or religious reasons in some societies. This notwithstanding, the unplanned reuse of water – the use of water from rivers that receive wastewater discharges upstream – is a reality in many places around the world.

Use of reclaimed water and Islam

Within the MENA region there is a persistent notion that water reuse is against Islam, given the importance that Islam – along with other religions – is placing on cleanliness and purity. However, as was noted in "Water Management in Islam" (Faruqui et al. 2001), water reuse is permissible for all purposes, provided that the wastewater is treated to the required level of purity for its intended use and does not result in any adverse public health effect. Water reuse is being practised with the consent of the religious authorities in Oman, UAE and Saudi Arabia. Saudi Arabia for example is currently reusing about 20 percent of its treated wastewater in refineries and in irrigating forage and landscape crops (Faruqui 2001). In 1978, a special fatwa on reuse of wastewater effluents for irrigation purposes was issued by the Council of Leading Islamic Scholars (CLIS) of Saudi Arabia. This fatwa (CLIS 1978) postulated that impure wastewater can be considered as pure water and similar to the original pure water, if its treatment using advanced technical procedures is capable of removing its impurities with regard to taste, colour and smell, as witnessed by honest, specialized and knowledgeable experts. Then it can be used to remove body impurities and for purifying, even for drinking. If there are negative impacts from its direct use on the human health, then it is better to avoid its use, not because it is impure but to avoid harming the human beings. The CLIS prefers to avoid using it for drinking (as possible) to protect health and not to contradict with human habits. This fatwa was an important step toward the reuse of treated wastewater for various purposes depending on its degree of treatment (Abderrahman 2001).

📖 For more information on water reuse and Islam please refer to "Water Management in Islam" (Faruqui et al. 2001).

Benefits	Risks and potential constraints
Water reuse • reduces the demand on conventional water resources, • reduces the volume of wastewater discharged into the environment, • recycles beneficial constituents of the wastewater (e.g., nutrients in agriculture), • can reduce the costs of WWT, as, e.g., nitrogen and phosphate might not need to be removed when reused for irrigation.	Health issues need to be considered. • Economic feasibility needs to be assessed. • Practices must be culturally and religiously accepted. • Insufficient wastewater quality can limit the possible reuse applications.

II.2 Information on different options for water reuse

Treated wastewater can be reused for many applications as listed above in Chapter II.1. The most common is agricultural irrigation, but industrial reuse and groundwater recharge are also widely applied. Water reuse in aquacultures and for landscape irrigation is also becoming more and more common.

This chapter gives an overview of the common reuse applications as well as quality requirements, benefits, risks and potential constraints.

Typical reuse applications

- Most common: reuse in **agricultural irrigation.**
- Industrial reuse and groundwater recharge also largely applied.
- Reuse in **aquacultures** and for **landscape irrigation** on the rise.

II.2.1 Irrigation in agriculture or landscaping

Treated wastewater is used for irrigation in many parts of the world. In the Mediterranean basin, wastewater has been used as a source of agricultural irrigation for centuries. Today, in addition to agricultural irrigation, treated wastewater is used for landscape irrigation.

Wastewater irrigation is different from freshwater irrigation and, consequently, calls for a specifically adapted management, if environmental and soil degradation is to be prevented and/or sustainable high crop yields are to be realised in the long term. 🕮 Information on conditions for successful irrigation, including selection of irrigation methods and crop selection can be found in Chapter 5 ("Irrigation with wastewater") of the FAO Irrigation and Drainage paper 47 entitled "Wastewater treatment and use in agriculture" (Pescod 1992).

Agricultural irrigation includes irrigation of crops, such as cereals, fruits, vegetables, fodder crops or pasture, flowers and trees, applied in agriculture and commercial nurseries.

Landscape irrigation includes irrigation of urban green areas and parks, school yards, hotel gardens, freeways (median strips), golf courses, cemeteries, residential areas.

Benefits

There are several benefits in using treated wastewater for irrigation in addition to the general benefits of water reuse mentioned in ➔ Chapter II.1:

- Treated wastewater increases the supply of agricultural water and can provide a reliable low-cost water source for farmers.
- The reuse of treated nutrient-rich (mainly through nitrogen and phosphorous) wastewater can increase agricultural production.
- The fertilising properties of reclaimed wastewater reduce the use of chemical fertilisers. Farmers can save on artificial fertilisers.
- The reuse of treated wastewater for landscape irrigation can help to control desertification and to support desert reclamation.

Risks and potential constraints

Water reuse is often associated with environmental and health risks. As a consequence, peoples' acceptance to use reclaimed water for irrigation will highly depend on whether health risks and environmental impacts entailed are acceptable. Information on how to minimise health risks when using reclaimed water for irrigation is presented in ➔ Chapter II.4

The amount of water required for irrigation will vary through the year depending on climatic conditions (rainfall, temperatures), and plant characteristics (plant type, stage of plant growth). Hence, amount and timing of reclaimed water irrigation have to be controlled. Otherwise surplus nutrients (such as nitrogen, phosphorous, etc.) may infiltrate into the soil and contaminate the groundwater.

Generally, reclaimed water storage systems are required to balance supply and demand fluctuations. During the rainy season when demand for irrigation water is low, provisions have to be taken in order to prevent overloading of treatment and disposal facilities. In exceptionally wet years, unintended discharge of reclaimed irrigation water into the aquatic environment may occur.

Usage of reclaimed water in irrigation (and especially in drip irrigation) entails the risk of clogging by suspended solids, algae or biofilm formation. This highlights the need for adapted irrigation system management.

Quality requirements

Reuse of treated wastewater for irrigation purposes entails quality requirements different from disposal into water bodies:

- Wastewater treated for reuse in irrigation must meet higher hygiene standards.
- BOD_5 standards can be eased, as the organic load in reclaimed water is decomposed when applied on soils.
- The nitrogen and phosphate compounds of reclaimed wastewater are agricultural nutrients that can substitute mineral fertilisers. While this makes them desirable for irrigation, they are potentially harmful to water organisms and need to be removed when the wastewater is meant for disposal into water bodies (risk of eutrophication). As mentioned above, amount and timing of nutrient application along with irrigation have to be controlled to prevent infiltration into the groundwater.

Stringent hygienic standards are to be maintained when using reclaimed water for irrigation in order to protect workers and potential consumers from transmission of excreta-related diseases.

Environmental concerns also demand precautionary measures against possible salinisation and contamination of soils and shallow aquifers by nitrogen and pathogens. There is also a risk of soil clogging by wastewater-borne grease and fats which would reduce soil permeability and aeration.

In conclusion, not only the quality standards of the reclaimed water must be taken into consideration when planning a reclaimed water irrigation project, but also the soil properties of the land under the irrigation scheme as well as the proximity to aquifers and sensible surface waters.

For more details on the suitability of soils and crops, environmental risks and health-related requirements please refer to ➔ Chapter II.3.3.

🕮 Detailed information on the water quality requirements for agricultural use can be found in the FAO's guidelines on "Water quality for agriculture" (Ayers & Westcot 1994)

II.2.2 Reuse in aquacultures

The term aquaculture refers to fish farming and to growing aquatic vegetables. Aquaculture is particularly common in the South-East Asian countries, India, China, Indonesia, Vietnam, etc.

🕮 Information on biota in aquaculture ponds, technical aspects of fish culture and health related aspects of fish culture can be found in Chapter 7 of the FAO's Irrigation and Drainage Paper 47 (Pescod 1992).

Benefits

Reclaimed wastewater can be profitably used as a fertiliser in fish ponds and aquatic vegetable ponds to increase algae and plankton growth and, thus, to produce natural food for fish. To optimize fish production in a wastewater-fed pond, the majority of the fish should be filter feeders, to exploit the plankton growth.

Risks and potential constraints

Since several species of fish feed directly on faecal solids, use of raw sewage or fresh human excreta (nightsoil) as influent to fish ponds should be prohibited for health reasons.

Toxic constituents (e.g., heavy metals and pesticides) from municipal wastewater entail the risk of bioaccumulation (storage of a chemical in a living organism at high concentrations): If such sewage is used in aquaculture, this needs to be monitored. Although algae are known to accumulate various heavy metals, fish raised in sewage-fed ponds have not been observed to accumulate high concentration of heavy metals, with the possible exception of mercury. The amount of wastewater fed into the ponds needs to be managed with care, as an overload in organic substances and ammonia may result in fish mortality.

Quality requirements

The wastewater used for aquaculture must be treated to a microbiological quality, which ensures that the products are safe and that there is no excess risk of infection to aquaculture pond workers.

🕮 Volume 3: "Wastewater and excreta use in aquaculture" of the 2006 WHO's Guidelines for Safe Use of Wastewater, Excreta and Greywater (WHO 2006), define the minimum water quality required for safe use in aquaculture.

II.2.3 Groundwater recharge

Purposes of groundwater recharge include:

- Establishment of **saltwater intrusion barriers** in coastal aquifers,
- **Replenishment of aquifers** to reduce, stop or reverse declines in groundwater levels, and
- Control or prevention of ground subsidence.

Methods of groundwater recharge are:

- **Surface spreading** – a direct method of recharge whereby the water infiltrates and percolates from the ground surface to the aquifer through the soil matrix.
- **Direct injection** – reclaimed water is pumped directly into the groundwater zone which is usually a well-confined aquifer. Direct injection is used where groundwater is deep or where hydrogeological conditions are not conducive to surface spreading. Direct injection is also an effective method for creating barriers against saltwater intrusion in coastal areas.
- **Recharge through riverbank filtration** – The water used for riverbank filtration is untreated surface water, usually a river, which infiltrates through the riverbank or percolates from spreading basins, canals, lakes, or drain fields into the groundwater zone. It is practiced in Europe (mainly Germany and Netherlands) as a means of indirect potable reuse.

Methods of groundwater recharge

- Surface spreading
- Direct injection
- Recharge through riverbank filtration

🕮 For more Information on methods of groundwater recharge see Chapter 2.5 of the United States Environmental Protection Agency's Guidelines for Water Reuse (U.S. EPA 2004).

📖 Principles, operations and effects of aquifer recharge with wastewater are explained in "Aquifer Recharge with Wastewater" – Chapter 4 of the FAO's Irrigation and Drainage paper 47 (Pescod 1992). This paper also introduces soil-aquifer treatment (SAT), soil requirements, hydraulic capacity and evaporation, pre-treatment requirements, and effects of wastewater constituents.

Benefits

Infiltration and percolation of reclaimed water take advantage of the subsoil's natural ability of biodegradation and filtration. This in-situ treatment of the wastewater adds to the treatment reliability of the overall wastewater management system. The cleansing achieved in the subsurface environment may eliminate the need for further advanced wastewater treatment processes, depending on the method of recharge, hydro-geological conditions, requirements of the downstream users, and other factors.

Risks and potential constraints

Groundwater recharge is associated with the risk of aquifer contamination. If poorly planned and executed, wastewater-derived chemical or microbial contaminants can harm the environment and human health. Human pathogens and trace organic compounds are of particular concern where groundwater recharge involves aquifers supplying domestic water (Tsuchihashi et al. 2002). The WHO state of the art report on "Health risks in aquifer recharge using reclaimed water" (Aertgeerts and Angelakis 2003) gives examples of the current state of research and highlights the importance of assessing and managing health risks.

Quality requirements

Quality requirements for groundwater recharge vary considerably, depending on the purpose of groundwater recharge, recharge methods and location. Requirements depend upon groundwater quality objectives, hydrologic characteristics of the groundwater basin, and the amount of reclaimed water to be recharged in relation to other waters to be recharged.

Possible chemical reactions between compounds of the reclaimed water and the groundwater, iron precipitation, ionic reactions, biochemical changes, temperature differences, and viscosity changes also need to be addressed prior to the construction and operation of a recharge system.

Direct injection requires water of higher quality than compared to surface spreading because of the absence of soil matrix treatment occurring in surface spreading.

II.2.4 Industrial recycling and reuse

Many industries treat and recycle their own process water, their cooling and boiler feed water and their wastewater (in-plant recycling). Water recycling within an industrial plant is usually an integral part of the industrial process. Types and methods of in-plant recycling are too specific and adapted to the particular production process to be described here in detail.

Typical industrial reuse applications

- Cooling water (predominant)
- Boiler feed water
- Process water

However, besides in-plant water recycling, external water sources, such as reclaimed municipal wastewater, are also used in industries. Industrial uses of reclaimed water from external sources include:

- cooling water,
- boiler feed water,
- process water,
- dust control on construction sites and quarries, and
- landscaping and maintenance of industrial grounds.

Cooling is currently the predominant industrial reuse application. In most industries, cooling creates the single largest demand for water within a plant. Worldwide, the majority of industrial plants using reclaimed water for cooling are power stations.

Benefits

In-plant recycling and reuse of process water when compared to end-of-pipe treatment strategies can facilitate to achieve stringent regulatory standards for effluent discharges or can help avoid regulatory issues pertaining to wastewater effluents. It can also facilitate recycling and reuse of other valuable wastewater constituents. This can be a cost-saving opportunity. Moreover, industries are often located near centralized wastewater plants where reclaimed water is readily available.

Risks and potential constraints

There are several unwanted constituents in reclaimed water that may cause scale and corrosion or may foster biological growth and fouling.

Public health concerns can arise particularly because of aerosol transmission of pathogens in cooling water. In order to provide an adequate water quality, additional treatment is often required beyond conventional secondary wastewater treatment.

Quality requirements

Water quality requirements for industrial purposes are determined by the needs of the processes being applied, and, hence, vary greatly.

Where the recycled water is used within open systems, the water must be hygienically safe, e.g. for dust suppression on construction sites where workers or passing cars may be subject to intermittent spray drift.

For industrial uses of recycled water within closed systems, e.g., for industrial cooling or boiler feed, the hygiene aspect is less important, but the water might need additional treatment to prevent fouling, scaling, corrosion, foaming or biological growth within the pipework. Both freshwater and reclaimed water are likely to cause such problems, but concentration levels of unwanted constituents are generally much higher in reclaimed water.

📖 Information on water quality requirements for industrial reuse of municipal wastewater can be found in Chapter 7.4 “Using recycled water for industrial purposes” of the Queensland Water Recycling Guidelines (State of Queensland 2005).

II.2.5 Other uses

Other uses of reclaimed wastewater include:

- **Potable water reuse** – use of reclaimed water for direct or indirect augmentation of drinking water supplies:

  For indirect potable reuse, the recycled water is added to a river, aquifer, dam or other water body where it mixes with the existing source for drinking water. For direct potable reuse, reclaimed water is directly fed into a potable water supply system (pipe-to-pipe water supply), often implying the blending of reclaimed water with fresh water.

  Reclaimed wastewater as a source of potable water (direct and indirect) is less desirable than using a higher quality source for drinking. Nevertheless, reuse might be an option if no other sources are available.

  Today's major concern as to potable reuse pertains to potential chronic health effects attributable to the mixture of unregulated trace inorganic and organic constituents. These constituents remain in the water even after advanced treatment for these parameters, such as microfiltration or reverse osmosis. The treatment required to ensure safe potable reuse needs to be determined on a case-by-case basis.

- **Non-potable urban uses**, such as fire protection, air conditioning, etc.:

  For economic reasons these uses are incidental depending on the location of the wastewater reclamation plant to the point of use. The economic advantage can be enhanced by coupling with other ongoing reuse applications, such as landscape irrigation.

- **Domestic non-potable uses**, such as toilet flushing, washing, etc.:

- **Recreational / environmental uses** in lakes and ponds, stream flow augmentation, etc.:

  Reclaimed water impoundments can be incorporated into urban landscape developments. Man-made lakes, golf course storage ponds and water traps can be supplied with reclaimed water. In the United States reclaimed water has been applied in the creation, restoration and enhancement of wetlands. Additional treatment prior to discharge into the receiving water is crucial, as is the provision of disposal alternatives or storage facilities during wet seasons.

These types of reuse are not further discussed here, due to their varying requirements that need to be assessed on a case-by-case basis. Further information is obtainable in:

🕮 Queensland Water Recycling Guidelines, Chapter 7 "Supply and use of recycled water" (State of Queensland 2005).

🕮 Guidelines for Water Reuse of the U.S. Environmental Protection Agency (EPA), Chapter 2 "Types of Reuse Applications" (U.S. EPA 2004).

II.2.6 Water reuse options – Overview

Table 12: Benefits of water reuse for irrigation, aquaculture, groundwater recharge, and industrial purposes

Irrigation	Aquaculture	Groundwater Recharge	Industrial reuse
Agriculture: • Additional water available to farmers • Nutrients of WW (N, P) can be used as fertiliser. • Need for artificial fertiliser reduced -> Cost reduction. Landscaping: Reuse of treated WW can help to control desertification and support desert reclamation.	Reclaimed WW can be profitably used as a fertiliser in aquacultures to stimulate plankton growth for fish feed.	Same advantages as in groundwater recharge with fresh water: • Establishment of saltwater intrusion barriers in coastal aquifers • Replenishment of aquifers • Control or prevention of ground subsidence • Storage of reclaimed water for future uses Additional WWT through infiltration and percolation though the soil. This may eliminate the need of advanced WW treatment.	In-plant recycling and reuse can facilitate to achieve stringent regulatory standards for effluent discharges or can help avoid regulatory issues pertaining to wastewater effluents. Recycling and reuse of the water can also facilitate reclamation of valuable constituents. A potentially cost-saving opportunity.

Table 13: Risks and constraints of water reuse for irrigation, aquaculture, groundwater recharge, and industrial purposes

Irrigation	**Aquaculture**	**Groundwater Recharge**	**Industrial reuse**
Reuse often associated with environmental and health risks Acceptability depends on whether health risks and environmental impacts are deemed tolerable. Water quantity requirements vary seasonally -> water storage systems required. Adapted irrigation management required (to prevent, e.g., risks of clogging and salinisation and soil deterioration).	WW needs to be treated before reuse. The amount of wastewater fed into aquaculture ponds needs to be managed properly to prevent overload.	Poorly planned recharge may lead to contamination of aquifers (with, e.g., pathogens, chemicals or trace organic compounds) and, hence, pose a risk to the environment and human health	Unwanted constituents in reclaimed water may cause or foster • scaling, • corrosion, • biological growth and • fouling. Health issues need to be considered, particularly with respect to aerosol transmission of pathogens in cooling water.

Table 14: Quality requirements of water reuse for irrigation, aquaculture, groundwater recharge, and industrial purposes

Irrigation	Aquaculture	Groundwater Recharge	Industrial reuse
High **hygiene requirements in order** to prevent transmission of excreta-related diseases to protect human health. **Nutrients** of WW (N and P) are desirable and do not need to be reduced. **BOD_5** standards can be eased as the wastewater organic load is decomposed in the soil. Grease and fats in reclaimed WW can reduce soil permeability and aeration by clogging pores. **Salinity**, sodium, heavy metals, nitrates, trace elements, excessive chlorine residuals need to be controlled to prevent soil or crop damage and pollution of groundwater. **TSS** should not be too high to prevent clogging of irrigation system.	**Hygiene requirements**: Regulation of microbiological quality in order to • mitigate infection risk to workers • ensure safe produce **Toxic constituents**, such as heavy metals and pesticides, need to be controlled to prevent bioaccumulation in algae and fish. **Organics** and **ammonia** need to be controlled as to prevent overload and fish mortality.	Requirements vary depending on location, recharge method and amount of reclaimed water to be recharged. Direct injection requires water of higher quality than compared to surface spreading because of the absence of soil matrix treatment. Possible reactions between the reclaimed water and the groundwater, temperature differences, and viscosity changes also need to be considered.	Water quality requirements vary greatly depending on the industrial processes being applied. **Hygiene requirements**: For reuse in open systems, the recycled water must be hygienically safe. For reuse within closed systems, the water might **need additional treatment** to prevent fouling, scaling, corrosion, foaming or biological growth in the pipework. **Residual organics** can cause bacterial growth, microbial fouling on surfaces, foaming in process water. **Ammonia** causes corrosion, promotes microbial growth and combines with chlorine thereby lowering its disinfection efficiency. **Phosphorus** can cause scale formation, algal growth, biofouling of process equipment. **TSS** causes deposition in materials and microbial growth. **TDS** causes corrosion and scale formation. **Dissolved minerals: calcium, magnesium, iron, and silica** cause scale formation.

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II.3 Selecting appropriate reuse applications

For a water reuse project to become a success it should clearly define in a first step **the overall goal that is to be pursued**: The goal might, for instance, be to save freshwater resources, or to provide additional water supply, or to make use of the nutrients contained in treated wastewater for agricultural purposes. Goal definition is important for selecting the most appropriate reuse application.

An integrated approach should be followed in the selection process involving experts from **different disciplines**. Technological, economical, legal, social, environmental, and institutional aspects need to be considered. While technological and legal issues might be readily identified and tackled, special attention should be given to market assessment for reuse options and to public acceptance of reuse.

Moreover, stakeholders of all fields –particularly the potential users – should be given an **opportunity to participate** in the planning process. Stakeholder consultations will allow for identifying their roles and responsibilities in the planning and implementation of a reuse project and ensure that the user side becomes aware of the benefits and requirements of water reuse.

The EMWater Guide will guide you through, and give ideas and suggestions for, the process of selecting feasible reuse applications. This selection process should address the following five elements:

- → Inventory of potential sources and demand for wastewater
- → Identification of legal requirements and responsible institutions
- → Detailed analysis of reuse options
- → Economic evaluation
- → Financial feasibility assessment

The selection process suggested here leads from an overall assessment of potential supply and demand for wastewater to a more detailed evaluation of related benefits and risks as well as an assessment of the costs involved (see Figure 2). These steps are not necessarily to be taken in the given sequence: For example, information on the acceptance of water reuse may already be available when starting to identify potential uses and users. Major legal constraints could well be clarified in a first step. However, for the purpose of structure and consistency the following chapters will adhere to the sequence of elements 1 to 5.

Figure 2: Suggested steps in the selection process for water reuse applications

1. Inventory of potential supply and demand for reclaimed water
Provide an overview of quantity, quality and location of potential sources and users of reclaimed water in a given project area

Stop/ Go decision point
Is there a potential source of reclaimed water in vicinity of a potential user? Does the quantity and quality of reclaimed water supply meet the demand of the application? **If yes**, proceed to the analysis of legal

2. Assess legal and institutional framework:
Analyse legal an institutional requirements
Objective: assess whether the selected potential reuse applications are legal and what requirements

Stop/ Go decision point
Do laws and regulations allow the potential reuse application? **If yes**, continue to a more detailed assessment of the application. If not, you may have to consider

3. Detailed analysis of reuse alternatives:
For each selected reuse application assess:

- Related environmental and health risks and identify respective requirements.
- Needs for additional infrastructure
- Public acceptance of reuse application

Objective: select most viable reuse applications based on the related risks and accordant counter

Stop/ Go decision point
Does the selected reuse application seem viable and does it not entail unpredictable risks? **If yes**, continue to the economic evaluation of the most favourable reuse applications.

4. Economic evaluation:
assess direct and indirect costs and benefits related to the selected reuse application and compare with a non-reuse scenario.

Stop/ Go decision point
Does the selected reuse application have an overall economic benefit? **If yes**, take the most favourable application through a financial feasibility check.

5. Check financial feasibility
prepare preliminary designs for the selected reuse systems and estimate

- all costs related to distribution and storage infrastructure, monitoring, etc.
- the marketability of goods produced with reclaimed water

Objective: assess whether the selected reuse application is financially feasible for a specific user of reclaimed water or participant in a reuse project

Stop/ Go decision point
Is the selected reuse application financially beneficial ?
If yes, you can continue to prepare a business plan

II.3.1 Inventory of potential sources of, and demand for, wastewater

Generally, the planning process will begin with an inventory of existing sources of wastewater in a given project area.

An inventory of potential sources of effluents to be reused should at least provide information on:

- Location of the wastewater source
- Quantity of effluents from a given source,
- Seasonal variation of flow (e.g., monthly flow rates could be identified for each month of the year),
- Effluent quality.

5-step decision making process

1. Potential sources and demand

2. Legal and institutional framework

3. Detailed analysis of reuse options

4. Economic evaluation

5. Check financial feasibility

Potential sources of water for reuse include:

- Municipal wastewater (e.g. from centralized and decentralized treatment plants, domestic on-site disposal, sewer networks, commercial or industrial estates)
- Commerce (e.g. Hotels, Car Wash, Laundry, Office Complexes, etc.)
- Agro-industry (e.g. Food-processing, beverage production, mills, etc.)
- Manufacturing industry
- Agriculture (e.g. dairy, livestock, irrigation drainage run-off
- Aquaculture
- Power plants
- Stormwater (on-site rainwater collection, stormwater drainage network)

Based on the inventory of potential sources of wastewater, potential uses of reclaimed water can be identified and quantified (possibly including, defining the timing of the demand). This can be done by looking at the current freshwater uses in the project area: Where and to which extent can reclaimed water replace or augment current freshwater supplies? In this initial phase, all kinds of potential reuse applications should be considered. ➔ Chapter II.2 gives a general overview of different water reuse applications.

Typical reuse applications

Most common: reuse in **agricultural irrigation**.

Industrial reuse and groundwater recharge also largely applied.

Reuse in **aquacultures** and for l**andscape irrigation** on the rise.

The next step involves a rough matching of the potential sources of wastewater with alternative reuse options in terms of

- water quality (present and future);
- water quantity (present and future, seasonal differences);
- adequate timing of supply;

🕮 Decision support programmes, such as WaterGuide can help in identification of potential applications.

The objective is to find the least effort path between a given wastewater source and the desired wastewater application. Although it is essential to be open and receptive to the possibility of additional treatment and storage options, reuse applications should be given priority where these are not necessary in order to safe costs and resources.

It is also suggested to start the assessment of existing legal restrictions already at this stage in order to open scope for further adjustments in planning as necessary (see below).

📖 Annex III provides useful links on the internet related to case studies of various reuse projects.

II.3.2 Identifying legal requirements and responsible institutions

Another element important to the decision-making process is the detailed analysis of the existing legal and institutional framework. As outlined in more detail in ➔ Chapter II.4 and Annex I, some countries already adopted explicit and detailed regulations on water reuse. (For an overview of applicable laws and regulations in Jordan, Lebanon, Palestine and Turkey, please refer to the ➔ Introduction).

> 5-step decision making process
>
> 1. Potential sources and demand
> 2. **Legal and institutional framework**
> 3. Detailed analysis of reuse options
> 4. Economic evaluation
> 5. Check financial feasibility

The inventory of relevant laws and regulations at the local and national level should include:

- specific legislation on water reuse
- regulations on environmental and groundwater protection,
- irrigation water quality standards,
- occupational health standards, etc.

Should no legal guidelines and standards exist, the 1989 WHO guidelines (➔ see Annex I) will provide adequate guidance for selecting feasible reuse options.

Furthermore, the inventory should include all **agencies** and authorities having jurisdiction: Which ministries / authorities are involved in controlling and licensing the use of reclaimed water? Which ministries / authorities monitor compliance with regulations? Which organisations are charged with safeguarding public health? Even if no legislation exists that corresponds to a reuse application, government institutions may have published official policies encouraging reuse that may give guidance. Legislatory aspects that may be relevant to a reuse application include aspects of water, wastewater, environment, agriculture, food, health, public works and housing. In addition agricultural cooperatives, river basin organisations, and water user associations may also have a say on reuse projects.

II.3.3 Detailed analysis of reuse options

Given that – according to the preliminary assessment– the quantity, quality and availability of effluents do meet the demand requirements of a potential reuse application and the legal framework is positive towards it, a more detailed assessments should be started involving the ranking of potential applications according to the potential risks they may entail. Table 15 summarises the potential risks to consider when selecting reuse applications. **Detailed surveys of the local situation** will be necessary in order to assess actual risks and constraints, and to identify the most appropriate technology and risk prevention measures. In a next step (➔ Chapter II.3.5), these potential risks and constraints are contrasted to the expected benefits of the various applications of water reuse.

Table 15: Categories of municipal water reuse and potential issues and constraints (Metcalf & Eddy 2003)

Water reuse categories	Potential issues and constraints
Agriculture and landscape irrigation	
Crop irrigation Commercial nurseries Park/School yards Freeways (median strips) Golf courses Cemeteries Greenbelts Residential areas	• Surface-and groundwater pollution, if not managed properly • Marketability of crops and public acceptance • Effects of water quality, particularly salts, on soils and crops • Public health concerns related to pathogens (e.g., bacteria, viruses, and parasites) • Use area control including buffer zone may resulting high user costs
Industrial recycling and reuse	
Cooling water Boiler feed Process water Heavy construction	• Constituents in reclaimed wastewater related to scaling, corrosion, biological growth, and fouling • Public health concerns, particularly related to aerosol transmission of pathogens in cooling water • Cross connection of potable and reclaimed water lines
Groundwater recharge	
Groundwater replenishment Salt water intrusion control Subsidence control	• Possible contamination of groundwater aquifers used as a resource of potable water • Organic chemicals in reclaimed wastewater and their toxicological effects • Total dissolved solids, nitrates, and pathogens in reclaimed water
Recreational/environmental uses	
Lakes and ponds Marsh enhancement Streamflow augmentation Fisheries Snowmaking	• Health concerns about bacteria and viruses (e.g., enteric infections and ear, eye, and nose infections) • Eutrophication due to nitrogen and phosphorus in receiving waters • Toxicity to aquatic life
Nonpotable urban uses	
Fire protection Air conditioning Toilet flushing	• Public health concerns about pathogens transmitted by aerosols • Effects of water quality on scaling, corrosion, biological growth, and fouling • Cross connection of potable and reclaimed water lines
Potable uses	
Blending in water supply reservoirs Pipe-to-pipe water supply	• Constituents in reclaimed water, especially trace organic chemicals and their toxicological effects • Aesthetics and public acceptance • Health concerns about pathogen transmission, particularly of enteric viruses

There are several factors of importance to the **viability of a reuse project**, ranging from the development of new or adjustment of existing infrastructure to changes in water use habits.

The assessment of the viability and sustainability of a proposed reuse project should address the following elements:

- → Suitability of soils and crops
- → Potential environmental risks and required counter-measures
- → Health-related requirements
- → Requirements of infrastructure amendments
- → Acceptance of water reuse

5-step decision making process
1. Potential sources and demand
2. Legal and institutional framework
3. Detailed analysis of reuse options
4. Economic evaluation
5. Check financial feasibility

Since reuse for irrigation is the most common application of reclaimed water in the Mediterranean region, the following information and suggestions will focus on benefits and risks associated to water reuse for irrigation.

Suitability of soils and crops

Nutrients, trace elements, and minerals contained in reclaimed water may occasionally reach levels detrimental to crops and soils. Hence, it may be necessary to select alternative crop species or to add dilution water from a non-wastewater source, which would decrease the economic benefits of the reuse project. **Salinity** usually is the most decisive parameter to judge whether the available reclaimed water is suited for irrigation purposes. This is because high salt contents hamper the plant's ability to take up water which may lead to yield losses particularly of salt-intolerant crops. In addition, high **sodium content** reduces the water permeability and aeration potential of loamy soils, which may also lead to yield losses.

Selection of alternative crop species requires the assessment of the marketability across the spectrum of target crops.

Soil characteristics are important for assessing the suitability of available reclaimed water for several reasons: On the one hand, the salt tolerance characteristics of crops vary according to certain soil attributes, such as soil permeability and drainage. Thus highly permeable sandy soils are much less prone to salinisation than weakly permeable clay soils; loamy soils exhibits medium permeability. On the other hand, there is a reversed proportional relation between the permeability and drainage attributes and the adsorption capacity of soils. Consequently, highly permeable soils are less suitable for irrigation, due to their low adsorption capacity and the likely risk of contaminant and nutrient leaching to the groundwater. In conclusion, slightly clayey soils, rich in humus are the most suitable soils for irrigation with reclaimed water.

The guideline values on plant salt tolerance characteristics as a function of soil types in Algeria provides a rough idea of the issue (see Table 4 in Neubert 2003a). However, for a precise assessment surveys are needed that consider the specific local conditions, as has been done, for example, by the GTZ Reclaimed Water Project (RWP) for the Jordan Valley (➔ see Annex III or http://gtz.jo/cms/node/60).

🕮 More detailed information on water quality, salinity and infiltration problems can be found, e.g., in the FAO Guidelines on "Water Quality for Agriculture" (Ayers and Westcot 1985).

🕮 The GTZ Brackish Water Project's report on international experiences in irrigation with marginal water compiles information on the effects of saline irrigation on crop yields and soil salinity thresholds for about 30 species of vegetables, cereals, fodder crops, and trees (see Ayesh 2001).

Potential environmental risk and required counter-measures

Major risks stemming from reuse of treated domestic wastewater are:

- groundwater contamination through leaching of nutrients and salts,
- eutrophication of surface waters from irrigation drainage,
- salinisation of soils (see above),
- clogging of soils by suspended solids, fat or grease,
- accumulation of heavy metals.

A leading issue of concern is the **nutrient conten**t of the available irrigation water. Raw wastewater often contains nitrogen, phosphate, and potassium in concentrations in excess of the nutrient requirements of crops. While trace elements and organic matter are beneficial for plant growth, this may be partly offset by the risk of nitrate leaching to groundwater and surface water. Nitrogen may also stimulate unwanted algae growth on cultivated soils (Neubert 2003a). Another risk is the groundwater **salinisation** particularly of highly permeable subsoils (see above).

The physical characteristics of an area determine its buffering capacity as well as the specific resilience or threshold levels. While some areas might turn out to be generally unsuitable for irrigation with reclaimed water (see assessment of soils above), in other areas adverse environmental effects may be avoided by setting up a forward-looking irrigation and backflow prevention management system.

🕮 More information on environmental aspects can be found in Chapter 8 of the 2006 WHO Guidelines. Annex 1: Good Irrigation Practice provides guidance on how to prevent negative environmental impacts (WHO 2006).

🕮 For more information on how to evaluate potential adverse impacts of water reuse on soils, groundwater and freshwater ecosystems, please refer to Hussain et al. (2002).

Health-related requirements

Health risks associated to water reuse are mainly due to **pathogenic microorganisms** contained in wastewater, such as bacteria, viruses and parasites (see ➔ Chapter II.4.). **Heavy metals** may also pose a health risk if accumulated in crops or fish to a level unsafe for human consumption. **Various groups of persons may be affected in different ways and to variable degrees**: Workers directly in contact with reclaimed water, irrigated soils and crops may be exposed to higher risks than consumers of produce and the population in the vicinity of a reuse application site inadvertently exposed to aerosols from wastewater irrigation. All these groups and their specific risks should be taken into account when assessing potential health risks and developing adequate counter-measures, such as crop restrictions, irrigation system management, occupational health and safety measures, consumer information, educational programmes etc. Guidance on health issues is found in existing legislation and in publications of health organisations and agencies.

It is important to include all health-related **costs** in the project viability assessment.

If uncertainty exists on potential risks to public health and / or to the environment or if the reliability of a technology is uncertain, precaution should always be the overall guiding principle when planning for water reuse.

Requirements of infrastructure amendments

Costs for distribution, storage and additional on-site treatment should already be roughly estimated at this stage, since they can present a major factor in feasibility of reuse projects. They will be assessed in more detail in step ➔ Chapter II.3.5

A major factor in determining the economic viability of a reuse project is the requirement of **infrastructure amendments for distribution**. As a thumb rule, a reuse scheme should be located close to the source of reclaimed water (e.g., a wastewater treatment plant) and should serve a small number of large users. Hence, an ideal solution in terms of economic feasibility would be a reclaimed water scheme serving a few large users, such as in an industrial park, located close to an existing wastewater treatment plant.

Where the quality of reclaimed water does not meet the needs of users, the development of **additional on-site treatment** would be an option, including the removal of suspended solids and excess nutrient as well as disinfection if necessary. Advanced treatment options at the source of effluent to be reused will not be considered at this stage. However, possibilities of improved wastewater treatment methods should be addressed in the economic evaluation of reuse versus non-reuse scenarios (➔ Chapter II.3.4).

As mentioned above (➔ Chapter II.2.1), the development of a water storage system may be required to balance supply and demand fluctuations.

Acceptance of water reuse

A most critical issue in planning for water reuse is its public perception. Hence, before starting a reuse project, a survey addressing the acceptance of water reuse should be conducted that encompasses the potential users of reclaimed water (e.g. farmers), representatives of relevant authorities as well as consumers of produce and the wider public. Their willingness to participate in the project or to buy products produced with reclaimed water is crucial to the success of any reuse project. Hence, in order to actively promote the perceptions of reusing reclaimed water and to initiate a change in attitudes and behaviour towards this issue, the proper approach is to start awareness raising and educational campaigns that are tailored to address potential stakeholders along with direct users and consumers of produce. For more information see ➔ Chapter II.5.

II.3.4 Economic evaluation

Based on the detailed analysis of selected reuse options done in the previous step, an economic evaluation should be done with the objective of identifying the reuse options with highest **net benefit to society**. A comprehensive economical assessment should also include external costs and benefits that arise from positive and negative impacts on health, environment etc. However, such costs are often difficult to determine in monetary terms.

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📖 For a detailed framework for assessing health and environmental impacts please refer to the Working Papers No 26 and 37 of the International Water Management Institute (IWMI) (Hussain et al. 2001 and 2002).

Table 16: Potential costs and benefits arising exclusively from the use of reclaimed water

Potential costs related to	Potential benefits
External effects	
Negative external effects: • Health-related impacts • Environmental impacts (groundwater contamination, soils) • Impact on adjacent lands, nuisances (bad odours, insects)	Positive external effects: • Preservation of freshwater resources, reduced investment in extending water supply systems and/or developing new water resources, sustained or increased availability of water for other uses • Positive health effects (where wastewater was discharged untreated before), • Positive environmental effects (no discharge of [un]treated wastewater into the sea or inland waters)
Sewerage system	
• Separate conveyance and distribution network for reclaimed water • Additional treatment to meet quality requirements for reuse • Administrative costs associated with reclaimed water supply services (customer billing etc.)	• Less treatment required than for discharge into the sea or inland waters (e.g. no advanced treatment for nutrient removal needed) • No conveyance or transport of effluents to discharge location • Savings in discharge fees / taxes
Project site	
• Adaptation of water application infrastructure to fit usage of reclaimed water • O&M costs (more frequent cleaning of water distribution system, monitoring of water quality) • Storage (investment in, and O&M of, storage facility) • Additional on-site treatment • Decreased income from crops (where water reuse in irrigation is only allowed for less profitable crops)	• Saving on costs for fresh water • Additional water availability • Savings in fertiliser costs • Higher crop yields (through the fertiliser effect of reclaimed water); shift to more profitable crops (where wastewater can provide additional irrigation)

Table 16 provides a (non-exhaustive) list of potential costs and benefits to be addressed in an economic evaluation of reuse projects. Of course, the extent of benefits and costs associated with a water reuse project will vary from community to community and from region to region according to the following factors:

- Volume and source of wastewater (residential, commercial, industrial);
- Composition of wastewater;
- Degree or level of treatment necessary prior to application;
- Availability of alternative water resources

The costs and benefits to be addressed in an economic analysis depend on the problem to be solved within, or overall purpose of, the project (see Chapter II.3). In order to obtain a clearer view of the economic benefits, the costs of a reuse project should also be **compared with a "baseline scenario without water reuse**".

📖 The **World Bank Guide for Planners** for Reuse of Wastewater in Agriculture (Khouri et al. 1994) suggests the following baseline scenarios for evaluation of water reuse for irrigation:

1. **No existing irrigation**: Where there is no existing agriculture or the only irrigation is from rainfall, benefits would be the introduction of agricultural production or more production from existing farms. Costs would include those for (a) setting up the irrigation system, and (b) transporting and treating the wastewater (but only the cost in excess of that required to discharge it into receiving waters). Where sound environmental disposal is enforced, the cost of treatment for reuse may be less than that for direct discharge, in which case the value for (b) would be negative--a benefit.

2. **Existing irrigation: Where wastewater can provide supplemental irrigation**, it might permit a shift to more profitable crops (for example, from grains to vegetables) or longer growing seasons. The additional revenues of this expansion minus its cost would be the benefit. Wastewater-associated costs would be the same as those in (1).

3. **Existing irrigation: Where wastewater can substitute for scarce freshwater** sources, a no-action scenario would imply (in the medium or long term) reducing or abandoning irrigated areas to increase the drinking water supply for domestic consumers; the crop production saved would be the benefit. Wastewater-associated costs would be the same as those in (1).

4. **Existing, uncontrolled wastewater irrigation:** This is a situation quite often encountered in developing countries. Shifting to a controlled operation using treated wastewater would result in public health and environmental improvements. These improvements should have a majorweight in project development, even if they are difficult to quantify. Two situations might further increase the overall feasibility of the controlled-reuse option. First, land application of treated effluent might be part of the least-cost wastewater treatment alternative. Second, irrigating with treated wastewater might lead to the production of more profitable crops.

5. **Existing or new freshwater irrigation of public parks or greenbelts:** Where this is the case, shifting to wastewater irrigation would be justified if it cost less than wastewater discharge to surface water and/or if it provided environmental benefits equal to the cost of reclamation and irrigation investments. These could be quantified or at least described qualitatively. Another benefit would be the value of the potable water saved, which could be substantial in cities where water is scarce.

6. **No existing irrigation, wastewater application as land treatment:** In this situation, there is no existing need or demand for irrigation water. The, least-cost wastewater treatment alternative, however, would include the disposal of treated wastewater on land. The cost of the entire system, including irrigation, should be included in wastewater-associated costs. Benefits from irrigation could enhance the feasibility of wastewater treatment.

(Khouri et al. 1994)

🕮 An example of an economic evaluation of alternative water reuse applications was published by Haruvy (1996) who provides sample calculations comparing net benefits of irrigation in southern and central Israel.

II.3.5 Assessing financial feasibility of the most promising solutions

It should be noted that in principle an economic justification does not necessarily ensure a project's financial viability. For example, estimates of the environmental benefits that result from preventing wastewater discharge to surface waters might make water reuse for irrigation economically attractive, but water reuse might be unaffordable for farmers or the local community. Hence the decision-making process should finally address the **costs and benefits for specific users or participants**. To this end, a preliminary outline of the selected most economic reuse applications should be prepared, listing separately all components

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required exclusively for water reuse. These costs will have to be compared with the benefits of reuse, such as savings in freshwater and fertiliser costs, as well as additional or higher crop yields.

The estimated costs for water reuse projects can be divided into capital costs versus operation and maintenance costs, including

→ Costs of reclaimed water

→ Conveyance and distribution of the reclaimed water

→ Storage of diurnal and/or seasonal excess reclaimed water

→ On-site pipework, treatment and use

→ Monitoring reclaimed water quality and health and environmental impacts

In order to assess the financial feasibility, these costs will have to be compared with the potential income generated through the water reuse scheme, which can be estimated through a

→ Market assessment

Whether the financial balance will be positive or negative also depends on who will contribute to the costs. In the end, an elementary factor will be the allocation of costs between users and suppliers of wastewater, consumers and the general public. The supplier of wastewater should generally be liable for the least-cost and environmentally most sustainable treatment and disposal option. The users of the reclaimed water should pay only the extra costs required for any additional treatment to achieve adequate water quality standards as well as the costs for conveyance and distribution.

🕮 For an exemplary calculation of financial feasibility of water reuse for irrigation of a golf course in Florida, see the Florida Reuse Coordinating Committee's Guidelines for Preparation of Reuse Feasibility Studies (Florida Reuse Coordinating Committee 1996).

Costs of reclaimed water

The financial feasibility of a reuse project will often depend on the price of reclaimed water attainable under the existing economic conditions. It is a political decision, whether charges for reclaimed water are set at a level to cover operation and maintenance costs or at a higher level to recover the capital costs of the scheme as well. In order to promote conservation of freshwater resources and to promote water reuse, it may be necessary to set the price for reclaimed water below the price that would have enabled full cost recovery. In any case, reclaimed water should be available at lower prices than the (sometimes subsidised) fresh water.

One way to set prices would be to introduce graduated tariffs that increase progressively with higher levels of water quality. However, in Pakistan, farmers have been found willing to pay higher charges for reclaimed water because they appreciate the fertilising effects of reclaimed water (WHO 2006, Chap 9).

🕮 For more information on different approaches to set prices please refer to Chapter 9 of the 2006 WHO Guidelines (WHO 2006).

🕮 Some examples of costs of reclaimed water in the MEDA region can be found in Lahlou 2005.

Conveyance and distribution of reclaimed water

As mentioned above, the conveyance and distribution systems for reclaimed water represent the main cost factor in most water reuse projects. Consequently, the financial feasibility of a reuse project will largely depend on the share of costs borne by the user and the extent of needed infrastructure investment. Construction costs for conveyance and distribution networks mainly depend on the required length and diameter of pipes and sewers, mean sewer invert depth, type of soils, water table level, required pumping capacity etc. Operation and maintenance costs include energy costs for pumping of reclaimed water, and expenses for cleaning and replacement of pipes and sewers.

Seasonal storage of diurnal and/or seasonal excess reclaimed water

Costs for storage do not only include costs for construction of the needed infrastructure, but may also entail higher quality requirements for the reclaimed water in order to avoid decrease in water quality during storage. Additional on-site treatment may, thus, become necessary to allow storage of reclaimed water. Moreover, storage facilities need to be cleaned and maintained and thus entail additional operation and maintenance costs which vary according to the size and design of the storage facilities.

On-site pipework, treatment and use

Connection to reclaimed water systems may require a separate on-site distribution network to be installed in order to avoid mixing of freshwater with reclaimed water. In addition, modifications to on-site facilities may be necessary to convert to water reuse, due to technological as well as environmental or health-related constraints. Technological constraints may arise from differences in chemical and physical attributes between reclaimed water and freshwater, such as higher loads of suspended solids and organic materials contained in reclaimed water. This may necessitate technical modifications to on-site irrigation facilities, in order to avoid clogging of valves, corrosion of pipeworks etc. Use of reclaimed water may also entail higher O & M costs for more frequent maintenance and replacement works such as sludge disposal and periodic cleaning of irrigation sprinklers and drippers. Moreover, legal standards as well as health and environmental concerns may require a change in water application technology, such as, e.g., the change from spray to drip irrigation.

In cases where the supplied reclaimed water does not meet the required quality standards, on-site treatment can be an option. However, the costs and benefits of additional on-site treatment need to be well assessed.

📖 The study by Neubert (2003b) provides detailed information on factors influencing the feasibility of disinfection for reuse in agriculture.

The following two tables list some important cost parameters for calculating costs of construction as well as of operation and maintenance of distribution, treatment and storage infrastructure.

Table 17: Examples of parameters for estimating construction cost of water reuse systems (adapted from Davis and Hirji 2003)

Item	Main factors influencing costs	Key parameters of cost functions
Reclaimed water pipes	Diameter, material, class of pipe	Diameter of pipe, length
Ground storage	Storage capacity, construction materials, shape and structure of reservoir, soil conditions	Storage capacity
Elevated storage reservoir	Storage capacity, height, construction materials, shape and structure, wind and earthquake loadings, soil conditions	Storage capacity and height of reservoir above ground level
Pumping station	Pump capacity, pump head, number and type of pumps used, construction material for station, class and material for pressure pipe	Pump capacity and pumping head
Wastewater treatment	Plant capacity, type of process and treatment facilities, construction materials, topography of plant site, soil conditions, raw wastewater intake	Area, population equivalent, effluent standard
Sewers	Diameter of sewer, depth of sewer, materials, shape of trench, soil conditions, water table level, static and dynamic loading on sewer	Diameter of sewer, mean sewer invert depth, length

Table 18: Examples of parameters for estimating operation and maintenance costs of water reuse systems (adapted from Davis and Hirji 2003)

Item	Main factors influencing costs	Key parameters of cost functions
Reclaimed water pipes	Total length of pipes, material and quality of construction, topography of area, pressure in pipes	Total length of pipe, or percentage of construction cost
Sewers	Total length of pipes, material and quality of construction, topography of area	Total length of pipe, or percentage of construction cost
Storage tank	Quality of construction, size of structure	Percentage of construction cost
Wastewater treatment	Plant capacity, designed efficiency of plant, type of process and facilities, quality of construction	Population equivalent, or raw wastewater quality
Pumping station	Pump capacity, pumping head, number and type of pumps, pump efficiency, quality of construction, energy cost	percentage of construction cost and pumping head

Monitoring reclaimed water quality and health and environmental impacts

Monitoring of reclaimed water quality requires additional staff and equipment for sampling and analysis. Furthermore, regulatory requirements, such as restriction on irrigation techniques, occupational health and safety requirements, or monitoring obligations may necessitate modification to on-site facilities. Additional outlets may be necessary in order to allow for water quality monitoring. Valves may have to be installed that allow switching to freshwater supply in case of insufficient quality of the reclaimed water resulting from malfunction of the treatment plant or hazards.

Market assessment

In order to assess financial viability of a water reuse project, it is necessary to assess marketability of the produce as well as the potential users' willingness and ability to pay for reclaimed water services. Table 19 gives planning questions to be answered in order to assess the market potential for reclaimed water and produce.

Table 19: Market feasibility: planning questions (WHO 2006)

Product for sale	Key questions
Produce	• Are products acceptable to consumers? • Can producers earn acceptable returns with restricted application and produce? • Is the project capable of supplying products that meet market quality criteria (e.g. microbiological standards for products to be exported)?
Reclaimed water	• What is the price for the treated wastewater that people are willing and able to pay? • What is the demand in the project area for treated wastewater? • Are there extra costs required to get the treated wastewater to where it will be used (e.g. pumping costs, transport etc.)?

If the public perception of products produced with reclaimed water is negative even if the relevant quality criteria are sufficiently met, the producers still may not be able to sell their products. For example, a study on water reuse in agriculture conducted in Tunisia revealed that just those crops that may be irrigated with reclaimed water according to existing laws and regulations are not marketable.

📖 For more information on different stakeholders perceptions of reuse see Neubert (2003a)

The benefits of water reuse can further be increased through adopting optimised reuse management practices along with changes of cropping pattern, irrigation management, and optimal application of nutrients contained in reclaimed water.

📖 An example of optimisation of reuse patterns is provided by Darwish et al. (1999). For recommendations on nutrient management under irrigation with reclaimed water see Meerbach (2004).

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II.4 Guidance on how to prevent health risks

Planned reuse of water is of major interest as a supplementary supply source in water-scarce regions. However, water reuse can also entail risks to human health due to **enteric viruses, pathogenic bacteria and protozoa** that are often found in untreated domestic wastewater. Industrial effluents usually contain toxic organic and inorganic chemicals as well as heavy metals that may be introduced into the food chain via the soil and roots of crop plants or via the groundwater and surface water bodies. This chapter will focus on ways to prevent health risks caused by pathogens and parasites when using reclaimed water for irrigation.

A first approach to minimize human exposure to health risks from water reuse is to focus on the specific situation of target **groups most at risk** from water reuse in agriculture, including

- farm workers and their families,
- crop handlers,
- consumers of produce,
- people living near wastewater-irrigated areas.

The degree of risk may vary among different age groups and according to the overall health situation. Hence, it is important to differentiate between the potential risk and the actual risk of contracting a disease. While the potential risk is determined by the number of pathogens occurring in the reclaimed water, the **actual health risk** depends on four more factors, namely the

- duration that pathogens remain viable in water or soil,
- infective dose,
- transmission paths
- immunity of affected persons.

Viewed from a scientific perspective, the assessment of actual health risks remains difficult as becomes obvious from the few available epidemiological studies: Their findings apply to the specific conditions under which they were obtained and there are yet too few studies available to allow general conclusions. For latest developments in methodologies for assessing health risks see ➔ Chapter II.4.3.

📖 For more information on how to prevent risks related to chemical pollutants, please refer to Chang et al. (2002).

II.4.1 Approaches to reduce health risks

There are several efficient methods and tools available to prevent health risks, apart from biological and chemical treatment. The protection of public health can best be achieved by using a **'multiple barrier' approach** that aims at interrupting the flow of pathogens from the environment (wastewater, soil, crops, etc.) to exposed workers or consumers. The measures available for health protection can be grouped into five categories:

→ Wastewater treatment
→ Crop restriction
→ Irrigation technique
→ Human exposure control
→ Microbial water quality standards

It will often be necessary to combine several methods. For example, if funds and/or land are lacking for adequate wastewater treatment, other health protective measure will have to be implemented. The **feasibility and efficiency of any health measure or combination of health measures** is strongly influenced by a number of parameters that need to be carefully considered before a health protection scheme is put into practice. These are:

- Availability of resources (labour, funds, land)
- Existing social and agricultural practices
- Market demand for reclaimed wastewater-irrigated products
- Existing patterns of excreta-related diseases.

The following paragraphs will give a short introduction to the main approaches to prevent health risks.

Wastewater treatment

The most obvious approach to reduce risks of infection from wastewater is the **removal or inactivation of pathogens** through wastewater treatment. Conventional treatment technologies, however, focus mainly on the removal of suspended solids, organic matter, and nitrate – and not on the removal of pathogens. Hence, water reclaimed through conventional treatment may require further treatment, such as filtration or disinfection, in order to reduce the concentration of pathogens to an acceptable level.

Conversely, some **alternative wastewater treatment technologies** have shown to be more effective in removal of pathogens. An example is the chemically enhanced primary treatment that uses specific chemicals to facilitate particle coagulation and flocculation and, thus, increases the removal of suspended solids, organic matter and intestinal nematode eggs. Another alternative solution are wastewater stabilisation ponds: If designed and operated properly, this treatment process is highly effective in removing pathogens and can be operated at low costs where inexpensive land is available. Where effective treatment is not available, storage reservoirs can improve wastewater quality through simple sedimentation.

🕮 Information on technologies suitable to produce microbiologically safe effluents for water reuse in the Middle East and North Africa has been compiled by Duncan Mara (2000).

Crop restriction

Health risks can also be reduced by restricting irrigation with reclaimed water to crops that are **processed or cooked** before consumption (e.g. wheat, potatoes etc.) or to **non-food crops** (e.g. fodder crops, energy crops, cotton etc.). Crop restriction is often adopted in order to allow for use of lower quality effluents for irrigation. This approach enables water reuse associated with less costly wastewater treatment and may be favoured for this particular reason. Crop restriction may, nevertheless, discourage water reuse where demand is low or lacking for wastewater-irrigatable crops.

Furthermore, crop restrictions are often difficult to enforce in practice. Effective control and law enforcement by public authorities is essential to avoid health risks. Moreover, while consumers and handlers of crops can be protected by crop restriction, this does not provide protection for farm workers and their families. Hence, crop restriction needs to be combined with further protective measures, such as appropriate irrigation system management and human exposure control.

Irrigation techniques

The issue of which irrigation technique to use has a major impact on the actual health risk situation: In general, health risks are greatest with spray/sprinkler irrigation, as this would contaminate large parts of the crops and may also expose off-site population to aerosols. Application of this technique should, therefore, be avoided where possible, and if used, more stringent microbial standards for reclaimed water have to be observed. Conversely, flood and furrow irrigation exposes on-site workers to the greatest health risk, especially if work is done by hand and without taking special protective measures. **Localized irrigation** (including drip and trickle irrigation) present the lowest health risks.

Regulations establishing a **time-limit for irrigation before the harvest** (usually of about one or two weeks) can allow die-off of bacteria and viruses. Time limits for irrigation prior to harvest are more practicable with crops that do not need to be harvested at their freshest, as with, e.g., fodder crops. Replacing wastewater with fresh irrigation water before harvest does not remove the risks of biological contamination of crops, since re-contamination of crops from the soil may occur. From the facts already mentioned above as to crop restrictions, such time-limits need to be effectively controlled and enforced.

Human exposure control

Farm workers and their families face the highest potential health risks from water reuse in agriculture, especially through parasitic infections. Protection can be achieved by applying low-contaminating irrigation techniques, along with wearing protective clothing (e.g. footwear and gloves for farmers and gloves for crop handlers) and improved levels of hygiene. Provision of adequate freshwater supplies for consumption (to avoid consumption of reclaimed water) and for hygiene purposes (e.g. for hand washing) is also important. Moreover, all reclaimed water channels, pipes, and outlets should be clearly marked (preferably painted in a characteristic colour scheme). The design of outlet fittings should be such to prevent misuse.

Where reclaimed water is used in spray/sprinkler irrigation, **people living nearby** can be protected by establishing a buffer zone of, e.g., 50 to 100 m from houses and roads. Local residents should be informed of the location of all fields under wastewater irrigation, so they can avoid these sites and prevent their children from entering them. Warning notices (using simple universal pictograms) should be posted along wastewater irrigated fields and at water tap sites.

Consumers themselves can contribute to mitigate risks, for instance, by complying with sanitary standards when preparing and consuming their food. **Health education** campaigns that focus on improving personal and domestic hygiene should address produce consumers, farm workers, **produce handlers and vendors**. Potential sources of crop contamination other than irrigation to be considered include crop handling, transportation and the sale of products in unhygienic market facilities. The best efforts to supply healthy crops according to health regulations are thwarted if the produce is afterwards 'freshened' with contaminated water in the market.

Microbial quality standards

Another instrument to prevent health risks from irrigation with reclaimed water is to set minimum microbial quality standards for reclaimed water to be used for irrigation. **Total coliform and faecal** coliform bacteria are the most common indicators for microbiological contamination of wastewater. Since *Escherichia coli* bacteria are almost always found in human and animal faeces, their presence is used as an indicator for faecal contamination. The presence of *E. coli* in a water sample will often (but not always) indicate presence of other excreta-related pathogens. Helminth eggs are used as an indicator for parasite microbiological contaminations. Limit values for coliforms and helminth eggs are often set in conjunction with specified requirements for wastewater treatment.

There are currently several approaches to define microbiological threshold values for reusing wastewater with each approach having a different result:

- total absence of faecal indicator bacteria in the reclaimed water (no risk),
- absence of excess cases of enteric disease in the exposed population (no epidemiological evident risk) and
- a model generated risk of disease which is below a defined acceptable risk (limited risk).

It remains controversial which of these approaches should be taken to assess health risks with highest possible confidence, which limit values for microbiological indicators would be required to ensure safe water reuse, and which level and type of wastewater treatment is needed to meet adequate health standards.

II.4.2 International experiences in regulating water reuse and guideline development

Putting one or more of the above-mentioned preventative approaches into a legal framework can help to ensure that water will be reused under safe conditions. If enforced effectively, laws and regulations can, thus, play an important role in increasing consumer confidence in wastewater-irrigated produce.

Some countries, such as the U.S.A. or Australia and international organisations, such as the WHO, have already adopted health standards and guidelines that regulate water reuse, especially in agriculture. Some experiences have also been gained in the Mediterranean region, especially in Jordan. Only a few European countries have established guidelines or regulations on water reuse, because they usually dispose of sufficient fresh water resources. Spain and a few other countries established regulations at sub-national level, only. Furthermore, general guidelines on water reuse for all Mediterranean countries have been proposed by Kamizoulis et al. (2003).

Examples of laws and regulations on water reuse are given in ➔ Annex I.

While the legal requirements typically stipulate a specified design of wastewater treatment in conjunction with a set of limit values on bacteriological quality, turbidity and suspended solids, it is the intended water reuse application that will determine adequate wastewater quality characteristics in terms of nutrient content etc. As to public health issues, most of the available guidelines generally follow one of two "schools of thought", namely the less stringent epidemiological-evidence school led by the WHO and the "no risk school" led by the United States. However, the quality targets of the "no risk" approach are difficult to meet, especially in less developed countries that on the one hand, lack the financial resources for expensive treatment systems, but urgently need reclaimed water for irrigation purposes, on the other. Establishing too tight requirements on water reuse entails the peril of wastewater being reused illegally and, thus, without any control at all. Hence, the adopted quality standards and guidelines should find a balance between affordability, health risks and the benefits of water reuse with a view to the local situation. Where economic constraints do limit the level of wastewater treatment quality, less strict microbiological guidelines should be complemented with other management measures for health protection (➔ see Chapter II.4.1 above) to establish standards more in line with reality.

Along this line, in many developing countries the pertinent legislation focuses on crop restrictions along with irrigation guidelines. For example, regulations often stipulate a total cessation of wastewater irrigation for a minimum time interval prior to crop harvest for vegetables that can be eaten raw or for edible plant parts in general. As mentioned above, the main problem with restrictions of this kind is their efficient monitoring and enforcement. This has led several countries, including Mexico and Tunisia (➔ see Annex I), to combine the two approaches by applying restrictions plus easy-to-measure limit values for chemical and biological sum parameters (BOD_5 and COD) and microorganisms. This results in a comprehensive and yet uncomplicated approach that provides for minimum health safety requirements, but at the same is conducive to promoting water reuse.

Legal standards and regulation for wastewater reuse should be:

a. **realistic** in relation to prevailing local conditions (epidemiological, socio-cultural and environmental factors),

b. **affordable**, and

c. **enforceable.**

(Kamizoulis et al. 2003)

II.4.3 Latest developments (new WHO approach)

The 1989 World Health Organization (WHO) guidelines on the "Safe Use of Wastewater in Agriculture" have long been the standard reference for regulating water reuse. Latest research and results from practice, however, have stressed the fact that the 1989 WHO guidelines needed to be broadened to better accommodate local conditions and, therefore, should be complemented with other health interventions, such as hygiene promotion, provision of adequate drinking water and sanitation.

The revised WHO (2006) guidelines now consider wastewater treatment as only one component of an integrated risk management strategy. To reduce risk from pathogens, the components focus on health-based targets, and offer various combinations of risk management options for meeting them (such as the measures described in ➔ Chapter II.4.1). These health protection options have to be applied in combination, since their effectiveness, for example, on pathogen removal, varies. The guidelines encourage countries to adapt guidelines to their own social, technical, economic, and environmental circumstances.

The revised WHO guidelines for wastewater quality now include health-based targets, which correspond to the **'tolerable' burden of disease** that would result from wastewater use in agriculture. Models were used to calculate the **required levels of pathogen reduction** to meet the targets for different types of irrigation scenarios and employing different degrees of wastewater treatment. For different health protection measures, their potential to reduce the amount of pathogens on the crop has been determined. In this way, it is possible to predict the pathogen reductions achievable with each combination of different health protection measures, and risk management strategies can be chosen based on the targeted pathogens removal.

The new WHO guidelines reflect that developing realistic guidelines for reusing wastewater in agriculture involves the **establishment of appropriate health-based targets** prior to defining appropriate risk-management strategies. Establishing appropriate health-based targets primarily involves an assessment of the risks associated with water reuse in agriculture by using evidence from available studies on epidemiological and microbiological risks, and risk-assessment studies. Addressing the issue of an "acceptable" or "tolerable" risk requires that one considers actual water-borne disease rates in a population in relation to all the exposures that lead to that disease. This would include risks and exposures related to poor water supply, sanitation and other sources of (e.g., after-harvest) food contamination. Positive health impacts resulting from increased food security, improved nutrition, and additional household income should also be considered. Individual countries may, thus, set different health-based targets, adapted to their own context.

📖 The 2006 WHO guidelines are available at:
http://www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html

The new WHO guidelines are intended to support the establishment of national standards and regulations that can be readily implemented and enforced. The setting of national standards should be based on a sound scientific basis with the objective of achieving a measured or estimated benefit or minimising a given risk at known costs. However, developing and implementing such standards may be a lengthy process. Therefore, the new WHO guidelines encourage progressive implementation and improvement of health protection measures. Meanwhile, the 1989 WHO guidelines will still serve as orientation.

📖 Some of the problems countries may encounter when setting up and implementing national standards have been reviewed by Sperling and Fattal (2001).

II.4.4 Importance of monitoring and control – Institutional aspects

Achieving the health-based targets requires monitoring and system assessment, defining institutional and supervisory responsibilities and independent confirmation that the system is working. However, monitoring and enforcing water reuse regulations sometimes seems more difficult a task than adopting legislation. Therefore, already when drafting new regulations it is important to plan for the institutions, staff and resources necessary to enforce their implementation.

Clear institutional responsibilities: Planned observations or measurements need to be done in order to assure that health risks are kept at a minimum. Regulatory agencies should monitor effluent quality and regularly assess the quality of wastewater treatment, storage facilities, irrigation techniques, crops, as well as encourage use of protective clothing improvements in sanitary conditions at markets etc. – and enforce existing regulations in case of non-compliance. Responsibilities for the monitoring of quality standards and health protection measures should be clearly defined in the relevant legislation and communicated to the public.

📖 Examples on how Mediterranean Countries have organised enforcement of regulations for water reuse can be found in Lahlou (2005).

Sufficient capacities (financial, human resources, technological): The efficient implementation of standards requires adequate infrastructure and institutional capacity in order to license, guide, monitor and control water reuse applications and to enforce quality standards and regulations. Strengthening the capacities of institutions is, therefore, essential in order to develop and to progressively improve sound reuse practices.

Achievable and affordable monitoring plans: Monitoring requirements and frequency of sampling should be defined in a way as to allow an unambiguous statistical interpretation of the data and a positive assessment of verifiable indicators. Frequencies of operational monitoring will vary with their specific objective. The costs need to be taken into account in the overall regulatory framework. Moreover, there should be clear operational rules on how to interpret the monitoring results and how to assess compliance with quality standards (e.g., mean values, maximum values, absolute values, percentiles or other criteria). Failure in doing so will inevitably lead to diverging interpretations and positions and will ultimately put into jeopardy the reuse project.

📖 Chapter 6 of the revised WHO guidelines gives information on how to set up viable monitoring schemes (WHO 2006).

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II.5 Importance of awareness raising, education, and capacity building

Why education is important. Public acceptance and awareness are a major issue with all water reuse projects and can be crucial to project outcomes. Empirical evidence of the last years has shown that “even the technically best-designed programmes fail or produce meagre results” if stakeholders “are not adequately consulted, informed, educated or mobilized” (Wegelin-Schuringa 2001).

Preconceptions about wastewater and reuse applications are widespread – for example, the notion that reuse of water inevitably entails health risks, irrespective of its prior treatment. Greywater, on the contrary, is often considered “clean” and safe to use, whatever contaminated it may be. Hence, while in public opinion water quality and health are strongly related, there is a common lack of knowledge of wastewater treatment processes and their results. UNEP (2004) emphasises the need to recognise and to address understanding and attitudes towards water reuse not only among the general public, but also among potential users and officials concerned.

Generally, acceptance of water reclamation has increased over the past two decades, along with a growing familiarity with the subject. *Early* information of the public clearly is an important aspect of awareness raising initiatives.

📖 Sociocultural acceptability of water reuse in Palestine has been surveyed by Khateeb (2001)

What factors count. Public acceptance of water reuse depends on various factors – including cultural and social – and varies greatly between different types of water reuse applications (cf. Wegelin-Schuringa 2001, UNICEF 1999). Thus, the average responses of a number of surveys conducted in the United States (Davis and Hirji 2003) show that recycling of wastewater for irrigation of lawns and parks was met with far less resistance (by about 4% of average responses) than for use as drinking water (by 55% of average responses); an average of about 12 percent of the respondents opposed to the use of reclaimed water in the agricultural sector (irrigation with reclaimed water of vegetable crops and vineyards etc.). Moreover, sanitation is very much a matter of social and cultural – sometimes specifically religious – norms and attitudes which are also highly relevant to a communication campaign for public behaviour change.

How to go about it. The progressive improvement of wastewater management and reuse practices, thus, requires an effective public awareness strategy. The target groups’ priorities, knowledge, specific behaviours, concerns and initial resistance need to be properly assessed. The way of how to spread information and how to actively involve stakeholders will depend on the targeted goals of the campaign (such as changing attitudes or behaviour, creating an enabling environment for participation) and the target group(s) to be addressed.

A host of methods and tools for implementing awareness raising programmes have been developed or modified for application in the field of sanitation and water reuse. These include:

- UNICEF’s (1999) process-oriented modified Triple A Framework (Assessment – Analysis – (Programme Design) – Action) addressing the programme design and overall development,
- The BASNEF model (Hubley 1993, as quoted in Wegelin-Schuringa 2001) which sets into relation the “actions needed” (or strategy to be adopted) with the social factor in question (beliefs, attitudes, subjective norms, enabling factors).
- UNICEF’s target-oriented *Communication for Development* Approach distinguishes between *advocacy, social mobilisation and programme communication* strategies and defines the level of participation according to target group(s) and objectives at stake,

- Participatory Rural Appraisal is a widely used set of participatory assessment and planning techniques, recommended by UNEP (2004).

Table 20: Tools for public awareness raising in water reuse and sanitation projects

Process phase	Aim	Tool
Assessment and analysis phase	• Assessment of situation, ongoing activities, missing information • Analysis of problem, stakeholders	• Modified Triple-A-Framework • Participatory Rural Appraisal
Programme design phase	• Designing of programme strategy and activities	• Modified Triple-A-Framework • Communication for Development
Implementation phase	• Information/ Advocacy • Awareness raising • Change of attitudes • Promotion of an enabling environment	• Modified Triple-A-Framework • BASNEF • Communication for Development • Guide to Effective Participation • Participatory Rural Appraisal

Using the modified Triple-A-Framework, the findings of the stakeholder and communication analyses form the basis for the segmentation of audiences. This is essential to design the programme strategy according to communication and mobilisation needs of the target groups. To successfully address the identified target groups, research has to be carried out regarding the most suitable place, timing and channels of communication of the campaign.

Following the *Communication for development model* (UNICEF 1999), there are three strategies to choose from in designing the programme. If the campaign aims at winning political and social leaders' commitment and active support, the *Advocacy* strategy will be a suitable approach, which is a process of gathering and formulating information into argument to be communicated to political and social leaders. *Social Mobilisation* pursues the goal of bringing together and linking the wider circle of stakeholders through participatory approaches, in order to mobilise them towards the attainment of the development objective. *Programme Communication* is a targeted consultation or training process with the aim of initiating behavioural changes that have impact on programme objectives.

Efficient ways to reach a large audience with the objective of distributing information (indirect communication) include the mass media, trusted third parties / authorities among the target group (elected officials, community leaders) and public institutions (schools, hospitals). Elements of a public-targeted awareness campaign are press releases, articles, broadcasts, presentations to key persons, brochures, and information events.

However, if individual behaviours and traditions need to be changed, it will not be sufficient to merely disseminate information or to share knowledge. Experience from a World Bank study shows that water reuse projects will obtain the best results when communities are actively involved early in project planning and implementation (Davis and Hirji 2003). It is other people's example that strongest influences people's behaviour (UNICEF 1999), which implies that model projects and participatory approaches play a key role in influencing behaviours. Moreover, stakeholders involved early in the process will feel that they can shape the project and, thus, have some control of its outcome. This alleviates fears or unease and promotes a sense of ownership.

The *Guide to Effective Participation*, developed by the Joseph Rowntree Foundation, outlines *10 key issues of community participation* (see textbox below). Methods of stakeholder involvement (direct communication) include brainstorming workshops, community mapping, transect walks, focus group discussions and community events, such as feasts and sanitation days (UNICEF 1999; Wegelin-Schuringa 2001).

10 Key issues about community participation

1. *Level of participation* – participation should be context-sensitive and meet the expectations of different interests, remaining negotiable if needed to build consensus.

2. *Initiation and process* – a participatory process needs careful preparation and a flexible management.

3. *Control* – the project initiator needs to decide consciously on how much control to confer to others.

4. *Power and purpose* – participation is a matter of power, which has to be well-balanced in order to create synergy and benefits for all participants.

5. *Role of the practitioner* – practitioners have to be particularly conscious of the various roles they play.

6. *Stakeholders and community* – communities typically consist of different stakeholders with varying (perhaps competing) interests, and it is necessary to consider who has most influence.

7. *Partnership* – true partnerships require time to build up trust and develop common commitment.

8. *Commitment* – participant commitment correlates to their problem consciousness and their sense of being able to achieve something.

9. *Ownership of ideas* – to foster identification with the underlying rationale of an intervention, initiators should give people a chance to feel that the idea could have been their own.

10. *Confidence and capacity* – enabling people to take complex decisions entails promoting confidence and may require additional capacity building.

Source: Rowntree Foundation; for further details see
http://www.jrf.org.uk/knowledge/findings/housing/H4.asp

How to implement the initiative. Springing into action requires an implementation plan to establish who is going to do what, and when. The action phase as recommended by UNICEF (1999) involves seven elements, that range from training and capacity-building measures to budget control (for further details see UNICEF 1999). In general, the communication strategy should consider appropriate outreach (wide dissemination of information) and terminology. Likewise, supportive supervision and ongoing documentation of the project's activities and outcome should be carried out from an early stage onwards.

II.5.1 References

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Annex

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Annex I: Information on existing legal frameworks

WHO - World Health Organisation

The World Health Organisation (WHO) has recognised both the potential benefits and risk of water reuse and, consequently, has developed guidelines to assist policy makers to legislate permission for the safe use of wastewater. Acknowledging the fact that previous health standards were unnecessarily high and did not reflect prevailing conditions of wastewater use in developing countries, the **1989 WHO guidelines** (see Table 21) were developed with the objective of protecting against excess infection in exposed populations. Faecal coliforms and intestinal nematode eggs are used as pathogen indicators. The recommended quality standards are combined with best practice guidelines for reuse management (crop restrictions, irrigation techniques, good personal hygiene, and use of protective clothing).

Table 21: 1989 WHO guidelines for using treated wastewater in agriculture [a]

Category	Reuse conditions	Exposed Group	Intestinal nematodes [b] (arithmetic mean no. of eggs per litre) [c]	Faecal coliforms (geometric mean no. per 100 ml) [c]	Wastewater treatment expected to achieve the required microbiological guideline
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks [d]	Workers, consumers, public	≤ 1	≤ 1000	A series of stabilisation ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees [e]	Workers	≤ 1	No standard recommended	Retention in stabilisation ponds for 8–10 days or equivalent helminthes and faecal coliform removal
C	Localised irrigation of crops in category B if exposure to workers and the public does not occur	None	Not applicable	Not applicable	Pre-treatment as required by irrigation technology but not less than primary sedimentation

(a) In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account and the guidelines modified accordingly.
(b) Ascaris and Trichuris species and hookworms.
(c) During the irrigation period.
(d) A more stringent guideline limit (≤ 200 faecal coliforms/100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.
(e) In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

Many countries have welcomed the guidance from the 1989 WHO standards and guidelines. France, for example, used a similar approach in setting guidelines, which were published in 1991. These guidelines adopt analogous water categories (called A, B and C in the WHO guidelines; Table 21) and microbiological limits, but stipulate additional rules of wastewater application: For example, for category A quality requirement must be complemented by the use of irrigation techniques that avoid wetting fruit and vegetables and spray irrigation of golf courses and open landscaped areas is only allowed outside public opening hours (Blumenthal et al. 2000a)

While the 1989 WHO guidelines were sometimes criticised for not guaranteeing health protection, its recommendations were still difficult to meet for some developing countries. Mexico and some other countries have modified the microbiological criteria to suit local epidemiological and economic circumstances.

The WHO has subsequently revised their guidelines on water reuse and the third edition was published under the title "Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture" in 2006 (also see Chapter II.3.3). The revised guidelines can be downloaded at:
http://www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html

References:

Blumenthal, U.J.; D.D. Mara, A. Peasy, G. Ruiz-Palacios and R. Stott 2000a: Guidelines for the microbiological quality of treated wastewater used in agriculture: recommendations for revising WHO guidelines. Bulletin of the World Health Organisation (WHO) 78, 9.
http://www.who.int/docstore/bulletin/pdf/2000/issue9/bu0741.pdf

U.S.EPA - U.S.Environmental Protection Agency

The U.S.Environmental Protection Agency (U.S.EPA) in their 2004 guidelines recommend much stricter standards for water reuse in the USA than those of the WHO (1989). The elements of the guidelines applicable to water reuse in irrigation are summarised in Table 22. The guideline for irrigation of crops likely to be eaten uncooked is no detectable faecal coliforms (FC)/100 ml (compared to ≤ 1000 FC/100 ml recommended by the WHO). Secondary treatment should be used followed by filtration (with prior coagulant and/or polymer addition) and disinfection. For irrigation of commercially processed crops, fodder crops etc., the EPA standard is ≤ 200 FC/100 ml, where only a nematode egg guideline is set by WHO (1989). No nematode egg guideline is specified by U.S.EPA.

Actual standard setting is the responsibility of individual states in the USA, and different US-States take different approaches (some specify treatment processes, others specify water quality standards) and a range of standards are in use (Blumenthal et al. 2000b). Standards in several countries have been influenced by American standards, especially by the Californian standards.

The 2004 U.S.EPA Guidelines for Water Reuse are available at
http://www.epa.gov/ord/NRMRL/pubs/625r04108/625r04108.htm

Table 22: U.S.EPA guidelines for water reuse for irrigation (extracted from Suggested Guidelines for Water Reuse (U.S.EPA 2004) [1]

Types of Reuse	Treatment	Reclaimed Water Quality [2]	Reclaimed Water Monitoring	Setback Distances [3]	Comments
Urban Reuse All types of landscape irrigation (e.g. golf courses, parks, cemeteries) – also vehicle washing, toilet flushing, use in fire protection systems and commercial air conditioners, and other uses with similar access or exposure to the water	• Secondary[4] • Filtration[5] • Disinfection[6]	• pH = 6-9 • ≤ 10 mg/l BOD[7] • ≤ 2 NTU[8] • No detectable FC/100 ml[9,10] • 1 mg/l Cl_2 residual (min.)[11]	• pH - weekly • BOD - weekly • Turbidity - continuous • Coliform - daily • Cl_2 residual - continuous	• 50 ft (15 m) to potable water supply wells	• At controlled-access irrigation sites where design and operational measures significantly reduce the potential of public contact with reclaimed water, a lower level of treatment, e.g., secondary treatment and disinfection to achieve < 14 faecal coli/100 ml, may be appropriate. • Chemical (coagulant and/or polymer) addition prior to filtration may be necessary to meet water quality recommendations. • The reclaimed water should not contain measurable levels of viable pathogens.[12] • Reclaimed water should be clear and odourless. • A higher chlorine residual and/or a longer contact time may be necessary to assure that viruses and parasites are inactivated or destroyed. • A chlorine residual of 0.5 mg/l or greater in the distribution system is recommended to reduce odours, slime, and bacterial regrowth.
Restricted Access Area Irrigation Sod farms, silviculture sites, and other areas where public access is prohibited, restricted or infrequent	• Secondary[4] • Disinfection[6]	• pH = 6-9 • ≤ 30 mg/l BOD • ≤ 30 mg/l SS • ≤ 200 FC/100 ml [9,13,14] • 1 mg/l Cl_2 residual (min.)[11]	• pH - weekly • BOD - weekly • TSS - daily • Coliform - daily • Cl_2 residual -continuous	300 ft (90 m) to potable water supply wells 100 ft (30 m) to areas accessible to the public (if spray irrigation)	• If spray irrigation, TSS less than 30 mg/l may be necessary to avoid clogging of sprinkler heads.

Table 22: U.S.EPA guidelines for water reuse for irrigation (extracted from Suggested Guidelines for Water Reuse (U.S.EPA 2004) [1] (cont.)

Types of Reuse	Treatment	Reclaimed Water Quality [2]	Reclaimed Water Monitoring	Setback Distances [3]	Comments
Agricultural Reuse – Food Crops Not Commercially Processed Surface or spray irrigation of any food crop, including crops eaten raw	• Secondary[4] • Filtration[5] • Disinfection[6]	• pH = 6-9 • ≤ 10 mg/l BOD[7] • ≤ 2 NTU[8] • No detectable FC/100 ml[9,10] • 1 mg/l Cl_2 residual (min.)[11]	• pH - weekly • BOD - weekly • Turbidity - continuous • Coliform - daily • Cl_2 residual - continuous	• 50 ft (15 m) to potable water supply wells	• Chemical (coagulant and/or polymer) addition prior to filtration may be necessary to meet water quality recommendations. • The reclaimed water should not contain measurable levels of viable pathogens.12 • A higher chlorine residual and/or a longer contact time may be necessary to assure that viruses and parasites are inactivated or destroyed. • High nutrient levels may adversely affect some crops during certain growth stages.
Agricultural Reuse – Food Crops Commercially Processed Surface Irrigation of Orchards and Vineyards	• Secondary[4] • Disinfection[6]	• PH = 6-9 • ≤ 30 mg/l BOD • ≤ 30 mg/l SS • ≤ 200 FC/100 ml [9,13,14] • 1 mg/l Cl_2 residual (min.)[1]	• pH - weekly • BOD - weekly • TSS - daily • Coliform - daily • Cl_2 residual - continuous	• 300 ft (90 m) to potable water supply wells 100 ft (30 m) to areas accessible to the public (if spray irrigation)	• If spray irrigation, TSS less than 30 mg/l may be necessary to avoid clogging of sprinkler heads. • High nutrient levels may adversely affect some crops during certain growth stages.
Agricultural Reuse – Non Food Crops Pasture for milking animals; fodder, fibre, and seed crops	• Secondary[4] • Disinfection[6]	• pH = 6-9 • ≤ 30 mg/l BOD • ≤ 30 mg/l SS • ≤ 200 FC/100 ml [9,13,14] • 1 mg/l Cl_2 residual (min.)[11]	• pH - weekly • BOD - weekly • TSS - daily • Coliform - daily • Cl_2 residual -continuous	• 300 ft (90 m) to potable water supply wells 100 ft (30 m) to areas accessible to the public (if spray irrigation)	• If spray irrigation, TSS less than 30 mg/l may be necessary to avoid clogging of sprinkler heads. • High nutrient levels may adversely affect some crops during certain growth stages. • Milking animals should be prohibited from grazing for 15 days after irrigation ceases. A higher level of disinfection, e.g., to achieve < 14 faecal coli/100 ml, should be provided if this waiting period is not adhered to.

Legend: TSS= total suspended solids; FC= faecal coliforms

Footnotes:

[1] These guidelines are based on water reclamation and reuse practices in the U.S., and they are especially directed at states that have not developed their own regulations or guidelines. While the guidelines should be useful in may areas outside the U.S., local conditions may limit the applicability of the guidelines in some countries. It is explicitly stated that the direct application of these suggested guidelines will not be used by USAID as strict criteria for funding.
[2] Unless otherwise noted, recommended quality limits apply to the reclaimed water at the point of discharge from the treatment facility.
[3] Setback distances are recommended to protect potable water supply sources from contamination and to protect humans from unreasonable health risks due to exposure to reclaimed water.
[4] Secondary treatment processes include activated sludge processes, trickling filters, rotating biological contractors, and may include stabilization pond systems. Secondary treatment should produce effluent in which both the BOD and TSS do not exceed 30 mg/l.
[5] Filtration means the passing of wastewater through natural undisturbed soils or filter media such as sand and/or anthracite, filter cloth, or the passing of wastewater through microfilters or other membrane processes.
[6] Disinfection means the destruction, inactivation, or removal of pathogenic microorganisms by chemical, physical, or biological means. Disinfection may be accomplished by chlorination, UV radiation, ozonation, other chemical disinfectants, membrane processes, or other processes. The use of chlorine as defining the level of disinfection does not preclude the use of other disinfection processes as an acceptable means of providing disinfection for reclaimed water.
[7] As determined from the 5-day BOD test.
[8] The recommended turbidity limit should be met prior to disinfection. The average turbidity should be based on a 24-hour time period. The turbidity should not exceed 5 NTU at any time. If TSS is used in lieu of turbidity, the TSS should not exceed 5 mg/l.
[9] Unless otherwise noted, recommended coliform limits are median values determined from the bacteriological results of the last 7 days for which analyses have been completed. Either the membrane filter or fermentation-tube technique may be used.
[10] The number of faecal coliform organisms should not exceed 14/100 ml in any sample.
[11] Total chlorine residual should be met after a minimum contact time of 30 minutes.
[12] It is advisable to fully characterize the microbiological quality of the reclaimed water prior to implementation of a reuse program.
[13] The number of faecal coliform organisms should not exceed 800/100 ml in any sample.
[14] Some stabilization pond systems may be able to meet this coliform limit without disinfection.

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Mexico

In Mexico, microbiological and chemical standards governing water reuse in agriculture have developed considerably over the last 15 years. Existing guidelines were reviewed in 1991, 1993, and again in 1996. Particular attention was paid to (1) the cultivation of vegetables and other crops eaten raw, (2) the importance of water reuse in agriculture as a form of wastewater treatment and disposal, and (3) the diversity of treatment processes available to achieve the guidelines. (Peasey et al. 2000)

The final revision of the microbiological standards was introduced in 1996. The adopted standard NOM-001-ECOL-1996 (Table 23) "establishes the maximum permissible limits of contaminants in wastewater to be discharged into national waters and onto national soil". As in the WHO guidelines, faecal coliforms are used as the indicator for pathogenic contamination. The maximum limit concentration of faecal coliforms imposed for wastewater to be discharged into national water or property and for wastewater application to soils is a monthly mean of 1,000 MPN (most probable number) per 100 ml and a daily mean of 2,000 MPN per 100 ml. Helminth eggs are used as the indicator for parasitic contamination. The maximum value for wastewater application to soils (for agricultural irrigation) is one helminth egg per litre for restricted irrigation and five helminth eggs per litre for unrestricted irrigation. In the annex of the Mexican regulations, suitable irrigation techniques are defined (Mexican Official Regulation as cited in Scott et al. 2000).

Table 23: Mexican Standard NOM-001-ECOL-1996 governing water reuse in agriculture (cited from Scott et al. 2000)

Irrigation	Faecal Coliforms /100 ml (MPN)	Helminth eggs/litre
Restricted	1000_m - 2000_d	≤ 5
Unrestricted	1000_m - 2000_d	≤ 1

(m=monthly mean, d=daily mean, MPN=most probable number)

Note: Unrestricted irrigation is defined as permitting irrigation of all crops, whilst restricted irrigation excludes salad crops and vegetables that are eaten raw.

The revised standards impose the same limit values regardless of the discharge source. The standards were designed to be accomplishable with the technology and resources available at present and in the near future in Mexico and to be easily enforced requiring only limited monitoring. The standard was further designed to sufficiently protect "at-risk" groups according to the actual state of research. The proposed microbiological standards take into account all possible treatment processes. A stricter helminth standard would have required additional use of filters in conventional treatment plants which would add as significant extra cost.

The Mexican reuse standard stipulates also limit concentrations for basic contaminants, heavy metals and cyanides in wastewater to be discharged into national water or property. The allowable range for pH is 5 to 10 units.

References

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Scott, C. A.; J. A. Zarazúa and G. Levine 2000: Urban-wastewater reuse for crop production in the water-short Guanajuato river basin, Mexico. Colombo, Sri Lanka. Research Report 41. Colombo, Sri Lanka: International Water Management Institute.
http://www.iwmi.cgiar.org/pubs/PUB041/Report41.pdf

Tunisia

Irrigation with recycled wastewater is well established in Tunisia. The Tunisian government is pursuing water reuse in agriculture as a strategic objective and is translating the objective into systematic practice (Neubert 2002). A water reuse policy was launched in the early eighties of the previous century (Kamizoulis et al. 2003).

Regulations of water reuse in agriculture are mainly based on use restrictions. water reuse in agriculture is regulated by the 1975 Water Code (law No. 75-16 of 31 March 1975), by the 1989 Decree No. 89-1047 (of 28 July 1989), by the Tunisian standard for the use of treated wastewater in agriculture (NT 106- 003 of 18 May 1989), by the list of crops than can be irrigated with treated wastewater (Decision of the Minister of Agriculture of 21 June 1994), and by the list of requirements for agricultural water reuse projects (Decision of 28 September 1995). These regulations prohibit wastewater irrigation of vegetables to be consumed raw. The same applies for heavily used pastures. Consequently, most reclaimed water is used in Tunesia to irrigate vineyards, citrus and other trees (olives, peaches, pears, apples, pomegranates, etc.), fodder crops (alfalfa, sorghum, etc), and industrial crops (cotton, tobacco, sugar beet, etc).Tunisia continues to permit wastewater irrigation in areas and for crops that pose little health risk to consumers, such as golf courses, public parks, and hotel gardens.

The 1989 Decree demands that the use of recycled wastewater must be authorised by the Minister of Agriculture in agreement with the Minister of Environment and Land Use Planning and the Minister of Public Health. It sets out the precautionary measures required to protect the health of farmers, consumers and the environment. Use restrictions are supplemented by biological and chemical sum limit values (BOD_5, COD, organic substances) and limit values for nematode eggs. Monitoring plans for these standards are specified: Physical-chemical parameters have to be analysed once a month, trace elements once every six months and helminth eggs every two weeks in 24h composite samples.

Moreover, specifications have been published that determine the terms and general conditions of reclaimed water reuse. These include, e.g., the precautionary measures to be taken in order to prevent any contamination (workers, residential areas, consumers, etc.). For example, in areas where sprinklers are used, buffer areas must be established. It is interesting to note that in Tunisia farmers pay for the treated wastewater they use to irrigate their fields.

However, despite the fact that in Tunisia the legal, technical, and political framework is relatively favourable for water reuse, only 20% of the treatment plant effluents are reused. It is reportedly the reluctance of farmers to reuse wastewater that poses the main obstacle to increasing the amount of reclaimed water that is reused. Another important impediment are the legal restrictions to wastewater irrigation of vegetables eaten raw, as vegetables are the most profitable and best marketable crops in Tunisia (Neubert 2002).

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Jordan

The key policy objectives of the Jordan water reuse management plan are to use reclaimed water, where practical, in exchange for present and future use of freshwater and to maximise the returns from reclaimed water resources. Therefore, the Government of Jordan has imposed that all new wastewater treatment projects must include feasibility aspects for water reuse and has set standards for treated domestic wastewater effluent (Jordanian Standards JS 893/1995 revised in 2002). The Jordanian standards for water reuse are based on reuse categories depending on the type of crops and areas to be irrigated (see Table 24). The standard prohibits the use of reclaimed water for irrigating vegetables to be eaten raw. Furthermore, it is prohibited to employ sprinkler irrigation for applying reused water, except for irrigating golf courses. In this case, irrigation should take place at night and sprinklers must be movable and not accessible for day use. When using reclaimed water for irrigating fruit trees, irrigation must be stopped two weeks prior to fruit harvest and all fallen fruits must be discarded.

Table 24: Allowable Limit for properties and criteria for reuse in irrigation (Jordanian Standard JS 893/2002)

Allowable limits per end use				
Parameter	Unit	Cooked Vegetables, Parks, Playgrounds and Sides of Roads within city limits	Fruit Trees, Sides of Roads outside city limits, and landscape	Field Crops, Industrial Crops and Forest Trees
		A	B	C
Biological Oxygen Demand	mg/l	30	200	300
Chemical Oxygen Demand	mg/l	100	500	500
Dissolved Oxygen	mg/l	>2	-	-
Total suspended solids	mg/l	50	150	150
pH	unit	6-9	6-9	6-9
Turbidity	NTU	10	-	-
Nitrate	mg/l	30	45	45
Total Nitrogen	mg/l			
Escherichia coli	Most probable number or colony forming unit/ 100 ml	45	70	70
Intestinal Helminth Eggs	Egg/l	< or =1	< or =1	< or =1

Source: http://www.mwi.gov.jo/mwi/JS-893.aspx

In addition, the Jordanian standards provide guide values for a range of chemical wastewater components for the purpose of guidance. In case of exceeding these values, "the end user must carry out scientific studies to verify the effect of that water on public health and the environment and suggest ways and means to prevent damage to either" (http://www.mwi.gov.jo/mwi/JS-893.aspx)

Table 25: Guidelines for Reuse in Irrigation (JS 893/2002)

Fat And grease	FOG	mg/l	8
Phenol	Phenol	mg/l	<0.002
Detergent	MBAS	mg/l	100
Total Dissolved Solids	TDS	mg/l	1500
Total Phosphate	$T\text{-}PO_4$	mg/l	30
Chloride	Cl	mg/l	400
Sulphate	SO_4	mg/l	500
Bicarbonate	HCO_3	mg/l	400
Sodium	Na	mg/l	230
Magnesium	Mg	mg/l	100
Calcium	Ca	mg/l	230
Sodium Adsorption Ration	SAR	mg/l	9
Aluminium	Al	mg/l	5
Arsenic	As	mg/l	0.1
Beryllium	Be	mg/l	0.1
Copper	Cu	mg/l	0.2
Fluoride	F	mg/l	1.5
Iron	Fe	mg/l	5.0
Lithium	Li	mg/l	2.5(0. 075 for citrus crops)
Manganese	Mn	mg/l	0.2
Molybdenum	Mo	mg/l	0.01
Nickel	Ni	mg/l	0.2
Lead	Pb	mg/l	5.0
Selenium	Se	mg/l	0.05
Cadmium	Cd	mg/l	0.01
Zinc	Zn	mg/l	5.0
Chrome	Cr	mg/l	0.1
Mercury	Hg	mg/l	0.002
Vanadium	V	mg/l	0.1
Cobalt	Co	mg/l	0.05
Boron	B	mg/l	1.0
Cyanide	CN	mg/l	0.01

Source: http://www.mwi.gov.jo/mwi/JS-893.aspx

The Jordanian Standard JS 893 2002 has been reviewed in 2006 to include limit values for reuse of teated wastewater for irrigation of cut flowers. Moreover, limit values for Nitrate and Nitrogen have been increased for irrigation of industrial crops and forest trees. No english version of the reviewed standard was available at the time of printing.

Jordan irrigation water quality guidelines - Proposal by Reclaimed Water Project/national working group

The Jordanian Standard JS 893/2002 addresses the standard requirements and quality control of reclaimed wastewater. Effluents that comply with these standards may be used under certain restrictions in agriculture or for groundwater recharge, or can be discharged into streams or wadis, provided the water is not used for drinking.

The JS 893/2002 standard does not cover the water quality of the receiving waters once the reclaimed water has been discharged and blended with other water sources. This is the background to the Reclaimed Water Project's (RWP) initiative to launch a national interdisciplinary working group that developed a proposal for irrigation water quality guidelines. The proposal is based mainly on the guidelines of the United Nations' Food and Agricultural Organisation (Ayers and Westcot 1985) and the World Health Organisation (WHO 1989). The proposal was approved by all relevant national authorities in 2004 and distributed and implemented during 2005. Meanwhile the proposal has been revised and amended. Table 26 summarises the proposed parameters and limit values of the revised guidelines.

The proposed guidelines start from the recognition of the specific conditions in Jordan, with a focus on the current institutional situation and the reality on the ground. Especially in the Jordan Valley diluted/blended reclaimed water is used for unrestricted irrigation and there has been increasing concern with regard to possible health risks and environmental hazards. The proposed limit values are less strict for BOD_5, COD, NO_3-N and for E. coli as compared to the JS 893/2002 standard. The boron ranges in the guidelines follow Maas (1990). The fact that some of the proposed limit values are more relaxed than the JS 893/2002 does not mean that the health of farm workers and consumers is put at risk as the complementary agronomic guidelines, also elaborated by the RWP, recommend irrigation methods and practices that prevent direct contamination with pathogens (e.g. drip irrigation in combination with plastic mulch) and because crop monitoring with regard to possible contamination is also recommended.

Table 26: Proposed irrigation water quality guidelines for Jordan (Reclaimed Water Project, as of October 2006)

Parameter	Unit	Limit value
pH		6 - 9
EC	dS/m	sensitive plants: < 1.7
		medium tolerant plants: 1.7 - 3.0
		tolerant plants: 3.0 - 7.5
		highly tolerant plants: > 7.5
Temperature	° C	4° C - 30° C
TSS	mg/l	< 50
BOD_5	mg/l	< 60
COD	mg/l	< 120
Ca	mg/l	< 400
Mg	mg/l	< 150
SAR		6 - 9
K	mg/l	< 80
HCO_3	mg/l	< 520
NO_3-N	mg/l	< 16
NH_4-N	mg/l	< 16
T-N	mg/l	< 50

Parameter	Unit	Limit value
SO_4	mg/l	< 960
B	mg/l	0.7 - 6
Fe	mg/l	< 1
Mn	mg/l	< 2
Zn	mg/l	< 2
Cu	mg/l	< 1
E. coli	MPN/ 100 ml	1,000
Int. Helm. eggs	eggs/litre	≤1

References

Maas E.V. 1990: Crop salt tolerance. In: K.K. Tanji (ed.): Agricultural Salinity Assessment and Management Manual. New York: ASCE: 262-304.

Ayers, R. S. and D. W. Westcot 1985: Water Quality for Agriculture. Irrigation and Drainage Paper no. 29, Rev. 1. Rome: Food and Agriculture Organization.
http://www.fao.org/DOCREP/003/T0234E/T0234E00.htm

WHO 1989: Health Guidelines for Use of Wastewater in Agriculture and Aquaculture. World Health Organization, Technical Report Series 778, Geneva: World Health Organisation.

Turkey

Water reuse was officially legitimised in 1991 through the Regulation for Irrigational Wastewater Reuse issued in by the Ministry of Environment. According to the “Water Pollution Control Regulations”, a written permission to use treated wastewater in irrigation must be obtained from the relevant government organisations. A commission appointed by the State Water Organisation, Iller Bank, Agriculture Ministry, and Environmental and Forestry Ministry will decide whether the effluent can be used for irrigation purposes or not.

The effluent quality criteria for irrigation with reference to the Turkish Water Pollution Control Regulations are given in Tables 27 and 28. In general, the WHO standards have been adopted except the limits for the intestinal nematodes and residual chlorine. The Turkish regulations seem insufficient as to the adopted microbiological standards and – as mentioned before – need to be revised according to the current state of knowledge.

Boron concentrations should be given special attention, because Turkey is rich in boron sources. Hence, a separate quality classification regarding boron concentrations in treated wastewater is recommended for irrigation.

Table 27: Turkish Water Pollution Control Regulation - Maximum Concentrations of Toxic Elements in Effluents for Irrigation

Elements	**Max. Concentration (mg/l)**	**Elements**	**Max. Concentration (mg/l)**
Aluminium (Al)	5.0	**Lead (Pb)**	5.0
Arsenic (As)	0.1	**Lithium (Li)**	2.5
Beryllium (Be)	0.1	**Manganese (Mn)**	0.2
Cadmium (Cd)	0.01	**Molybdenum (Mo)**	0.01
Chromium (Cr)	0.1	**Nickel (Ni)**	0.2
Cobalt (Co)	0.05	**Selenium (Se)**	0.02
Copper (Cu)	0.2	**Vanadium (V)**	0.1
Fluorine (F)	1.0	**Zinc (Zn)**	2.0
Iron (Fe)	5.0		

Table 28: Turkish Water Pollution Control Regulation - Effluent Quality Criteria for Irrigation

Effluent quality criteria	**First class effluent (very good)**	**Second class effluent (good)**	**Third class effluent (usable)**	**Fourth class effluent (usable by care)**	**Fifth class effluent (can not be used)**
EC25 * 10^6 (umhos/cm)	0.250	250-750	750-2000	2000-3000	>3000
Sodium percent (Na %)	<20	20-40	40-60	60-80	>80
Sodium absorption range	<10	10-18	18-26	<26	
Sodium carbonate residual					
meq/l	<1.25	1.25-2.5	>2.5	12-20	
mg/l	<66	66-133	>133	625-710	

Effluent quality criteria	**First class effluent (very good)**	**Second class effluent (good)**	**Third class effluent (us-able)**	**Fourth class effluent (usable by care)**	**Fifth class effluent (can not be used)**
Chloride (Cl)					
meq/l	0-4	4-7	7-12	12-20	>20
mg/l	0-142	142-249	249-426	626-710	>710
Sulphide (SO_4)					
meq/l	0-4	4-7	7-12	12-20	>20
mg/l	0-192	192-336	336-575	576-960	>960
Total salts mg/l	0-175	175-525	525-1400	1400-2100	>2100
Boron[1] concentration mg/l	0-0.5	0.5-1.12	1.12-2.0	2.0	-
NO^3 or NH^+_4	0-5	5-10	10-3	30-50	>50
Faecal colif-orms (in 100 ml)	0-2	2-20	20-102	102-103	>103
BOD_5 (mg/l)	0-25	25-50	50-100	100-200	>200
Suspended solids mg/l	20	30	45	60	>100
pH	6.5-8.5	6.5-8.5	6.5-8.5	6-9	<6 or >9
Temperature ºC	30	30	35	40	>40

[1] An additional water quality classification regarding boron concentrations in treated wastewater is recommended for irrigation.

Palestine

Minimum effluent quality standards for reuse of wastewater (Environmental Limit Values – ELV) have been recommended by the Environment Quality Authority (EQA) and have been adopted by the Institute of Palestinian Standards. However, these limit values have not been enforced so far. The draft Palestinian standards include quality standards for reuse of treated wastewater depending on the crops and areas to be irrigated (Table 29). They further stipulate that some best practices have to be adopted when reusing wastewater. These include:

- Irrigation has to be stopped two weeks before harvest where treated wastewater is applied to productive crops and field crops; fallen fruits or fruits close to the ground must be discarded. The same applies for animal feeding crops, where irrigation has to cease two weeks before grazing.
- Sprinkler irrigation is prohibited.
- Use of treated wastewater is forbidden for irrigation of all types of vegetables.
- Closed pipes have to be used when wastewater is transported in areas with high soil permeability in order to prevent adverse effects to aquifers or surface waters used for drinking.
- Dilution of treated water with fresh water to meet the required standard for reuse is forbidden.

Table 29: Palestinian Standards Institute - Recommended Guidelines for Treated Wastewater Characteristics according to different applications

Quality Parameter (mg/l except otherwise indicated)	Fodder Irrigation		Gardens, Playgrounds, Recreational	Industrial Crops	Groundwater Recharge	Seawater Outfall	Landscapes	Trees	
	Dry	Wet						Citrus	Olive
BOD_5	60	45	40	60	40	60	60	45	45
COD	200	150	150	200	150	200	200	150	150
DO	> 0.5	> 0.5	> 0.5	> 0.5	> 1.0	> 1.0	> 0.5	> 0.5	> 0.5
TDS	1500	1500	1200	1500	1500	-	1500	1500	500
TSS	50	40	30	50	50	60	50	40	40
pH	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9
Colour (PCU)	Free	Free	Free	Free	Free of coloured matter	Free of coloured matter	Free	Free	Free
FOG	5	5	5	5	0	10	5	5	5
Phenol	0.002	0.002	0.002	0.002	0.002	1	0.002	0.002	0.002
MBAS	15	15	15	15	5	25	15	15	15
NO_3-N	50	50	50	50	15	25	50	50	50
NH_4-N	-	-	50	-	10	5	-	-	-
O.Kj-N	50	50	50	50	10	10	50	50	50
PO_4-P	30	30	30	30	15	5	30	30	30
Cl	500	500	350	500	600	-	500	400	400
SO_4	500	500	500	500	1000	1000	500	500	500
Na	200	200	200	200	230	-	200	200	200

Table 29: Palestinian Standards Institute - Recommended Guidelines for Treated Wastewater Characteristics according to different applications (cont.)

Quality Parameter (mg/l except otherwise indicated)	Fodder Irrigation		Gardens, Playgrounds, Recreational	Industrial Crops	Groundwater Recharge	Seawater Outfall	Landscapes	Trees	
	Dry	Wet						Citrus	Olive
Mg	60	60	60	60	150	-	60	60 60	60
Ca	40	40	40	40	40	-	40	40	40
SAR	9	9	10	9	9	-	9	9	9
Residual Cl2	-	-	-	-	-	-	-	-	-
Al	5	5	5	5	1	5	5	5	5
Ar	0.1	0.1	0.1	0.1	0.05	0.05	0.01	0.01	0.01
Cu	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
F	1	1	1	1	1.5	-	1	1	1
Fe	5	5	5	5	2	2	5	5	5
Mn	0.2	0.2	0.2	0.2	0.2 0.2	0.2	0.2	0.2	0.2
Ni	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Pb	1	1	0.1	1	0.1	0.1	1	1	1
Se	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Cd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zn	2.0	2.0	2.0	2.0	5.0	5.0	2.0	2.0	2.0
CN	0.05	0.05	0.05	0.05	0.1	0.1	0.05	0.05	0.05
Cr	0.1	0.1	0.1	0.1	0.05	0.5	0.1	0.1	0.1
Hg	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Co	0.05	0.05	0.05	0.05	0.05	1.0	0.05	0.05	0.05
B	0.7	0.7	0.7	0.7	1.0	2.0	0.7	0.7	0.7

Table 29: Palestinian Standards Institute - Recommended Guidelines for Treated Wastewater Characteristics according to different applications (cont.)

Quality Parameter (mg/l except otherwise indi-cated)	Fodder Irrigation		Gardens, Playgrounds, Recreational	Industrial Crops	Groundwater Recharge	Seawater Outfall	Landscapes	Trees	
	Dry	Wet						Citrus	Olive
FC (CFU/100 ml)	1000	1000	200	1000	1000	5000	1000	1000	1000
Pathogens	Free	Free	Free	Free	Free	Free	Free	Free	Free
Amoeba & Gardia (Cyst/L)	-	-	Free	-	Free	Free	-	-	-
Nematodes (Eggs/L)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

Annex II: Link-list: Regional and international experience with water reuse

Project Name	Grey water Reuse in Urban Agriculture Special Features	Special Features	Wastewater treatment + reuse at household level
Location	Tafila, Jordan		Arid / Semiarid climate
Date	2002		
Institution	Inter-Islamic Network on Water Resources Development and Management (INWRDM)		
Description	Installation of minor facilities at household level for the diversion of grey water, deploying a simple natural filter system to pre-treat the effluent, which is then used for garden crop watering. Thus, wastewater treatment costs are reduced to the treatment of septic toilet wastewater, and higher crop yields contribute to household income additionally.		
Contact	Murad J. Bino, Project Leader Inter-Islamic Network on Water Resources Development and Management (INWRDAM) P.O. Box 1460 Jubieha, Amman JORDAN 11941 http://www.nic.gov.jo/inwrdam Email: inwrdam@nic.net.jo		
Links	http://www.idrc.ca/en/ev-82039-201_100880-1-IDRC_ADM_INFO.html http://www.crdi.ca/en/ev-6322-201-1-DO_TOPIC.html		

Project Name	Duckweed Wastewater Treatment and Reuse for Fodder	Special Features	Biological treatment + subsequent use of biological agent as fodder
Location	Jordan Valley / West Bank		Semiarid climate
Date	2002-2003		
Institution	Water and Environmental Development Organisation (WEDO)		
Description	Duckweed is used for biological wastewater treatment, considerably reducing BOD, TSS, nitrogen and phosphorus load. Due to its high concentration of protein, duckweed is then used as fodder for poultry, livestock and fish. The remaining effluent meets standards for restricted irrigation. A training farm of the Agricultural Development Society (ADS) investigates growth conditions of duckweed to enhance duckweed cultivation.		
Contact	Naser Faruqi, Senior Program Officer Water and Wastewater Projects, Programs Branch International Development Research Centre (IDRC) PO Box 8500, Ottawa, Ontario, Canada K1G 3H9; Tel: (613) 236-6163 ext. 2321; Fax: (613) 567-7749; Email: nfaruqui@idrc.ca		
Links	http://www.ipcri.org/watconf/papers/nader.pdf http://idrinfo.idrc.ca/Archive/Corpdocs/116101/No_8_files/20_mena.pdf http://www.idrc.ca/en/ev-6314-201-1-DO_TOPIC.html		

Project Name	The Jeezrael Valley Project	Special Features	Combination of semi-intensive (urban WW) + extensive (rural WW) treatment.
Location	Jeezrael Valley, Israel		Semiarid climate
Date	1996 -		
Institution	No data available		
Description	Irrigation (crops not specified) in the Jeezrael Valley is supplied with reclaimed wastewater from the Haifa metropolitan area and towns / small settlements around the valley. The "Kishon complex" scheme combines and interconnects semi-intensive treatment plants (anaerobic pond + aerated lagoons, partly screen bars as pre-treatment) for Haifa and other urban wastewater with wastewater reservoirs (SBR, Sequential Batch Reactors) in rural areas. A main advantage of the scheme lies in the proximity of municipalities to agricultural areas.		
Contact	Eran Friedler, Senior Lecturer Israel Institute of Technology Tel: +972-4-829 2633 Fax: +972-4-822 8898 Email: eranf@tx.technion.ac.il		
Links	http://www.uest.gr/medaware/reports/report_task3_part1.doc		

Project Name	Constructed Wetland at Haran Al-Awamied	Special Features	Treatment in artificial ecosystem (wetland/reed beds).
Location	Haran Al-Awamied, Syriah		Semiarid climate
Date	1999 -		
Institution	Gesellschaft für Technische Zusammenarbeit (GTZ)		
Description	Combined sewage (rain + wastewater) of Haran Al-Awamied (7,000 inhabit.) is treated in an artificial wetland (pre-treatment: bar screens + sedimentation tank, wastewater treatment: 2 reed beds, sludge treatment: 1 reed bed) to be reclaimed for fertilising and watering of surrounding agriculture. Reed from the reed beds is used for roof tops and as wicker. Note: Extensive WW treatment in Constructed Wetlands (CWs) is considered a cost-efficient and particularly suitable tertiary treatment solution in sparsely populated areas in terms of TSS, BOD_5 and COD removal (communities of up to 2,000 inhabitants) (Source:http://www.medreunet.com/docs_upload/Barbagallo.pdf)		
Contact	Contact Christine Werner Tel.: +49 6196 79-4220, Fax: +49 6196 79-7458 Email: ecosan@gtz.de		
Links	http://www.gtz.de/de/dokumente/en-ecosan-pds-015-syria-haran-al-awamied-2005.pdf		

Project Name	Vathia Gonia Wastewater Treatment	Special Features	Treatment of problematic WW (Industrial WW of variable composition)

Location	Vathia Gonia, Cyprus
Date	1998 -
Institution	No data available
Description	Treatment of domestic and industrial wastewaters (incl. dairy + metal process.) of variable composition for irrigation of fodder crops (pre-treatment: screening, grit removal, dissolved air flotation, chemical precipitation of metals; secondary treatment: two parallel balancing tanks, anoxic tank, two parallel aeration tanks and two secondary settlement tanks, tertiary treatment: continuously back-washed tertiary sand filters), deploying biological filters for odour control
Contact	
Links	http://www.uest.gr/medaware/reports/report_task3_part1.doc

Project Name	Dan Region Wastewater Treatment	Special Features	Improvement of WW quality and WW storage through Soil Aquifer Treatment

Location	Dan Region, Israel
Date	No data available
Institution	Mekorot(h) National Water Co./ Il
Description	Largest WW scheme in Israel (120 mcm/ yr; 2.1 million inhabitants). Tel Aviv municipal wastewater to be used for field-crop irrigation in the Negev is sent through spreading sand basins to improve effluent quality (denitrification, filtration of organic substances), in addition to chemical / biological treatment processes. Aquifer recharge provides multiyear storage of water supplies.
Contact	H. Cikurel Mekorot National Water Co., 9 Lincoln Street, Tel Aviv 61201, Israel Email: hchikurel@mekorot.co.il
Links	http://www.biu.ac.il/Besa/waterarticle3.html

Project Name	Wadi Mousa Pilot Project	**Special Features**	High degree of farmer participation; crop-depending different irrigation methods; demonstrable increase in crop yield; planned revolving fund for financing of wastewater irrigation infrastructure

Location	near Petra, Jordan
Date	2003
Institution	PA Consulting Group; Jordan. Ministry for Water & Irrigation, USAID
Description	Wastewater from four communities and several hotels around Petra city is treated in the Wadi Musa WWTP (pre-treatment: bar screen, grid channel; secondary tr.: oxidation ditch, clarifiers, MLE process train; tertiary tr.: polishing pond) to be distributed to adjacent farms to water different crops (fodder crops, cut flowers, trees) with a drip irrigation system adapted to crop cultivation. Problem: WWTP output quantities depend to great extent on tourism => seasonal and politically sensitive fluctuation
Contact	Sarah Bergin PA Consulting Group 1750 Pennsylvania Avenue Washington 20006 / United States Tel: + 1 202 442 2741, Fax: + 1 202 442 2832 Email: sarah.bergin@paconsulting.com
Links	http://www.paconsulting.com/industries/water/international/jordan/wadi/ http://ag.arizona.edu/OALS/ALN/aln57/addison.html#wwtp

Project Name	Wastewater reuse under saline conditions in Quarzazate	**Special Features**	Problem of high (ground)water salinity in irrigation; experimental use of different irrigation methods

Location	Quarzazate, Morocco
Date	1990-1993
Institution	No data available
Description	Domestic WW was treated (pre-treatment for coarse materials and sand; anaerobic pond/ water stabilisation pond), then used for irrigation on both salt sensitive (e.g. cucumber, turnips) and salt tolerant (e.g. alfalfa, corn, beans) crops deploying surface, drip ("Bas Rhône" and "Rain Bird" systems) and trickle irrigation, respectively. Experimental results showed that (1) treated effluents mitigate the negative impact of water salinity on crops, (2) "Bas Rhône" drip irrigation performed best with regard to irrigation performance and crop yield, and (3) "the morphology and the way the crop was handled were found to play an important role" (El Hamouri et al 1996) with regard to crop bacteriological quality.
Contact	No data available
Links	http://www.iwaponline.com/wst/03310/wst033100327.htm (article in *Water Science & Technology*, for purchase)

Project Name	Ville de Drarga Wastewater Treatment Plant	**Special Features**	Concept for use of resources (wastewater, sludge, reed, biogas) very thought-through; participation of farmers (incl. formation of associations of wastewater users)

Location	Community of Drarga/ Souss Massed, Morocco
Date	2001 (start of operation)
Institution	Municipality of Drarga, Al-Amal Water Users Association, Regional Agency (Planning), ERAC-Sud (Construction)
Description	Domestic WW (approx. 5,700 inhabitants) undergoes treatment in infiltration-percolation system (pre-tr.: screen bars, anaerobic basin; primary tr: aerobic basin, secondary tr: sand filters, tertiary tr.) and is distributed through surface, microjet and drip irrigation to water tomatoes, alfalfa, Italian ray-grass, zucchini and corn, thus, significantly reducing fertiliser demand. Sludge is dried and then added to municipal compost, reed of wetland is dried and sold, biogas of anaerobic basins will be used for energy recovery. - Farmers participate in choice of irrigation technologies and system management, organised in wastewater users associations. Note: Very well documented.
Contact	Not available
Links	http://web.idrc.ca/uploads/user-S/10637138661Morocco.doc Medaware – Development of Tools and Guidelines... Task 3: Analysis of Best Practices and Success Stories

Project Name	Reclaimed Water Project Amman	**Special Features**	WW reuse including awareness raising on health / environmental issues among WW users

Location	Amman, Jordan
Date	2003 – 2006
Institution	Executive Institution: Jordan Valley Authority Planning Institution: GTZ
Description	Effluents of the treatment plant Khirbet As Samra is first discharged into two consecutive wadis and temporarily stored in a reservoir, being diluted with surface and precipitation water on its way, to irrigate approx. 10,000 ha of agricultural land. Environmental impacts on soil and groundwater quality are monitored on a number of sites. The project also entailed awareness raising and training on health and environmental risks, as well as good agricultural practices for farmers and extension workers.
Contact	Artur Vallentin, Ecosan Team GTZ, Postfach 5180, 65726 Eschborn Tel: +49 (0)6196-794220 Reclaimed Water Project P.O. Box 926238, Amman, 11190 Jordan Email: rwp@gtz.jo
Links	http://www.gtz.de/de/dokumente/en-ecosan-pds-013-jordan-valley-2005.pdf

Project Name	Sewage sludge humification in El Minia and Nawaq	**Special Features**	Recycling of sewage sludge for agricultural purposes

Location	El Minia, Nawaq, Egypt
Date	03/ 2001 – 08/ 2002
Institution	Executing Institutions: University of Mansoura, Egypt; IPP Consult, Germany Planning Institution: IPP Consult, Germany
Description	The project targets an optimisation of the sewage sludge humification process. As in hot and dry climates, sludge dries too rapidly to allow for sufficient purification rates and decomposition of organic substances, the humus produced emits an unpleasant odour and contains substances inhibiting plant growth. Remaining pathogenic germs (helmiths, salmonellae) pose additional health risks. In this case, the sludge of two treatment plants was cultivated in reed and grass beds. In the course of 2.5 months, the roots effected aeration as well as the development of microorganisms, turning the sludge into a fertile soil-like substrate without hygienical risks. The reed of sludge beds is used as combustible matter or for biogas production, as it is not hygienically safe enough to be used as construction material; the converted sludge, however, is successfully applied to agricultural land.
Contact	Prof. Dr. Ahmed Fadel Email : afadel@egyptnetwork.com University Mansoura Mansoura, Egypt Tel: 002-050-333050/ Fax : 002-050-332783 IPP Consult Barienroder Str. 23, 31139 Hildesheim Germany Tel: ++49-5121-2094-0 Fax: ++49-5121-2094-44 Email: info@ipp-consult.de
Links	http://www.gtz.de/de/dokumente/en-ecosan-pds-014-egypt-nawaq-2005.pdf

Project Name	Haran-Al-Awamied	**Special Features**	WW treatment in constructed wetlands and reuse in agriculture

Location	Haran-Al-Awamied, Syria
Date	2000 (Start of operation)
Institution	Ministry of Housing and Utilities (MoHU), Syria GTZ
Description	The project entails the installation of a sewer system for the municipality as well as a wastewater treatment plant for the sewage discharged by the 7,000 inhabitants. Treatment encompasses pre-treatment (bar screens, primary sedimentation tank), 2-reed beds for wastewater treatment, one reed bed for sludge treatment, and a collection tank for subsequent irrigation. Remaining nutrients replace the use of inorganic fertilisers. Sludge is being dewatered, and then turned into humus in one of the reed beds; reed are cut and used as wicker and roof materials.
Contact	Municipality of HARAN AL-AWAMIED Damascus Rif, Syria Tel.: +963 11 5513275 Ministry of Housing and Utilities (MoHU) Mr. Abir Mohamed, Engineer Email: abirgh@scs-net.org
Links	http://www.gtz.de/de/dokumente/en-ecosan-pds-015-syria-haran-al-awamied-2005.pdf

Annex III: Link-list: Sources of awareness raising material

Project Name	NEWater **Special Features**
Location	Singapore
Date	from 1998 onwards
Institution	Public Utility Board (PUB), Government of Singapore; Ministry of Environment and Water Resources (MEWR)
Description	Initiative to promote the use of treated / purified wastewater as raw water for water supply. Besides the investigation of wastewater suitability for various purposes, the initiative encompasses a public education campaign using posters, advertisements, brochures and the broadcast of a documentation in 2002, as well as the provision of a visitor centre in 2003, to raise awareness on the issue and increase acceptance of wastewater recycling for (drinking) water supply. PUB also awards an annual price for organisations involved in awareness raising and education on water and water supply issues ("Friends of Water") and launches a school competition ("Water for all") on water saving and supply (not specifically oriented towards water reuse).
Contact	NEWater Visitor Centre, Koh Sek Lim Road Tel: 65467874 / 65410511 Email: pub_newatervc@pub.gov.sg
Links	http://www.unep.or.jp/Ietc/Publications/Water_Sanitation/wastewater_reuse/Booklet-Wastewater_Reuse.pdf

Project Name	Winning minds over to water reuse **Special Features**
Location	Jordan, nationwide
Date	Information not available (however, project has yielded first results already)
Institution	PA Consulting Group
Description	As Jordanian farmers and wider public took a rather sceptic view of water reuse, Jordanian authorities jointly with PA Consulting launched a campaign to raise awareness on water scarcity and to build confidence in wastewater reclamation practice. This entailed presentations on the topic to stakeholder groups, the foundation of a specialised library, various capacity building measures for wastewater managers, farmers and field workers, as well as press releases on project achievements and demonstration projects.
Contact	PA Consulting Group Sarah Bergin 1750 Pennsylvania Avenue, Washington, 20006 / United States Tel: + 1 202 442 2741, Fax: + 1 202 442 2832 Email: sarah.bergin@paconsulting.com
Links	http://www.paconsulting.com/industries/water/international/jordan/winningminds/

Project Name	Awareness raising programme on waste-water treatment and reuse	Special Features	

Location	Egypt/ Palestine/ Israel
Date	1998 - 2005
Institution	Appropriate Technology Consortium (ATC) (Egyptian-Palestinian-Israeli co-operation of NGOs, scientists, municipalities, and consultants in the field of wastewater treatment and reuse in Middle Eastern rural areas)
Description	The project comprised three components: First, scientific research on the question which wastewater treatment technologies would be best adapted to the project area setting, second, the connection either of households to the sewage system (Palestine) or of farmers to a wastewater irrigation system, and third, a public awareness raising programme on the benefits of wastewater treatment and reuse. The campaign consisted of workshops and conferences to generate awareness for the project's scientific findings (participants including municipalities, government officials, universities, and businesses), and to educate community members on general wastewater treatment (participants including municipalities, farmers, and students). One extensive workshop for local farmers at the Sakhnin Wastewater Treatment Plant included lectures, tours, and discussion groups on wastewater treatment and irrigation systems, another workshop targeted Palestinian women in Ramallah, which included a visit to our Bani Zaid Treatment Plant.
Contact	Dr. Isam Sabbah- Scientific Director Research & Development Center, The Galilee Society P.O.BOX 437, Shefa-Amr 20200, Israel Tel: (+)972-4-9504523/4; Fax: (+) 972-4-9504525
Links	http://www.gal-soc.org/en/?x=ATC&s=ATC%20Overview

Project Name	Water reuse programme	Special Features	Awareness raising campaign encompassing all media

Location	Florida, U.S.
Date	Not available
Institution	Department of Environmental Protection, Government of Florida
Description	Reuse plays a major role in Florida wastewater management and water supply, irrigation for public spaces accounting for half of reused wastewater quantities, and 14-15% being used for agricultural irrigation, industrial uses and groundwater recharge, respectively. DEP Educational Materials include a video "Every drop counts - Use it again, Florida!" (1998), a one-minute public service announcement for TV broadcasting, a reuse brochure (2000) and a CD-ROM-based "Reclaimed Water Guide" (1999) to assist new and established reclaimed water systems, as well as a fact sheet on unregulated organic compounds. Moreover, the DEP website provides ample information, relating to facts and figures, applied law and practice of water reuse, to ensure transparency to wastewater users and the wider public.

Contact	Lauren Walker-Coleman, Reuse Specialist 2600 Blair Stone Rd., Mail Station 3540 Tallahassee, Florida 32399-2400 Tel: +1 -(850)245-8611, Fax: -8621 Email: lauren.walker-coleman@dep.state.fl.us David York, Reuse Coordinator 2600 Blair Stone Rd., Mail Station 3540 Tallahassee, Florida 32399-2400 Tel: +1-(850)245-8610, Fax: -8621 Email: david.york@dep.state.fl.us
Links	http://www.dep.state.fl.us/water/reuse/index.htm/

Project Name	Water Awareness Education Programme	**Special Features**	Comprehensive and long-term school curriculum

Location	Irvine Ranch Water District, Ca, U.S.
Date	Not available
Institution	Irvine Ranch Water District
Description	The regional water supplier's (waste) water education programme encompasses a school curriculum starting in elementary grades, with issues such as forms of water, the water cycle and water transportation, including a water awareness poster contest. In Grade 5, workbook and field-trips introduce students to water reclamation, to move on to questions of water pollution prevention in Grade 6. The scheme also offers an information brochure on wastewater reclamation for adults, as well as an Annual Reclaimed Water Quality Report.
Contact	Marilyn Smith, IRWD education coordinator P.O. Box 57000 Irvine, CA 92618-7000 Tel: +1 - 949/ 453-5321 Email: smithm@iwrm.com
Links	http://www.irwd.com/WaterEducation/program_descriptions.php http://www.epa.qld.gov.au/publications/p00415aa.pdf/Todays_water_recycling_issues_for_Queensland_information_paper_/_prepared_on_behalf_of_Queensland_Water_Recycling_Strategy_by_CSIRO_Built_Environment_Sector.pdf

Project Name	Wastewater 2040	**Special Features**	Community involvement from situation assessment onwards, education including school curricula

Location	Western Australia
Date	1995 -
Institution	Water Corporation Western Australia (WAWA)
Description	Wastewater 2040 is a wastewater-related community involvement strategy adopted by the Water Corporation (Western Australia), covering Perth metropolitan area and other major urban regions in South-Western Australia. The programme entailed a community consultation process, as well as the development and circulation of 15 issues papers and of an extensive discussion paper on wastewater treatment issues. All media were used for the purpose of community awareness raising. Education curricula were conceived for primary to tertiary levels, being implemented at secondary level from 1995
Contact	Debbie Ericson, Waterwise Schools Program Officer Tel: 08 9420 3505 Email: debbie.ericson@watercorporation.com.au
Links	http://www.epa.qld.gov.au/publications/p00415aa.pdf/Todays_water_recycling_issues_for_Queensland_information_paper_/_prepared_on_behalf_of_Queensland_Water_Recycling_Strategy_by_CSIRO_Built_Environment_Sector.pdf http://www.watercorporation.com.au/education/index.cfm

Project Name	"We all use water"	**Special Features**	Comprehensive water education strategy, including the set-up of a network and database

Location	Australia
Date	2002 -
Institution	Australian Water Association (AWA)
Description	AWA published a series of educational materials named "We all use water", comprising of a 230-page folder, 30 flyers on various issues, a poster and a storybook set, a community involvement manual and other components. Topics covered include water sources (surface water, groundwater, rainwater tanks, desalination), water storages (water uses, environmental flows, stratification), catchments, pathogens and disinfection, water treatment plants (drinking water monitoring, endocrine disrupters, understanding risk), sewage treatment plants (water quality, case studies of STP's), on-site systems and effluent management. The set has been developed for teachers and further educational staff. To promote experience exchange and resource sharing in the field of water education, AWA inaugurated a "Water Education Network" (WEN) in 2004, and development of a water education web portal and a database of water education is under way.
Contact	C. Cheeseman, Education Program Manager Phone: + 02 9495 9907 Email: ccheeseman@awa.asn.au
Links	http://www.waterwatch.org.au/publications/2005conference/pubs/cheeseman.pdf

Annex IV: List of selected institutions involved in water reuse in the EMWater MEDA countries

Institution	**Address/ Contact Person Tel. / Fax**	**Website/ Email**
	Palestine	
Palestinian Water Authority	Eng. Yousef Awayes P.O. Box: 2174 Al Bireh Palestine Tel : + 970 2 240 9022 Fax: +970 2 240 9341	pwa@pwa-pna.org
Ministry of Agriculture	Mr. Isam Nofal P.O.Box: 197 Ramallah -Palestine Tel: +970 2 298 9576-6 Tel: +970 2 296 1080-9 Fax: +970 2 296 1212	kasimabdo@yahoo.com
	Jordan	
Ministry of Water and Irrigation / Reuse Unit	Mr. Saleh Malkawi Ministry of Water and irrigation P.O.Box: 2412 Amman11183 Jordan Telefax: +962 6 5686950 Mobile: +962 795235110	http://www.mwi.gov.jo Saleh_Malkawi@mwi.gov.jo
GTZ- Reclaimed Water Project	Mr. Arthur Vallentin GTZ Office Amman P.O. Box 92 62 38 Amman 11190 Jordan Tel: +962 6 566-7021	Artur.Vallentin@gtz.de
MEDWA	Hanan Salah Amman, Jordan Mob. +962-79-5406365 Office: +962-6-5523576	http://www.emwis.org/MEDA/medwa.htm Salah@hwa.or.at
MEDAWARE	Prof. Dr. Munir J. Mohammad Rusan Faculty of Agriculture Jordan University of Science and Technology (JUST) PO Box 3030; Irbid 22110, Jordan Tel: 962-2-7201000, ext. 22200 Mobile: 962-795573970 Fax: 962-2-7201078	http://147.102.83.100/projects/meda/meda.htm mrusan@just.edu.jo
USAID	Dr. Amal Hijazi P.O.Box: 354 Amman 11118 Jordan Tel: +962 6 5920101 Fax: +962 6 5920143	ahijazi@usaid.jo
WHO- Jordan	Dr. Hamed A. Bakir Tel: +962-6-5524655 & 5531657 Fax: +962-6-5516591	bakirh@ceha.emro.who.int

Institution	Address/ Contact Person Tel. / Fax	Website/ Email
IRWA/ NCARTT	P. O. Box: 639, Baqa'a 19381 Jordan Fax: 962-6-4726099 Tel. Office : 00962-6-4725071	http://www.irwaproject.com/ jordan@irwaproject.com www.ncartt.gov.jo/ esmatk@ncartt.gov.jo
EMPOWERS/ INWARDA	Mrs. Mouna Bargout P. O. Box: 1460 Amman, 11941 Jordan Phone: + 962 6 533 2993 Fax: + 962 6 533 2969	http://www.empowers.info/ monainw@nic.net.jo
Lebanon		
Ministry of Energy and Water Resources	Mr. Fadi Comair Tel:+961 1 565013/4 Fax:+961 1 576666	gdher@terra.net.lb
IRWA- Lebanon	Beirut, Riyad El-Solh Banks St., Stefan Bldg. 1st. Fl. P.O. Box: 17522 - Post St. Michel, Beirut. Tel: +9611966099 Fax: +9611 966564	lebanon@irwaproject.com
Litani River Authority	Mr. Kamal Karaa P.O.Box: 3732, Beirut. Tel: +961 1 825 433 Tel: +961 1 663143 Fax: +9611 825440	Am-rural@litani.gov.lb
Turkey		
Istanbul Water and Sewerage Administration	Mevlut VURAL ISKI Kagithane Tesisleri Alibey Caddesi. Nurtepe Yolu 34406 Kagithane / Istanbul. TURKEY Tel : +90 212 321 77 93, +90 212 321 77 94 Fax: +90 212 321 77 92	http://www.iski.gov.tr mvural@iski.gov.tr
General Directorate of State Hydraulic works (DSI)	Prof.Dr. Veysel EROGLU. Ismet Inonu Bulvarı 06100 Yucetepe-Ankara,TURKEY Tel:+90 312 418 34 09 +90 312 418 34 15 Fax:+90 312 41824 98	http://www.veyseleroglu.gen.tr eroglu@dsi.gov.tr

Annex V: Further sources of information

U.S.Environmental Protection Agency (U.S.EPA) – Office of Wastewater Management's online section

EPA's Office of Wastewater Management supplies information on a wide range of wastewater management issues in the U.S., including texts of relevant U.S. laws, EPA wastewater programmes, wastewater standards, treatment and reuse.

Source: *http://www.epa.gov/owm/*

MED-REUNET Mediterranean Network on Wastewater Reclamation and Reuse

Med-Reunet.com is the online platform of the Mediterranean Network, offering a member forum section (with restricted access) for experience and expertise exchange as well as an open information section with links to institutions and programmes, classified by topic.

Source: *http://www.med-reunet.com/home.asp*

UNEP Division of Technology, Industry and Economics – Water and Sanitation section

This page gives a survey of the International Environmental Technology Center's (IETC) work in the field of water and sanitation, listing news, projects and publications. The IETC is affiliated to the Division of Technology, Industry and Economics of the United Nation Environment Programme.

Source: *http://www.unep.or.jp/ietc/ws/index.asp*

World Health Organisation (WHO) – Water, Sanitation and Health section

The Water, Sanitation and Health service offers WHO's guidelines for the safe use of wastewater as well as a number of further publications in the field for download. More information can be found on a wider range of water and sanitation issues, and interested readers can subscribe to the WHO water and sanitation mailing list.

Source: *http://www.who.int/water_sanitation_health/wastewater/en/index.html*

WHO Regional Centre for Environmental Health Activities (CEHA)

CEHA is a specialised centre established in Amman, Jordan, by the World Health Organisation's Regional Office for the Eastern Mediterranean (EMRO). CEHA's mandate is to promote environmental health through technical support for national capabilities and programmes in the Member Countries of the Region.

Source: *http://www.emro.who.int/ceha/*

The United Nations Human Settlements Programme (UN-HABITAT) - Water and Sanitation Programme

UN-HABITAT is mandated by the UN General Assembly to promote socially and environmentally sustainable towns and cities with the goal of providing adequate shelter for all. The highest priority for UN-HABITAT's Water and Sanitation Programme is improving access to safe water and helping provide adequate sanitation to millions of low-income urban dwellers and measuring that impact. Source: *http://www.unhabitat.org/*

International Water Management Institute (IWMI) – Wastewater Resource Page

On its resource page on the reuse of wastewater for agriculture, IWMI has compiled a number of brief case studies as well as a list of its own research publications on the topic.

Source: *http://www.iwmi.cgiar.org/respages/Wastewater/index.htm*

EAWAG Department of Water and Sanitation in Developing Countries (SANDEC)

While the SANDEC project section is still under construction, the online platform already covers a range of topics in water and sanitation infrastructure development, ranging from strategic environmental sanitation planning to rural and peri-urban wastewater management. Contents available at the moment are downloadable publications and a link list on environmental sanitation sites.

Source: *http://www.sandec.ch/*

IDRC Regional Water Demand Initiative (WaDimena)

While the WaDimena programme website spans the whole range of water management issues in MENA countries, the focus area on water reuse provides ample literature references. A description of WaDimena's research and field-level pilot projects offers information of water reuse case studies in the MENA region.

Source: *http://network.idrc.ca/en/ev-57064-201-1-DO_TOPIC.html*

International Water and Sanitation Centre (IRC)

IRC's theme site on environmental sanitation contains a mixture of brief case studies on ecosan and water reuse projects, related news and fact sheets, literature reviews and a list of external downloadable publications.

Source: *http://www.irc.nl/*

Water and Sanitation Project (WSP)

Online platform of the Water and Sanitation Project, a joint initiative by several development agencies under the aegis of the World Bank. The publications section on waste and wastewater management and reuse lists relevant WSP projects, and partly offers more detailed downloadable information. The rich water links section contains not only references to further online resources, but also videos, country fact sheets, WSS statistics and a compilation of major water and sanitation-related events.

Source: *http://www.wsp.org*

World Bank – Sanitation and Wastewater Management

This is a subsection of the Water Supply and Sanitation department, containing case studies of World Bank sanitation and wastewater management projects from around the globe, as well as some technical notes and strategical documents.

Source: *http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTWSS/0,,contentMDK%3A20521254~menuPK%3A1194933~pagePK%3A148956~piPK%3A216618~theSitePK%3A337302,00.html*

Water and Wastewater Treatment Technologies for Appropriate Reuse (WAWWTAR)

WAWWTAR is a Windows-based predictive computer programme designed to support planners in the choice of water conditioning and wastewater treatment technologies appropriate to any given setting. Its website serves as a means of distribution and marketing, as a user's forum and as a source for updates.

Source: *http://firehole.humboldt.edu/wawttar/wawttar.html#introduction*

Euro-Mediterranean Information System on Know-how in the Water Sector (EMWIS)

EMWIS, a programme of the Euro-Mediterranean Partnership, was conceived as a knowledge base to collect and share experience and information in the water sector. What can be found on its website ranges from participating countries' pages to programme-related documents and a public forum.

Source: *http://www.emwis.org/*

MEDAWARE

MEDAWARE is a project under the Euro-Mediterranean Regional Programme on Local Water Management of the European Commission, targeting the "development of tools and guidelines for the promotion of sustainable urban wastewater treatment and reuse in the agricultural production in the Mediterranean countries". The website contains a description of the project aims and methodology, project-related publications, and training schedules.

Source: *http://www.uest.gr/medaware/index.htm*

ZER0-M

ZER0-M is a project under the Euro-Mediterranean Regional Programme on Local Water Management of the European Commission. Zer0-M aims at concepts and technologies to achieve optimised close-loop usage of all water flows in small municipalities or settlements (e.g. tourism facilities) not connected to a central wastewater treatment – the Zero Outflow Municipality (Zer0-M).

Source: *http://www.zer0-m.org*

World Water Council (WWC)

The World Water Council is an international multi-stakeholder platform. It was established in 1996 on the initiative of renowned water specialists and international organisations, in response to an increasing concern about world water issues from the global community. Its mission is to promote awareness, build political commitment and trigger action on critical water issues at all levels, including the highest decision-making level, to facilitate the efficient management and use of water in all its dimensions and on an environmentally sustainable basis. The Council aims to reach a common strategic vision on water resources and water services management amongst all stakeholders in the water community. In the process, the Council also catalyses initiatives and activities, whose results converge toward its flagship product, the World Water Forum.

Source: *http://www.worldwatercouncil.org*

Glossary

Aquifer	An underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using a water well.
Biochemical oxygen demand (BOD)	The amount of oxygen required to biochemically convert organic matter into inert substances: an indirect measure of the amount of biodegradable organic matter in the water or wastewater.
Blackwater	Toilet wastewater that contains organic matter from urine, faecal matter and toilet paper.
Denitrification	Process of reducing nitrate (and nitrite) into gaseous nitrogen. In wastewater treatment, this process is commonly used to remove nitrates in order to prevent eutrophication of receiving water bodies.
Digestion	In wastewater treatment: Process basically applied to sludges, allowing the biological conversion of highly putrescible organic matter to relatively stable or inert organic and inorganic compounds.
Disinfection	The inactivation of pathogenic organisms using chemicals, radiation, heat or physical separation processes (e.g. membranes).
Disposal of wastewater	Collection and removal of wastewater by means of drainage networks and treatment plants.
Effluent	Liquid (e.g. treated or untreated wastewater) that flows out of a process or confined space
Enteric disease	Bacterial and viral infections of the gastrointestinal tract. The enteric pathogens cause disease symptoms ranging from mild gastroenteritis to life-threatening systemic infections.
Epidemiology, epidemiological	The study of distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health-problems.
Eutrophication	The process of an aquatic body becoming enriched with nutrients that stimulate aquatic plant growth, such as algae, resulting in depletion of dissolved oxygen.
Exfiltration	A loss of water from a drainage system as the result of percolation or absorption into the surrounding soil.
Exposure	Contact with a chemical, physical or biological agent by swallowing, breathing, or through the skin or eyes.
Grey water	Effluent from the kitchen bath and/or laundry, which generally does not contain significant concentration of excreta.
Groundwater	Water located beneath the ground surface in soil pore spaces and in the fractures of geologic formations. Can sometimes be extracted through wells.
Groundwater recharge	Refers to water entering an underground aquifer through faults, fractures, or direct absorption.
Helminths	Worms classified as parasites. Their eggs contaminate food, water, air, faeces, pets and wild animals, and objects, such as toilet seats and door handles. They may enter the human body through the mouth, nose and anus.
Nutrient	A chemical element or compound used in an organism's metabolism or physiology. In agriculture, nutrients such as Phosphorus or Nitrogen are applied to fields as fertiliser. Excess quantities of nutrients in wastewater discharges can have negative impacts on the environment, as they can lead to eutrophication.

Organic material, organic matter	Biological material, in municipal wastewater mainly consisting of excreta and food residues. Organic material can be biologically consumed in the secondary treatment process. As a food source for various microorganisms it can pollute water resources.
Pathogen	A disease-causing organism such as bacteria, helminth eggs, viruses, and protozoa
Reuse, direct	Use of reclaimed wastewater without intervening discharge to a natural body of water.
Reuse, indirect	Use of reclaimed wastewater with intervening discharge to a natural body of water.
Reuse, planned	Direct or indirect use of reclaimed wastewater without losing control over the water during delivery through specifically designed projects to treat, store, convey and distribute treated wastewater
Reuse, unplanned	Use of wastewater after surrendering control of the water after discharge. A common example of unplanned water reuse occurs when water from rivers that receive wastewater discharges upstream is used downstream for urban water supplies and/or irrigation.
Salinisation	The accumulation of free salts in soil (or groundwater) to such an extent that it leads to degradation of soils and vegetation, or makes water inappropriate for use.
Sanitation	• Control of physical factors in the human environment that could harm development, health, or survival. • The study and use of practical measures for the preservation of public health.
Sedimentation	A large scale treatment process where solids settle to the bottom of the treatment tank. Sometimes flocculation agents are used to support agglomeration of small particles and facilitate settlement.
(Wastewater) Sludge	A semi-fluid, slushy, murky mass of sediment resulting from treatment of water, wastewater, or industrial and mining wastes.
Stakeholder	Any person group or organisation that has a legitimate interest in a project or issue.
Stormwater	Stormwater runoff, snow melt runoff, and surface runoff and drainage; rainfall that does not infiltrate the ground or evaporate because of impervious land surfaces but instead flows onto adjacent land or watercourses or is routed into drain/sewer systems.
Suspended solids	Solid particles dispersed in wastewater that can be separated by physical processes (filtration or settling).
Wastewater	Water carrying wastes from homes, businesses and industries that is a mixture of water and dissolved or suspended solids.
Wastewater management	All of the institutional, financial, technical, legislative, participatory, and managerial aspects related to the problem of wastewater. Can be administered centrally or decentrally.
Water reuse	The use of reclaimed water for a direct beneficial use or a controlled use that is in accordance with the state and local regulatory requirements.
Wastewater treatment	Mechanical, biological and chemical processes applied to an industrial or municipal wastewater or other contaminated water to remove, reduce, or neutralise contaminants.
Wastewater, domestic	Wastewater principally derived from households, business buildings, institutions, etc., which may or may not contain surface runoff, groundwater or storm water.

Wastewater, industrial	Wastewater that results from industrial processes and manufacturing. It may either be disposed of separately or become part of the municipal wastewater.
Wastewater, municipal	A mixture of domestic wastewater, effluents from commercial and industrial establishments, and urban runoff.
Water demand management	Implementation of policies or measures which serve to control or influence the amount of water used.
Water reclamation; Reclaimed water	Treatment or processing of wastewater to make it reusable; Wastewater which has been treated to a quality suitable for a beneficial use.
Water recycling	Use of wastewater that is captured, (treated) and redirected back to the water-use scheme from which it originates. This technique is applied, particularly in industry.
Yellow water	Wastewater that contains urine.

Acronyms

ASCE	American Society of Civil Engineers
BASNEF	Beliefs, Attitudes, Subjective Norms and Enabling Factors
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CW	Constructed Wetland
DBP	Disinfection By-Products (i.e. chloramines)
DWM	Decentralised Wastewater Management
EPA	Environmental Protection Agency
EPA	US Environmental Protection Area
EU	European Union
FAO	Food and Agriculture Organisation of the UN
FTR	Fill Time Ratio
FWS	Free Water Surface
GSS	Gas-Solids Separator
HF	Horizontal Flow
HRT	Hydraulic Retention Time
IDRC	International Development Research Centre
InWEnt	Internationale Weiterbildung und Entwicklung GmbH
IWMI	International Water Management Institute
MEDA	Euro-Mediterranean Partnership Programme
NGO	Non-Governmental Organisation
NH_3-N	Ammonia Nitrogen
NIMBY	Not-in-My-Backyard Syndrome
O&M	Operation and Maintenance
PE	Population Equivalent
RBC	Rotating Biological Contactor
SBR	Sequencing Batch Reactor
SRT	Sludge Retention Time (also known as Sludge Age)
SS	Suspended Solids
SS	Sub-Surface
SS-HF	Horizontal Flow Sub-Surface System
SS-VF	Vertical Flow Sub-Surface System
TKN	Total Kjeldahl Nitrogen
TS	Total Solids
TSS	Total Suspended Solids
UAE	United Arab Emirates
UASB	Up-flow Anaerobic Sludge Blanket
UNDP	United Nations Development Department
UNEP	United Nations Environment Programme
UNICEF	United Nations Children’s Found
UNU	United Nations University
U.S.EPA	U.S.Environmental Protection Agency

VER	Volumetric Exchange Ratio
VIP	Ventilated Improved Pit
VF	Vertical Flow
WHO	World Health Organisation
WPCR	Water Pollution Control Regulation
WSP	Waste Stabilisation Ponds
WW	Wastewater
WWT	Wastewater Treatment
WWTP	Wastewater Treatment Plant

InWEnt
Internationale Weiterbildung und Entwicklung gGmbH
Capacity Building International, Germany

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