Integrated Concepts for Reuse of Upgraded Wastewater

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Report on integrated water reuse concepts

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CONTENTS

1 INTRODUCTION

Recurring droughts throughout the last decades have revealed that water supply is often insufficiently balanced to the demand and thus vulnerable to extreme climatic events and spatial or seasonal demand peaks. In the context of a more sustainable water management, wastewater reuse opens up an alternative dependable water resource.

This AQUAREC work package 3 seeks to develop a water reuse strategy based on the anticipation of major factors that promote or slow down the development of water reuse. The investigations distinguish between substantial issues related to the physical, measurable variables of water management and the analysis of normative issues as laid down in legislation and guidelines and reflected by the institutional settings. Moreover, water reuse particularly faces the challenge to comply with the precautionary principle and affords a robust risk management. In this context the importance of establishing a best management practice framework and increasing public awareness of the water cycle have to be emphasised as two important aspects in strategic planning of water reuse.

Work package 3 is one of the strategic work packages in the AQUAREC project (Figure 1.1) and has the objective to integrate aspects investigated in the different parts of the project in a holistic view on the current status and future development of municipal wastewater reclamation and reuse in Europe.

Figure 1.1 Work packages in the AQUAREC Project

Strategy:

WP1: Analysis of European water market and supply & demand studies

WP2: Definition of key objectives for water reuse concepts

WP3: Development of integrated water reuse strategies

Management:

WP4: Development of analysis tools for social, economic and ecological effects of water reuse

WP5: Methodologies for public acceptance studies and consultation

WP6: Management guidelines for the implementation and operation of water reuse cycles

Technology:

WP7: Characterisation and assessment of technology in water reuse cycles

WP8: Development and validation of system design principles for water reuse systems

The activities in Work package 3 have been primarily addressed to a end-users on the water management, water technology and water policy level which have an interest in a supra-regional and supra-national view on the Integrated Water Resources Management in Europe. This report is not dedicated to give step by step advice for water reuse operators or consultants as outputs of other work packages such as WP4-6.

The report presented here strives to achieves a comprehension of important elements in European water recycling and is structured into two parts:

Part A - Substantial and normative issues

This part encompasses the analytical phase to describe the current state of water management and the role of wastewater reuse in Europe. The work contains a survey of Europe's water resources availability as well as a quantification of water abstraction and utilisation by different sectors, thus allowing to identify which countries suffer from water stress due to which activities or natural circumstances (Chapter 2.1 to 2.5).

Furthermore, a review of the state of wastewater treatment in terms of population connection rate, treatment level, treatment plant capacity and volume of treated effluent is performed. Data on existing wastewater reuse projects concerning types of reuse and volumes were also collected in connection with other AQUAREC work packages (Chapter 2.3 and 2.4).

Based on this analysis the study developed an approach to quantitatively assess the potential of municipal wastewater reclamation and reuse in a European context (Chapter 3). The model developed interrelates the afore described elements of water management. In conjunction with information about the current status of wastewater reuse simple key figures are deduced, which allow future projection of wastewater reclamation and reuse. These estimations were performed for different scenarios of water availability and demand.

Developing the reuse potential also has to cope with balancing the benefits and risks as described in Chapters 4 and 5. The extent to which planned wastewater reuse is practiced is supposed to depend on long-term deficiencies in the water balance or frequency and severity of droughts. But the institutional settings and the legislative frame are aspects of equal importance when designing a favourable environment for the development of water reuse.

Chapter 6 investigates the general principles of water governance focusing on different policy instruments. Water related directives of the European Union and their potential impact are presented with regard to both their contemplative character for defining limit values and standards being already transposed into wastewater reuse related guidelines and the indirect impact they might exert on the development of wastewater reuse. This will include an analysis of the adequateness of existing limit values for wastewater reuse in comparison to comparable applications with conventional water.

Part B – Framework for development of wastewater reuse

While taking into account the current status and trends in water reuse this section deals with means for a better integration of wastewater reuse in sustainable integrated water resources management. Among the identified crucial issues are financial and economic questions (Chapter 7). Approaches to lower or to better manage the risks associated with water reuse are subject of Chapter 8.

The technological status and development trends with respect to municipal wastewater treatment technology will be depicted in Chapter 9 as a background for the further evolution of water reuse activities. The technological opportunities with regard to risk management will be illustrated too.

The necessity and challenge to effectively involve the public in the implementation of water reuse schemes is set forth in Chapter 10.

The report concludes with a summary of ideas to point the way towards a European water recycling policy (Chapter 11).

PART A - SUBSTANTIAL AND NORMATIVE ISSUES

Introductory remarks on data collection

Data sources

Many institutions collect data on water availability and water use. If not otherwise stated the data presented in this report are based on the following sources.

The **water availability** as total renewable freshwater resources was taken from the FAO AQUATSTAT database. This database forms a comprehensive source of information as it calculates freshwater resources in a standardised way thus allowing comparing countries with each other. Together with FAOSTAT it provided data on total area, arable land, and permanent crops as well as irrigated area.

Most of the information concerning **water abstraction, wastewater collection and treatment** is taken from

- Eurostat (Environmental Yearbook, the New Cronos Database, Statistic in Focus),
- National State of the Environment Reports,
- National statistical offices' publications
- UNECE's Environmental Performance Reviews.

The intent was to depict the situation in the year 2000; and with a few exceptions, all data refer at least to the late 1990s (1998 or 1999).

Scope

The investigation carried out in this report comprises the member states of the European Union (EU), the Accession and Candidate Countries (which have become New Member States, in the meantime), Turkey, Norway and Switzerland.

As Israeli partners were involved in the AQUAREC project, Israel is included in all considerations and examinations especially as it serves as a model-state, that counters severe water scarcity with advanced wastewater reuse practice.

Data for Cyprus refer only to the Greek-cypriotic part under governmental control.

2 ANALYSIS OF EUROPEAN WATER RESOURCES EXPLOITATION

The countries of Europe cover an area reaching from 10° western to 66° eastern latitude and from 36° to 71° northern longitude thus covering a range of bio-geographical regions and climatic zones characterised by dissimilar annual average temperatures, precipitation and evapo-transpiration rates. These parameters are the basis for the hydrological conditions water management has to cope with.

This chapter attempts to provide a quantitative survey of water availability, water uses, wastewater treatment and reuse practice in Europe. It aims at identifying water stress constellations and water-use profiles. Their implications for the potential for wastewater reuse in integrated water management strategies will be outlined and described in more detail in Chapter 2.5).

2.1 Water availability

Water availability in European countries – measured as long-term annual average (ltaa) of renewable freshwater resources – ranges from 51 Mm³/a in Malta to 382,000 Mm³/a in Norway coming up in per-capita availabilities between 131 m³/cap/a and approximately 85,500 m³/cap/a (see Figure 2.1 top).

An amount of 2,000 m³ per person and year is considered necessary for adequate living standards in western and industrialised countries. Water availability between 1,000 and 2,000 m³/cap/a is associated with water stress whereas below 500 m³/cap/a a countries suffers from water scarcity (Bouwer, 2002). According to this classification, Denmark, Germany, Belgium, Poland, the Czech Republic and Cyprus are water stressed, while Malta's and Israel's resources are even scarce. Another group of countries (UK, Bulgaria, Italy, Spain, Turkey, France) has to manage its water demands on per-capita availability of 2,500 to 3,500 m³/cap/a. All other countries have at their disposal more than 5,000 m³/cap/a.

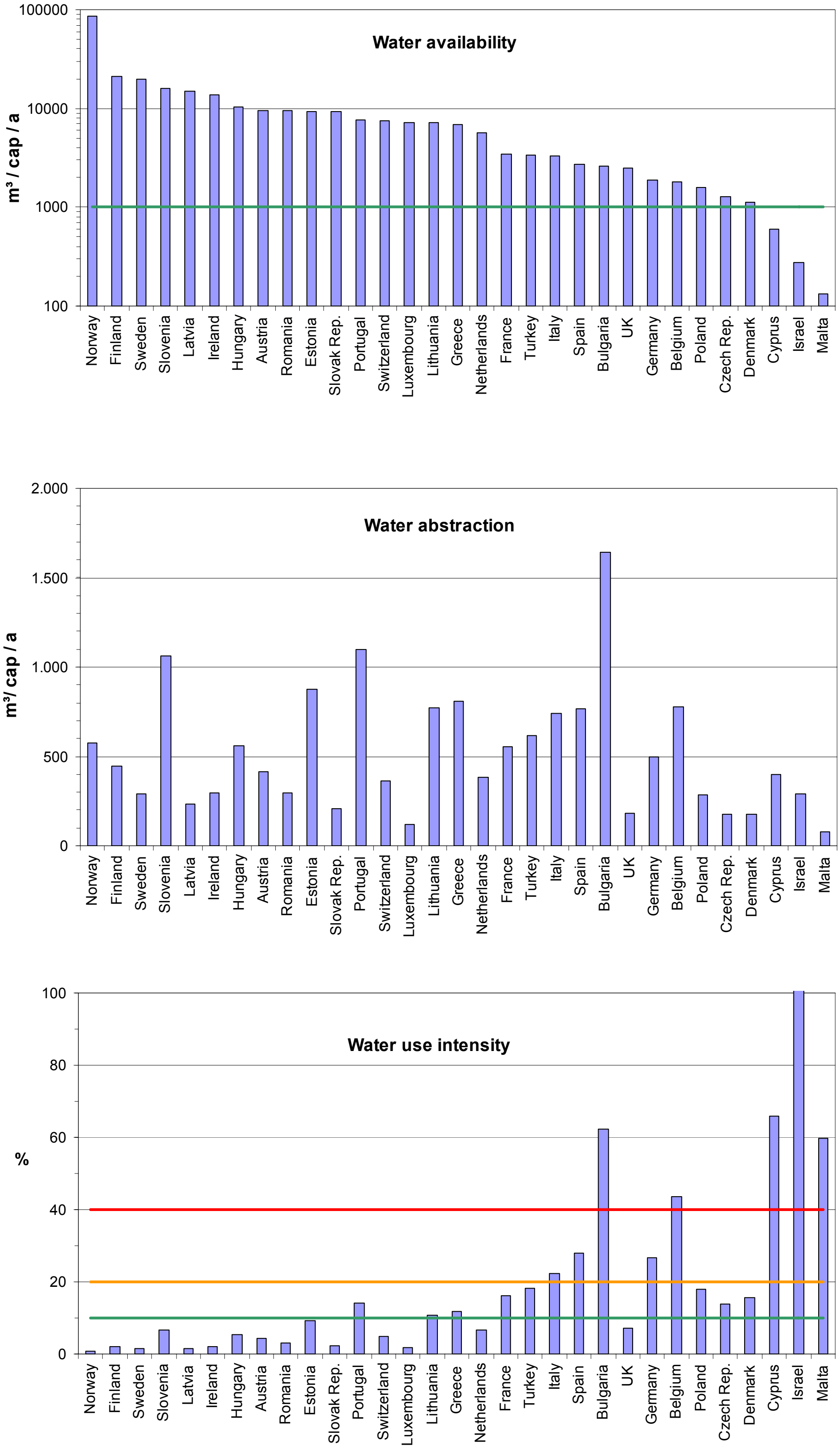
One has to keep in mind that all these figures give an impression of the annual average on a country level thus disregarding the spatial and temporal uneven distribution of precipitation, groundwater layers and water courses. Furthermore, due to available infrastructure, storage capacity or topographical peculiarities not all of these resources can actually be developed.

2.2 Water abstraction and use

2.2.1 Total abstraction

Each European country abstracts different amounts of water according to the size of population and the characteristics of its economy. Specific water abstraction varies markedly less than specific water availability. Per-capita abstractions range from 73 m³/cap/a in Cyprus to 1,600 m³/cap/a in Bulgaria.

Figure 2.1: Water availability, abstraction and use intensity for European countries and Israel. *Annual abstractions for the year 2000 (or latest available data) are divided by the ltaa availability*



Setting these amounts in relation to the available water resources gives an impression of how much water stress is put on the country's water resources. This water use intensity or water stress index is a rough indicator for the urgency of water management in order to assure supply and avoid conflicts among competing uses. The OECD (2003) defines water use intensity of more than 40% as high water stress, 20% to 40% classifies as medium-high, whilst more than 10% is defined as moderate water stress. Figure 2.1 reveals that approximately half of the European countries and almost 70% of the population are facing water stress issues.

Countries not considered water stressed on the basis of per-capita availabilities only, now exhibit a water use intensity of more than 20 % (Italy, Spain and Bulgaria) and are classified as medium-high and high water stressed. On the other hand water stress for Denmark, the Czech Republic and Poland is evaluated as low, but existing.

2.2.2 Abstraction for sectoral uses

Water use within the EU varies not only with regard to its intensity but also considerably with regard to use for different sectors. Concentrating on three water use sectors, namely public water supply (PWS), agriculture (AGR) – often identical with irrigation, and industrial uses (IND) – which sometimes include electricity generation and electricity production (ELE) - different abstraction patterns become obvious, as illustrated in Figure 2.2.

Countries with predominantly agricultural uses are the southern and south-eastern countries such as Portugal, Spain, Italy, Greece, Cyprus and Israel where this share equates to 45 % to 75 % of total water consumption.

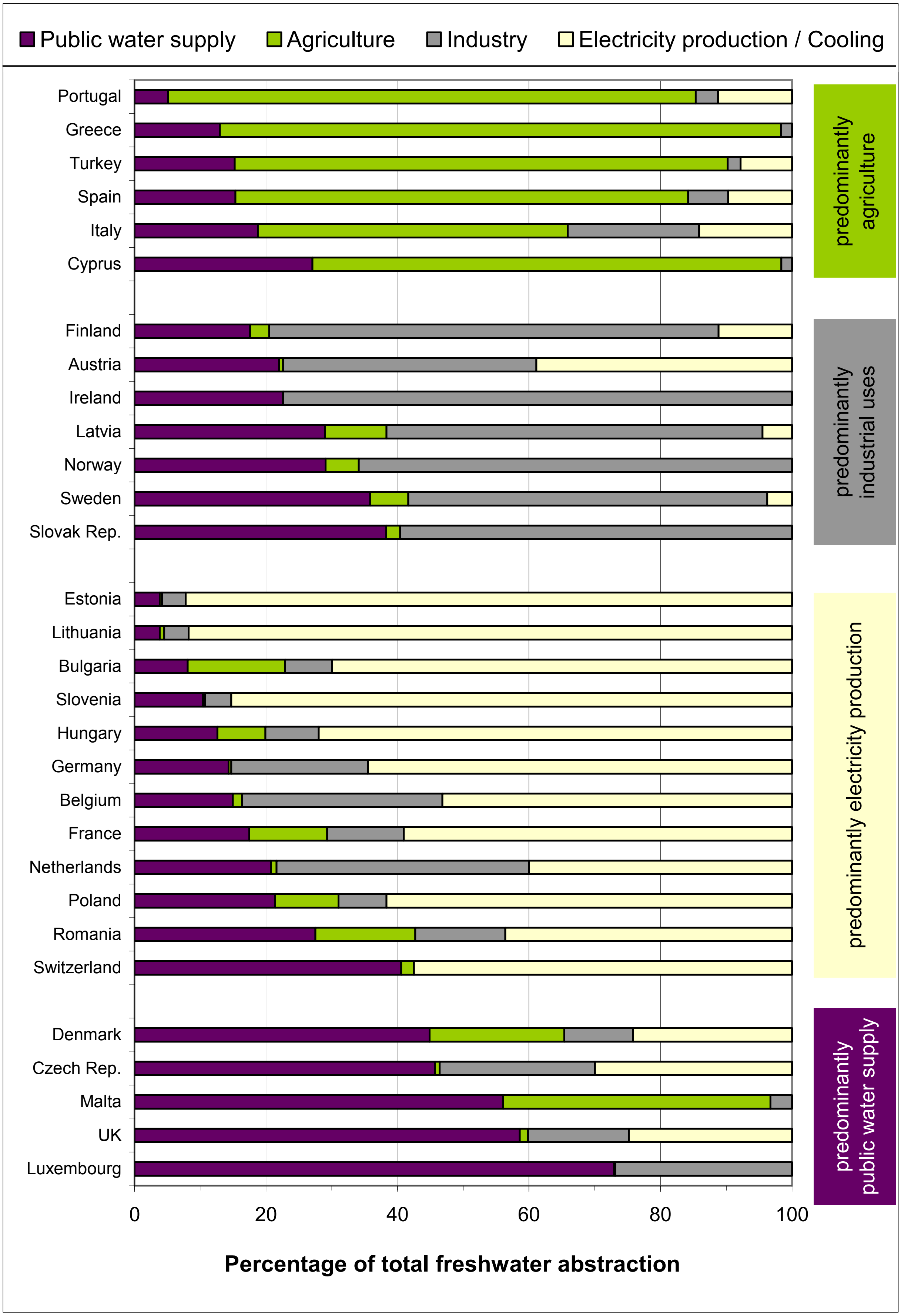
Allocations of water to electricity production, often amounting up to 90 % of total water withdrawal, is prevalent in industrialised western countries (Germany, Belgium, France and Switzerland) and some of the New Member States and Accession Countries (Estonia, Lithuania, Bulgaria, Slovenia, Hungary, and Poland). Their rather short or non-existent coastlines (in relation to the whole country area) forces the use of freshwater to support electricity production, whereas countries like the United Kingdom, Sweden, The Netherlands or Finland make use of non-freshwater sources like brackish or sea water to cover cooling water demand (Eurostat, 2003).

Industrial uses dominate the water use profile of Nordic countries mainly due to the existence of water intensive industries like pulp and paper, and because of minimal power plant cooling water demand. This fact, together with negligible agricultural water abstraction, is the reason for relatively low per-capita abstraction rates of below or around 500 m^3/cap/a.

Countries where the preponderant share of abstracted volume is used for public water supply include Denmark, Malta, the UK and the Czech Republic. Israel also dedicates a relatively high proportion of abstracted waters to municipal use (44 %). The reasons for high proportions of public water supplied can either be high domestic waster consumption or a major share of industry supplied via public services where self abstraction of ground- or surface water is not permitted or not feasible.

One can point out, that the total abstraction figures for Israel, Malta, UK and other countries mentioned above are less than the total water demand, as only the abstraction of freshwater is considered. Brackish water, desalinated seawater or even reclaimed wastewater is not included.

Figure 2.2: Water use profiles of European countries; freshwater abstraction by sector

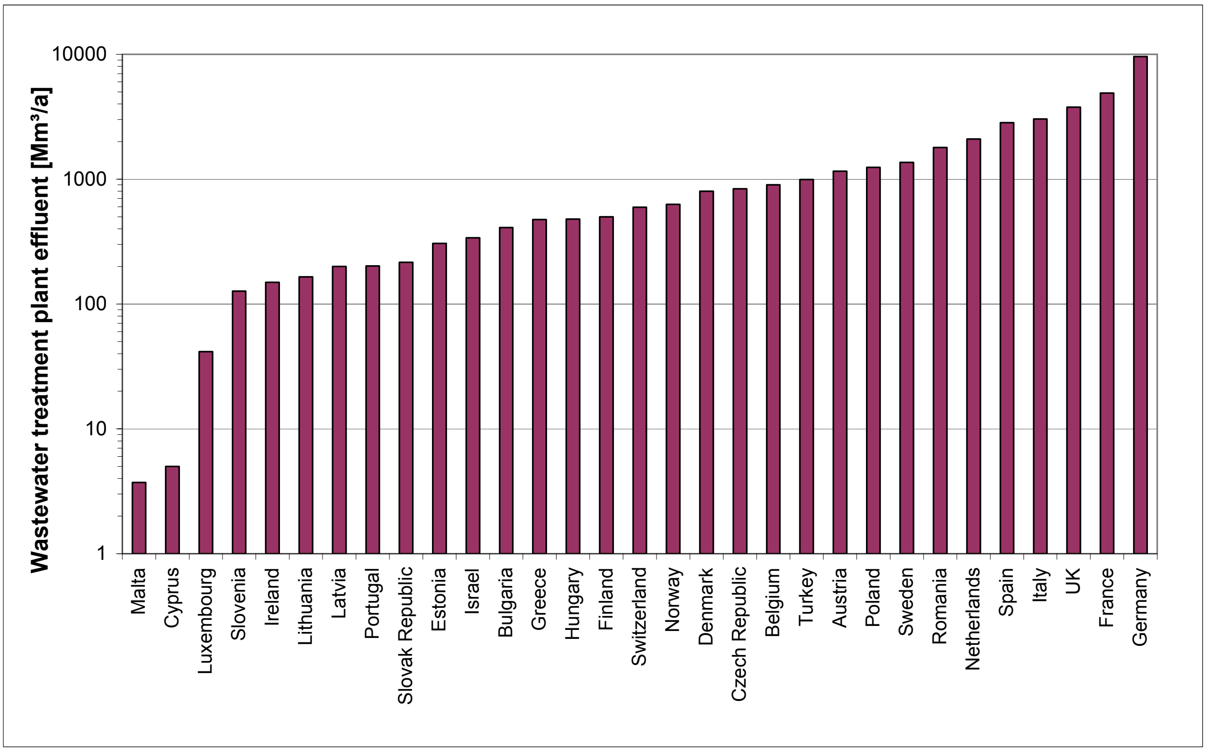


The different water use patterns help to identify and develop approaches for wastewater reuse implementation in the specific regional context, presupposed the dominant water use sector today will be the main target sector for present-day or future wastewater reuse applications.

2.3 Wastewater treatment

The availability of wastewater is the basic requirement for any direct reuse activity. The amount of wastewater generated and treated will define the range of the wastewater reuse potential. Figure 2.3 gives an impression of the volumes of treated wastewater in different European countries[1].

***Figure 2.3: Wastewater treatment plant effluent (late 1990s or 2000)** Source: Eurostat, OECD, National Statistics or estimates from other parameters as design capacity*



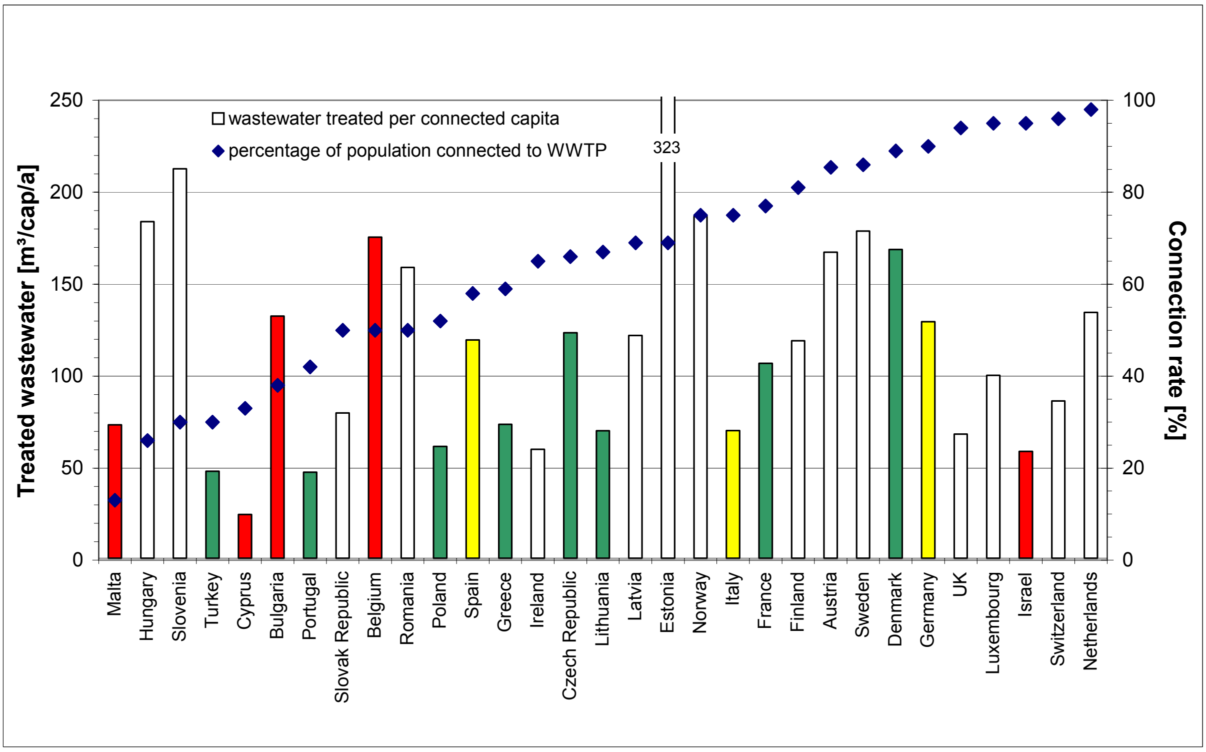
The treated wastewater volumes cover a range of 4 logs with Malta and Cyprus at its lower end (3.5 Mm³/a) and France and Germany at the top (4,900 Mm³/a and 9,600 Mm³/a respectively). The total volume of treated wastewater in all considered countries amounts to 40,145 Mm³/a.

But in order to evaluate the current status of wastewater treatment the data have to be viewed more specifically. Important influencing parameters for today's and future wastewater volumes are the population size and the share connected to wastewater treatment plants. Figure 2.4 depicts these interdependencies.

[1] The figures refer to municipal wastewater treatment plants thus disregarding both decentralised domestic treatment schemes (common in Norway, Cyprus and Austria for example) and industrial direct discharges.

The connection rates reflect a remarkable inhomogeneous status of wastewater treatment across Europe. Most of the Accession Countries have less than 50 % of their population connected to wastewater treatment plants. Only in the Baltic States and the Czech Republic approximately 65 % of population is serviced with wastewater treatment. Most EU member states exhibit connection rates of more than 75 %, with Denmark, Germany, the UK, Luxembourg and the Netherlands providing wastewater treatment for 90 % - 100 % of their population. Only Greece, Spain, Belgium and Portugal are behind with rates between 45 % and 60 %.

***Figure 2.4: Connection rates to wastewater treatment plants and sewage collected per capita** (coloured columns represent the country's water stress index ■ low water stress ■ medium-high water stress ■ high water stress)*



It is striking that especially the countries under high and medium-high water stress (Malta, Cyprus, Bulgaria, Belgium, Turkey, Portugal and Poland) rank lowest with respect to the connection rate of their population.

In general the specific amount of wastewater is influenced by the per-capita consumption, the share of rainwater collected in sewers, the contributions of indirect dischargers and unintended water intrusion.

For the countries under consideration, the average volume of wastewater treated per capita connected to wastewater treatment plants is 120 m³/cap/a. Values of more than 150 m³/cap/a indicate either a high share of rainwater (Belgium, Sweden), a high per-capita domestic water use (Romania) or indirect discharges from industry (Austria, Slovenia). The value for Estonia definitely seems to be an extreme.

2.4 Wastewater reuse

2.4.1 Types and examples of wastewater reuse applications

In principle, reclaimed wastewater can be used for all those purposes which freshwater is used for in the different sectors (appropriate pre-treatment presupposed). In fact the applications are restricted to non-potable uses or at most to indirect potable uses. Unlike in Windhoek; Namibia, direct potable reuse is not practiced in Europe(cf. chapter 9.3.4).

Having regard to the anthropogenic water cycle (Figure 2.5) it is obvious that wastewater is commonly reused, although mostly unintended. Once discharged to the aquatic environment, wastewater treatment plants effluents are recycled to the natural water flows from which they are withdrawn again for diverse human purposes. This fact has to be acknowledged in evaluating any direct reuse activities. A very detailed review of different types of reuse applications can also be found in different AQUAREC Deliverables (e.g. Management Manual for Water Reuse Schemes).

Figure 2.5: The anthropogenic water cycle with direct and indirect water reuse (modified from Veolia Water, Durham 2005, where : indirect reuse : direct reuse, GWR: groundwater recharge, IRR: irrigation, POT: potable reuse, IND: industrial reuse, URB / DOM: urban & domestic reuse, ENV: environmental enhancement)

2.4.1.1 WASTEWATER REUSE FOR AGRICULTURAL OR LANDSCAPE IRRIGATION

Irrigation of agricultural land with wastewater is far and away the most established application and the one with the longest tradition - soil treatment was the first form of wastewater treatment and disposal (Angelakis *et al.*, 1999). Sewage farms in Achères near Paris, 'Rieselfelder' in Germany (Münster, Berlin) and irrigation with untreated sewage in Italy and Spain (Angelakis, 2002) are only a few examples of this practice in Europe. Because of health concerns, guidelines were enacted by the WHO in 1989, a step which acknowledged at the same time the importance of this type of wastewater use, especially in developing countries.

Even though the use of treated effluent constitutes a massive advance compared to the former practice, the hygiene aspects are still contentious whereas the fertilising value of reused wastewater is undisputed and can be economically beneficial in agricultural and golf course irrigation (Mujeriego *et al.*, 1996; Oron, 2000; Sala, 2001; Tsadilas, 2002).

Reclaimed water is applied to the land by different irrigation techniques which require different water qualities. Some characteristics of reclaimed wastewater like suspended solids and minerals may be detrimental for advanced irrigation techniques like drip irrigation, whereas microbiological features are more relevant for spray or spate irrigation. Hence, the reuse of wastewater for agricultural purposes should be carried out in a way that neither population, workforce and technical installations nor plants, soil or groundwater are compromised. With these points in mind, some countries have adopted guidelines or regulations for the use of treated wastewater in agriculture.

Spain and Italy, the main consumers of water for irrigation in Europe, are logically the main users of reclaimed water for this purpose. Large irrigation schemes in Gramicelle, Sicily, or in the Puglia region of Italy are in operation or will soon be commissioned. In Spain, approximately 76% of reused wastewater is dedicated to agricultural irrigation. In addition, golf course irrigation is becoming more and more prominent at the Spanish Mediterranean coast and on the islands, allied to the importance of tourism in these regions.

France irrigates agricultural land mostly by applying an activated sludge stage followed by a lagooning system, e.g. at the Ile de Noirmoutier for potato irrigation and near Clermont-Ferrand for seed maize, sugar beets, sunflowers and wheat (Faby and Brissaud, 1997).

2.4.1.2 WASTEWATER REUSE FOR INDUSTRIAL PURPOSES

Water in industry is used for diverse purposes. Large volumes are needed as cooling water. For steam production boiler feed water is prepared. Process water of different qualities is used for rinsing, cleaning, washing or as a solvent in many industrial sectors.

The cooling water demand of a conventional thermal power plant with once-through cooling water systems amounts to 50 m^3/s per 1,000 MW installed capacity, i.e. 180 L/kWh produced. This water is abstracted and reintroduced with only minimal losses but with highly increased temperature. Power plants, which cool the water down before discharging it, have evaporation losses of 0.3 – 0.6 m^3/s per 1,000 MW installed capacity, i.e. 1.1 – 2.2 L/kWh which have to be replaced by additional abstraction (Wagner, 2003).

It is characteristic for industrial uses – in contrast to irrigation application – that even water from conventional sources (drinking water, self-abstracted groundwater or surface water) is treated according to specific requirements. Filtration and desalination are common treatment procedures. Thus, replacing conventional water by reclaimed water does not preclude the need to ensure its suitability as feed water for existing treatment schemes. Moreover continuity and reliability of supply are vital issues in industrial wastewater reuse.

The reused wastewater might either stem from the company's treatment facility (on-site recycling) or from a municipal wastewater treatment plant into which households and industries discharge. A large scale system is operated for the textile industry in Prato, Tuscany (Italy). Industrial and municipal wastewater is reclaimed (3.5 Mm^3/a) and augmented to 5 Mm^3/a by river water withdrawal. A separate industrial aqueduct redistributes the reclaimed water to the enterprises. The steel industry in Piombino is provided with about 3.5 Mm^3 of upgraded wastewater.

Another example involves the provision of cooling water for a power plant in Poland (~ 2 Mm^3/a) which is prepared by membrane technology. A pilot plant with wastewater treatment plant effluent for the preparation of boiler feed water was successfully run in Hoogvliet (Netherlands). It is intended to commission a full-scale plant with a flow of 2.5 Mm^3/a (van Naerssen *et al.*, 2001).

2.4.1.3 Wastewater reuse for non-potable urban and recreational purposes

Municipal water demand for fire protection, street cleaning and irrigation of public greens or golf courses could be satisfied by reclaimed wastewater. Even for some household uses which do not require drinking water quality (e.g. toilet flushing, garden watering, washing machine) a secondary water quality can be supplied. The reclaimed water can be provided either through a second distribution network or by in-house recycling of greywater, blackwater or rain-water harvesting. The most problematic issue is once again the possibility of biological contamination through aerosols. In order to minimise the exposure risk the wastewater has to be sufficiently treated, and safe application methods have to be designed.

Domestic use of recycled wastewater is the main water recycling application in Japan, especially for congested urban areas and high rising buildings in cities centres, whereas in Europe only a few projects for single houses or case studies in apartment houses have been implemented. An example of an external system that supplies a whole district can be found in the Waterwise project in Blackburn, UK, where part of the sewage collected from the houses is tertiary treated and redistributed (Catchwater, 2001).

Another full-scale regeneration system is operated in Rouse Hill, Sydney, Australia, which supplies 17,000 houses with tertiary treated effluent from the municipal wastewater treatment plant for non-potable domestic purposes (Savoye *et al.*, 2001).

2.4.1.4 Wastewater reuse for artificial groundwater recharge

Groundwater recharge is a beneficial application of reclaimed water to preserve groundwater levels, to protect coastal aquifers against saltwater intrusion, and to store surface water or reclaimed wastewater for future use. Recharge methods commonly used are infiltration and injection into the aquifer (World Bank, 2003). Infiltration is either carried out in spreading basins, where the water percolates vertically through the unsaturated zone, or via riverbank infiltration. In both cases the passage through the soil contributes to a further purification of the effluent and is therefore called Soil Aquifer Treatment (SAT). The infiltration rate of the system depends on the soil permeability which can be negatively affected by clogging with operation time. Injection wells which are drilled into the aquifer enable groundwater recharge in insufficiently permeable soils. By-passing SAT, the reclaimed wastewater is directly injected into the aquifer. In this technique the well – aquifer interface is prone to clogging.

But not only mechanical complications are evident. Water quality aspects are particularly significant in groundwater recharge schemes: these include microbiological quality, total mineral content (total dissolved solids), presence of heavy metals, and the concentration of persistent organic substances. Thus, groundwater recharge with reclaimed wastewater presents a wide spectrum of technical and health challenges that must be carefully evaluated (Asano, 1999).

Aquifer storage and recovery (ASR), a technique whereby water is stored underground in times of supply surplus for use in times of water shortage, can be an instrument of water management of paramount importance in arid climates, where natural groundwater formation rates are very low, due to high evapotranspiration (Bouwer, 2000).

It is worth noting that ground water recharge itself does not anticipate the purpose, the water is used for after re-abstraction, if it is re-abstracted. Spain, for example, recharges coastal groundwater layers (at least) in Blanes and Barcelona (Costa Brava, Catalonia) (Borras, 2002; WHO 2002), primarily to stop saltwater intrusion. Similar projects are also planned in Greece (Georgiadou *et al.*, 2003).

Israel's Dan-Region Reclamation Project is one of the renowned, large-scale groundwater recharge schemes. Biologically treated wastewater (122 Mm^3 in the year 2000) is recharged via spreading basins. The only additional treatment is the soil-aquifer-treatment exercised during the passage through the soil. After re-abstraction, the water is transported via a pipeline to the South of the country, where it is destined for agricultural irrigation in the Negev desert.

Artificial aquifer recharge with treated surface water (containing up to 50% treated effluents) is practised e.g. in Berlin, Germany (Heinzmann, 1995) in order to augment the groundwater resources and thus ensuring public water supply.

2.4.1.5 INDIRECT POTABLE REUSE

Aquifer recharge can be closely related to indirect potable reuse, i.e. through the production of drinking water from re-abstracted groundwater. This utilisation is only acceptable when the quality meets the pertaining criteria for drinking water.

Indirect potable reuse is an exceptional application in Europe but becoming more and more prominent in the USA. The Southern Californian Groundwater Replenishment Scheme (former Water Factory 21) project (managed by the Orange County Water District) reclaims approximately 265,000 m^3 wastewater per day. The treatment chain comprises a double membrane system with microfiltration and reverse osmosis as well as an advanced oxidation processes ($UV+H_2O_2$) for final removal of disinfection by-products. Eventually, the product water is chemically stabilised with lime and then injected into the local aquifers. An annual volume of 96.72Mm^3 provides both a saltwater intrusion barrier and replenishes the drinking water aquifer (Deshmukh, 2004).

A similar scheme – with respect to its purpose– is operated by the Veurne-Ambacht Intercommunal Water Company in Belgium. The effluent treatment train uses different membrane technologies (microfiltration and reverse osmosis). About 2,5 Mm^3/a are pumped to the infiltration ponds in the dunes (Dewettinck, 2001).

2.4.1.6 WASTEWATER REUSE FOR ENVIRONMENTAL ENHANCEMENT

The use of treated wastewater for environmental enhancement primarily comprises the use of a treated effluent for the restoration of habitats like marshes, wetlands or fens. These systems, normally embedded in the natural water cycle and fed by rain or natural water courses, have often been damaged by human intervention. Construction of dams, drainage of land or excessive groundwater pumping causing dropped groundwater levels have led to periodical or permanent desiccation of such ecoystems (EEA, 2002). In this context wastewater reuse can contribute to nature conservation and to increased biodiversity. Another option is to enable reforestations in drier climates e.g. for the Athens region (Tselentis, 1996)

Compared to other sectoral uses where reclaimed wastewater replaces and thus saves conventional water, the benefits derived from environmental uses are different. They create new or recover vanished qualities that were not previously thought to be worthwhile accomplishing by use of conventional water sources.

In Valencia, 31 Mm^3/a of disinfected effluent from the Pinedo II wastewater treatment plant will be used for the augmentation of the neighbouring Albufera lagoon (Generalitat Valenciana, 2005). The Cortalet Lagoon at Empuriabrava (Northern Costa Brava) is supplied with 0.5 – 0.75 Mm^3/a denitrified wastewater treatment plant effluent. The continuous application of an average 7 Mm^3/a of reclaimed wastewater at the Braunschweig Rieselfelder (Germany) turned them into permanent wetlands no longer endangered by periodical dry-up (Abwasserverband Braunschweig, 2001). Approximately 9 Mm^3/a of treated effluent are indirectly reused at the Münster Rieselfelder to preserve the wetlands protected by the Ramsar Convention.

Wastewater reuse categories and related issues of concern are summarised in Table 2.1.

***Table 2.1: Types of wastewater reuse and related issues of concern** Sources: (EEA, 2001; World Bank 2003)*

Type of reuse Abbreviation	Application	Issues of concern
Agricultural uses AGR	irrigation of fodder, fibre and seed crops irrigation of edible crops, irrigation of horticulture irrigation of orchards and vineyards frost protection irrigation of nurseries aquaculture stock feed water	health concerns and hygiene risk for field workers and consumers hazards for the plants (heavy metals, trace elements, viruses, salts) prevention of groundwater contamination compatibility with soil characteristics seasonal demand peaks, storage capacity compatibility with irrigation technique
Industrial uses IND	cooling boiler feed process water flue gas wash-down construction	scaling, corrosion, biofouling liability of supply
Urban uses URB	fire protection street cleansing, dust control irrigation of (public) park, cemeteries etc. car washing private garden watering air condition toilet flushing	innocuous handling biological contamination through aerosols

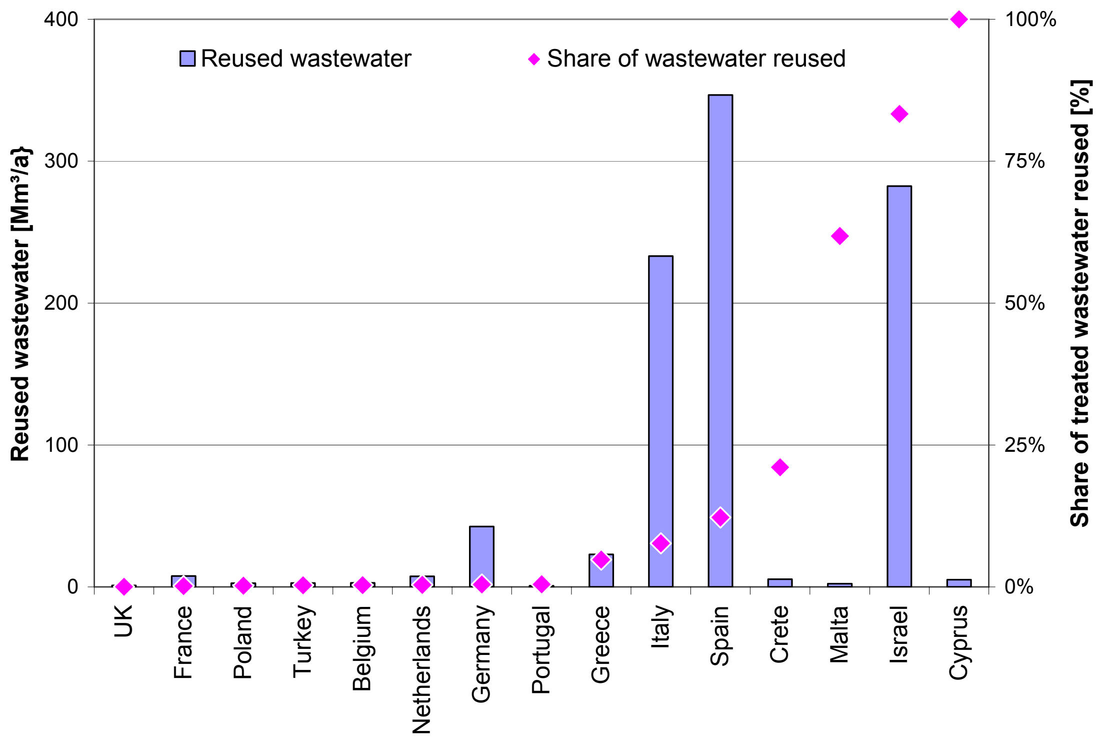
Type of reuse Abbreviation	Application	Issues of concern
Groundwater recharge GWR	groundwater replenishment storage salt water intrusion control subsidence control	land requirements soil permeability clogging aquifer characteristics
Environmental, ecological uses ECO	streamflow regulation marshes and wetlands fen restoration reforestation	impact on aquatic life
Recreational uses URB	ornamental lakes and ponds golf course irrigation snowmaking	health concerns, possible exposure of visitors

2.4.2 Quantitative assessment of wastewater reuse

Besides the various possibilities for wastewater reuse explained in the previous paragraphs a quantitative analysis of wastewater reuse in Europe will be given in this section. Data on reused wastewater volumes were gathered from literature and the review carried out by WP6 within the Aquarec Project. It has to be admitted that quantitative information on wastewater reclamation and reuse is difficult to obtain. Where no volumetric information was available reused amounts were estimated according to irrigated area.

The total reused wastewater volume in Europe is 964 Mm^3/a, which accounts for 2.4% of the treated effluent. The shares of different countries' wastewater which is reused range from far below 1% to 100% (Cyprus). High irrigation demand (174 Mm^3/a) in Cyprus offers enough possibility to reuse the small amount of treated effluent (4 Mm^3/a). In comparison, the Netherlands, which produce an annual wastewater volume of 2,097 Mm^3, has an irrigation demand of only 52 Mm^3/a. Nonetheless the Netherlands' water use pattern (Figure 2.2) offer reuse opportunities in the industrial sector. Figure 2.6 depicts both the volume of wastewater reused and the share of the treated wastewater this equals.

Figure 2.6: Status of wastewater reuse in selected countries



Greece, Italy and Spain reuse between 5 % and 12 % of their effluents whereas Israel and Malta utilise 83% and 60 % of their wastewater. In Greece most of the reuse applications are small ones, whereas the planning of big single projects in Thessaloniki for example are just under development (Soupilas and Papastergiou, 2003).

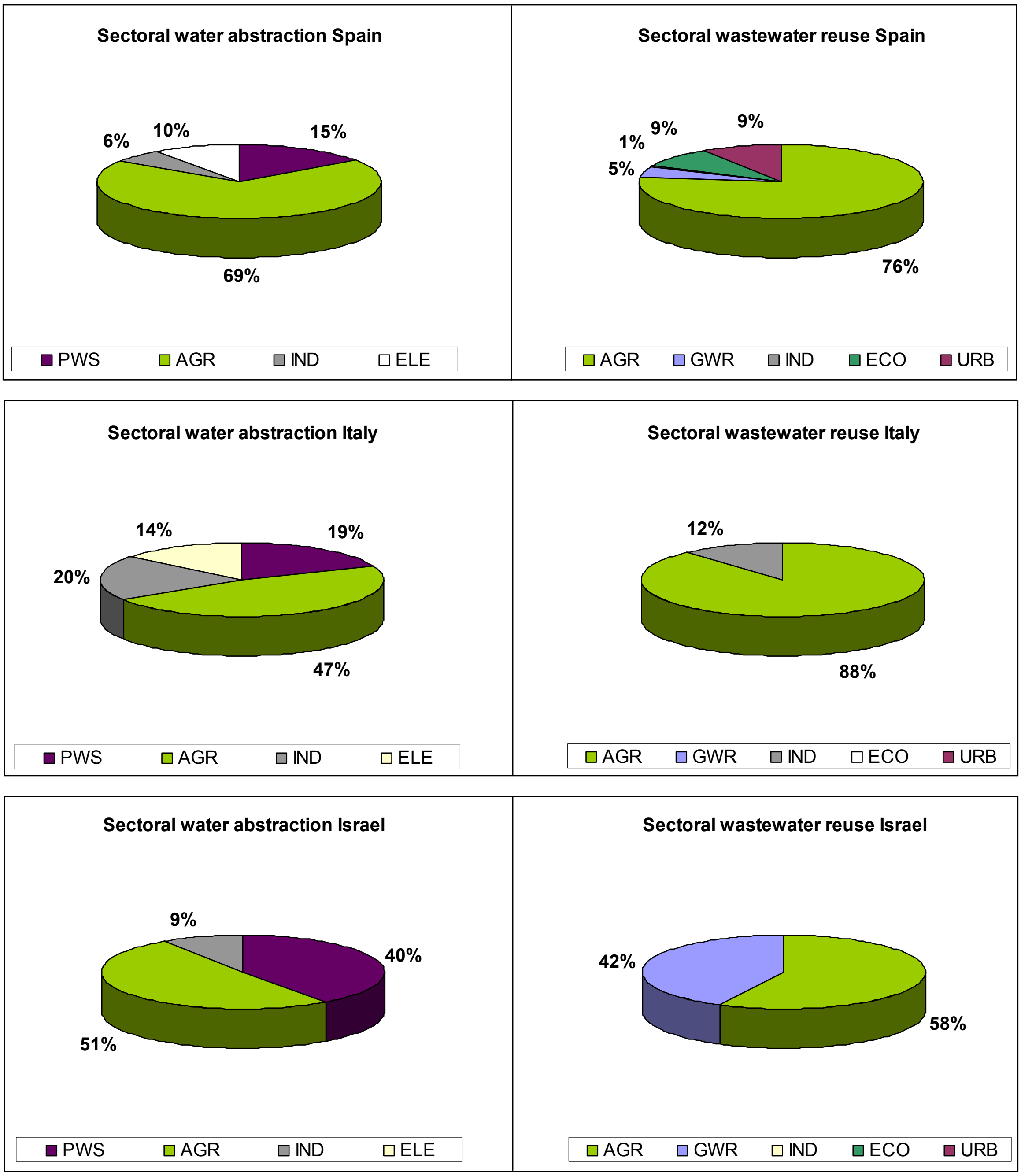
In relation to a country's total water abstraction, the contribution of wastewater reuse is marginal, in most of the cases less than 1%. Only Malta and Israel augment their water supply by 10 % and 18 % respectively using reclaimed wastewater as an alternative source.

Comparing the reuse pattern with the water abstraction pattern for conventional sources one can distinguish three types of applications:

- reuse to accommodate an existing major water demand
- reuse for additional purposes, not dominating the freshwater demand
- reuse to augment or to replenish natural resources

In Spain the reuse pattern almost reflects the abstraction pattern (cf. Figure 2.7 and Table 2.1 for abbreviations). In both cases the main emphasis lies on agricultural irrigation use. Most of the reclaimed volumes are exploited for the segment with the highest demand.

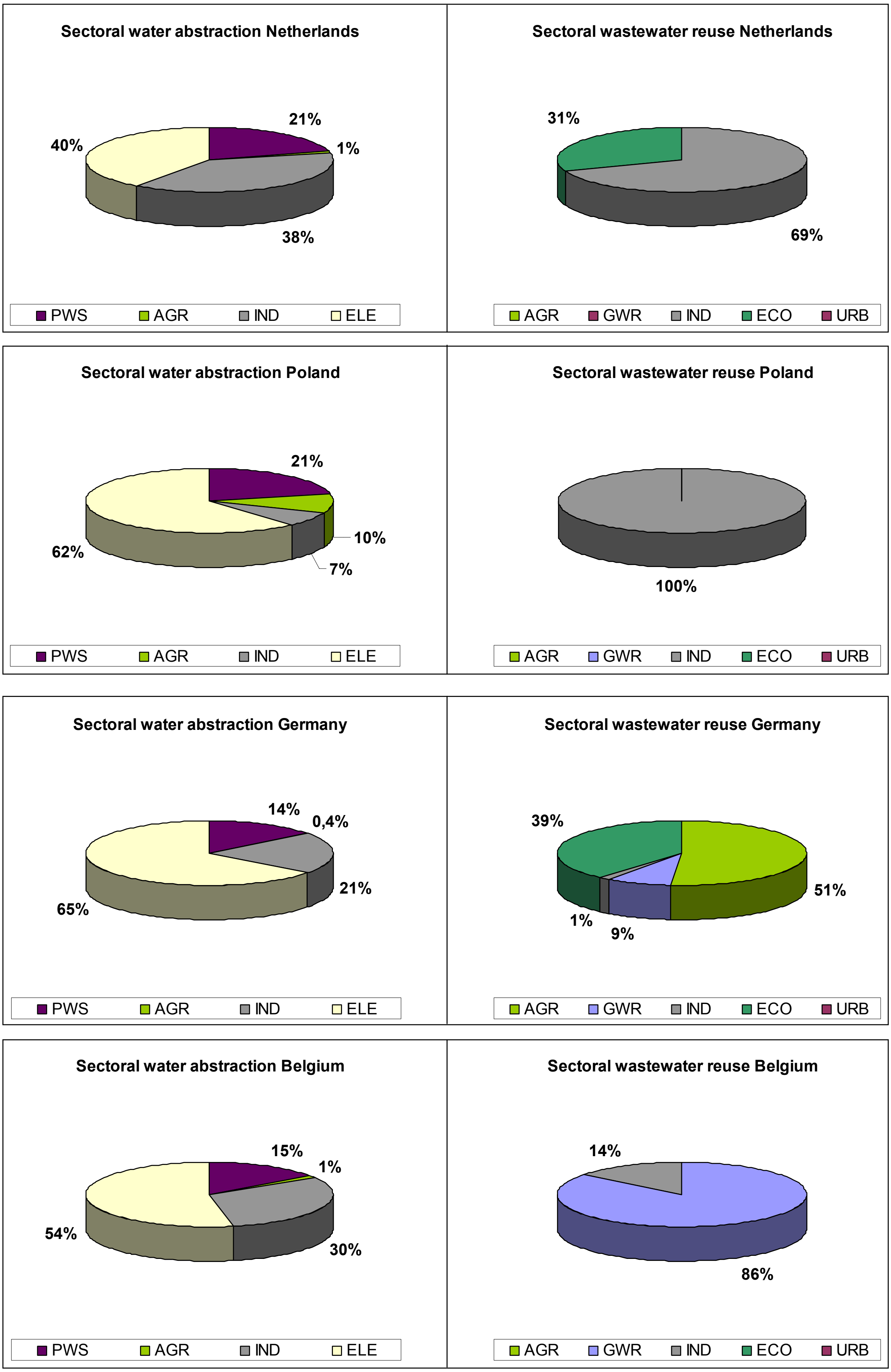
Figure 2.7: Water abstraction and wastewater reuse pattern of selected countries - I



A similar situation is evident for Italy where agriculture and industry are the main targets for wastewater reuse. Urban applications are under-represented compared to the abstraction profile. Israel uses almost all reclaimed wastewater for agricultural and landscape irrigation. Even the water recharged into groundwater via soil aquifer treatment (SAT) is afterwards used for irrigation.

Typically, countries with little agricultural water demand, exhibit reuse activities in other sectors. In terms of volumes, The Netherlands focus on industrial reuse of reclaimed wastewater (process and boiler feed water) or apply it for ecological purposes (see Figure 2.8). This trend is partly in line with the sectoral water demand. Besides the replacement of freshwater use in industry the environmental benefits of ecological reuse are fostered. In Poland, efforts to establish wastewater reuse were merely found in the industrial sector.

Figure 2.8: Water abstraction and wastewater reuse pattern of selected countries - II

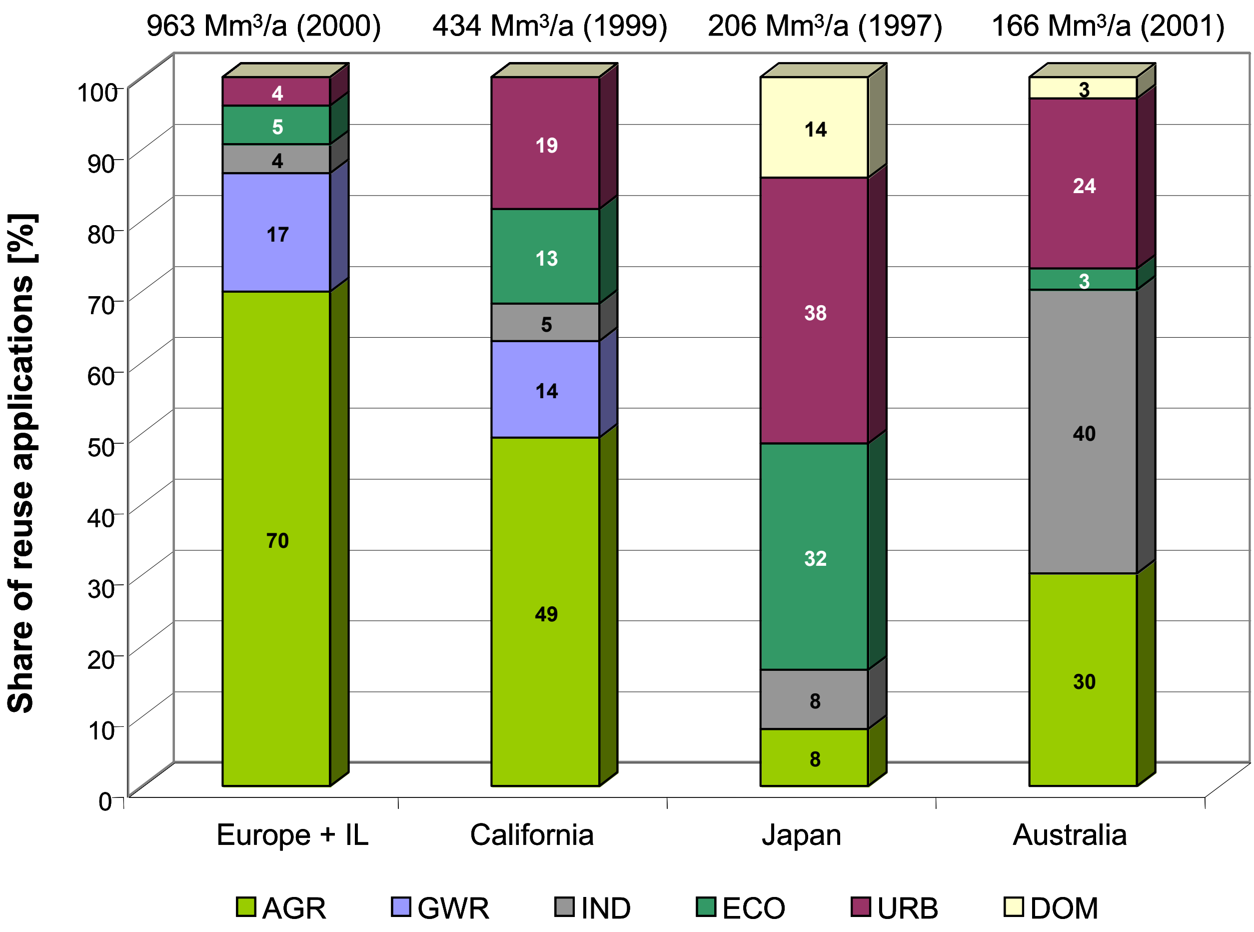


A completely different picture is revealed for Germany (Figure 2.8). While the abstraction profile is dominated by industrial uses and electricity production, most of the reclaimed water is applied in agriculture or for ecological purposes. It seems that wastewater reuse in this context does not serve an existing demand for water but is rather beneficially used from the perspective of minimising pollution load discharge.

The dominant reuse in Belgium is for groundwater recharge and at the same time a rare example for indirect potable reuse in Europe, as the reclaimed water is finally treated for drinking water purposes. The diagrams suggest that there is huge potential to develop, for example, the industrial sector much more purposefully.

It is interesting to compare this irrigation focused use of reclaimed wastewater in Europe to the much more diverse pattern in other countries and regions (Figure 2.9). In Japan, urban and domestic uses are predominant (Asano, 2000). As argued above this can be interpreted as a reaction to the very particular water stress situation of the country (see also chapter 2.5). Also the Australian reuse activities present a more balanced pattern of different types of reuse, where industrial reuse applications account for 40 % of the reused volumes.

Figure 2.9: Comparison of reuse pattern for Europe, California and Japan
Reference: AQUAREC (2004), Asano (2000), AATSE (2004; IL=Israel)



2.4.3 Scope of agricultural reuse

Agricultural irrigation is the predominant application for reclaimed water in Europe with 70 % of the reused volumes. The relation of conventional water resources used to reclaimed water application gives an indication about the possible impact in the particular sector.

Table 2.2 compares the extent of agricultural irrigation with both conventional water and reclaimed water. For many of the countries reclaimed water makes up around 1% of the conventional water irrigation (Spain, Italy, Cyprus). But the agricultural production in Malta and Israel covers already 19-30% of its demand from reclaimed water.

Table 2.2: Irrigation with conventional water (CW) and reclaimed water (RW)

	Arable and permanent crop	Conventional water			Reclaimed water		RW/CW [%]
		Irrigated area	Irrigation water demand		Irrigated area (calculated)	Use of reclaimed ww for irrigation	
	1000 ha	1000 ha	Mm³/yr	m³/ha	1000 ha	Mm³/yr	
Spain	18218	3655	21512	5886	45.36	267	1.24
Cyprus	143	40	174	4350	0.32	1.4	0.80
Malta	9	2	12	6200	0.37	2.3	19.2
Israel	418	180	880	4889	57.27	280	31.82
Portugal	2705	787	8814	11199	0.45	5	0.06
France	19582	2200	3916	1780	3.78	6.73	0.17
Italy	10825	2700	20015	7413	27.52	204	1.02

Taking into account the commodity flow on the European Single Market, it becomes evident that agricultural produce from Italy and Spain is mainly absorbed by northern European countries (Figure 2.10 and Figure 2.11).

As food safety has for a long time been a major issue in trade regulations, agreed rules for the production of food whether regarding the use of pesticide or standards for reclaimed water are rather a Community issue than only a matter of national agreement.

Sometimes even the wholesale trade demand of their producer to comply with a particular certificate defining specific requirements. The EurepGAP (Euro-Retailer Produce Working Group) certification system defines a series of rules for market gardening and fruit growing to comply with Good Agricultural Practice (GAP). They explicitly prohibit the use of untreated wastewater and demand at least to keep the standards of the WHO Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture, when reclaimed wastewater is used for irrigation, thus representing a quite moderate attitude (EUREP, 2004). This practice shows that wastewater reuse standards, at least in this case, are not abused in trade regulations, as the OECD (2005) was worried about.

Figure 2.10: Imported agricultural produce from Italy in 2000 (total: 2.7 Mio ton) (Eurostat, 2005)

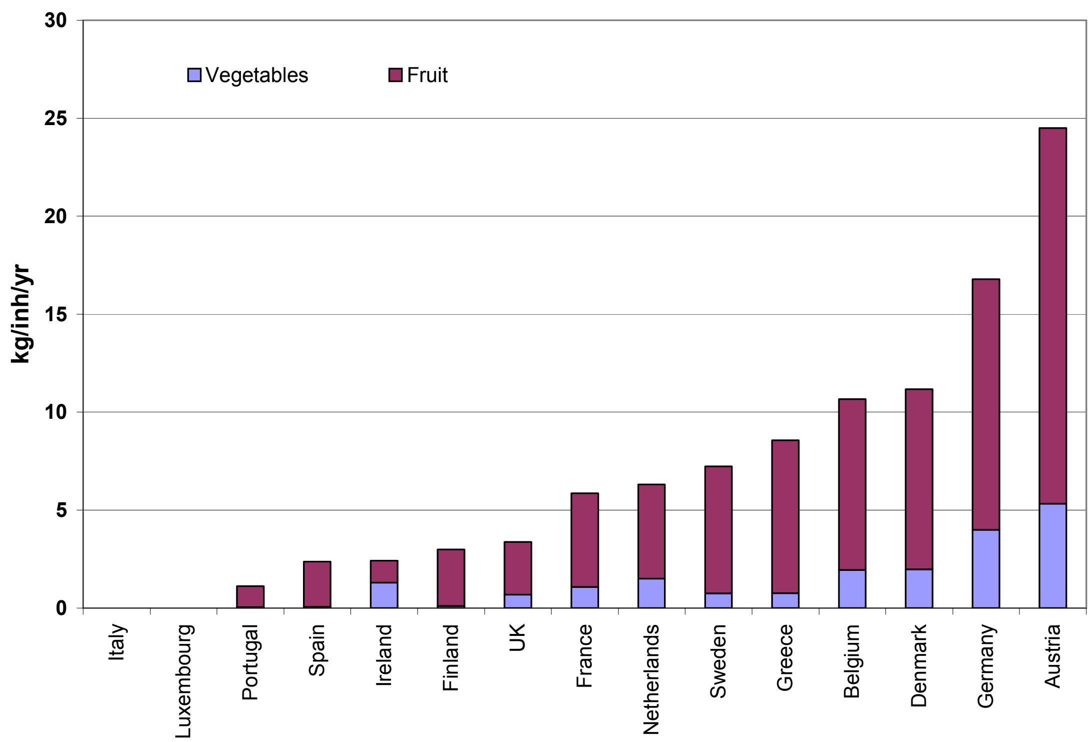
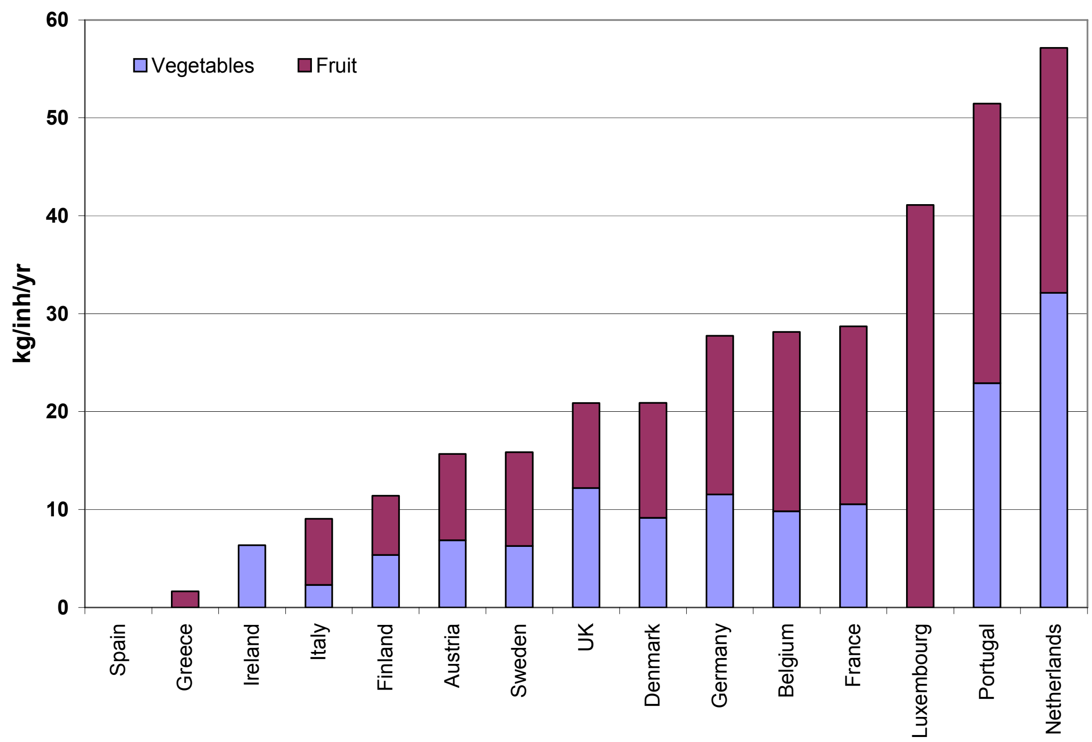


Figure 2.11: Imported agricultural produce from Spain in 2000 (total: 8 Mio tons) (Eurostat, 2005)



2.5 Water stress – the main driver for water reuse

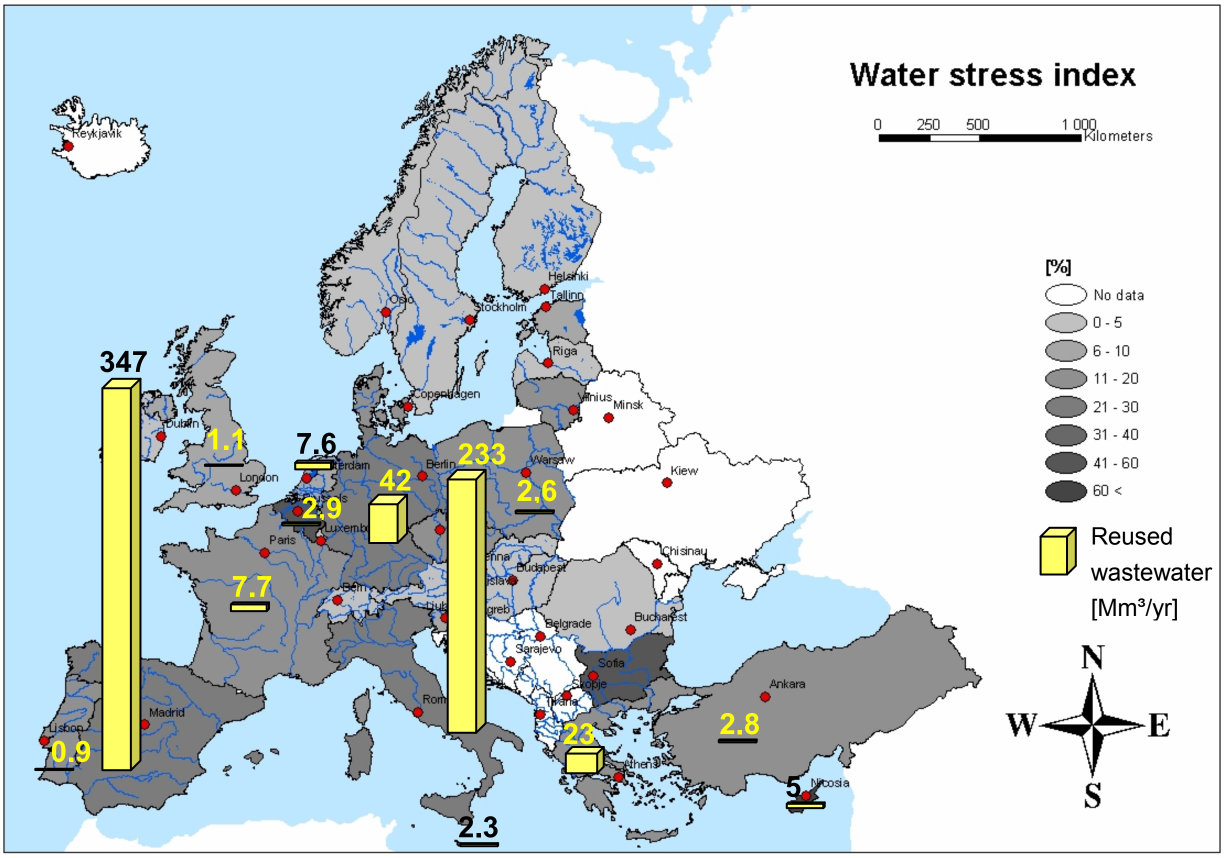
As could be derived from the previous chapters, wastewater reuse has developed from a basic method of disposing wastewater without any treatment to an often highly engineered technique of wastewater upgrading and water resources augmentation in water scarce regions throughout the world.

Due to limited water resources, typically water stressed countries in dry climates like Australia, Israel and the State of California have developed wastewater reuse strategies and programmes acknowledging the beneficial role wastewater reuse can play in integrated water management (Rubin, 2001; DoWR, 2003; AATSE, 2004).

According to EEA (1999c) "water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. Water stress causes deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.)". Water stress leads to sectoral competition and thus necessitates to expand water supply and to tap new or alternative sources as the conventional resources become exhausted. Wastewater reuse can make a contribution to mitigate regional or seasonal water scarcity.

This chapter will give an overview of the water stress situation in European countries and the implication this has for the development of water reuse. Figure 2.12 depicts the year 2000 state of water reuse in different countries against the respective water stress index.

***Figure 2.12: Water stress and wastewater reuse in Europe** (where Water Stress Index is the ratio of water abstraction to the total renewable freshwater resources on a country wide level)*



It is obvious that water reuse is practiced more intensively in countries with water stress indices of 20% or more. The next sections will analyse the different factors exacerbating water stress which can either constitute

- use related circumstances (sectoral demand, seasonal and regional demand peak),
- water quality issues (inappropriate water quality for certain uses - salt content, nitrates) or
- climatic conditions (temperature, precipitation)

2.5.1 Sectoral demand

Public water supply

The extent of abstraction for public water supply purposes is closely interconnected to population growth and the percentage of population and consumers served. Even though there is no significant population growth expected in Europe overall in a long term perspective (UN Population division, 2001) there will be some increase in specific countries such as France and the UK. Furthermore the trend of resident populations migrating to coastal regions (e.g. Spain and Portugal) or from the town centres to the suburbs will create more densely populated conurbations there (EEA, 1999b).

Tourism on coastlines, on islands or in mountainous resorts creates seasonal and regional peak demands for water and exacerbates the situation in already water stressed regions.

Agricultural irrigation

Irrigated land in the EU has steadily increased during the last 20 years. France, Greece Portugal and Spain mainly contributed to the rise during the 1990s (FAO, 2000).

There are plans to expand irrigated areas as irrigated agriculture is much more productive (EEA, 1999b). But most of the planned extension is subject to funding and sufficient water resources (MMA, 2000; INAG, 2002). During severe short-term droughts it is not unusual that farmers experience restrictions on water use so that only a small proportion of irrigable land can actually be irrigated (Massarutto, 2001).

Climate change will probably amplify the demand for irrigation water across Europe. On the one hand, specific irrigation needs might increase because of increased evapo-transpiration. On the other hand supplementary irrigation of formerly rain-fed agricultural land might be necessary to assure profitable yields. Moreover, climate warming will expand the area of cereals cultivation northwards thus changing the cropping pattern and probably the irrigation water demand to maximise yields (Kundzewicz, 2001).

Against this background, the use of reclaimed wastewater can contribute to filling the gap between water demand and availability. Thus it helps to alleviate the economically disadvantageous effects of deficient and unreliable irrigation water supply (Barbagallo, 2001).

Industry and electricity production

Water use efficiency in industry has improved considerably during the last decades. Based on in-process water recycling and re-circulation, the water use factor[2] for manufacturing and mining industry is 4.6. Public power plants operate with a water use factor of around 2.5. (figures for Germany; BMU, 2001). But these are progresses due to technical developments that countries with less economic power cannot (yet) afford. Although economic growth initially accelerates the demand for water, with time, a steady demand level will be reached and even enable optimisation of water use efficiency.

Electricity production depends upon sufficient availability of cooling water. Not only is the availability of sufficient volumes of water is important, but availability must be at the right time and at the right place. If minimum river flows or reservoir levels are preserved to secure electricity production, other users of the same water resource will probably have to suffer restrictions on their water supply.

Especially in many Mediterranean river basins the situation is exacerbated as low flow in streams during summer coincide with demand peaks in various secotors thus exerting remarkably pressure on groundwater.

2.5.2 Quantitative and qualitative status of water resources

Water scarcity is not only generated by quantitative deficits but as well by the qualitative status of the resource.

2.5.2.1 Groundwater

One problem ensuing to excessive groundwater abstraction caused by intense sectoral demand is aquifer depletion. Problems related to over-exploitation of aquifers are reported for almost all European countries, as summarised in Table 2.3 (EEA, 1999a, 1999d, Angelakis *et al.*, 1999; van de Peer, 2001). Falling groundwater tables, resulting from over-abstraction, interfere with wetland and related ecosystems which are endangered to dry off.

Reduced groundwater tables may entail groundwater quality deteriorations. For Danish aquifers one can observe an increase in metals due to lowering groundwater tables which affects oxidation conditions of metal minerals in the soil. Some drinking water wells have already become contaminated with nitrate, zinc, aluminium, pesticides or their residues which urged water companies to close drinking water wells (NERI, 2002). Another detrimental effect is the intrusion of saltwater into coastal aquifers making them inappropriate for any use in some catchments or at least call for intensified treatment efforts. All Mediterranean countries are prone to this problem (cf. Table 2.3).

[2] The water use factor describes how often water is used before it needs to be substituted. For example, a water use factor of 3 means that a freshwater water input of 1 m³ is sufficient to run processes that actually need 3 m³ primarily by regenerating and recycling used volumes instead.

Table 2.3: Implications of aquifer overexploitation in European countries
(Source: EEA,1999d; Euro Waterbase)

Country	Groundwater over exploitation	Groundwater over exploitation leading to: Saltwater intrusion	Groundwater over exploitation leading to: endangered wetlands	Nitrate pollution
	X = yes	O = no	— = no data available	bold print symbolises severe problems
Austria	O	O	O	X
Belgium	X	X	—	**X**
Denmark	**X**	X	X	X
Finland	O	O	O	O
France	—	—	—	X
Germany	—	—	—	X
Greece	X	X	—	X
Ireland	O	O	—	O
Italy	X	X	—	X
Luxembourg	O	O	O	—
Netherlands	X	—	—	X
Portugal	X	X	O	X
Spain	X	X	X	**X**
Sweden	O	—	—	O
UK	X	—	—	X
Norway	O	O	O	O
Switzerland	—	—	—	—
Israel	X	X	—	—
Cyprus	X	X	X	
Czech Republic	O	O	O	X
Estonia	X	X	O	O
Hungary	X	O	X	X
Latvia	X	X	X	O
Lithuania	X	—	—	O
Malta	**X**	X	—	**X**
Poland	X	X	X	X
Slovak Republic	—	—	—	X
Slovenia	O	O	O	X
Bulgaria	—	—	—	X
Romania	X	O	O	X
Turkey	X	X	X	

Additional groundwater pollution by industry, agriculture or landfills further reduces water resources of appropriate quality for diverse purposes. Agricultural activity, for instance, has polluted groundwater with nitrate and pesticides to a great extent, above all in Spain and Belgium, where a high share of groundwater layers exceeds the limit concentration of 50 mg NO_3/L for drinking water (EEA, 1999d, Eurowaterbase, 2003).

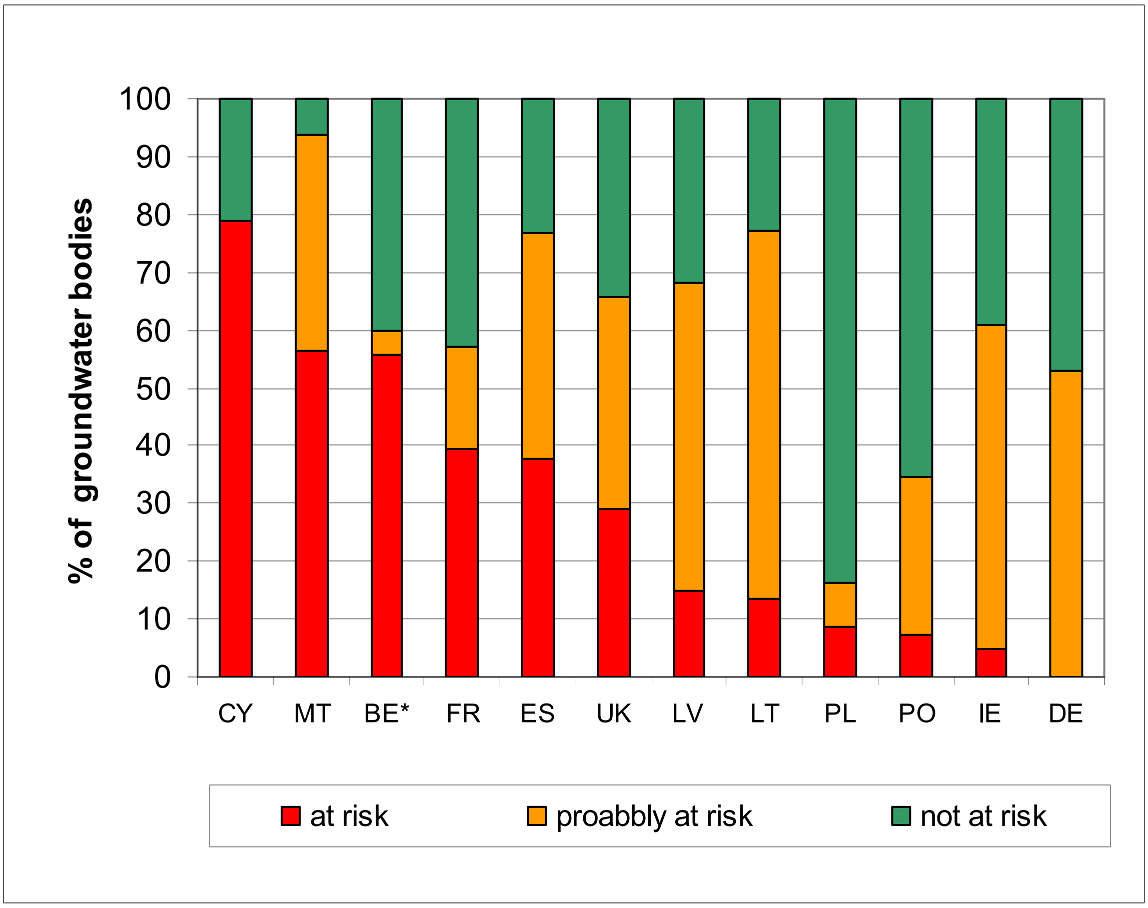
Soil and groundwater contamination are reported for some of the Accession Countries. It is estimated that 25 % of Poland's groundwater resources are contaminated (MoE-PL, 1997). In Romania and Bulgaria many hydrographical basins are polluted by oil-products or other noxious compounds (UNECE, 2000, 2001).

The alarming situation has already led to the initiation of regulatory measures in some countries. In The Netherlands, in regions with desiccation problems due to over-abstracted aquifers, abstraction permits especially for commercial users are revised (Kramer *et al.* 2002), driving the search for alternative water sources like reclaimed wastewater. The same applies for Belgium where in the region of West Flanders groundwater tables have been falling dramatically over the last decades. The higher costs associated with the abstraction of groundwater from deeper boreholes might prompt thinking about investments in reclamation and reuse facilities instead.

The beneficial effects of wastewater reuse concerning aquifer overexploitation consist in a replenishment of the aquifer thus avoiding salt water intrusion or in the replace of the conventional water sources for specified uses thus saving groundwater reserves for future or priority uses.

In course of the implementation of the Water Framework Directive (2000/60/EC) the status of water resources has been analysed and evaluated with regard to achieving a "good status" by 2015. The investigation has revealed that quite a number of water bodies are at risk of failing to meet the quality objectives by 2015, as set in the Water Framework Directive. Between 30 % and 75 % of the groundwater bodies in UK, France, Spain, Malta and Cyprus are categorised “at risk”, additional 15 % to 50 % were evaluated as being probably at risk (partly due to lack of data for a secure determination (Figure 2.13).

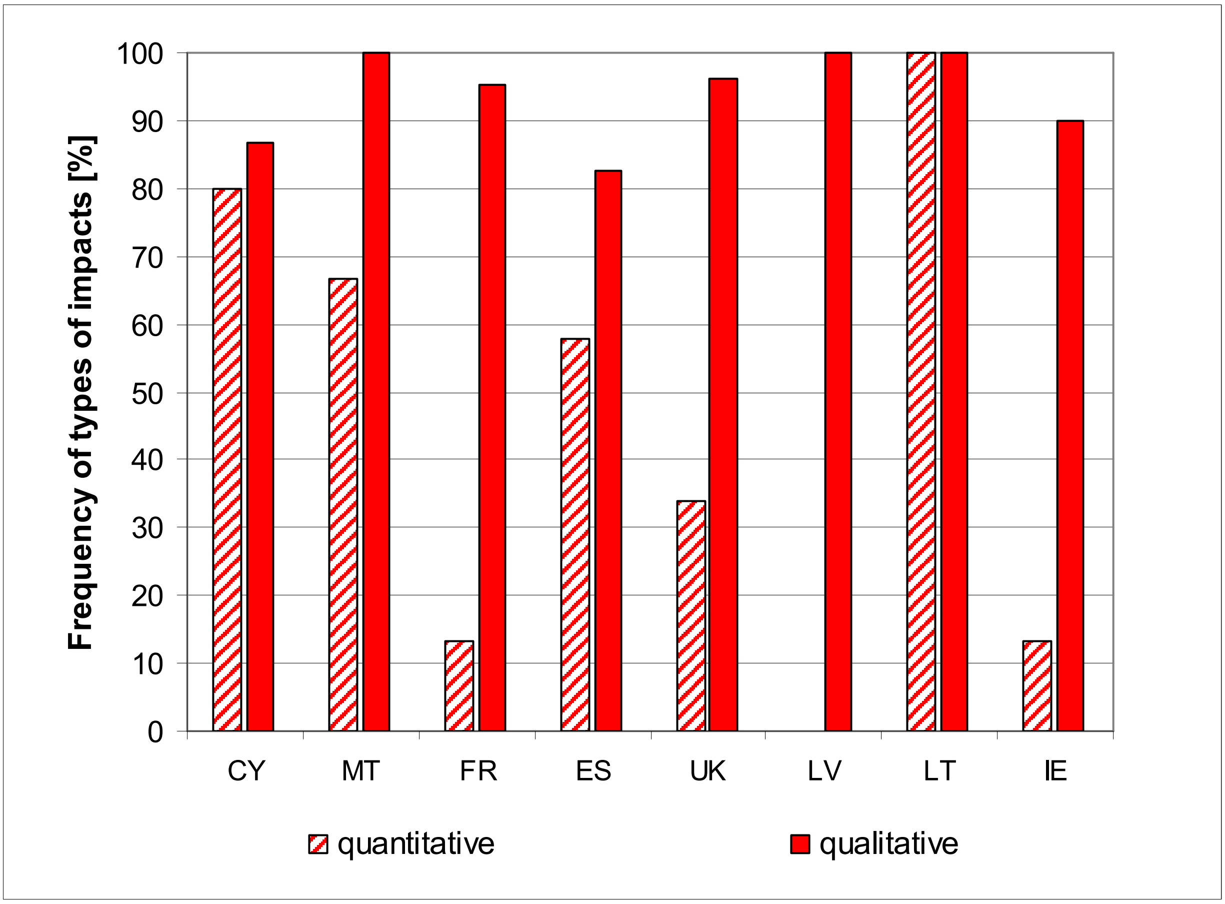
Figure 2.13: Status of groundwater in selected European countries *(National reports on Art. 5 WFD accessed via CIRCA; * only Schelde River Basin)*



The types of pressures exerting a significant impact on water resources are either qualitative (diffuse or point pollution with nitrates, pesticides or saltwater intrusion) or quantitative (abstraction). Figure 2.14

illustrates that pressures impacting on the qualitative status of groundwater are dominating, being relevant for 80 - 100% of groundwater bodies at risk in most countries under consideration. Nitrate pollution is a major reason for groundwater bodies being at risk due to poor quality. But also water abstraction from aquifers exerts remarkable pressures on 55 % - 80 % of the groundwater bodies in Spain, Malta and Cyprus. Even 30 % of UK groundwater bodies being at risk suffer significantly from over-abstraction.

Figure 2.14: Frequency of significant impacts on groundwater bodies at risk (in-group percentages) in selected European countries (National reports on Art. 5 WFD accessed via CIRCA)

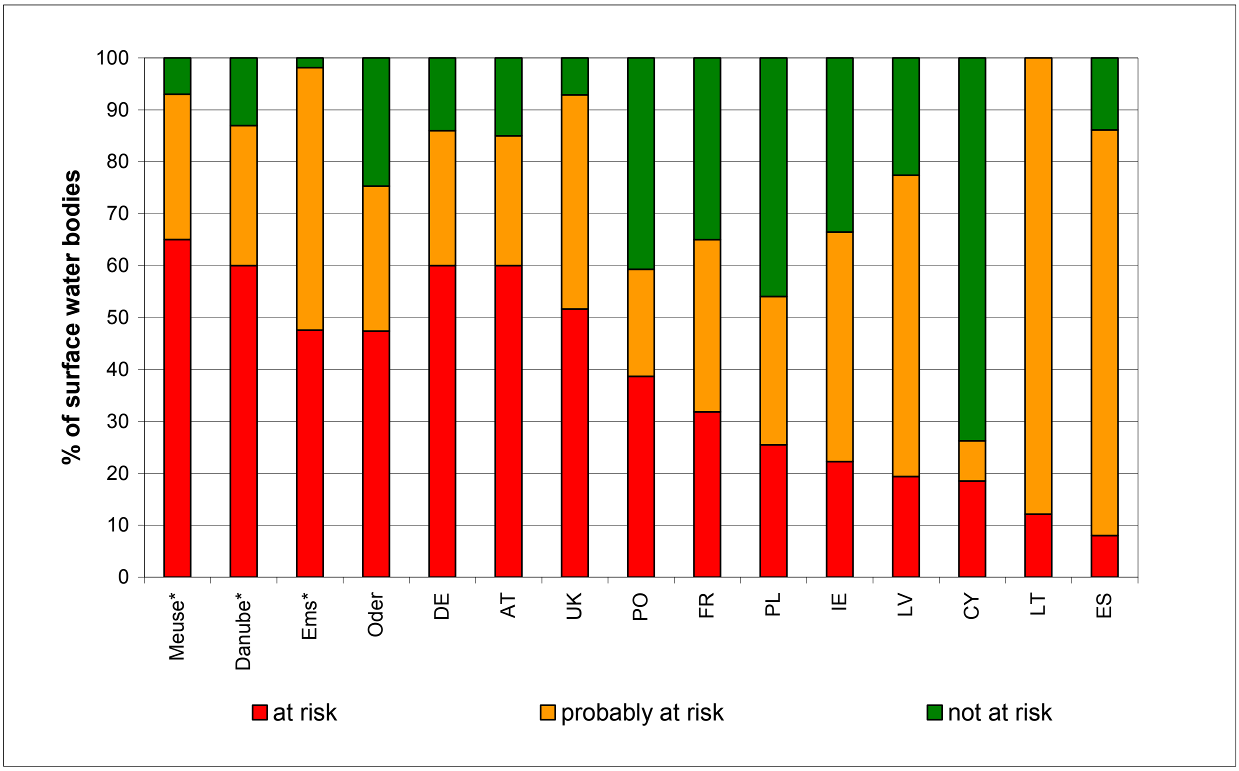


2.5.2.2 SURFACE WATERS

With respect to the quality requirements for surface waters intended for drinking water abstraction (Council Directive 75/440/EEC) some countries show higher BOD_5 values than recommended. Unfortunately amongst them are countries like Spain and Romania, whose public water supply highly depends on surface water resources.

A number of Article 5 reports (acc. to WFD) has clearly revealed that a high proportion of the water resources is at risk of not achieving a good status by 2015 (Figure 2.15). The most significant pressures are qualitative deficits (Portugal, Spain, UK) and morphological obstructions (Germany, Austria, UK). For some countries (Latvia, Lithuania and Spain) the high share of not yet finally assessed risk (category "probably at risk") bears the possibility of a future increase of unfavourably evaluated water bodies.

*Figure 2.15: Status of surface water in selected European countries (National reports on Art. 5 WFD accessed via CIRCA; * international River Basins)*



2.5.3 Climate conditions - climate change

Temperature, precipitation and evapo-transpiration define a region's climate (humid, arid, semi-arid) and are characteristic for run-off and groundwater recharge which form the renewable water resources.

The impact of climate change will be multi-factorial. Climate models predict temperature inclines entailing an alteration of annual precipitation pattern and intensified evapo-transpiration. This will cause changes in the annual average water availability: river and stream flow as well as groundwater recharge potentials will diminish in some regions. The impacts of more frequent droughts or floods would be even more difficult to manage (Lehner *et al.*, 2001).

On the whole, climate change will exacerbate the problems already suffered especially in the Mediterranean region and will exert advanced pressures on water resources. Apart from impacting on water availability, influences on the water demand especially in the agricultural sector are expected. One reckons that conflicts between competing water uses will aggravate. This might include increased water demand for irrigation as well as amplified water uses for tourism activities due to prolonged tourist seasons facilitated by warmer spring and autumn temperatures (EEA, 1999e). On the other hand, reduced river flows may encounter power plants with cooling water shortages or result in restrictions to the availability of irrigation water – depending on prioritisation and water allocation to different users.

Besides the repercussions of climate warming on water availability and water demand qualitative deterioration of water resources could be expected. The elevation of the sea level, e.g. will exacerbate the problem of coastal aquifer salinisation (EEA, 1999e). Low stream flows and higher water temperatures will affect determinants of water quality such as dissolved oxygen concentrations, and might endanger the aquatic biocoenosis. The vulnerability of the system will be reinforced by discharge of insufficiently treated wastewater. This could increasingly make them unusable for diverse purposes (cf. 2.5.2).

A future decrease of run-off in catchments, deemed to be water rich today and thus feeding transfer schemes, might reduce the significance and feasibility of such water import schemes on the long-term. A diverse mix of water supplies comprising both conventional and alternative sources helps reducing a region's vulnerability to climate change effects (Beuhler, 2003).

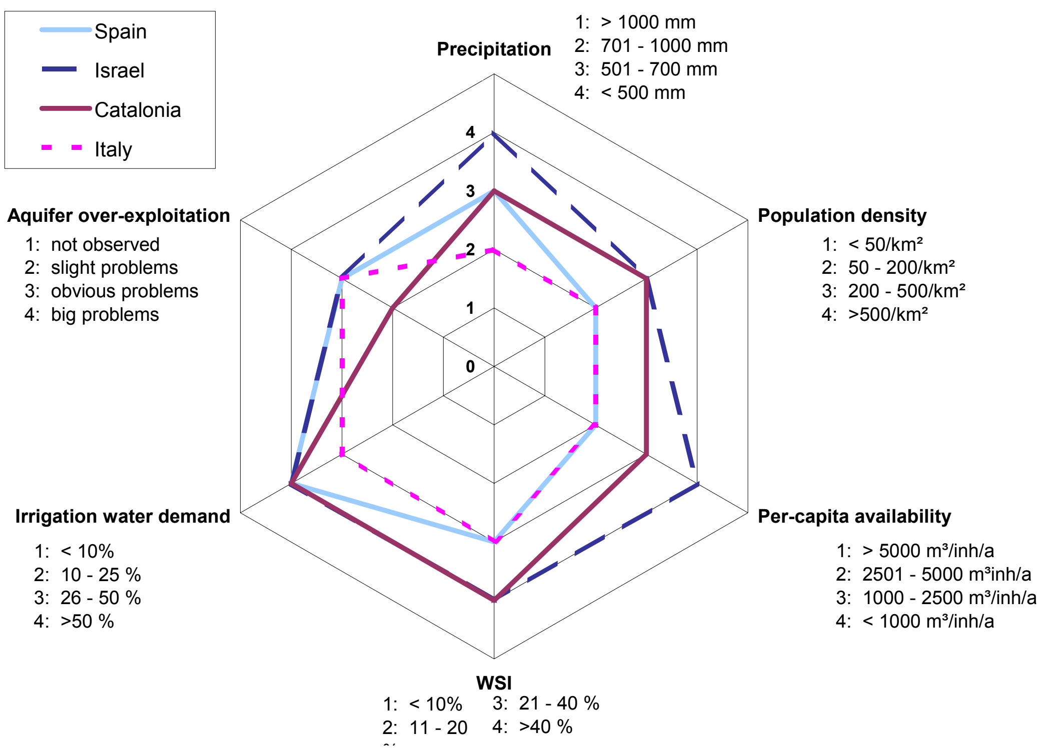
Adaptation to increased water stress will have to involve measures on both the demand and the supply side, and will require the development of management systems that allow short-term actions as well as measures affecting regional and urban planning. This requires an appropriate legal framework which fosters good water quality as a prerequisite for sustainable water management.

2.5.4 Water stress - a multi-dimensional phenomenon

Declining water availability calls for more integrated approaches to balance supply and demand in future. This in turn has to take into account that there are multiple reasons on both demand and supply side, which drive the situation of insufficient water availability. Water stress that might promote reuse activities can obviously be of different characteristic across Europe. The following diagrams represent two different types of water stress characterising countries and regions along with different parameters relevant for water stress situations.

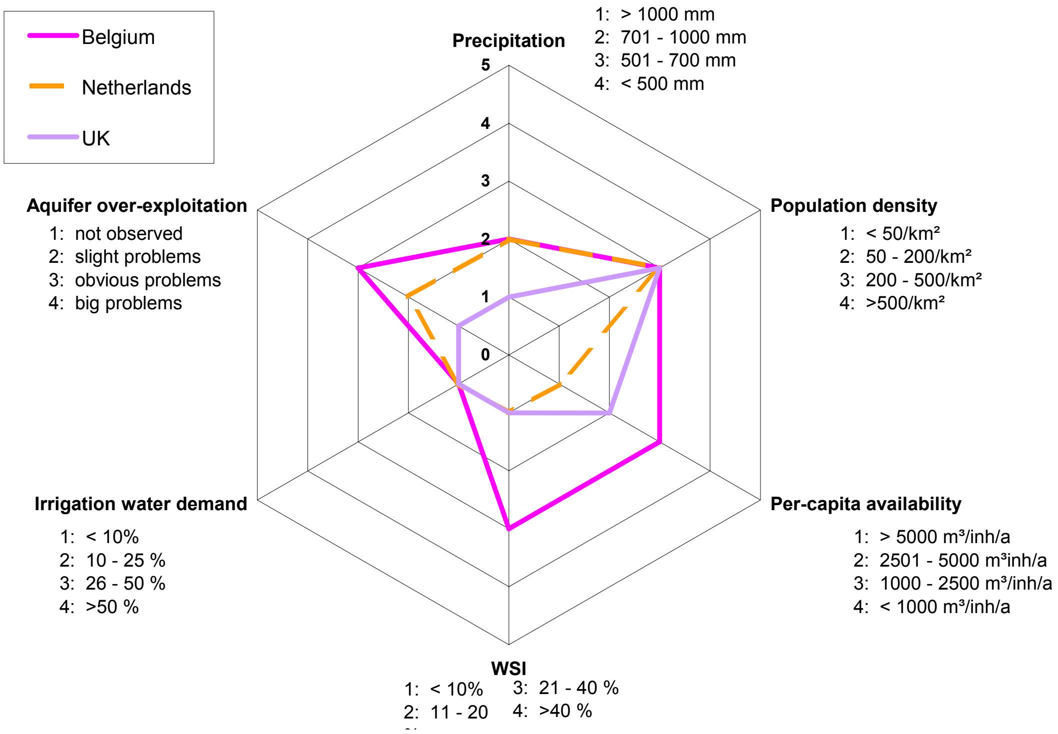
Figure 2.16 illustrates the situation for some Mediterranean countries with regard to water management parameters such as precipitation, population density, water use and alike. Form most categories these countries score high indicating a multi-dimensional water stress.

Figure 2.16: Water stress characterisation of some southern European countries



The shape of the amoeba diagram appears different for some western European countries (Figure 2.17). Although considered "water-rich" with regard to precipitation, the per capita water availability is often in the same range as for dryer regions due to high population densities which in turn often exert pressure on water quality.

Figure 2.17: Water stress characterisation of some northern European countries



It has to be acknowledged that this chapter mostly depicts the water resources and water stress situation on a national or country level. Often water stress appears on a regional level even if the country as a whole is not water stressed (by means of the average figures). A prominent example is the South East of England where seasonal droughts and a huge increase in residential developments entail water stress and will most likely require the utilisation of alternative water resources in the future (IPPR, 2006; McIntosh *et al.*).

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3 WASTEWATER REUSE POTENTIAL ESTIMATION

3.1 Model development

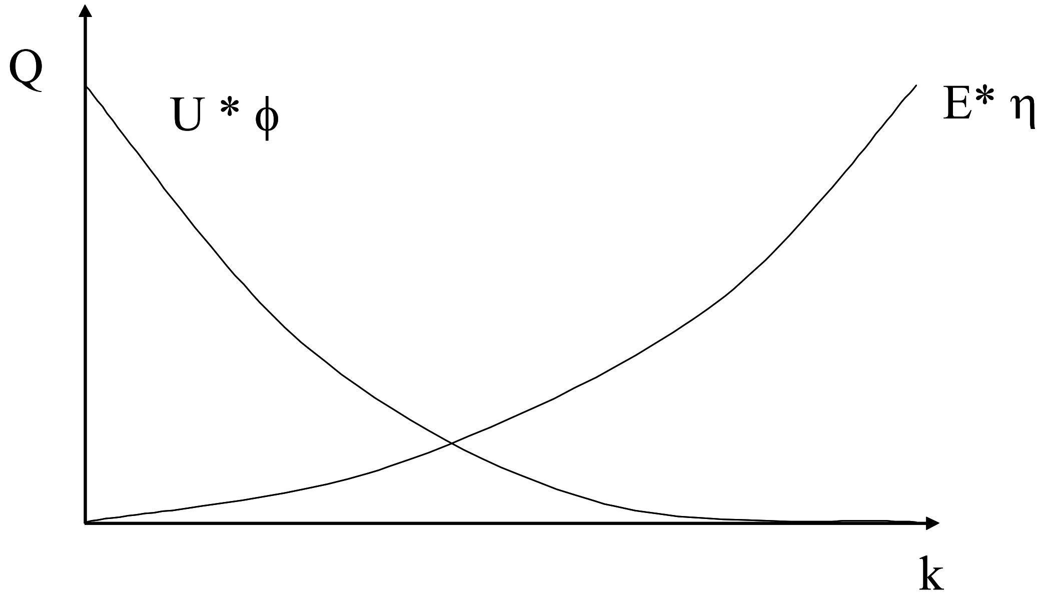
The wastewater reuse potential estimates presented in the literature (Dillon, 2000; Barbagallo, 2001,;Thijssen, 2001) exclusively cover particular regions or countries and are presented without any reference to quantification methods applied to derive the appraisal. The estimation of water reuse potential in Europe presented in this study is based on a mathematical representation of water demand and supply covered by reclaimed wastewater. The model is based on a simple mass balance approach describing the volumetric flow of reused wastewater Q in a particular spatial or temporal context at an equilibrium point of supply and use of reclaimed wastewater. The amount of wastewater treatment plant (WWTP) effluent reclaimed is assumed to be equal to the amount reused to cover a particular fraction of the demand. If wastewater reuse takes place in different sectors like agriculture, domestic or industry, then these segments are treated separately. The basic model equation for the assumption of reuse in different sectors computes as follows, assuming constant liquid density through the whole cycle:

$$E \cdot \eta = U \cdot \phi = \sum U_i \cdot \phi_i = Q \quad \Rightarrow Q = \frac{1}{2} \cdot \left(E \cdot \eta + \sum U_i \cdot \phi_i \right) \qquad \text{(Equation 1)}$$

E : Effluent of WWTPs [Mm³/a]
U : Total water demand [Mm³/a]
U_i : Use of water in a specific sector i [Mm³/a]
Q : Volumetric flow of reused wastewater [Mm³/a]
η : Fraction of wastewater reclaimed, hereafter reclamation-factor [-]
ϕ : Fraction of total demand covered by reclaimed water, hereafter reuse-factor [-]
ϕ_i : Fraction of demand covered by reclaimed water in a sector i

Although a strict market approach is obviously not valid in the water recycling sector some consideration of equilibrium points of supply and demand might be appropriate for an appraisal of further water recycling development. Based on a model describing an ideal market situation the total supply of reclaimed waster $E*\eta$ and the use of reclaimed water in various sectors $U*\phi$ are in equilibrium at a particular unit price k (Figure 3.1). In fact, no ideal market situation can be applied to either the primary (freshwater supply) or secondary (alternative water sources) water market due to baseline demand and institutional duties for supply, fixed (or no) prices, etc. – hence, not even estimates of functions describing dependencies of reclaimed wastewater supply and demand on unit prices exist. Price does certainly play a crucial role in the feasibility of water recycling schemes but other drivers and barriers like water scarcity, environmental issues, regulative measures and public perception cannot easily be accommodated in a market model.

Figure 3.1: Wastewater reclamation and reuse from a market perspective



Consequently the estimation approach followed is not based on cost considerations and incorporation of externalities but on a straightforward extension of the mass balance approach. The intention is to combine various general water management data presented in the earlier sections of this paper and the currently verifiable status of wastewater reclamation and reuse in Europe as a basis to calculate key figures, which describe the main influencing parameters on further development. A crucial feature adapted from the market model is the equilibrium state concept of supply and demand as a baseline assumption for any estimate of future wastewater reclamation and reuse utilisation. But the equilibrium is not assumed to be achieved by producer related price adjustments and customer related price acceptance but based on complex water management mechanisms, e.g. the publicly enforced reduction of freshwater abstraction in water stressed areas with corresponding utilisation of alternative water sources like WWTP effluent as a substitute.

This model is obviously only a first step into the mathematical representation of drivers and barriers for wastewater reuse, basically neglecting or just summarising some of them in a black-box type of fashion. As the estimation is based on the accumulation of highly dispersed data on the current water management situation in Europe and only depicts future developments, no accurate calibration or even validation is possible.

Water reuse potential in the sense of the model presented here is defined as the equilibrium state of the utilised volumetric flow Q of reclaimed wastewater at any time t in the future. Realistic prediction periods depend on the availability of more general water management data and estimates are required as input parameters. Discussing the change of the utilised flow of reclaimed wastewater for reuse leads inevitably to the introduction of a time-derivative of the model equation.

Figure 3.2: Time derivative of the mass balance equation

$$\frac{dQ}{dt} = \frac{1}{2} \cdot \left(\frac{dE}{dt} \cdot \eta + E \cdot \frac{d\eta}{dt} + \frac{dU_i}{dt} \cdot \phi_i + U_i \cdot \frac{d\phi_i}{dt} \right)$$

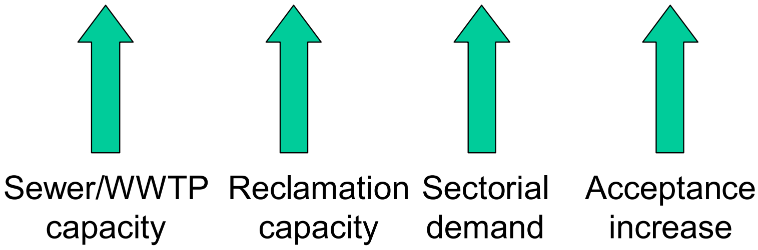


Figure 3.2 presents the time derivative of the mass balance equation and describes the different partial derivatives of the supply and demand terms of the parent equation. Hence, the model can account for a change (increase) of wastewater reclamation volume due to:

- increased wastewater collection and treatment capacity at a constant fraction of wastewater reclamation, assuming that in regions/countries with some “reuse history” the current practice will be continued at least to the same extent. The driver behind these actions is predominantly expected to be pollution prevention and control leading to the installation of sewage disposal capacities as required for full compliance with the urban wastewater treatment directive,
- increased wastewater reclamation and reuse capacity at a constant capacity of basic wastewater treatment, marking a clear progression in water reuse practice and involving the upgrade of existing installations or initial capacities to supply more reclaimed wastewater,
- increased water demand in sectors, which utilise reclaimed wastewater as a water source, at a constant rate of demand coverage by recycled water, again assuming that the continuation of a current practice in the sense of a “business as usual” scenario is a conservative baseline approach for prediction. Changes in water demand per sector will be related to population growth, economic influences like GDP growth, climatic conditions etc.
- increased utilisation of reclaimed wastewater in a particular sector of application at a constant total water demand, again marking a progression in reuse practice and enhanced acceptance of water reuse as a consequence of many potential influences such as supply shortages, economic advantages or environmental awareness.

For a quantitative evaluation of the wastewater recycling development the above mentioned time-derivative has to be put in a time-discrete form, distinguishing the reference point t=0 and the end point of the estimation period t=Δt, considering only one sector of water reuse application or the total amount of reclaimed water instead:

$$t = 0 : E(0) \cdot \eta(0) = U_i(0) \cdot \phi_i(0) = Q(0)$$ (Equation 2)

$$t = \Delta t : E(\Delta t) \cdot \eta(\Delta t) = U_i(\Delta t) \cdot \phi_i(\Delta t) = Q(\Delta t)$$ (Equation 3)

To compute a change in the total wastewater reuse volume during a time interval, the current wastewater treatment capacity, the fraction reused and the water demand have to be known. Both the change of wastewater treatment capacity and the water demand per sector will be regarded as “external” factors and estimated independently of particular water recycling trends. In fact, some of the influences are highly interconnected, e.g. the agricultural development in specific regions might be hampered by a lack of adequate water supply and the economic development of specific sector might depend on the cheap provision of a secondary water source. These cross-relations are regarded as second order influences and not explicitly considered.

The progressive contributions to change are represented in the factor η respectively by its development. The equilibrium assumption leads to the hypothesis that an increased water recycling activity is based on planned actions balancing regional or local supply and demand as well as involving suppliers and customers of reclaimed wastewater. The connection of η and ϕ under equilibrium conditions expresses that there has to be some sort of agreement between supply and demand side to achieve change. Some particular cases should be considered to check the consistency of the model approach:

- $\eta(\Delta t) > \eta(0)$: in regions/countries without any “water reuse tradition” alterations might occur due to radical changes in water management practice enforced by e.g. climate change, economic development or cost advantages of advanced water recycling technology,
- $\eta(\Delta t) = \eta(0)$: no qualitative change in the current reuse pattern occurs, but the total amount of reused wastewater might change due to larger treatment capacities and higher demand, assuming coordination action to balance both trends.

The estimation of the so called *wastewater reclamation factor* $\eta(\Delta t)$ is a major challenge. Although the present value can be calculated for many countries, no quantitative correlation between this factor and other water management indicators has ever been derived. As discussed before, in the sense of the model this factor is independent of the basic water treatment capacity and the “normalised” (without consideration of water stress limitations) demand of particular water use sectors. The factor has to include the need to change the water management pattern and turn towards alternative water sources from a demand point of view and, due to the equilibrium conditions, concluding in progressing employment of water reclamation practice, on the supply side, or vice versa when considering the provision of cheap secondary sources by the supply side with a corresponding response of the customers. As limited water availability and water stress are regarded as the main driving mechanism behind wastewater reclamation and reuse, the correlation of η to a water stress indicators is investigated.

As outlined in Chapter 2.5, a country’s water stress is not only determined by the water availability but also its water use. The different concepts of defining water stress mentioned in the relevant sections are supplemented by another aspect which takes into account the consumptive character of water uses. For this purpose the water stress index was modified by weighting the abstraction by the different sectors according to its water consumptive character. Thus it is indicated how definitely the abstracted water is ‘lost’ for other uses in a short-term perspective. The so-called consumptive water use intensity A' is defined as:

$$A' = \frac{\text{weighted abstraction}}{\text{total renewable freshwater resources}} \cdot 100\,[\%] = \frac{\sum U_i \cdot \alpha_i}{AV_{tot}} \cdot 100\,[\%] \qquad \text{(Equation 4)}$$

where

A' : Consumptive water use intensity [%]

U_i : Use of water in a specific sector i [Mm³/a]
α_i : Conversion factor for specific water use i [-]
AV_{tot} : Total water availability [Mm³/a]

The conversion factor for irrigation is set to 0.77 as most of irrigation water leaves the liquid water cycle by transpiration and evaporation or is incorporated into biomass. The remainder is retained in the soil according to its water storage capacity or percolates into the groundwater. In drained areas excess irrigation water is usually discharged into surface waters. The factors for public water supply purposes and industry are estimated to be 0.18 and 0.14 respectively (Shiklomanov, 1998). Water supplied to households and industry is rather used than consumed and thus reintroduced into the hydrological cycle. Losses in badly maintained distribution networks which can amount up to 40 % are not considered in this transformation.

Countries with current reuse activity are taken as examples based on the availability on wastewater reuse data. Countries or regions with severe water stress like Israel, Malta and Cyprus recycle or respectively plan to recycle basically the whole wastewater, leading to a reclamation factor close to one. Accordingly, in countries with abundant water availability wastewater reuse is less developed. But some countries like Greece or Italy with strong regional differences are difficult to categorise from a whole-country perspective as the reuse practice is based on regional water management practices and are difficult to correlate with a national average of water availability.

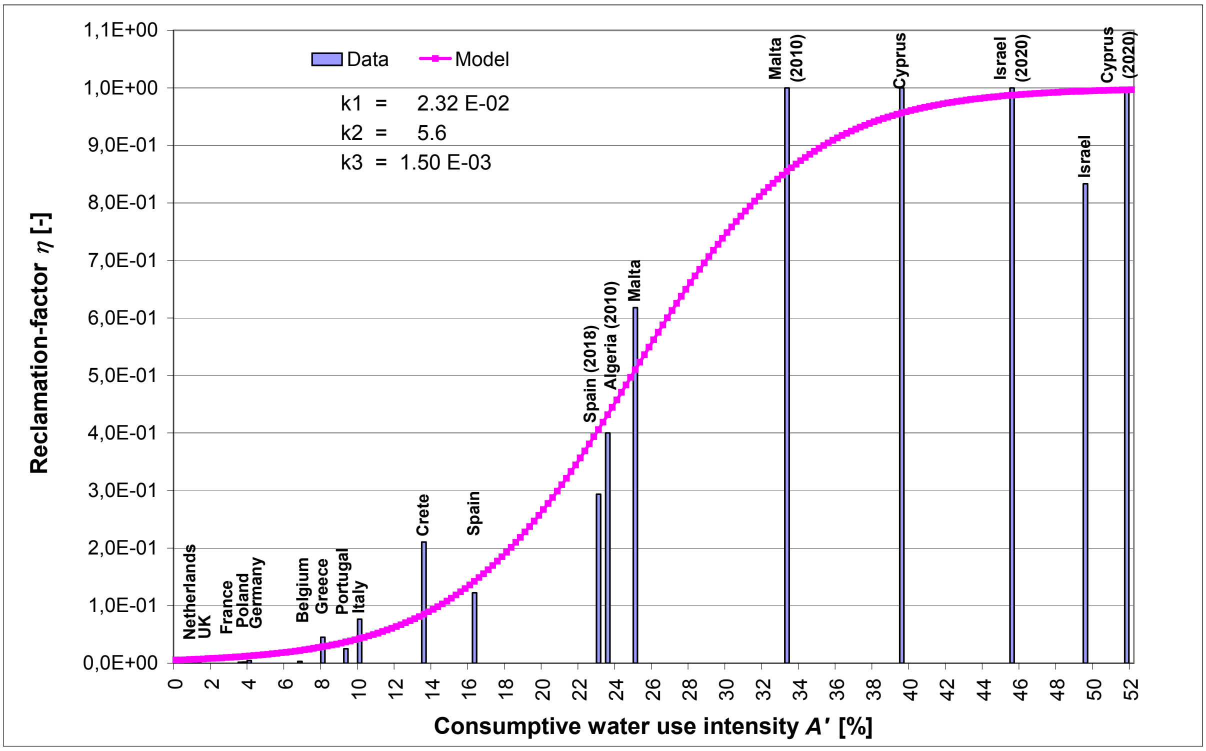
Based on the general trends observed, a correlation between consumptive water use intensity *A'* and the water reclamation and reuse factor for a particular country was established and mathematically modelled by an empirical function, which proved to be most appropriate in representing the type of observed evolution.

The model equation has the following structure:

$$\eta(A') = \frac{1}{\left(1 + \exp(-k_1 \cdot (1 - A') + k_2\right)} + k_3 \qquad \text{(Equation 5)}$$

Equation 5 includes three empirical model parameters k_1, k_2, and k_3, which were adjusted by a least-square-error-minimisation method to fit the curve with the considered data. The resulting reclamation-factor function, when converting all abstraction figures to consumption figures and calculating the consumptive water use intensity, is given in Figure 3.3.

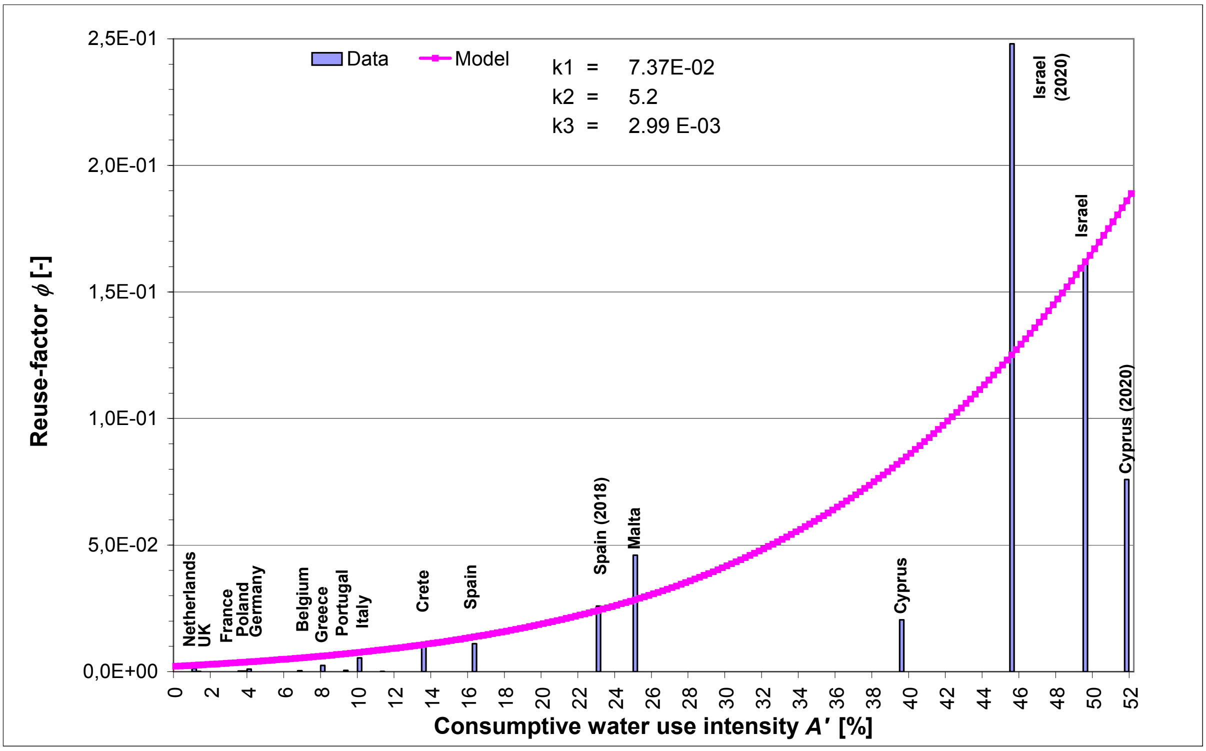
Figure 3.3: Reclamation-factor η as a function of consumptive water use intensity



One has to keep in mind that water stress, as represented by the consumptive water use intensity in this model, is not the only influence promoting high reclamation factors. In fact, analysing the current status of wastewater reuse practice, high reclamation rates are achieved easier where the total treated effluent flow is rather low and willingly absorbed by a "market" established as an agricultural or landscape irrigation demand (Malta, Cyprus, Crete).

Analogue to the procedure for the estimation of the reclamation-factor and based on the same mathematical correlation as presented in Equation 5 the reuse-factor ϕ was quantified as well with respect to a country's consumptive water use intensity. Based on existing and proposed reuse applications, ϕ is expressed as the share of total water demand of all sectors covered by reclaimed wastewater. The following correlation, which reflects a best fit of the available data sets, is proposed (cf. Figure 3.4).

Figure 3.4: Reuse-factor ϕ as a function of consumptive water use intensity



3.2 Scenario analysis

The scenario analysis aims to vary major driving forces and evaluate their impact on future wastewater reuse potential. As pointed out in the previous section the reuse potential is estimated on the basis of present and future total water demand and availability of reclaimed wastewater as an alternative water resource. The potential estimations were calculated applying the wastewater reclamation and reuse-factors in their relation to the consumptive water use intensity..

Values for these variables were predicted using the following data and applying the methodology described in Chapter 3.1. In general, the same statistics and information sources were utilised as for the assessment of the water management data in Chapter 2.

3.2.1 Scenarios, basis for estimation

In order to model the impact of different supply and demand related changes on the wastewater reuse potential as stated in the previous chapter, different scenarios were set up.

Varied demand influences the wastewater reuse potential by reinforcing demand for reclaimed water (ϕ*dU) but at the same time implicates changes of the consumptive water use intensity. A demand-independent variation of the consumptive water use intensity and consequently the reclamation and reuse factors was depicted by decreasing water availability. The different assumptions are outlined in the following paragraph and summarised in Table 3.1.

Table 3.1: Different scenarios and underlying basic conditions

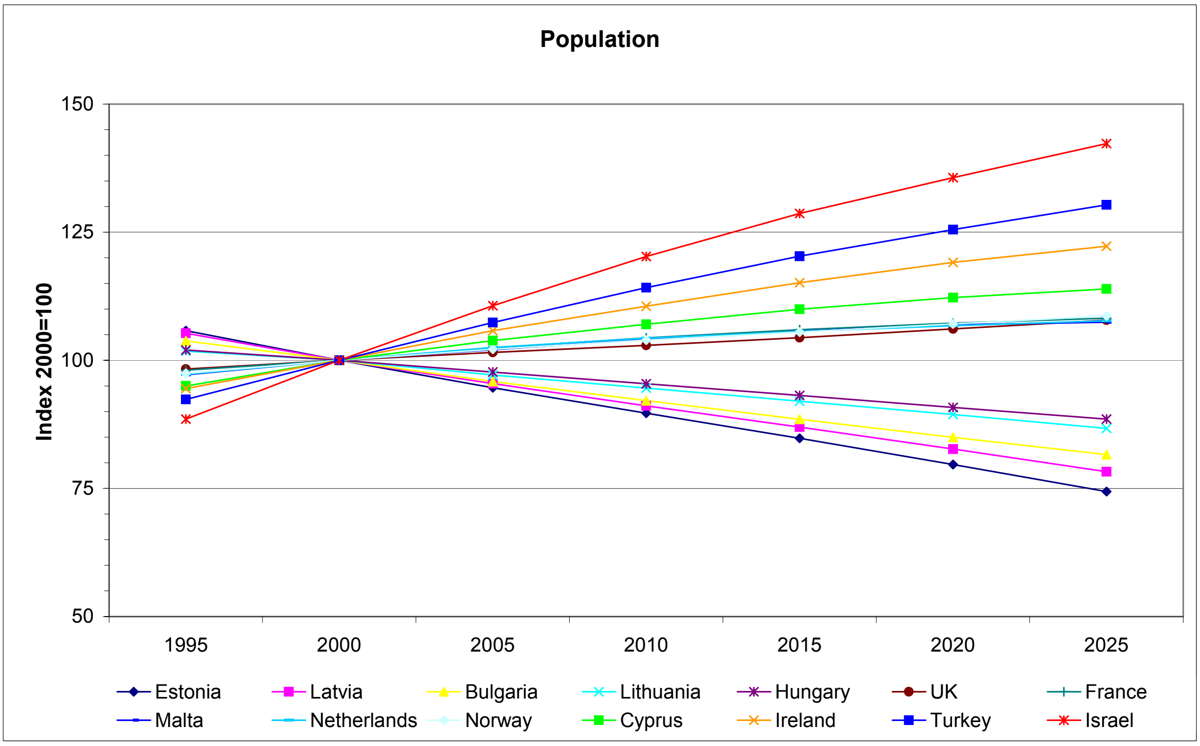
Scenario	**I**	**II**	**III**	**IV**
Projection year	2025	2025	2025	2025
Population	UN Population Division, Medium variant			
Water availability	constant (ltaa 1961-1990)		- 10 %	- 25 %
Water demand	▪ changes due to population growth ▪ constant specific water demand ▪ irrigated area and specific water use invariant ▪ slight increase of IND and ELE due to minor economic growth	▪ changes due to population growth ▪ economic recovery of AC ▪ increased electricity production AC ▪ intensified agricultural IRR		
Treated wastewater	assumption of full compliance with UWWTD by 2025			
General characterisation	conservative	demand increase	demand increase + water shortage	

ELE: water use for electricity production, IRR: irrigation water use, IND: industrial water use AC: Accession Countries, ltta: long term annual average

3.2.1.1 Population

The population figures for 2000 and all future years are taken from the medium variant of the UN Population Division 2001, so were the share of urban population. Figure 3.5 depicts the estimated development for selected countries. Only those countries are shown whose population is supposed to decrease or to increase by more than 5 % by the year 2025. Decreases in population are expected for the Baltic States, Bulgaria and Hungary whereas in Western Europe Ireland, UK, France and the Netherlands will record population incline of almost 10 %. Most significant population growth rates of 30 % and 42 % respectively are forecasted for Turkey and Israel.

Figure 3.5: Countries with estimated changes in population of more than plus/minus 5% relative to 2000



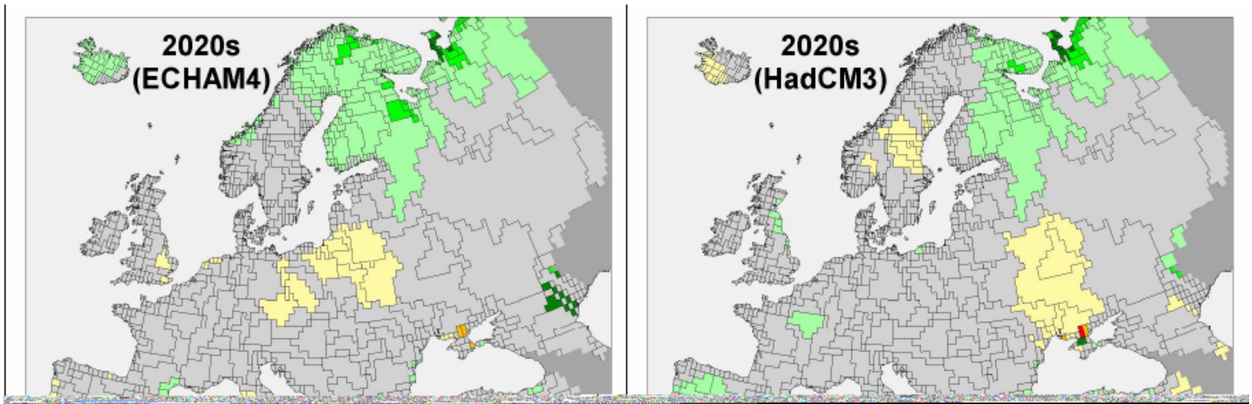
3.2.1.2 WATER RESOURCES

The water availability is adopted from the FAO Aquastat database and is actually the long-term annual average covering the period 1961-1990.

For **Scenario I**, neither increases nor decreases in renewable freshwater resources are assumed for future years.

But as climate change is unanimously supposed to impact on the hydrological cycle, reduced water availability was taken into consideration within alternative scenarios. The EuroWasser model (Lehner *et al.*, 2001) is forecasting the impact of climate change on water availability in Europe. Figure 3.6 illustrates the change in water availability according to two different Global Circulation Models for the time horizons 2020s and 2070s. It is visualised that some river basins will have to cope with heavily reduced water availability. Decreases of more than 10 % are projected for some continental countries (Poland, Hungary) and South Eastern countries (Bulgaria, Romania, parts of Turkey) whereas most South European countries will suffer from shortenings of 25 % and more. A reduction of the mean annual flow in Portuguese river basins of 10 % to < 20 % was predicted as well by the First European Climate Assessment (EEA, 1996). For a manageable approach, the figures of Lehner *et al.* (2001) were taken as a rough yardstick for reasonably, expectable changes on a country level which **Scenarios III** (-10 %) and **IV** (- 25 %) were based upon.

***Figure 3.6: Percentage change in average annual water availability** (natural discharge without subtraction of consumptive use) for European river basins as compared to today's levels, realised with two different GCMs (ECHAM4 and HadCM3) for the 2020s and the 2070s; Lehner et al. (2001)*



3.2.1.3 WATER DEMAND

The future water demand is forecasted for each sector separately. When available, existing scenarios in national hydrological planning is referred to (Spain and Portugal). Calculation of possible changes in per capita availability and water stress index are indicated.

Public water supply

Based on the actual per capita abstraction, future withdrawals are estimated according to population development and the share of population living in urban areas. For EU Member States the connection rates of the population to public water supply networks are high whereas in Candidate Countries, namely Romania only 64 % of the inhabitants have access to public drinking water supply. For Romania with an extraordinary high per-capita water abstraction in the public water supply sector a reduction was assumed for future years. It can be expected that the supply will drastically decrease with the renovation of the distribution network and an increase of water prices. Similar tendencies could be observed in the Baltic States (BEF, 2000) and Hungary (EEA, 2003a)

Agriculture

Future water withdrawal for irrigation is rather difficult to assess as irrigation needs vary notably with the meteorological characteristic of a year. Dry years can easily afford two or three times higher water volumes (Downing, 2003). If nothing opposite was reported, the extent of irrigated practice was supposed to be stable in both area and intensity (**Scenario I**).

At present, the irrigation demand of most of the Accession Countries is very low compared to former decades, when large irrigation schemes were operated in the era of socialism. Since then the irrigated area has decreased owing to the liquidation of the kolkhoz and sovkhoz. After the privatisation most farmers lack the necessary investment resources needed for appropriate irrigation systems (EEA, 2001; UNECE 2001). Consequently crop yields have decreased substantially due to droughts. It can be expected that this situation will improve with the accession to the EU. In Bulgaria, e.g. the objective is to revive agricultural production by restructuring the irrigation network and to develop the technical-economic feasible irrigation of 400,000 ha (UNECE, 2000). Shiklomanov (1998) even expects an area of 100,000 ha being irrigated in Lithuania by 2025 compared to today's 7,000. A poor ratio of irrigated area to area equipped for irrigation is documented as well for Slovakia and Hungary (Öko Inc., 2001).

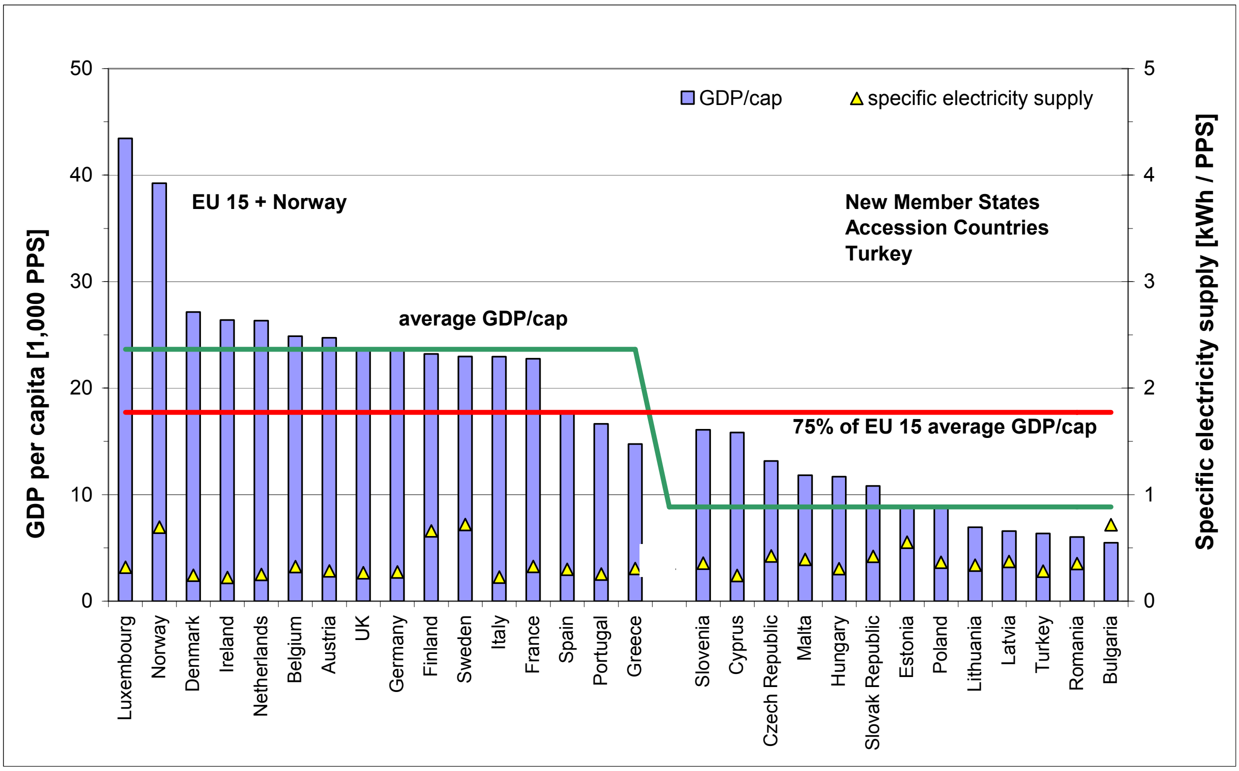
Within the scenario of increased water demand (**Scenarios II, III, IV**) a restoration of irrigation practice in the Accession countries (according to literature values) was assumed. Moreover, forecasts of expanded irrigation in Portugal and Spain (laid down in respective National Hydrological Plans) were taken into account. Literature statements on additional irrigable areas in Italy and increasing irrigated areas in Greece were considered.

Industrial water uses and electricity production

Industrial water use is linked to economic growth even though the linear relation of resources consumption (energy, water) and economic growth has been decoupled in developed industrial countries. Nonetheless for the estimations a moderate economic growth was assumed resulting in an 1% increase in industrial water use and electricity production (**Scenario I**).

Especially in Eastern European countries, the drop in industrial water demand has been caused by the lack of markets for heavy industry products due to the break down of the Russian economy (UNECE, 2001). As soon as the economy will recover an increased demand is expected but at the same time improved, water saving technologies are supposed to be established. In order to examine the implications of these developments (**Scenario II – IV**) it was presumed, that electricity production – and the corresponding water demand – would increase to an extent that allows to equal 75% of today's average per-capita GDP of EU 15 countries (cf. Figure 3.7). Furthermore a discount of 10% due to efficiency increase in cooling water use was included in the calculations.

Figure 3.7: Gross domestic product per capita and specific electricity supply in EU and Accession countries (Eurostat, 2001)



On the whole this will lead to demand increases of approximately 40%, clearly contradicting estimates for the Central and Eastern European countries that "the per capita water withdrawal and use of water resources is reduced by 10 % in all countries of the region, compared to 2000" (Guerrie *et al.*, 2002).

3.2.1.4 WASTEWATER

Several factors influencing the amount of wastewater generated, collected and finally treated are complexly interrelated with each other and have to be taken into account for the estimations.

The type of sewerage system influences the quantity of wastewater transported to treatment plants (if connected to them). Mixed sewers that collect domestic and industrial sewage as well as rainwater will produce much higher per capita wastewater flows than those with separate sewers. In humid climates the wastewater is much more diluted than in arid or semi-arid regions. Sewage concentrations range from 170 mg/L BOD_5 in the Netherlands (CBS, 2003) to up to 600 mg/L BOD_5 in Spain (Calleja *et al.*, 2001).

The amount of wastewater will be significantly influenced by the proportion of population connected to sewers and treatment plants. For many European countries this share is already very high (> 80%; Austria, Germany, Netherlands, Sweden) whereas others are still coming up with the improvement of the sanitary system. For some Member States of the European Union the UWWTD has triggered an enormous effort to enlarge the wastewater treatment systems (Spain, Greece, Portugal, Italy, Belgium). The population connected to sewerage systems was presumed to correspond to those living in urban areas, if no explicit information was available. The treatment capacities (expressed in population equivalents, p.e.) supposed to be installed in Member States pursuant to the objectives of the Directive form a good data basis for future effluent flow estimations. The chosen projection horizon (2025) will even allow the full compliance with the Directive's requirements in the accession countries as transitional arrangements for most of them are made for the period between 2007 and 2015.

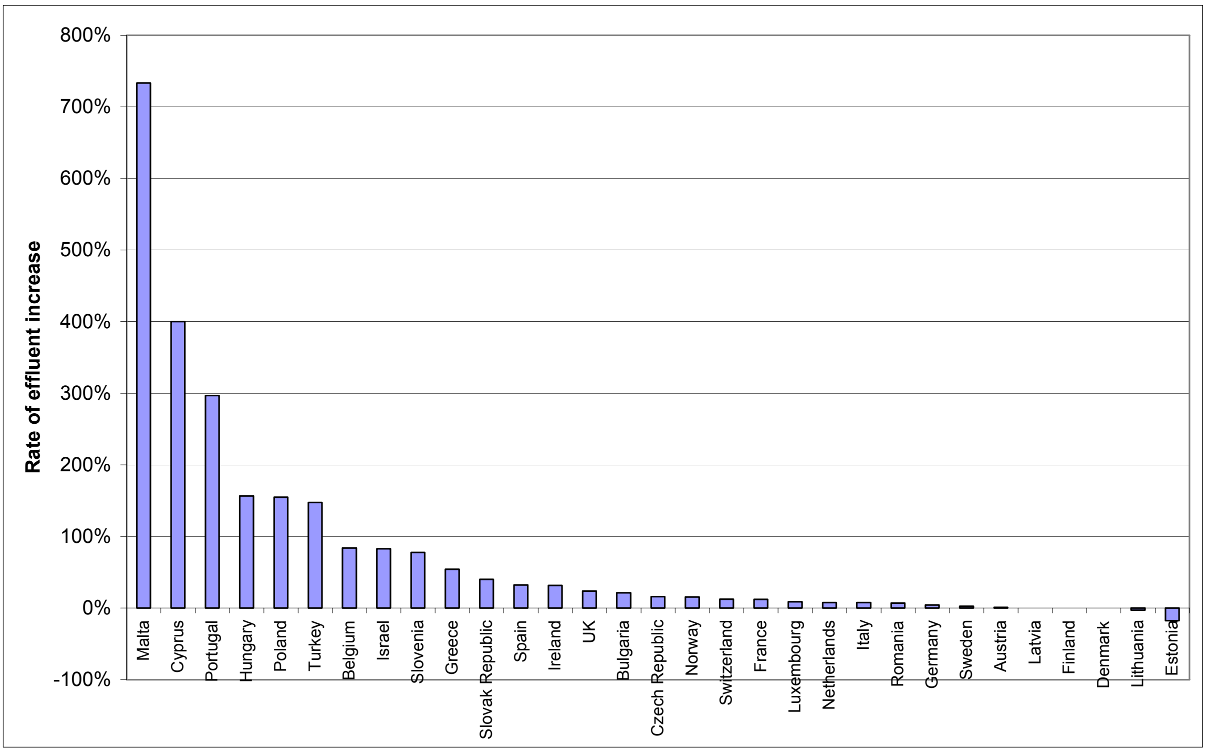
Furthermore the consumption of water by households and small businesses (those supplied by the public water supplier) will determine the amount of wastewater collected and treated. Any industrial on-site recycling will reduce the wastewater volumes treated in public sewage plants. The same applies to domestic greywater recycling but this is supposed to be of less volumetric importance. The degree of urbanisation plays a role, too. In urban areas higher per capita water consumptions in the domestic sector, industrial indirect discharges and sealed surfaces contribute to sizeable wastewater flows.

If consistent wastewater volume data were available for several years, future amounts were calculated just taking into account changes in population. If wastewater volumes had to be derived from other parameter like design capacity a 75% capacity use was assumed and cross-checked with population figures.

In compliance with the situation described in Chapter 2.3, remarkable increases of connections rates would augment available wastewater flows, offering potential for intensified reuse. A look at the estimated changes of treated effluent (Figure 3.8) illustrates a more than doubling in the volumes for Poland, Hungary and Turkey. Portugal, Malta and Cyprus even exhibit rates of increase of 300% to 700%. For Belgium, Slovenia, Greece and Israel the treated effluent will exceed current values by approximately 80%. In most countries this increase involves improvements in sewerage services. Only Israel's increase is caused mainly by population growth. The expected decrease of treated effluents in Lithuania and Estonia is due to continuing reduction in water abstraction and declining population

The treated wastewater flow was assumed the same in all scenarios.

Figure 3.8: Changes in treated effluent flow by the year 2025 (reference year 2000)



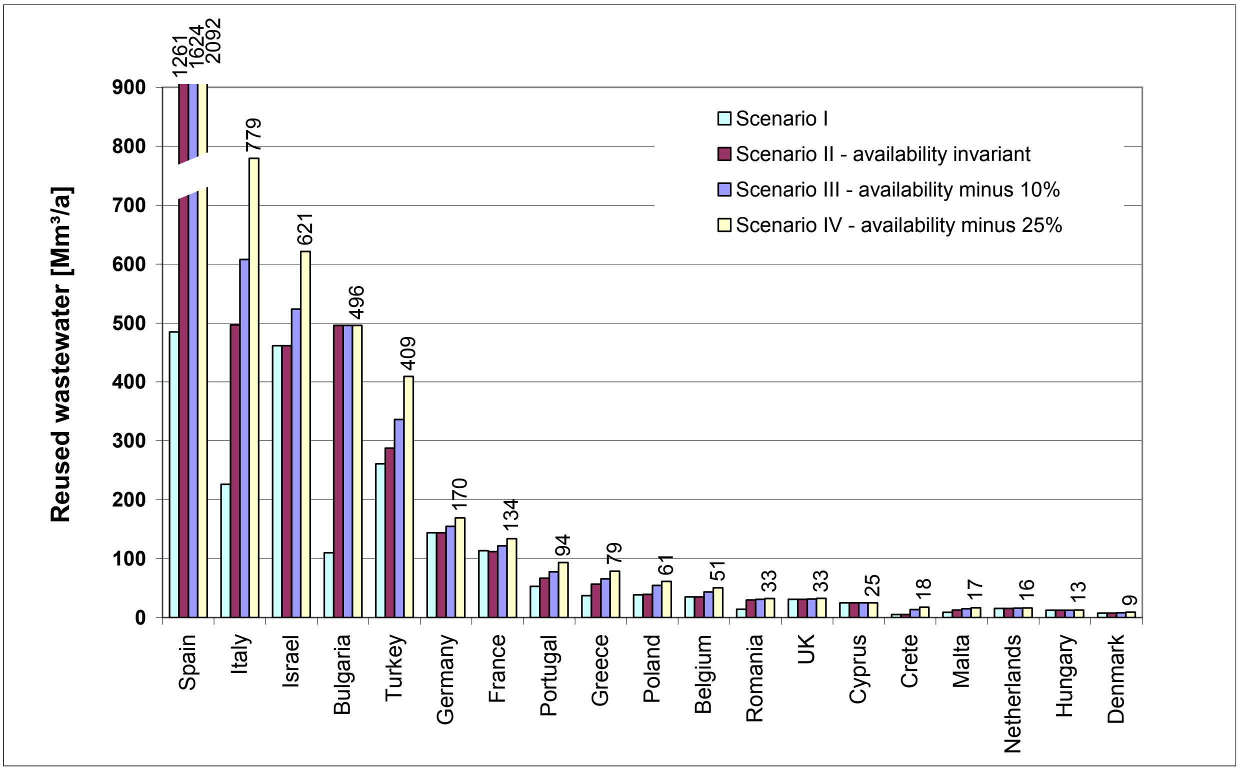
3.3 Model output

In a first computation the wastewater reuse potential was appraised under scenario I conditions. For most countries an intensification compared to the current practice of wastewater reuse is expected. Increases of 40% to 60% are observed for Greece, Israel and Spain. The reduction for Italy is partly due to the scenario assumptions which come out in a population proportionate decline of abstraction for public water supply. Wastewater reuse is supposed to be started or extended considerably in Bulgaria, Turkey, France, Germany and Belgium. But in half of the countries wastewater reuse will stay below 10 Mm³/a.

According to this version, the volume of wastewater reused in Europe will increase from 962 Mm³/a to 2,134 Mm³/a. Spain and Israel will probably reuse 20 % of this amount, each. Italy and Turkey account for equal shares of 12 %. Bulgaria's, Germany's and France's contribution make up 5 % each.

The estimation results for different scenarios are depicted in Figure 3.9. The illustration is restricted to those countries which are supposed to develop a reuse practice of around 10 Mm³ per year. It is clearly visible that a shortage of water availability pushes the reuse of wastewater in most countries.

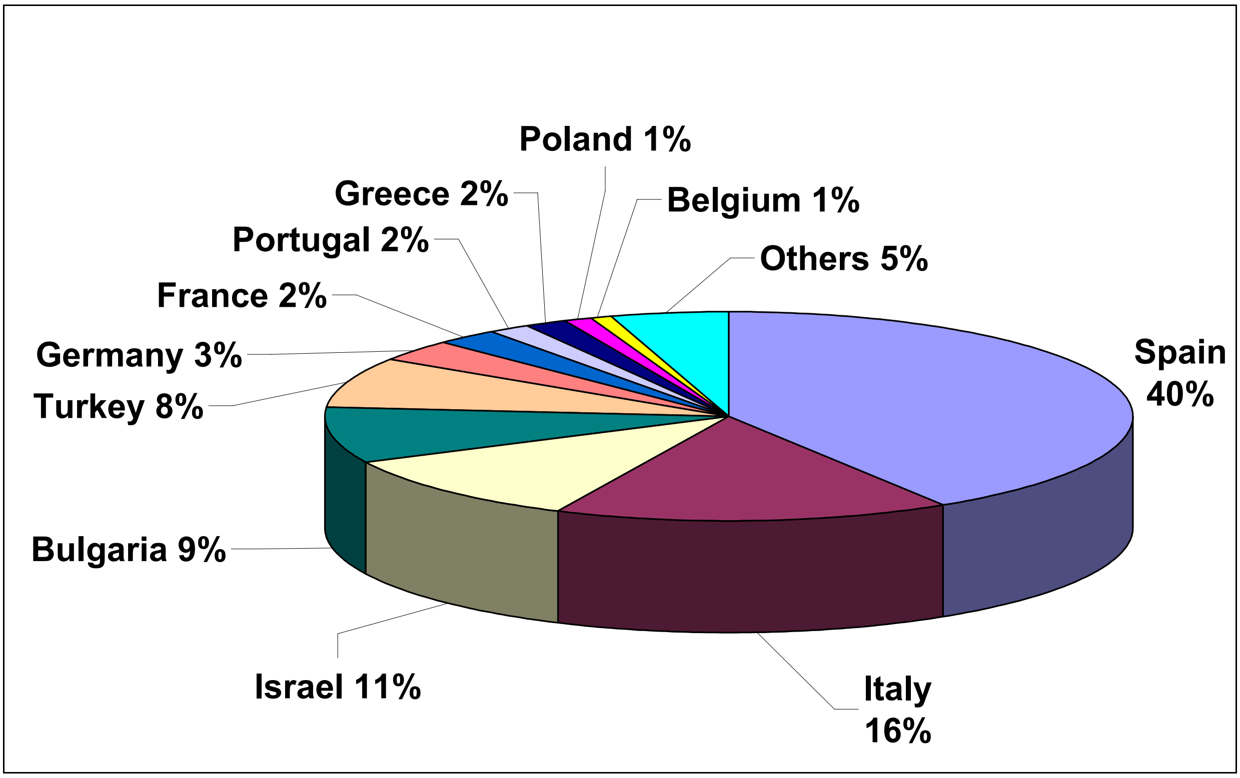
Figure 3.9: Wastewater reuse potential estimation - model output for different scenarios



The overall reused volumes in Europe sum up to 2,134 Mm³/a, 3,633 Mm³/a, 4,289 Mm³/a and 5,670 Mm³/a for the scenarios I to IV. On the whole, the reused wastewater volume would save between 1.0 % and 1.5 % of total water abstraction of European countries (+ Israel) in the year 2025. This is close to estimations for the USA, that estimated a substitution of 1.5 % of total freshwater abstraction by wastewater reuse in the year 2000 (Kamizoulis *et al.*, 2003).

Moreover, with progressing wastewater reuse, Spain gradually takes over a dominant role in this practice. Under scenario IV assumption Spain accounts for 40% of the total reused volumes, followed by Italy, Israel and Bulgaria, who contribute 16%, 11% and 9% respectively (cf. Figure 3.10).

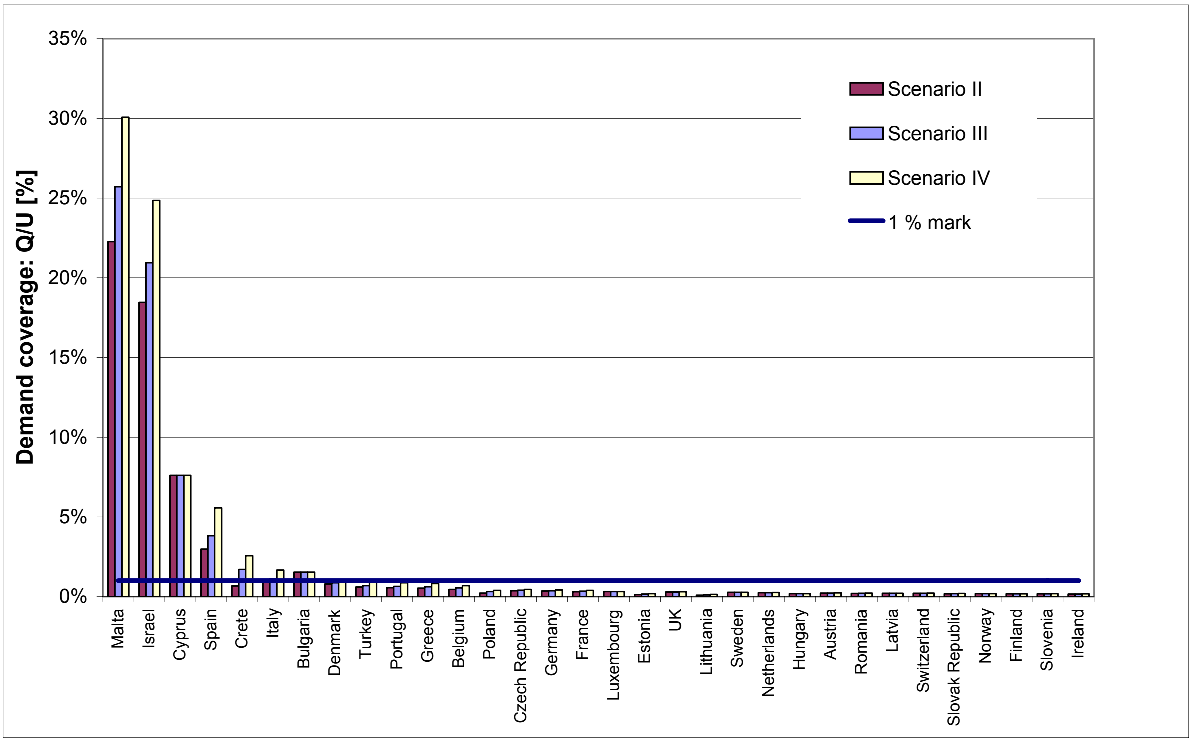
Figure 3.10: Countries' share of total wastewater reuse potential, Scenario IV



In order to estimate the significance of wastewater reuse within a country's water management the demand coverage rate is calculated, setting the reused volumes into relation to the total water abstraction (Q/U). According to the model outcome, the share of demand covered by wastewater reuse ranges from 17% to 30% in Israel and Malta and amounts to 3% - 7% in Cyprus and Spain (Figure 3.11).

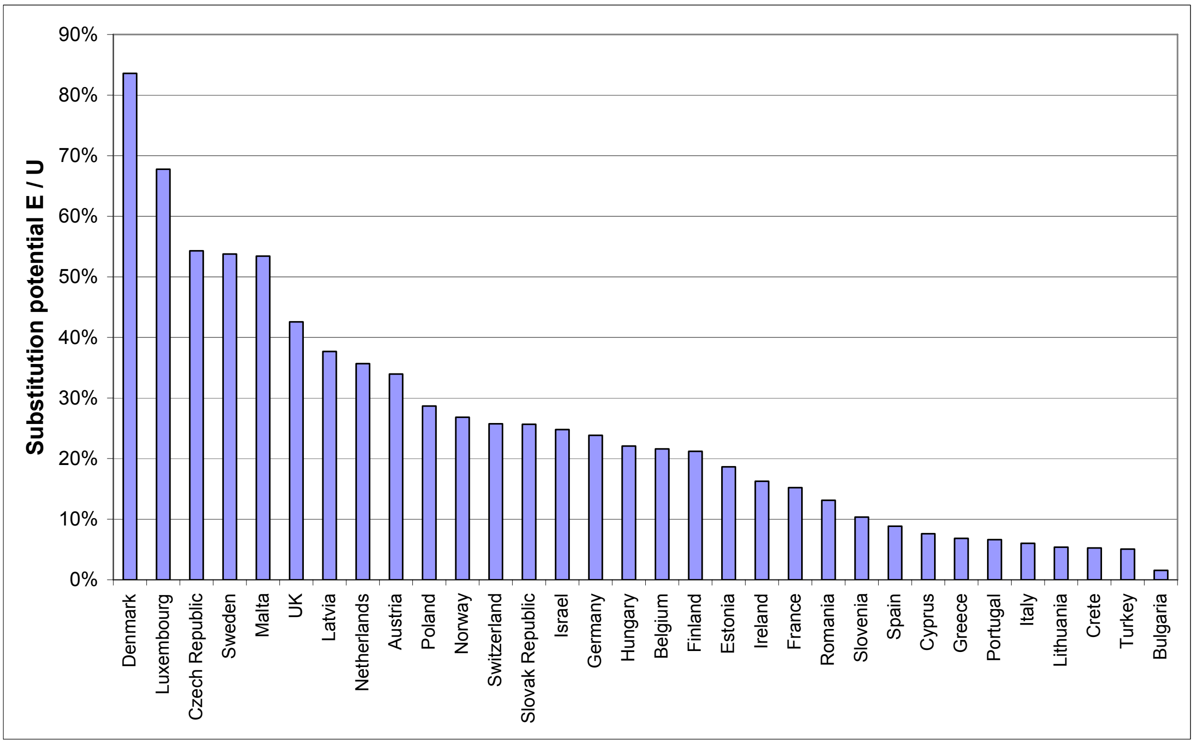
Even countries, which are prone to water stress (cf. Chapter 2.5) such as Greece, Portugal and Belgium, could replace less than 1% of their water demand by wastewater recycling. For the remaining countries the substituted fraction makes up even less than 0.5% of their water demand.

Figure 3.11: Demand coverage by reused wastewater under various scenarios



Wastewater reuse potential impact (independent of the actual and future extent) can also be evaluated and expressed as the ratio of total amount of treated effluent E and the total water demand U. The derived substitution potential and its utilisation is depicted in Figure 3.12 and Figure 3.13.

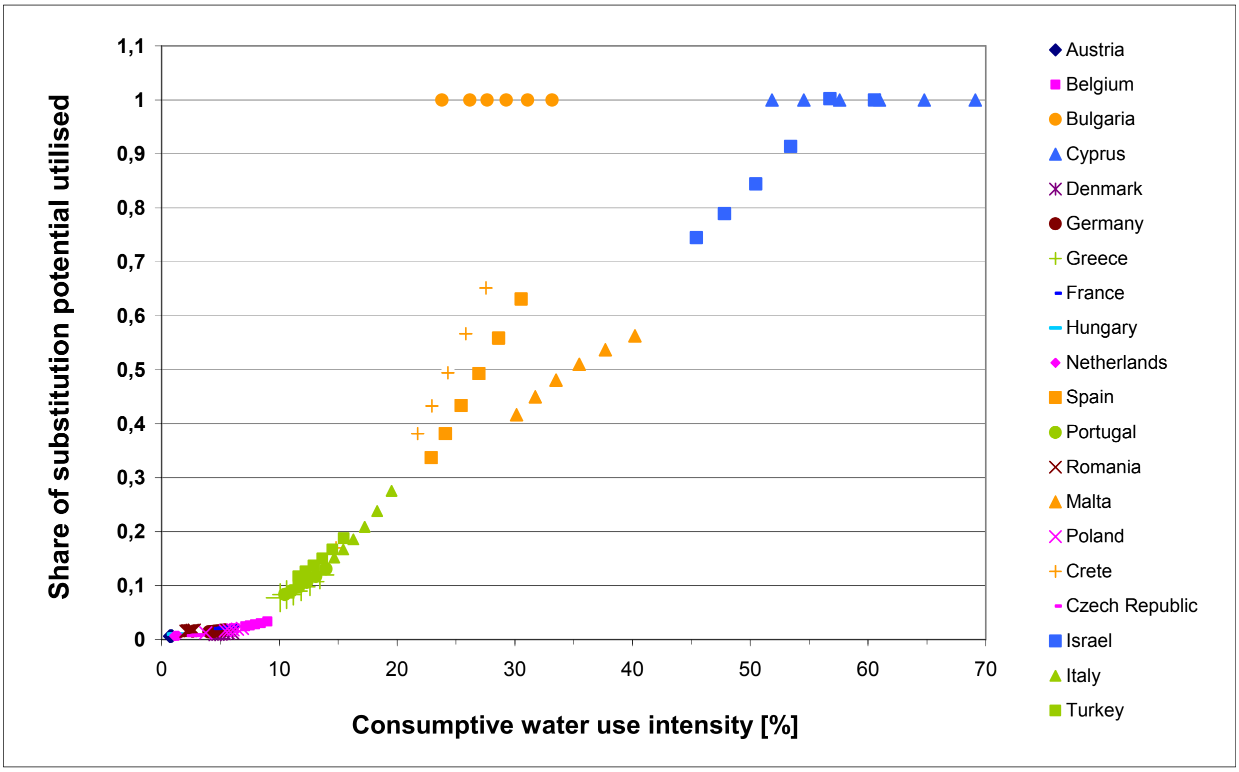
Figure 3.12: Substitution potential for different countries (scenario II assumptions)



This clearly reflects the water use pattern of the considered countries. Those distributing the biggest share of abstracted water to domestic or industrial uses (Denmark, UK, Malta, Sweden, Netherlands, Austria) have the best opportunities to substitute high shares of their water demand as water supplied to these uses can easily be collected, treated and reused – adequate infrastructure presupposed.

On the other hand, countries dedicating most of the abstracted water to consumptive uses like irrigation are unable to recycle a significant share of the water supplied – as it is lost to the atmosphere, the groundwater or as surface water run-off. It is a similar case with water abstraction for cooling purposes, as this use does not produce a "piped" wastewater flow either.

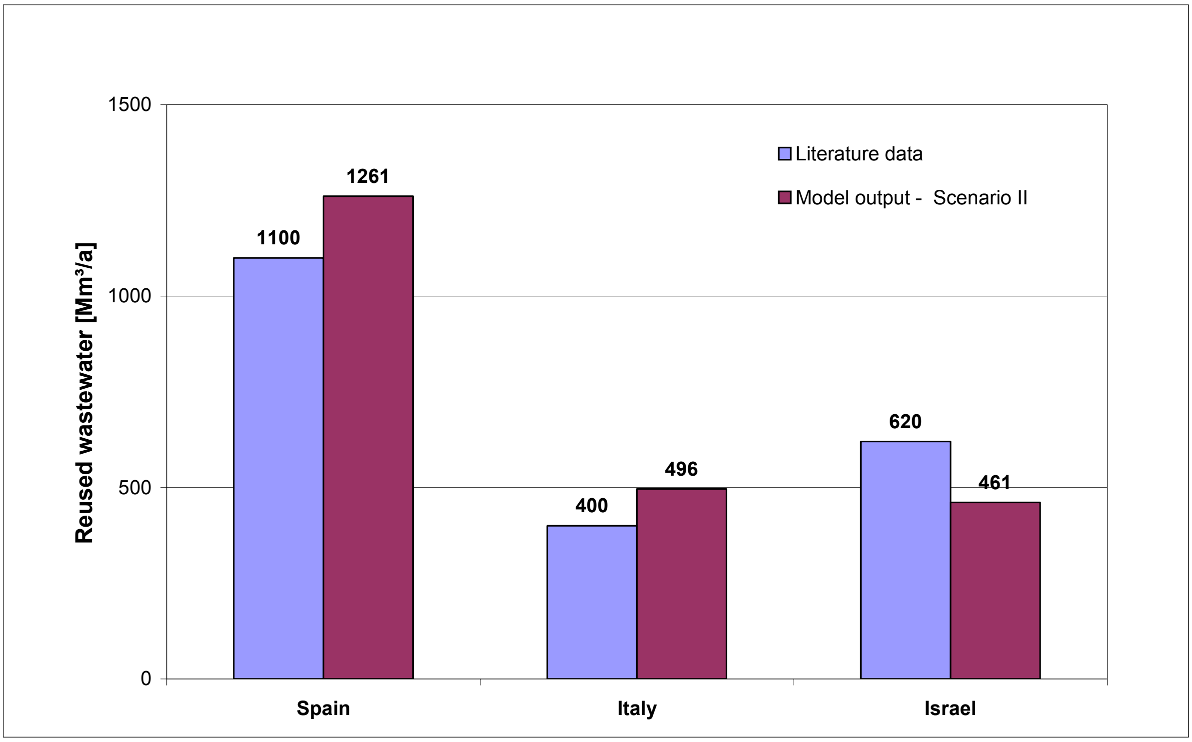
***Figure 3.13: Model appraisal of substitution potential utilisation in relation to consumptive water use intensity** Scenarios with reduction of water availability (constant, - 5 %, - 10 %, - 15 %, - 20 %, - 25 %)*



In Figure 3.12 a steady incline of the substitution potential utilisation with water stress can be observed. Nonetheless it seems a rather poor performance that countries with a consumptive water use intensity of approximately 20% utilise not more than 30% of their substitution potential. The graph illustrates once more that for certain countries the development of wastewater reuse practice primarily is limited by a low E/U ratio (Bulgaria, Cyprus) resulting in a 100% potential utilisation, independent of increasing water stress.

Disregarding possible objections against the model premises, a comparison of the model outcome for wastewater reuse potential estimation for Spain, Italy and Israel with appraisals found in literature was undertaken and is depicted in Figure 3.14.

Figure 3.14: Comparison of model output and literature data on wastewater reuse potential



The quality of compliance of model-output and literature is fairly good for all three countries, when referring to the scenario II results. For scenarios with reduced water availability (III + IV) the compliance will be less favourable.

The result for Spain comes close to the reclamation goal of 1,100 Mm³/a aimed at in the Spanish Whitebook of Water, which refers to 2018 and takes into account major increases in water demand (MME, 2000).

Estimates for wastewater reuse potential in single regions of Italy (Sicily, Sardinia, Puglia) as presented by Barbagallo (2001) amount to approximately 400 Mm³ whereas the model suggests 496 Mm³. The 'gap' will be easily closed considering substitution potential in northern irrigation areas or industrial applications, which is supposed to be investigated according to the proposal for a water conservation programme for the region of Emilia Romagna (STRRA, 2002). An investigation of the reuse potential in agricultural irrigation is as well carried out in the region of Tuscany (Regione Toscana, 2003) and in Apulia, the driest region of Italy (Lopez and Vurro, 2006).

The future scenario for Israel, with a calculated reuse of 461 Mm³/a, does not exactly match the long-term perspective to reclaim 620 Mm³/a (Shelef, 2001) which equals 25% of total water demand. Explicit reuse estimations for Israel aim at covering 50% of irrigation demand by reclaimed wastewater in the year 2020. Today the share is around 40% (Schwarz, 2001).

3.4 Conclusion

The discrepancy in the case of Israel underlines a principle weakness of the introduced model. As it is fed with water management data at the national level, regional details and characteristics are not adequately depicted. Working with a country-wide averaged consumption intensity, regional aspects and extremes of water stress are veiled. Water stress in densely populated areas in combination with relevant wastewater volumes in these regions can promote wastewater reuse in line with the assumptions of the model introduced in this study, but due to highly aggregated data on a country-wide level this cannot be recognised.

Even though applied on a country-wide level, the model disregards all the natural variability within a country and socio-economic objections against implementing wastewater reuse, a quantitative information will help to focus on the perspective of developing wastewater reuse practice and thus encourages to set the right framework. In principle, the model is suitable for the estimation of water reuse potential on a much smaller scale as well. Applying it on a catchment scale, for example, could provide a supporting tool for river basin management plans.

Especially as water shortage might be much more severe than is expressed by the long term annual average which is just a very rough figure characterising a country's water availability. It does not take into account the uneven spatial and temporal distribution and thus the efforts it might already take to balance demand and supply on a regional level. The coverage of seasonal demand peaks, e.g. for irrigation or public water supply in tourist regions, involves the risk of aquifer over exploitation (De la Orden-Gómez, J.A. and Murillo, 2002) if no abstraction restrictions or price incentives are asserted.

In addition, a series of dry years can easily push the average annual rainfall below any long term average. Recent declines in average precipitation compared to the 1960-1990 ltta are reported for several countries (MoE-PL, 1997; MoA, 2002; EEA, 2003).

Moreover, a reduction of water availability is often caused by inappropriate quality of water resources (brackish groundwater due to saltwater intrusion, excessive nitrate content - cf. 2.5.2) as well as by stipulated abstraction or supply restrictions for certain users. Such trends cause even more severe decreases in water availability than assumed in the scenario presented here.

Realisation of reuse potential

Nonetheless, the results do raise but naturally leave open the question how to accompany the realisation of this massive potential from a regulatory point of view and how to shape an appropriate framework of incentives and implementation support measures.

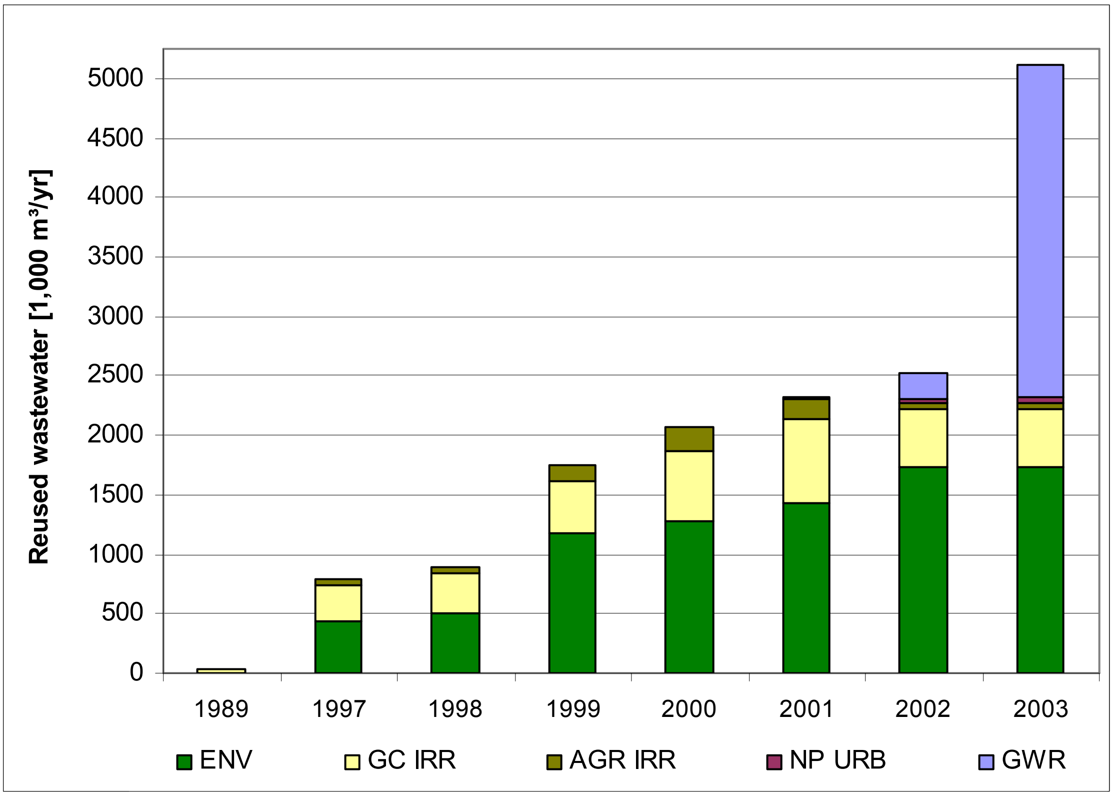
These aspects will be of paramount importance for the wastewater potential realisation in applications that could absorb huge volumes of water but are at the same time sensitive to health objections, as for example groundwater recharge.

The development of the reuse activities of the Costa Brava Water Board in Catalonia, Spain, might be a good example for the steady growth of water reclamation in a water stressed region (Figure 3.15). Over the last two decades water reclamation and reuse have experienced a respectable growth. What was starting with a single golf course irrigation and a recycled volume of 40,000 m³/year, today absorbs more than 5 million m³ per year (DDGI, 2005; CCB, 2006).

But not only the total volumes of reused water have increased over time, there was also a diversification of the uses. For a long time, environmental applications (wetland, stream flow augmentation) and golf course irrigation were predominant. But as the practice as such became more and more established with increasing experience and confidence in the technology, also non-potable urban uses were considered and lately even groundwater recharge. The existence accordingly differentiated guidelines could be considered a favourable circumstance.

In 2004 the total reclaimed water flows in Catalonia augmented to ca. 22 Mm³/year which equals 4 % of the total treated effluent (Borras, 2005), hence still offering potential for further activities.

Figure 3.15: Development of wastewater reuse in Catalonia - only plants operated by the Consorci de la Costa Brava (DDGI, 2005; CCB, 2006)
where ENV: environmental enhancement, GC IRR: golf course irrigation, AGR IRR: agricultural irrigation, NP URB: non-potable urban uses, GWR: groundwater recharge



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4 BENEFITS OF WATER REUSE

The Urban Wastewater Treatment Directive (UWWTD) states that "treated wastewater shall be reused whenever appropriate" and hence implicitly suggests that wastewater reuse is potentially beneficial. Yet the term appropriateness is still legally undefined.

Triple bottom line assessment

The evaluation of impacts of water reuse as benefits or rather risks is naturally highly dependent on the point of view of the considered party, which is influenced by its degree of involvement and specific concerns. Different stakeholders might argue differently, when it comes to an evaluation. It is a rather individual appreciation governed by the user's standpoint.

The benefits of recycling have been canvassed extensively among specialists and encompass:

- additional drought-proof water supply
- reduced discharge of pollution
- reduction of water withdrawal from natural systems
- more local sourcing of water
- avoid the use of drinking water quality sources where such high quality is not needed

These effects, grouped by different aspects, will be outlined in more detail in the next sections. In the following it will be discussed which features constitute a benefit and who is the beneficiary.

4.1 Economic benefits

Economic benefits arising from water reuse can mean the saving of expenses, the optimisation of costs or the gain of profit from an activity. Hence the extend and type of economic benefit is depending on the considered activity and the particular user.

It has to be noted that economic benefits are often not yet describable or simply not yet correctly factored into economic analyses. This controversial debate and recent trends to establish an appropriate framework for the economic evaluation of water uses (which includes water reuse) and water management options will be in the focus of Chapter 8.

4.1.1 Economic benefits for different end-users

Agriculture

In commercial activities reuse becomes viable when it constitutes the more economic option of water supply. In the agricultural sector, secured production due to sufficient irrigation water poses a valuable advantage which is paid for.

Reliable irrigation water supply is a main characteristic acknowledged by most farmers in semi arid regions across Europe. A survey among farmers in Sardinia revealed that 64 % of them were willing to pay at least 10 % more for reclaimed water than for conventional water at the moment. Their attitude reflected the monetary advantage of ensured continuity of (reclaimed) water supply during the irrigation period (Virdis *et al.* 2001). Their risk of a crop failure decreases and consequently the risk of income losses.

The maintenance of irrigated agriculture is a major aspect of economic importance in the Alméria region in Spain. Thomas and Durham (2003) report of an annual horticulture turnover of 80 million EUR which could only be assured by sufficient irrigation. Especially high-value agriculture production like vineries can even afford to pay a reasonable price for this reliable water resource (Seguí, 2004) (cf also 7.4.4.)

But not only the water as such but also the nutrients it contains may materialise as considerable advantages. The fertilising value of reused wastewater is undisputed and can be economically beneficial in agricultural and golf course irrigation (Mujeriego *et al.*, 1996; Oron, 2000; Sala, 2001; Tsadilas, 2002; Muñoz 2005). The Northern Shoalhaven Reclaimed water management scheme (REMS) in New South Wales, Australia has proven to be assisting to the long-term viability of local dairy farms. Irrigated dairy farms were remarkably better off (relative to previous years) when compared with adjacent non-irrigating farms (Shoalhaven Water, 2004).

Industry

Industrial use of reclaimed water can be beneficial to the entrepreneur. Large industrial applications for cooling water might become attractive in particular if they compete with desalination of seawater.

The Eraring Power Plant (NSW, Australia) was able to substitute 60 % of its non-saline process water, formerly covered from drinking water, by reclaimed effluent. The boiler feed water production by a double membrane process was characterised by very low dissolved salts in the reverse osmosis permeate, allowing for reduced use of regeneration chemicals resulting in operational cost reduction (Thomas and Durham, 2003). At the same time the wastewater treatment plant operator benefited, due to deferring the coastal discharge pipeline.

4.1.2 For the supplier

Water reclamation and reuse sometimes turns out to be a less costly alternative for providing additional water than other options such as water transfer and desalination. In this respect it constitutes an economic benefit to avoid unnecessary high investment. Capital cost savings of up to 50 % in the best case and around 15-20 % on average can be expected (Anderson, 2003). Such economic benefits materialise even better when the business activities cover both water supply and wastewater treatment. Water recycling can exhibit monetary advantages of not unnecessarily expanding the potable water supply system, as was the case for the Luggage Point installation near Brisbane (Australia). It was an attractive option for supplying the adjacent refinery when compared with the cost of the alternative of bringing in a large new water main for the supply of potable water, apart from also representing a significant saving in potable water cost (AATSE, 2004).

For operators of wastewater treatment facilities it might be particularly interesting to recycle the treated wastewater when disposal of wastewater is charged with a fee. Effluent charges can be saved when the water is not discharged into the water environment as is the case for the Braunschweig agricultural reuse scheme (Abwasserverband Braunschweig, 2001).

4.2 Social benefits

The social dimension of water reuse is of paramount importance. In times of increased water demand and more and more areas suffering from water shortage the main social benefit of water reclamation is to meet the water need of whatever kind. In water stressed regions, the most important benefit of water reuse is the release of high quality water resources for priority uses while supplying surrogate water for uses that can afford a lower quality.

This is particularly true for densely populated or water scarce areas. There water reuse can form a significant contribution to sustainable development allowing the community to grow. The reuse of municipal wastewater of Peterborough (UK) for industrial use (steam generation in a gas-fired power plant) is going to release a considerable amount of freshwater water for the expanding local domestic demand. (www.waternunc.com/gb/angliw08.htm and www.water.org.uk/index.php?raw=429).

A typical urban application of water reuse is irrigation of public greens, sports fields or golf courses. That way, improved areas can benefit from tourist activities due to the good quality of the seawater and beaches, quantity of golf courses and the other recreational areas (Anderson, 2003; Thomas and Durham, 2003).

The effect on local employment might be relevant in some specific situations but can in general not be regarded a job engine. Nonetheless, water reclamation can generate new qualified jobs for the construction, operation and maintenance of the wastewater treatment and reclamation scheme as well as the distribution systems. Moreover suppliers for systems, equipment and chemicals for wastewater treatment and reuse are needed.

An example from the Almeria province in Spain shows that the use of reclaimed water for farmland irrigation led to increased crop production and thus 1 million working hours are offered during the crop season. Not only new jobs but also some other criteria can lead to an increase of the quality of life of the population such as (Thomas and Durham 2003):

4.3 Environmental benefits

Environmental benefits are rather intangible benefits that often still lack an evaluation yardstick. They summarise the beneficial effects reuse exerts on the environment, either directly or more indirectly.

The most prominent positive effects are

- reduced diversion and withdrawal from natural systems
- reduced discharge of pollution into natural systems

where the first leads to a relief of water stress in aquatic ecosystems whereas any avoided pollution discharge improves the water quality. Both impacts are supportive in achieving a good status of surface water and groundwater as demanded by the Water Framework Directive.

Primarily **quantitative effects** like flow augmentation or rising groundwater tables due to reduced abstraction can promote environmental enhancement. Restoration of natural wetlands is often facilitated by water reuse activities. Additionally, some of the environmental benefits resulting from wastewater reclamation and reuse are entailed to the chosen natural treatment step, e.g. constructed wetlands which can be considered both a way to clean water, and an environmentally beneficial reuse application

(Brawley-Chesworth and Kinshella, 2005). The rehabilitated or newly created functional habitats accommodate wild-life with an increased biodiversity which often is acknowledged by the visiting population (Carlsson *et al.*, 2003). The success can primarily be measured in breeding bird numbers and rare species (endangered, threatened, sensitive). Many projects in the USA have proven enormously effective in this respect (Brawley-Chesworth and Kinshella, 2005), at the same time exerting positive acceptance impacts due to the recreational value recognised by the neighbours.

The Western Treatment Plant of Melbourne for example (10850 ha with lagoons, land infiltration and grass filtration) has been included in the Ramsar convention as a wetland of international importance for bird conservation. Also constructed wetlands at the European coastlines in Spain and the Benelux offering roosting and feeding places for migratory birds have developed to attractive bird watching spots.

Some of these natural systems assist to biologically revitalise or reanimate the almost non-living albeit treated effluent and help to adapt it to the biocenoesis of a surface water, a concept established as the so called WATERHARMONICA (Claassen and Kampf, 2004). This constitutes an additional benefit, especially in places where dilution flows are low, as in Mediterranean streams but also in small streams and canals in northern Europe (Sala *et al.*, 2006).

In Bajo Andrax (Almeria province, Spain) over abstraction of the groundwater resources resulted in an increasing salinity. Nowadays reclaimed water is used for irrigation so the pressure on the environment to provide sufficient water for potable uses decreased and the saline ingress problem was limited. Reduced withdrawals from overexploited aquifers can also help to restore their **qualitative status**. Especially in coastal areas the replenishment of groundwater tables functions as a saltwater intrusion barrier thus protecting these water resources. Such schemes are in operation or under planning for the Spanish Mediterranean coast (Compte, 2005; Thomas and Durham, 2003) and are practiced in large scale in the Groundwater Replenishment Scheme in California (**www.gwrsystem.com/about/need.html**, Deshmukh, 2004).

Every wastewater flow (although treated) that is not discharged to the environment can be considered a pollution avoidance and contribute to a quality improvement. Hence a number of water reuse projects are not merely developed to meet a water demand but also to eliminate water pollution. Especially in coastal areas this leads to improved littoral bathing conditions (Thomas and Durham, 2003, Sala and Serra, 2004).

Moreover water reuse is an option when discharge of effluent conflicts with the protective status of the receiving water. Nature conservation objective have e.g. driven the implementation of the Reclaimed Water Management Scheme in Shoalhaven (Gould *et al.*, 2003).

From the sections above it becomes evident that the beneficial effects of water reuse, although exemplified from three points of view in this chapter, are closely related and interwoven partly causing each other. In order to fully acknowledge the benefits of reuse when deciding on a proposed reuse project its possible contribution to achieving sustainability should be taken into account. Indicators like the reduction in per capita effluent discharge and the substitution of recycled water for existing water supplies are seen as integral components to achieving sustainability (AATSE, 2004).

In any feasibility study the merits of a reuse project should be carefully balanced with its risks or shortcomings (indicators: reduction in per capita sewage flows and substitution of recycled water for existing water supplies are seen as integral components to achieving sustainability.

In the best case, a reuse scheme supports all three aspects addresses all three types of benefits, as is the case for the agricultural irrigation reuse scheme in Braunschweig, Germany. The region is characterised by sandy soils, that require irrigation in any case, and a weak receiving water, which would require an advanced treated effluent. The Abwasserverband Braunschweig reuses the total of 22 Mm^3/a of treated wastewater: 15 Mm^3 for all year irrigation and 7 Mm^3 in a constructed wetland and Rieselfeld operation.

The benefits arising from the scheme are summarised in Table 4.1 (Teiser and Ripke, 2006)

Table 4.1: Benefits arising under the particular circumstances of the Braunschweig water reuse scheme

<table>
<tr><th>Economic</th><th>Social</th><th>Environmental</th></tr>
<tr><td></td><td colspan="2">constructed wetland attracting diverse bird species during migration period, recreational area</td></tr>
<tr><td>fertilising effect of irrigation</td><td></td><td>improved surface water quality in receiving creek</td></tr>
<tr><td colspan="2">increased crop yields (20-40%)</td><td>less soil erosion</td></tr>
<tr><td>growing of crops for biogas production and energetic independence of the operator</td><td></td><td>soil melioration (increased humus content)</td></tr>
<tr><td>avoided invest in upgrading of treatment plant</td><td></td><td></td></tr>
<tr><td colspan="2">reduced payment of effluent charge</td><td></td></tr>
</table>

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5 RISKS AND CONSTRAINTS OF WASTEWATER REUSE

Wastewater reuse indisputably provokes controversial discussions about the entailed risks. The objections are primarily concerned with a variety of risks imposed by reuse. Therefore risk is a central issue in wastewater reuse discussions, involving infectious risk for humans, possible detrimental effects of micro-pollutants and environmental hazards. The following section will summarise the most frequent concerns and objections that are related to the use of reclaimed water.

5.1 Human health risks

The safe application of wastewater reuse should regard the protection of human health as its first concern. The major risks related to wastewater reuse are associated with microbial and chemical compounds contained in reclaimed wastewater.

Microbial pathogens

Among the pathogens potentially present in raw sewage are bacteria, viruses, protozoa and helminths causing acute health impacts mostly related to gastroenteric diseases of different severity (see Table 5.1)

Table 5.1: Types of waterborne pathogens and diseases they cause **(EPHC, 2005)**

Pathogen type	Examples	Disease
Bacteria	*Salmonella*	Gastroenteritis, reactive arthritis
	Campylobacter	Gastroenteritis, Guillain-Barré syndrome
	Pathogenic *Escherischia coli*	Gastroenteritis, haemolytic uremic syndrome
	Shigella	Dysentery
	Yersinia	Gastroenteritis, septicemia
	Vibrio cholerae	Cholera
	Atypical *Mycobacteria*	Respiratory illness (hypersensitivity pneumonitis)
	Legionella spp	Respiratory illness (pneumonia, Pontiac fever)
	Staphylococcus aureus	Skin, eye, ear, infection, septicaemia
	Pseudomonas aeruginosa	Skin, eye, ear, infection
	Helicobacter pylori	Peptic ulcers
Viruses	Enterovirus	Gastroenteritis, respiratory illness,
	Adenovirus	Gastroenteritis, respiratory illness, eye infection
	Rotavirus	Gastroenteritis
	Norovirus	Gastroenteritis
	Hepatitis A	Infectious hepatitis
	Calcivirus	Gastroenteritis
	Astrovirus	Gastroenteritis
	Coronavirus	Gastroenteritis
Protozoa	*Cryptosporidium*	Gastroenteritis
	Giardia	Gastroenteritis
	Naegleria fowleri	Amoebic meningitis
	Entamoeba histolytica	Amoebic dysentery
Helminths	*Taenia (T. saginata)*	Tapeworm (beef measles)
	Ascaris	Roundworm
	Trichuris	Whipworm

Most standards defined in water reuse guidelines focus on the risk of bacterial or parasite infection, not directly addressing the hazards posed by viruses. Having regard to the fact that viruses are in general more contagious than bacteria and often also more environmentally resistant it is of utmost important to monitor the right indicator organism to assure a safe use of reclaimed water (Paranychianakis, 2006; Toze, 2006).

Chemicals of concern

Besides biological hazards, usually causing diseases within a rather short period after infection, chemical substances in wastewater are capable of evoking detrimental, chronicle health effects in the long-term. The risks of organic halogens, pesticides, endocrine disrupters and a bulk of undefined organic constituents is not yet comprehensively quantified (Crook, 1998). The paucity of information on environmental persistence, fate and effects of pharmaceutically active compounds and their concentration in reclaimed water raises additional concerns at health authorities and the public (Toze, 2006)

In the context of wastewater reclamation and reuse not only wastewater inherent substances are of concern but also disinfection by-products possibly generated during the treatment with chlorine.

5.2 Environmental risks

The use of reclaimed water does not only have environmental benefits but can also cause negative impacts on and pose risks to different environmental compartments.

Soil and plants

High salt contents of effluents resulting from human and industrial water uses may pose a constraint to soil applications of reclaimed water or even the threat of salinisation if not properly monitored. Adverse effects of land irrigation on soil properties are subject of both agronomic and health concern. Chemical constituents of the irrigation water may impair soil fertility or its capacity to assimilate, attenuate and detoxify pollutants. Leaching of heavy metals into underlying groundwater might result again in human health risks.

Furthermore, little is known about possible phyto-toxic impacts of perennial irrigation with reclaimed water; whether harmful substances are taken up, assimilated or even accumulated or how plants and pathogens might interact, whether e.g. parasites could intrude into edible plant parts.

Water environment

Different water compartments can be influenced depending on the recycling application. Especially groundwater that is replenished with reclaimed water either purposefully or by chance when over-irrigation takes place, is prone to contamination with substances still present in the reclaimed water.

As wastewater treatment plant effluents comprise the majority of river flow volumes in arid and semi-arid regions during summer, ecological minimum flows can only be guaranteed when treated wastewater is discharged into the river. These circumstances demand an advanced wastewater treatment to augment the stream flow without damaging the ecosystem.

The impact of wastewater recycling on hydrological flows was modelled by Jeffrey and Oxley (2002), concluding that 'regional schemes which do not transfer water across catchment borders have the potential to adversely influence hydrological flows and river water quality'.

5.3 Social, legal and financial risks

In consequence of the above noted concerns, the operator of a reuse plant faces a particular risk and obligation of liability. This refers to both the environmental liability for detrimental effects of his business activities and the product liability for harm caused by his products. Any proved damaged and assumed liability can constitute a financial risk that has to be covered by reserves or insurance services.

Legal uncertainty

The guidelines and standards for water reuse vary greatly among countries and organisations. The striking difference between the WHO Guidelines and the Title 22 standard for unrestricted irrigation have been cited often.

An unsteady, changing legislative frame complicates a sound economic analysis of a scheme and can cause largely variant cost, depending on the required quality criteria and the prescribed treatment and surveillance efforts (Salgot, 2001).

It is quite usual that the provider of reclaimed water has to guarantee a specific quality at a defined point of delivery.

Recently the Queensland Environmental Protection Agency (Australia) has published a manual of how to design such an agreement between providers and users of reclaimed water. It also recommends to incorporate measures for limiting legal liability in water recycling projects (EPA QLD, 2005).

Constancy of public attitude and user needs

Support for water reuse in the public might change due to new issues arising. The stability of attitude is uncertain (Russell and Hampton, 2006) especially against the background of reported failure. Cases of cross-connection in domestic reclaimed water distribution systems can easily upset the public - and the press possibly generating a hostile atmosphere.

The acceptance for food grown with reclaimed water might also be inconstant in time and place and put into question the demand for reclaimed water.

Even changes in industrial production processes might alter the requested water quality. The case of Hunter Water's Edgeworth wastewater treatment plant whose effluent was used in a colliery for fire suppression. When the technique of fire suppression was changed which meant there was increased human exposure while cleaning the equipment, the treated effluent from Edgeworth STP was no longer of adequate standard for this purpose (AATSE, 2004).

Economic viability

Efforts to maintain the required quality of the effluent may increase over time and challenge the viability of a scheme. This does not only apply to the tightening of limit values but also to the quality of the raw wastewater. High conductivity of domestic wastewater as reported for Malta makes the treated effluent rather unattractive for irrigation purposes or industrial applications (MEPA, 2006).

If the project fails to contract sufficient water users, it risks to fail and to produce sunken investments. This aspect will also influence and even complicate the decision on whether to implement high standard treatment suitable for all uses or rather to produce a lower quality for only a restricted number of applications.

To achieve an adequate price for the reclaimed water or to be able to recover the cost for the treatment is a prerequisite for entrepreneurship. Hence funding of up-front cost of construction is one of the major issues in initiating reuse projects (Bixio *et al.*, 2006).

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6 WATER GOVERNANCE - PREPARING THE GROUND FOR WATER REUSE?

According to the World Bank's definition governance is "the exercise of political authority and the use of institutional resources to manage society's problems and affairs". It is also suggested that governance is "the use of institutions, structures of authority and even collaboration to allocate resources and coordinate or control activity in society or the economy"(Wikipedia, accessed 10th April 2006). For the water sector this refers in particular to the different political, social and administrative mechanisms that must be in place to develop and manage water resources and the delivery of water services at different levels of society.

In doing so, governance makes use of and often combines different approaches:

- top-down methods that primarily involve governments and the state bureaucracy,
- use of market mechanisms where market principles of competition are employed to allocate resources while operating under government regulation and
- networks involving public-private partnerships or with the collaboration of community organisations.

These modes of governance are often characterised as hierarchical, incentive-based and participatory.

Especially when governance is aiming at (ecologically) sustainable development, guidance is needed as sustainable behaviour does not automatically pay off in an unregulated setting (Harding, 2006)

This chapter seeks to give first an overview of range of instruments (section 6.1). In a second step a review of the existing structures and the underlying regulatory framework of water management in Europe will presented analysing which instruments are actually applied and what their impact on the development of water reuse might be (section 0).

6.1 Instruments for environmental policy

There are a variety of instruments to implement environmental policy and to facilitate a change in behaviour. In selecting an instrument or mix of instrument three important aspects should be considered:

- ecological effectiveness and markmanship (is the tool suitable to achieve the desired goal?)
- cost-efficiency (are the costs for achieving the environmental objective allocated to the right party, and is the aim achieved by the lowest possible cost)
- dynamic incentive character for technological developments

6.1.1 Command and control instruments

Since the beginning of regulating environmental impact of human activities, command and control have been used intensively to define standard, emission limits or environmental goals. The multitude of regulations and directives testifies the prevalent use of this instrument.

Most of this legislation defines standards or emission limit values for a particular activity which the operator has to comply with.

6.1.2 Market-based instruments

The objective of all these instruments is to encourage a more efficient allocation of natural resources when aiming for a better status of the environment. They seek to overcome the situation that environmental assets are not exchanged on markets hence often lacking a price which signals their scarcity (EEA, 2005).

6.1.2.1 Environmental taxes

This term is often used as generic term for all charges levied on particular activities. But in contrast to charges (see below) taxes are determined as a fixed share existing product or service price put on top without any entitlement for reward. Hence they can be characterised by their fiscal function and that their direct impact on prices.

6.1.2.2 Environmental and pollution charges

A water pollution charge takes the form of a direct payment based on the measurements or estimates of the quantity and quality of a pollutant discharged to the environment. Pollution charges are directly addressed to the polluter and hence an important tool in applying the polluter-pays principle (Kraemer *et al.*, 2003).

6.1.2.3 Environmental subsidies and incentives (bonus - malus systems)

It is common practice in the field of environmental policy to subsidise measures and technologies that help to protect the environment, save energy or use resources more efficiently. This makes politically preferred and environmentally beneficial actions and behaviour more attractive, compared to their alternatives. Subsidies can help new technologies to penetrate the market and improve their competitiveness.

6.1.2.4 Liability and compensation schemes

Based on the Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage plant operators can be held liable for caused adverse effects and damages to the environment. This also refers to many occupational activities in the water sector and forces in general taking any arrangements for major compensation payments.

Table 6.1: Pros and cons of different policy instrument

Instrument	Example	Pro	Con
Command and control	Water Law Discharge permit, Emission limit values	the environmental objective is set	often high administrative effort for "control"
Taxes		good steering function possible re-distribution of funds	often a "user pays" approach
Charges	Effluent charges	fundraising implementing the polluter pays principle	only an effective incentive if high enough
Subsidies		establishes standards of e.g. Best Available Technology	
Liability	Environmental Liability Product liability	accelerates technological innovations promotes good management practices	only a complementary tool

6.2 Legislative boundary conditions for water reuse

The development of reuse can be considered appropriate when it happens within the boundary conditions set by related pieces of legislation and according to the key water policy principles. Additionally, appropriateness can be characterised by the benefits reuse generates with regard to both the water management and socio-economic area, as they were described in chapter 4.

The regulatory regime governing the establishment and operation of water reuse schemes can be taken in the broadest sense to include:

- a range of national, regional and local legislation and policies directly referring to water provision and use;
- industry codes and expectations of best practice;
- conditions set for specific projects or sites;
- general legislation for planning and environmental protection;
- national, regional and local policies and plans for land use and environmental protection;
- general legislation on products and services, including product liability provisions;
- legislation in areas related to particular applications of recycled water, like food safety, prevention of disease in livestock, or occupational health and safety;

The next sections will point out which existing legislation form the current regulative framework and how the requirements have been adopted by reuse specific guidelines or how far new approaches were chosen or are needed.

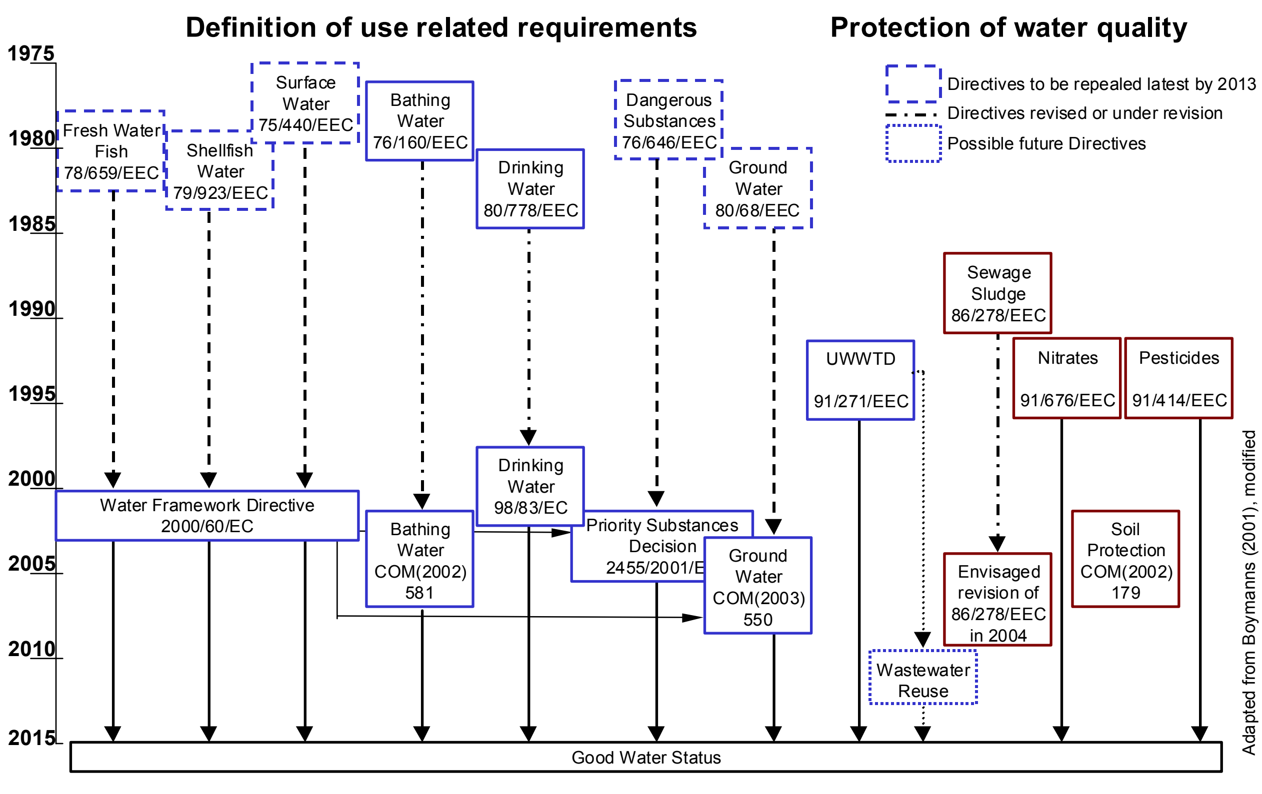
6.2.1 Water related legislation

Water is one of the most comprehensively regulated areas of European Union (EU) environmental legislation. Directives issued by the European Council and the European Parliament do not directly enter into force in the Member States. The suggestions for re-orientation and revision given have to be transposed into national law within a defined period.

A first wave of water related legislation starting in the mid 1970s was characterised by directives that primarily defined water quality standards related to specific uses (Fish Water Directive, Shellfish Water Directive, Bathing Water Directive, Surface Water Directive). These initial directives mainly dealt with water for human consumption and uses. In the following decades the legislation was supplemented by directives which have placed increased emphasis on the environmental effects aiming at the protection of water bodies by limiting both point and diffuse pollution due to emission from specific sectors (Nitrate Directive, Pesticide Directive, Urban Wastewater Treatment Directive, Sewage Sludge Directive). Throughout the late 1990s the trend developed towards an even more integrated approach in water resources management which led to the adoption of the Water Framework Directive in 2000. It aims to advocate a comprehensive approach to safeguard surface and groundwater resources in both qualitative and quantitative respects and to achieve their good status.

Figure 6.1 presents an overview of EU legislation in force and pending revisions. The scheme illustrates the mentioned successive development and diversification of European water legislation.

Figure 6.1: Overview of major European legislation for water and soil



The most important directive for all future developments in the water sector is without doubt the Water Framework Directive which is supposed to replace many of the early directives within the next years

(Fresh Water Fish Directive, the Shellfish Water Directive, the Surface Water Directive, the Dangerous Substances Directive and the Groundwater Directive). Under its umbrella necessary measures to achieve a good status of water bodies will be summarised. An enhanced protection and improvement of the aquatic environment shall be achieved through specific measures for the progressive reduction of discharges, emissions and losses of priority substances and the cessation or phasing-out of discharges, emissions and losses of priority hazardous substances.

With regard to a potential legislation on wastewater reuse it is to emphasis that such a piece of regulation is not actually foreseen or in preparation. Placing it as an annex or a daughter directive to the Urban Waste Water Treatment Directive (UWWTD) is merely hypothetical but also logical as the UWWTD requests that that *"treated waste water shall be reused whenever appropriate*". Nevertheless, this suggestion does not depict ongoing legislative considerations.

6.2.1.1 Surface Water Directive (SWD)

The Council Directive 75/440/EEC concerning the quality required of surface water intended for the abstraction of drinking water (Surface Water Directive – SWD) defines quality criteria for the raw water to be used for the production of drinking water. Taking account of different treatment methods, the surface water shall not exceed limits laid down for *E. coli*, Coliforms, Streptococci, surfactants, pesticides, aromatic hydrocarbons, phenols, nitrate and a variety of metals.

6.2.1.2 Bathing Water Directive (BWD)

The Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water (Bathing Water Directive) regulates the quality of bathing waters in Europe with respect to physical, chemical and microbiological parameters. It stipulates monitoring programmes and defines which level of pollution conflicts with a good bathing water quality. An annual bathing water report depicts the state of Europe's bathing waters. On 24 October 2002, the European Commission has adopted the proposal for a revised directive of the European Parliament and of the Council concerning the quality of bathing water COM(2002)581. which has entered into force as directive has 2006/7/EC at the beginning of 2006. It makes use of only two bacteriological indicator parameters, but sets a higher quality standard than the 1976/160 directive (see Table 6.2). This revised directive focuses on *E. coli* and intestinal enterococci which are limited to 500 and 200 cfu/100 mL (for excellent quality of inland freshwater bodies) whereas the 1976 directive had fixed the mandatory value for faecal coliforms at 2,000 MPN/100 mL.

Table 6.2: Parameter and limit values of the revised Bathing Water Directive (cfu: colony forming unit, ILFW: inland freshwater, CTW: coastal and transitional water)

Parameter	Unit	Limit values for different types of quality					
		excellent		good		sufficient	
		ILFW	CTW	ILFW	CTW	ILFW	CTW
Intestinal enterococci	cfu/100mL	200	100	400	200	330	185
E. coli	cfu/100mL	500	250	1000	500	900	500

The revised directive aims to reduce both monitoring frequency and monitoring costs whilst providing long-term quality assessment and management methods. Furthermore it introduces a change from a pure monitoring and retrospective compliance approach to a well-developed management of bathing waters and extensive information given to the public.

6.2.1.3 Groundwater Directive (GWD)

The Council Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances *(*Groundwater Directive– *GWD)*

This directive provides a protection framework by preventing the direct discharge of high priority pollutants (list I) and subjecting the discharge of other pollutants (list II) to an authorisation procedure preceded by a thorough investigation on a case-by-case basis. Among the regulated substances are: organohalogen compounds, organophosphorus compounds, organotin compounds, substances which possess carcinogenic mutagenic or teratogenic properties in or via the aquatic environment, mercury and its compounds, cadmium and its compounds, mineral oils and hydrocarbons (list I) as well as (list II): metalloids and metals and their compounds (Zn, Cr, As, Ti, Be, V, Te, Cu, Pb, Sb, Sn, B, Co, Ag, Ni, Se, Mo, Ba, U, Tl), biocides and their derivatives not appearing in list I, substances which have a deleterious effect on the taste and/or odour of groundwater, toxic or persistent organic compounds of silicon, inorganic compounds of phosphorus and elemental phosphorus, fluorides, ammonia and nitrites.

In September 2003 the European Commission adopted a proposal for a new directive to protect groundwater from pollution (COM(2003)550). Based on an EU-wide approach, the proposed directive introduces, for the first time, quality objectives, obliging Member States to monitor and assess groundwater quality on the basis of common criteria and to identify and reverse trends in groundwater pollution. The proposed directive will ensure that ground water quality is monitored and evaluated across Europe in a harmonised way. The proposed approach to establish quality criteria takes account of local characteristics and allows for further improvements. It represents a proportionate and scientifically sound response to the requirements of the Water Framework Directive related to the assessment of the chemical status of groundwater and the identification and reversal of significant and sustained upward trends in pollutant concentrations.

6.2.1.4 Drinking Water Directive (DWD)

Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption (Drinking Water Directive – DWD) concerns the quality of water intended for human consumption. The objective of this directive shall be to protect human health from the adverse effects of any contamination of water intended for human consumption by ensuring that it is wholesome and clean. As human health is directly concerned the list of surveyed compounds is the most comprehensive of all the water related directives with 48 parameters to be monitored.

6.2.1.5 Urban Wastewater Treatment Directive (UWWTD)

The Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment (Urban Wastewater Treatment Directive - UWWTD) aims to protect the environment from any adverse effect due to the discharge of wastewater which has caused eutrophication and damaged aquatic life over years. It defines which wastewater has to be collected and treated thus determining the available amount of potentially reusable flows. Secondly, it stipulates the minimum treatment level thus giving a first rough estimate of the quality of wastewater treatment plant effluents. Reductions of organic load (in terms of

BOD_5) and nutrients are set depending on the sensitivity of the receiving water. BOD and COD are always limited to 25 mg/L and 125 mg/L respectively, whereas discharge into sensitive areas additionally requires an effluent with less than 15 or 10 mg/L total nitrogen and 2 or 1 mg/L total phosphorous (where the stricter value applies for treatment plants > 100,000 p.e.). It has to be noted that the limit values indicated are emission standards that might be tightened by the national governments due to local requirements. The concept and minimum requirements are depicted in Figure 6.2.

6.2.1.6 Water Framework Directive (WFD)

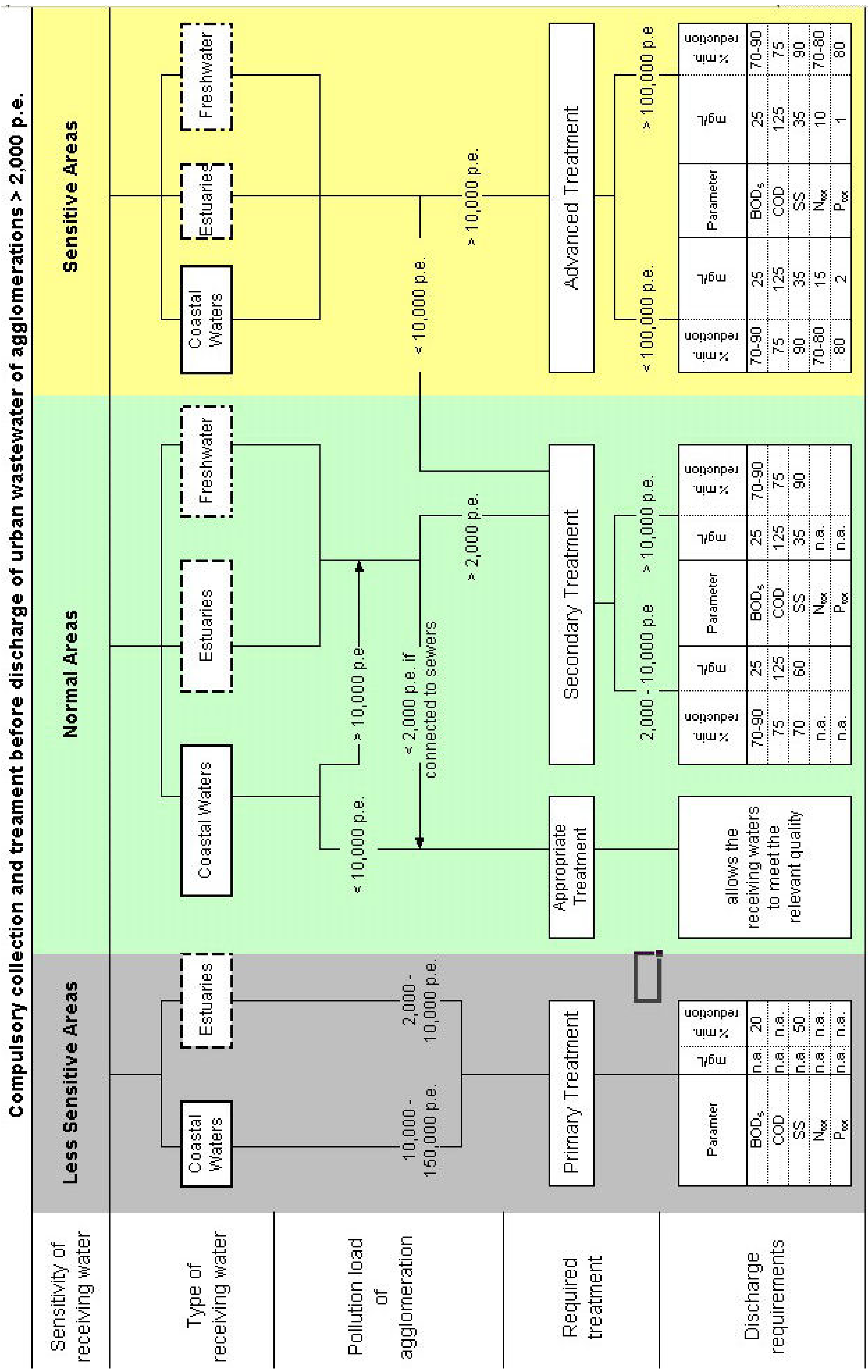
Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishes a framework for the Community action in the field of water policy. This directive introduces a long term and co-ordinated river basin planning framework for water management. The WFD rationalises and updates several pieces of existing water legislation. For example, it will replace the Fresh Water Fish Directive, the Shellfish Water Directive, the Surface Water Directive, the Dangerous Substances Directive and the Groundwater Directive.

Its primary objectives are to promote the sustainable use of water, reduce water pollution, particular by ‘priority’ and ‘priority hazardous’ substances, lessen the effects of floods and droughts, rationalise and update existing water legislation, and introduce a co-ordinated approach to water management based on the river basin as the appropriate scale for planning. Central to the directive is the requirement to produce a strategic management plan for each river basin setting out how the objectives are to be achieved. The plan must be based on a detailed analysis of the pressures on the water bodies within the river basin, and an assessment of their impact. The success of the approach shall be assured by a self-improving cyclical procedure.

The directive has a broad agenda, setting the protection of aquatic ecosystems as a priority and promoting public participation and information dissemination. Surface waters are required to meet ‘good ecological and chemical status’ and groundwaters to meet ‘good chemical and quantitative status’ by 2015. Significantly, the WFD also requires that no deterioration in water status takes place and that protected area objectives are met.

In the water sector, the need to involve concerned parties in management and planning decisions has also been repeatedly advocated by the international community. The Water Framework Directive is in keeping with this change in governance paradigm. It represents a new approach to water resources management through its nature as an enabling tool for planning rather than a plan itself, it adopts a strategic and integrated approach, and the approach is participatory. Participation is clearly identified as a key issue and a challenge, as shown by preamble 14 which states that “the success of this directive relies […] on information, consultation and involvement of the public, including users”.

Figure 6.2: Treatment standards and effluent quality requirements under the Urban Wastewater Treatment Directive*(n.a.: not applicable)*



6.2.1.7 Irrigation water

There is no supranational legislation about the quality of water for irrigation. Nonetheless there are a number of recommendations defining a preferred quality of irrigation water. The German DIN 19650 on "Hygienic Aspects of Irrigation Water" sets limit values for microbial contamination (faecal streptococci and *E. coli*) with variable values depending on the intended use. Four quality classes appropriate for different kind of uses are distinguished. For unrestricted irrigation (crops eaten raw, public green and sports fields) *E. coli* may not exceed 200 cfu/100 mL (DIN, 1999). In Portugal a limit of to 100 FC/100 mL is established (D. Lei 236/98 of 01.08.98).

With regard to limit values for substances toxic to plants or with detrimental effects on soil fertility many reuse guidelines refer to various national recommendations concerning irrigation water quality, which are often based on the FAO Irrigation and Drainage Paper.

6.2.2 Soil related legislation / aspects

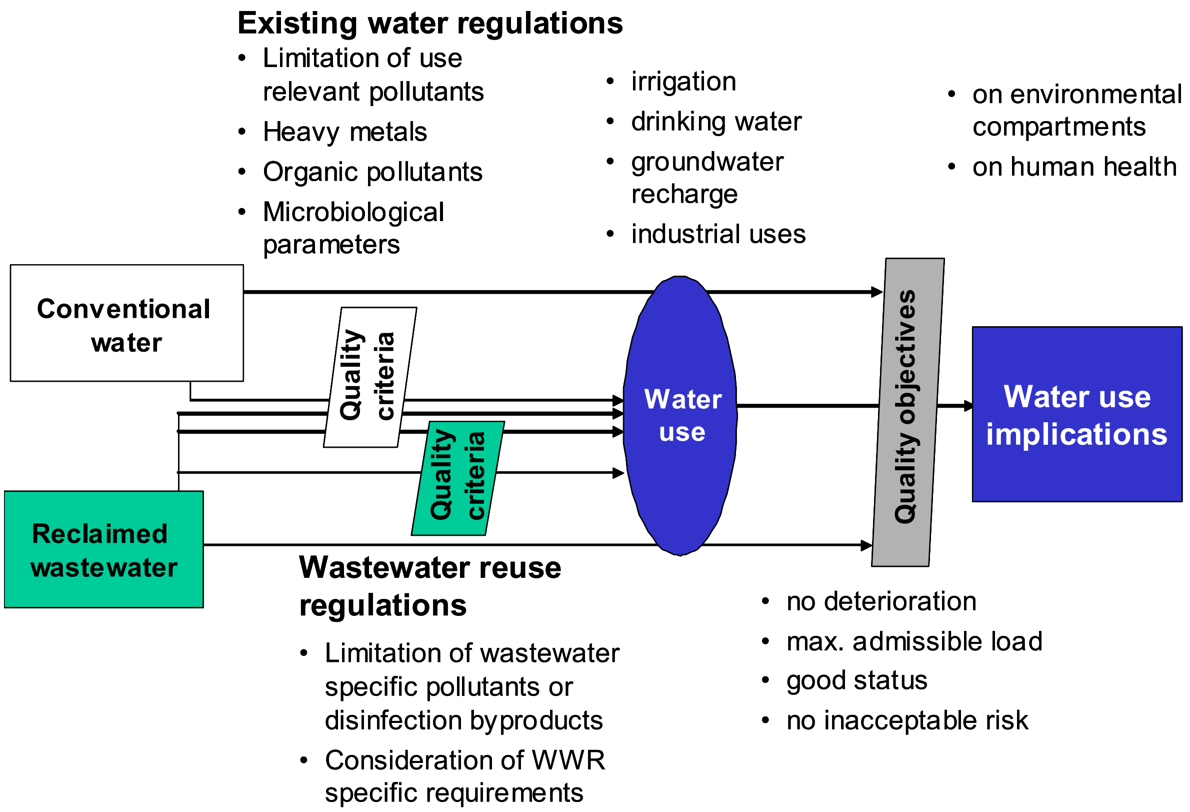
As some of possible reuse types are soil applications the existing regulations concerning this environmental compartment have to be considered, too. Agricultural irrigation and soil-aquifer recharge are two options that directly impact on soil. Thus far there is no legislation covering soil aspects but the Commissions Soil Strategy focuses on a more comprehensive protection of soil from deterioration caused by different activities.

6.3 Key water policy principles

In the water sector, the directives under consideration are typically tailored to a specific subject of protection which may be an environmental compartment, e.g. groundwater, or the human health in general. In order to avoid or minimise detrimental impacts of different water use activities on these target systems quality objectives or quality aims are defined.

As exemplified in Figure 6.3 the definitions may be either more relative when (good status, no deterioration, no unacceptable risk) or more concrete setting e.g. maximum admissible loads. To meet these qualitative aims, existing regulations determine the characteristic of the water use by defining quality criteria for the water originating from conventional water resources. The set of considered parameters comprises dangerous substances both organic and inorganic, microbial parameters and use relevant substances (e.g. salt and boron for irrigation purposes). The quality criteria for water uses supplied by reclaimed water might generally be the same but have to take into consideration wastewater specific pollutants. Figure 6.3 illustrates these common approaches and different aspects in regulating conventional or reclaimed water uses.

Figure 6.3: Regulatory approaches to wastewater reuse

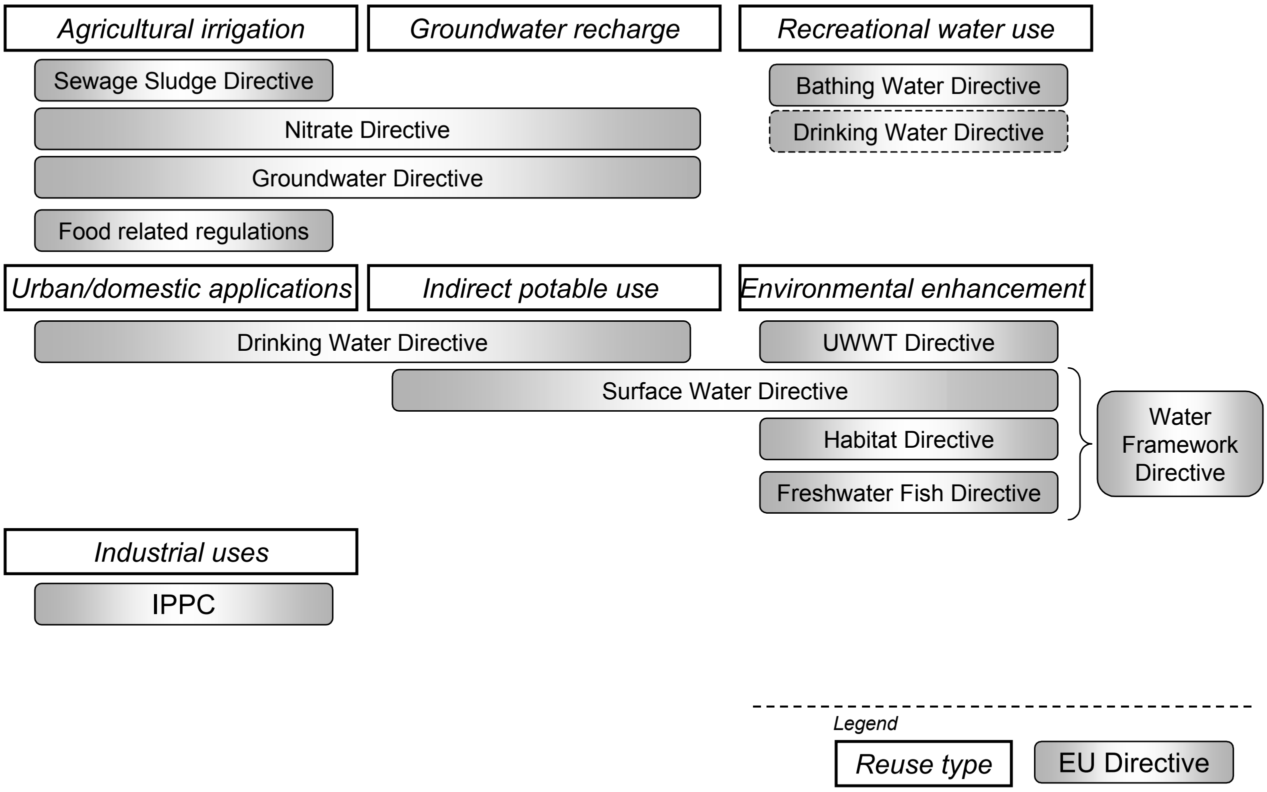


6.3.1 Relation of water legislation in force and wastewater reuse applications

In the following it will be outlined on which basis the parameters in existing or contemplated wastewater reuse guidelines for specific uses are deduced, relations to water quality targets in relevant EU directives are depicted. Within the existing regulatory frame, some of the concerns relevant to wastewater reuse applications have already been addressed by separate directives. Figure 6.4 gives an overview of legislation which may serve as reference in setting reuse quality criteria for particular purposes.

Health implications are the most prominent concerns in most wastewater reuse applications. Acute health risks imposed by micro-organisms are explicitly addressed in the Bathing Water Directive and the Drinking Water Directive. Whereas the former has to cope with hazards related to an accidental infection during swimming, the latter aims to more strictly limit the infection risk associated to the purposeful ingestion of drinking water.

Figure 6.4: Reuse types and corresponding existing European Directives



From this analysis it becomes obvious that the objectives and quality criteria spelled out in the directives are relevant for different applications of reclaimed water, but a supranational guideline or directive on water reuse is missing in Europe. Notwithstanding this „gap“ in European wide legislation, most European countries practising wastewater reclamation and reuse have issued national or regional standards to guide the official authorisation of reuse schemes (Table 6.3).

Their legal status ranges from provisional standards (Cyprus) over guidelines (France) to technical norms fixed as Ministerial Decree (Italy) (Angelakis *et al.*, 2003, Brissaud, 2006). In Spain the regulation of wastewater reuse is managed by the Autonomous Regions some of which have adopted their own regulations (Andalusia, Catalonia, Balearic Islands). The permission has to be issued in line with either specific regulations for reuse or general water and environmental law, but always with a permission.

Table 6.3: Existing water reuse regulations in Europe

Country or Region	Type of regulation	Uses	Limits
Cyprus	Provisional standards, 1997	▪ agricultural irrigation	▪ stricter than WHO standards for irrigation but less than Californian Title 22
France	Art. 24 decree 94/469 of 3 June 1994 Circulaire DGS/SD1.D./91/n°51	▪ agricultural irrigation	▪ WHO standards ▪ additional restrictions for irrigation techniques and set back distances between irrigation sites and residential areas and roadways
Italy	D.M. 12 June 2003, n. 185	▪ agricultural irrigation ▪ non-potable urban uses and ▪ industrial uses	▪ value for E. coli in irrigation < 10/100 mL ▪ list of 56 parameters! ▪ standards for industrial uses less stringent
Spain	Proposed National Guidelines	5 use categories ▪ urban uses ▪ agricultural uses ▪ industrial uses ▪ environmental and recreational uses ▪ groundwater recharge	▪ 5 quality types categories ▪ proposed microbiological tiers: 0 E.coli/100 mL < 200 E.coli/100 mL < 1,000 E.coli/100 mL < 10,000 E.coli/100 mL no restriction
	Guidelines by the Regional Authorities Catalonia Balearic Islands	▪ up to 14 use types, inter alia ▪ groundwater recharge, different irrigation categories, urban applications, domestic uses, industrial uses, cooling water purposes	▪ based on the WHO guidelines of 1989 for irrigation ▪ partly tighter restrictions
Greece (Tsagarakis et al,2002)	Draft Proposal	▪ six reuse categories with sub-catogories (urban, agriculture, aquiculture, industrial, environment and groundwater recharge)	▪ different quality categories ▪ proposed microbiological standards range from 0 FC/100 mL to < 10,000 restriction

6.3.1.1 IRRIGATION USES

In accordance with the prevailing use of reclaimed water, all wastewater reuse regulations deal with irrigation uses; although in most countries agricultural and landscape irrigation is not subject to regulation when the water is withdrawn from „natural“ or conventional water resources (WHO, 2003). Issues concerning irrigation water quality are not explicitly addressed in any EU-directive.

With regard to limit values for substances toxic to plants or with detrimental effects on soil fertility the reuse guidelines refer to various national recommendations concerning irrigation water quality, which are often based on the FAO Irrigation and Drainage Paper (FAO, 1994).

In irrigation health concerns with regard to exposed workers and consumer are a major issue. Most reuse guidelines distinguish different irrigation uses with regard to the level of contact that may occur. The most sensitive application is the so called unrestricted irrigation of crops eaten raw. Table 6.4 lists the values for *E. coli* in various regulations.

Table 6.4: E. coli limits standards in European and other international reuse guidelines or regulations (cfu: colony forming unit)

Country		Wastewater reuse application	E. coli	BWD	DWD
			cfu/100 mL	cfu/100 mL	#/100 mL
Spain	Proposed National Guidelines	Unrestricted irrigation, crops eaten raw	200	250 (excellent bathing water quality) 500 (good bathing water quality)	0
Spain	Catalonian Guidelines	Unrestricted irrigation, crops eaten raw	200		
Spain	Balearic Islands	Unrestricted irrigation, crops eaten raw	200		
Portugal	National Proposal	Unrestricted irrigation, crops eaten raw	200		
Italy	Decree No. 185	Unrestricted irrigation, crops eaten raw	10		
France	Recommendation	Unrestricted irrigation, crops eaten raw	1000		
Greece	Proposed Guidelines	Unrestricted irrigation, crops eaten raw	1000		
Israel	Proposed guidelines	Unrestricted irrigation, crops eaten raw	10		
WHO	Guidelines	Unrestricted irrigation, crops eaten raw	1000		
CA	Title 22	Unrestricted irrigation, crops eaten raw	2.2		

The limit values in the different reuse guidelines range within a 4 log scale with very restrictive standards in California at the lower end and the WHO guideline value of 1,000 E.coli/100 mL at the upper. A comparison with microbial restrictions in water directives (although the uses are not identical) shows that the more stringent Title 22 criteria are close to the Drinking Water Directives requirements whereas the WHO recommendation are less strict than that of the European Bathing Water. The European reuse guidelines specify at least the same order of magnitude for microbial pollution as in the BWD.

6.3.1.2 GROUNDWATER RECHARGE

Not risking jeopardising groundwater resources is one quality objective of artificial recharge which has to be addressed in regulating this reuse application. In this context, long-term effects like accumulation and degradation of compounds to either harmless or possibly even more noxious substances play an important role. Also, the risk of groundwater microbial contamination has to be considered. In defining a required quality for groundwater recharge, the quality of the receiving aquifer and the technique applied (infiltration or injection) may be taken into account as well as the intended end-use after re-abstraction, with drinking water production as the most sensitive end use (Table 6.5).

Table 6.5: E. coli and heavy metals limits in European and other international guidelines or regulations (cfu: colony forming unit; n.d.a - no data available; n.l.d. - no limit defined)

Country		Wastewater reuse application	*E. coli*	Heavy metals							Reference directive
			cfu/100 mL	µg/L							
				Cd	Cr	Cu	Hg	Ni	Pb	Zn	
Spain	Proposed National Guidelines	Recharging of aquifers by percolation through the land	1000	5	50	5000	1	n.l.d.	50	3000	Surface Water Directive SWD
Spain		Recharging of aquifers by direct injection	0	5	50	5000	1	n.l.d	50	3000	
Spain	Catalonian Guidelines	Recharge of aquifer by percolation	200	5	50	2000	1	20	10	n.l.d.	Drinking Water D.
Spain	Balearic Islands	Recharge of aquifer by percolation	0	5	50	2000	1	20	10	n.l.d.	Drinking Water D.
Greece	Proposed Guidelines	Groundwater recharge: surface spreading (through soil)	1000	n.d.a.							

Actually, the Catalonian and proposed Spanish guidelines refer to this differentiation, as they either orient the limit values at the Drinking Water Directive parameters and thresholds or those of the Surface Water Directive as regards the heavy metal concentration.

6.3.1.3 RECREATIONAL USES

This category often distinguishes between uses with body contact (surfing, bathing) and those of non-body contact (fishing, ornamental lakes). For activities with possible temporary contact the acute infection risk is the water use implication to be regulated. What can be seen from the comparison is that even though bathing is excluded in these reuse category, the limit values are more stringent than those in the Bathing Water Directive (Table 6.6).

Table 6.6: E. coli limits for recreational uses in European and other international guidelines or regulations

Country		Wastewater reuse application	*E. coli*	76/160/EEC (BWD)	2002 (BWD) Revision
			cfu/100 mL	MPN/100 mL	cfu/100 mL
Spain	Proposed National Guidelines	Ponds, bodies of water and circulating flows, for recreational use in which the public's contact with the water is permitted (except bathing)	200	Faecal coliforms 2,000	*E. coli* 500
Spain	Catalonian Guidelines	Bodies of water for leisure use with public-water contact (non-bathing)	200		
Greece	proposed guidelines	Streams for recreational purposes, where the public is allowed contact (except for bathing purposes)	200		
California	Title 22	Recycled water used as a source of supply for restricted recreational impoundments where recreation is limited to fishing, boating, and other non-body-contact water recreational activities	2.2		

Most wastewater reuse guidelines simply adopted limit values already established in existing legislation in force. This is particularly true for chemical parameters such as heavy metals, pesticide residues and other organic components. Apart from the „classical concerns or subjects of protection“ covered by existing legislation, new risks arising with wastewater reuse have to be coped with.

6.3.2 Other command and control instruments

Alongside legislative means authorisation and licensing is another import command and control instruments applied in water management by regulative agencies and authorities. Use restrictions like quotas for abstraction or even prohibition of water withdrawal are applied as suitable means to manage water resources.

In France withdrawal from the Beauce aquifer for irrigation is metered since 1992. The total allotment for irrigation is restricted to 450 Mm^3/year for all farmers who organise the allocation themselves. When drought events are foreseeable (based on piezometric measurements) a further curtail to 40 - 50 % of the quota can be imposed (Davy, 2004)

There are tendencies in Italy to prevent industry from continuing to abstract groundwater. The change to surface water use can impose conveyance and additional treatment cost to the enterprises and probably just transposes the problem of water scarcity to another water resource. The merits of water transfer projects to augment the available amounts are uncertain because of the possible negative impacts on the catchment of abstraction. Investigations and planning to reuse wastewater instead are on their way (Marucci, 2002).

Likewise, in the Athens region, industry suffers from water rationing during drought periods (Tselentis, 1996) and would thus profit from having access to a dependable water resource.

The prohibition or at least limitations on the exploitation of a groundwater resource in the region of Limburg (The Netherlands) initiated investigations into the potential for wastewater reuse for industrial uses. Also Denmark limits groundwater abstraction to 25 % of the natural recharge (de Haan *et al.*, 2000)

It is also quite common that authorities impose conditions on water use or privilege certain behaviour. In Japan, compulsory reuse rates for high-rising buildings (< 30,000 m²) in congested urban areas are laid down (Savoye *et al.*, 2001), whereas in Israel curtailments on water supply are not administrated to farmers who are connected to a system providing reclaimed wastewater (Shelef, 2001). Consequently, the use of reclaimed wastewater has become more attractive as it is more reliable, thus offering clear production advantages.

Also in the urban environment water restrictions are applied. In Australia certain activities are prohibited unless reclaimed water is applied. Hence inhabitants connected to dual reticulation systems (Sydney Water).

6.3.3 Economic instruments

Water abstraction fee or tax

Abstraction fees are levied in a number of countries. Differentiating fees shall influence the relative consumption of groundwater and surface water. Belgium applies steeply increasing rates for groundwater abstraction which discourages large water consumers from tapping this resource. In Germany (Federal State of Baden-Wuerttemberg) abstraction of groundwater is on average charged 10 times the rate for surface water use (0.05 EUR/m³ instead of 0.0051 EUR/m³). Especially the abstraction tax introduced in Denmark 1998 (0.67 EUR/m³) caused price increases with subsequent decrease in water consumption and leakage (Kraemer, 2003) and could thus be judged a success.

Effluent charges

Effluent charges are widely used in European countries but differ remarkably with regard to their purpose and the revenues they actually raise. Only a sufficiently high charging rate can serve as an incentive to either reduce the pollution load or to avoid discharges.

As listed in Table 6.7 most European countries apply such fees and charges. Nonetheless their effectiveness differs remarkably as do the purposes for which they were established.

Table 6.7: Application of effluent charges and abstraction fees in European countries (Hansen et al., 2001; EEA, 2005; OECD/EEA, 2006)

Country	Effluent charge	Purpose	Abstraction fee
Austria	x		
Belgium	x		x
Bulgaria	x	70% of the revenue is earmarked for the National Environmental Fund for financing environmental protection projects; remaining 30% is revenue of the municipal environmental funds.	x
Cyprus	x		
Czech Republic	x	All the revenues go to the State Environmental Fund and are used for the protection of the environment.	x
Denmark	x	x	x
Estonia	x	Revenues are earmarked for the Environmental Investment Centre operating within the Ministry of Finance, and are used for financing the environmental protection projects.	x
Finland	x		
France	x		x
Germany	x	Measures to maintain and improve water quality (especially financing of WWTP), compensation payment for agricultural land set-aside, research funding	x
Hungary	x		x
Ireland	(x)		
Italy	x?		x
Latvia	x		x
Lithuania	x	70% of the total revenue from water effluent charges is earmarked for municipal environmental protection funds, 20% for the national Environmental Investment Fund. Remaining 10% is non-earmarked revenue for the central budget.	x
Luxembourg			
Malta			x
Netherlands	x	The costs of measures to counter and prevent pollution of surface waters.	x
Norway	x		
Poland	x	Financing Funds for Environmental Protection and Water Management as follows: 20% for municipal level, 10% for county, 50.4 % for provincial and 19.6% for National Fund .	x
Portugal	?		?
Romania	x	The National Company "Romanian waters" budget.	x
Slovak Republic	x	Revenues are earmarked for investments of water treatment plants, waste water collection systems and other investment measures related to water protection.	x
Slovenia	x		x
Spain	x		x
Sweden	x		
Switzerland	x		x
UK	x		x

Subsidies

Many activities in the water sector are heavily subsidised. Bulk water supply infrastructure like dams are often financed by international donor organisations (e.g. World Bank), establishment of wastewater treatment infrastructure through European Cohesion Funds and Structural Funds is quite common as are national subsidising schemes for irrigation infrastructure (Portugal, Greece, France, Spain) (WWF, 2006).

Table 6.8: Supposed impacts of conventional water management instruments on the development of water reuse

Measure or instrument	Impact or effect
Hierarchial measures Command and control Several water related directives	Template for many water reuse guidelines Yardstick for limit values
Liability arrangements	Promotion of responsible acting
Price	Reference frame work feasibility of reuse; if too low reduced competitiveness of water reuse
Effluent charges	Promotion of high treatment standards and good effluent quality

The European Environment Agency emphasises that a well functioning political, institutional and regulatory framework is essential for the effectiveness of all market-based instruments in displaying their beneficial effects (EEA, 2005). The next chapter will look into this issue in more detail with special reference to the implementation of water reuse projects.

6.4 Institutional settings - institutional capacities for water reuse

Responsibility for the overall management of water is often spread across several entities. This applies to both the water services side as well as the authority side. Drinking water production and wastewater collection and treatment services are often segregated activities performed by different legal entities or companies. But also the surveillance of natural water resources and the licensing of water use are accomplished by different authorities. Against this background the institutional attitudes to water reuse project are as expected quite diverse.

The ways in which institutional characteristics and relationships influence the success or failure of water management projects is, perhaps, the least understood aspect of sustainable water use. The 'lifecycle' of reuse schemes in institutional terms has to be depicted in more detail; particularly at what stage different institutional actors become involved, what their roles are, to what extent arrangements between actors are formal or informal, how responsibilities are demarcated and adopted etc.

There exists very little domain specific knowledge on which to base best practice in this area and many reported studies only allude to institutional relationships as influences on scheme success or failure. Perhaps the only direct evidence comes from a recent study by Lawrence *et al.* (1997) who, through the use of case study material, have emphasised that the planning and development of the institutional framework that monitors, controls and delivers treated wastewater (particularly where there are many institutions working in the same or similar areas) is vital for the safe and efficient exploitation of the resource.

One may ask, quite justifiably, why institutional issues are of importance in this context. The answer lies in the distribution of power and influence within our communities. Most of us live in societies where responsibility for different aspects of our environment (in its widest sense) has been distributed between a range of different political, regulatory, and community based institutions which use a mixture of legal, financial and educational instruments to influence, and hopefully modify, behaviour.

Natural resource management projects as extensive and multifaceted as water reuse schemes require planning and control across a range of professional and institutional boundaries. Within the context of water reuse for agriculture, the key institutional responsibilities which we might be interested in will cover subjects such as water quality, treatment plant design and operation, water distribution, cost recovery, agricultural product promotion and quality control. Responsibility for these aspects of a specific scheme will normally lie with a number of bodies, and will doubtless vary by nation state and maybe even regionally.

In addition, there will be social and economic groupings that, whilst they have no legal responsibilities, nevertheless have an economic or other interest in a reuse scheme. We can thereby list a supplementary set of stakeholders who may seek influence in the design, construction and operation of a reuse scheme; local residents, environmental protection groups, farmers organisations, wholesalers, retailers, and consumer groups. Finally, we should not overlook the organisation (which may be from the private or public sector) which will build and operate the reuse scheme. They may be the primary beneficiary of the scheme, but they are a key institutional actor. Different institutions, different incentives, different objectives, different viewpoints, different ways of articulating and arguing about the issues will exist. How can the often competing and incompatible aspirations of such a wide variety of factions be reconciled?

There are indeed many institutional factors which can cause reuse schemes to falter before they are even implemented, or fail to achieve their ambitions. We may speculate that, as has been noted with many human activities, novelty generates a conservative or even openly negative response from existing institutions. This is not to imply that such a reaction is necessarily unconstructive or harmful. It helps to remember that institutions, like individuals, have both purpose and principle; they react to propositions for reuse schemes for a reason and we do well to try and understand the stimuli which generate institutional perspectives and attitudes. In broad terms, institutional barriers to the implementation of reuse schemes in the agricultural sector are very similar to those found in schemes which provide recycled water for other purposes. Primarily, they revolve around issues of legality, legitimacy, responsibility, and trust.

The necessity to implement an interdisciplinary control board supervising the effects of the reuse practice on different environmental media, products and exposed persons might require new forms of institutional structure. As an additional new aspect, wastewater reuse asks for co-operation of experts form water suppliers and wastewater management (Okun, 2002).

It has also to be acknowledged that the promotion of wastewater reuse implementation will always require a new thinking. The Spanish case is exemplifying that the self-conception of sanitation services affords to shift from "treating for discharge" to "reclaiming for supply" (Borras, 2005) and this development has to be supported by the authorities. A successful example of tackling several shortcomings and pitfalls of institutional arrangements is the "samenstromen" in Tilburg (The Netherlands) where the municipality, the water works company and the wastewater treatment service formed an ad-hoc new structure for the undertaking of a defined water reuse activity (Maas, 2004).

Legality

Legality is an important consideration for institutional entities. Innovation in any form presents a challenge to existing legislation, particularly where the integrity and strength of petitions is judged against precedent. In countries where there is little or no regulatory guidance for reuse schemes, and there has been no previous litigation to base precedent on, institutional actors (both public and private) are understandably wary about taking on new responsibilities. They are, in legal terms at least, being encouraged to sail in uncharted waters!

The extent to which institutions can claim legitimacy to act is partly a function of their legal standing, and partly a function of how they are themselves perceived by other institutions and actors. The obvious problem here is that an institution's legitimacy profile will vary across other actors, making it difficult for all parties to reach a consensus about which actors are justified to play which role or take which responsibility. The same is true for the financial aspects of a project with regard to the distribution of cost between stakeholders.

Legal and regulatory arrangements are typically concerned with rights and responsibilities. Therefore, it often takes significant effort to take on new responsibilities and integrate their implications into existing administrative practices and procedures. Care must also be taken that any new responsibilities do not clash with existing ones or create inconsistencies or contradictions in the institution's activities.

In this respect, a lack of both knowledge and guidelines and the unwillingness to create a regulatory framework does not encourage investment in wastewater reuse especially in privatised water industries which need legitimacy. Without guidelines, authorities on the other hand lack a decision support tool when approving wastewater reuse and consequently ask for lengthy environmental monitoring to prove that no harm is being incurred to the environment or public health. This happened, for example in Greece, when reuse schemes were licensed on the basis of the most stringent rules in force, i.e. the Title 22 California (Sbiliris and Kanaris, 2003).

Impediments

Finally, some of the more common institutional issues which have been observed to restrict enthusiasm for water reuse projects can be listed as follows;

- Lack of agreement between institutional actors on appropriate regulations, standards, and / or monitoring procedures.
- Difficulty in identifying a win-win strategy
- Late or non entry of influential institution
- Waiting for reconfiguration of incentives to take effect
- Inability to envisage a resolution
- Sensitivity to negative publicity
- High perceived financial risk of the project

These points emphasise the importance of developing a 'consortium of the willing' for any type of water reuse initiative. Our experiences suggest that institutions are perhaps more pack oriented in their behaviour than might be thought. Key regulatory and commercial actors like to keep abreast of each others' opinions and intentions. Hence, reuse initiatives can fail to gain momentum if a common understanding of the problem and consensus about possible feasible solutions is not engendered amongst important institutional bodies. Unlike individuals, institutions are typically embedded in wider legal and /

or financial systems and their commitments / level of exposure to these must be recognised and addressed.

But even if the water suppliers or water agencies are willing to deliver reclaimed water, they face obstacles that may impede them in employing effective marketing strategies for recycled water. Traditionally, water agencies have not needed to engage in significant marketing activities and as a consequence may not have a track record for marketing. The diversity of the target audience might even complicate the approach (WateReuse Foundation, 2003).

6.4.1 Degree of integration of water reuse into water management

Approaches to promote and direct a desired behaviour or to avoid a detrimental behaviour are manifold but sometimes it is questionable whether wastewater reuse is a desired behaviour. This should be clearly declared as political will and be represented in the water management planning. Obviously reuse is just one out of many in water resources and demand management tools amongst which one can choose. The vague use of "one" reflects the controversial views about who should decide in these issues. In this respect the Water Framework Directive clearly demands the involvement of the public. How this could be managed for proposed reuse schemes is elaborated in chapter 10.

It sometimes appears that the implementation of wastewater reuse is hampered by one-track minded attitudes or the fragmentation of water management between disciplines and sectors.

In situations, where opportunities for demand management are not yet fully developed, water suppliers might favour the implementation of water conservation programmes which involve leakage detection and repair, water metering and consequently increasing profits instead of investing in a dual distribution system for alternative water whose quality requirements are not even well defined. In most Accession Countries, the renovation of the water supply and treatment system is a priority task (UNECE, 2001) but there are no hints on a simultaneous wastewater reuse implementation detectable in the relevant action plans. Wastewater reuse is not yet explicitly named as a tool to balance demand and supply.

Even in the case of agricultural irrigation, the possibility to augment reservoir capacities or to change to less wasteful irrigation techniques is often considered whilst wastewater reuse is not mentioned in the priorities for future water policy (e.g. the UK; Defra, 2002). Implementing wastewater reuse often appears to be the second step before even the first step of understanding it as a supplementary approach within an integrated concept has been addressed. Such lack of awareness at the supplier's side will of course slow down the development of safe reuse applications. For a better promotion of wastewater reuse it should be regarded as a fundamental element in any integrated planning among others options like leakage reduction in distribution network, water metering, reservoir capacity augmentation and so on.

The comprehensive analysis of **pressures and drivers** in the course of implementing the Water Framework Directive (Art. 5 reports) has revealed for several river basins across Europe a risk to fail the "good status" of surface water and groundwater partly due to abstraction or pollution from point sources. Appropriate measure to mitigate the detected deficiencies might include reuse.

It is documented almost uniformly: where water stress and pressures are identified, wastewater reuse is among the proposed responses, especially in semi-arid South European countries (see Table 6.9).

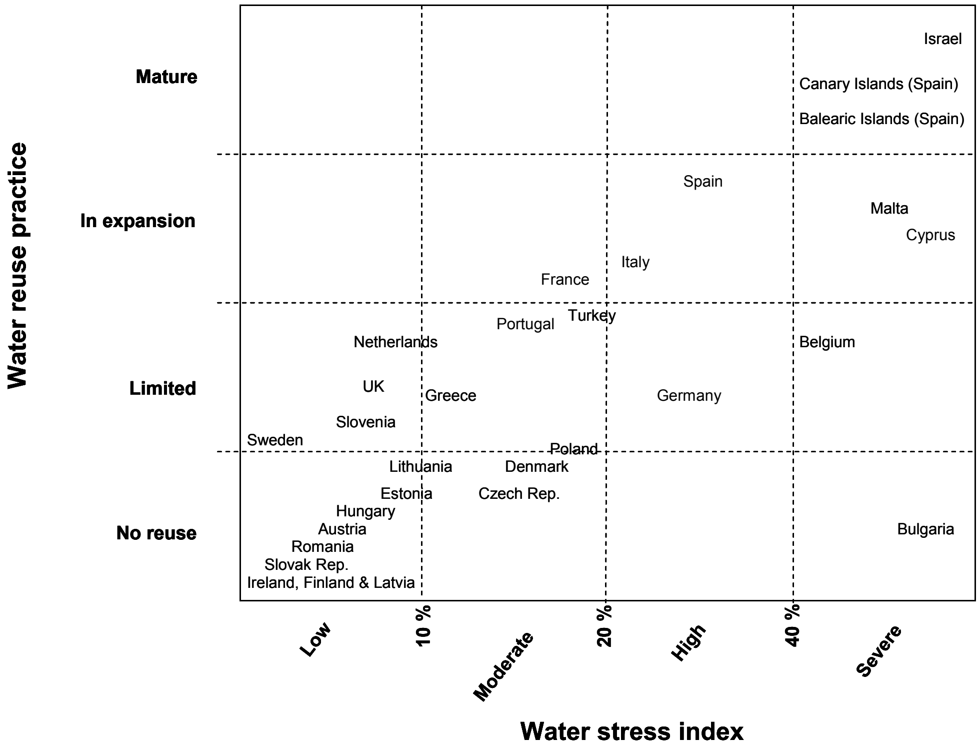
Table 6.9: State of integration into water planning in some European countries

Country / Region	Reuse as option in Water Planning	Regulation for water reuse	Financial incentives / support	Remarks
Portugal	yes PEAASAR	Norm concerning the reuse of treated wastewater for irrigation (NP4434) (2006)	?	The Strategic Plan for Water Supply and Treatment of Wastewater (PEAASAR) suggests the exploitation of water reuse opportunities.
Spain	yes A.G.U.A	yes (regional guidelines in force - national guidelines under development)	yes funding programme, subsidies for prioritised measures	The National Hydrological Plan and in particular the program A.G.U.A. clearly reflect the willingness and decisiveness to develop water reuse in order to augment available water resources. Especially on the Mediterranean coastline and islands reuse is an integral component in water resources management. Tenerife has issued a Wastewater Reutilisation Plan (Water Strategy Man, D14)
Cyprus	yes	yes Provisional Standards (1989)	?	Facing severe water stress and very limited resources water recycling is acknowledged as an integral element in the "Responses" scheme (Water Strategy Man, D14)
Israel	yes White Book	yes	yes subsidies	expansion of reuse activities (Water Strategy Man, D14), establishment of a true second water market based on this non-conventional resource
Italy	partly on regional level	yes Decree no. 185 (2003)	no ?	
Belgium	?	draft guideline		reuse activities were primarily triggered by the demand from industries

The previous chapters and sections have demonstrated that the reuse scene in Europe is quite diverse and in different stages of development. There are many different ways and motivations to arrive to a wastewater reuse practice. Moreover the concepts to develop and implement the upgrading of treated wastewater and its beneficial use are varying. Figure 6.5 illustrates the extent of water reuse practice in a semi-quantitative way.

According to this grouping Israel is considered to be in a mature state of reuse practice with both high reclamation and reuse rates and a well-founded legislative frame. Spain, Italy, France, Portugal and Cyprus are countries with expanding reuse activities under increasing regulative guidance. Still limited actions are going on in countries of different levels of water-stress, where reuse activities happen more or less on specific local or regional initiative. In countries with low water stress, reuse is not of national concern.

Figure 6.5: Extent of water reuse practice (Bixio et al., 2006)



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PART B – FRAMEWORK FOR DEVELOPMENT OF WASTEWATER REUSE

7 AN ECONOMIC FRAME TO FOSTER WASTEWATER REUSE

The establishment of an economic frame for water reuse has to take into account the existing economic background conditions given by the conventional water market. The question arising is whether reclaimed water can be placed in this market as a new product without receiving the same privileges.

The intent of this chapter is to give an overview of the status of water economics in Europe, to point out new concepts under elaboration in course of the Water Framework Directive implementation and to highlight some examples and implications for the promotion of water reuse activities.

7.1 Externalities and market failure

Although water could theoretically be a perfect private good with the characteristics of excludability (provided the ownership is clearly defined) and rivalness, the commonly rather free access to it distorts the market and generates externalities (Becchis, 2005). Other schools of thought categorise water as a common resource which is not excludable but shows features of a rival good because one person's use reduces the benefits that accrue to other users (http://www.csc.noaa.gov/coastal/economics/index.htm). Thus when these resources are available to any consumer at no cost, consumption or pollution diminishes their availability and usability to other consumers. Associated problems like overexploitation can be dealt with by defining property rights and by regulating private behaviour (e.g. abstraction limits and fees) as was already mentioned in chapter 6.3.3. Otherwise the unregulated use of the resource causes external costs which can be further distinguished as

- scarcity costs, that correspond to the opportunity value of water in alternative economic uses;
- economic externalities, that means positive or negative effects for other economic actors that are not accounted for by users;
- environmental externalities (e.g. damage and harm exerted on ecosystems),

These external costs might be intra-generational, i.e. that downstream users have to sustain extra costs for upgrading the deteriorated water quality caused by up-stream users, or inter-generational when e.g. groundwater gets contaminated due to industrial or agricultural pollution, making it unsuitable for any beneficial use (Antonioli *et al.*, 2003).

7.2 Water value - water costs - water prices

Value

One approach to properly recognise the value of water is the concept of Total Economic Value. As depicted in Table 7.1 it looks after both use and non-use values of water (or water resources and water ecosystems). The direct use values of water are related to the goods and services produced from it (drinking water, irrigation water) or the function it fulfils in a production process (cooling water, hydropower, aquaculture, shipping). Hence, access priority to water and access reliability are valued rather than the water itself (Hattan MacDonald and Dyack, 2004). Indirect use values are related to environmental functions of water and intact environmental systems whose value is not easy to assess in monetary terms.

Table 7.1: Categories of water resources and ecosystem values (adapted and modified from Spurgeon 1998, Koundouri and Karoukakis, 2005)

Total Economic Value (TEV)			
Use values		Non-use values	
Direct use goods and services	**Indirect use** indirect benefits arising from ecological systems	**Option use**	**Existence**
Drinking water Irrigation water Cooling water Hydropower Aquaculture Shipping Recipient of effluent Recreational uses	Flow Habitat Biodiversity	Future use values	Intrinsic value Spiritual value
Financial cost		Resource Cost	Environmental Cost

Cost

Utilisation of water as a good or in a production process always entails production costs, which comprise all the necessary expenses to produce a good, service or asset. The cost structure established in the water sector at most represents the operation and management cost of water supply and wastewater treatment and disposal. The bigger part is to cover capital cost as well as O&M cost of treatment schemes, distribution and collection network thus reflecting the financial cost of water services. The above mentioned externalities are typically not accounted for.

Costs therefore reflect the efficiency of the undertaking. Especially in the water sector the costs are highly dependent on the level of the provided service influenced by its reliability and its overall quality.

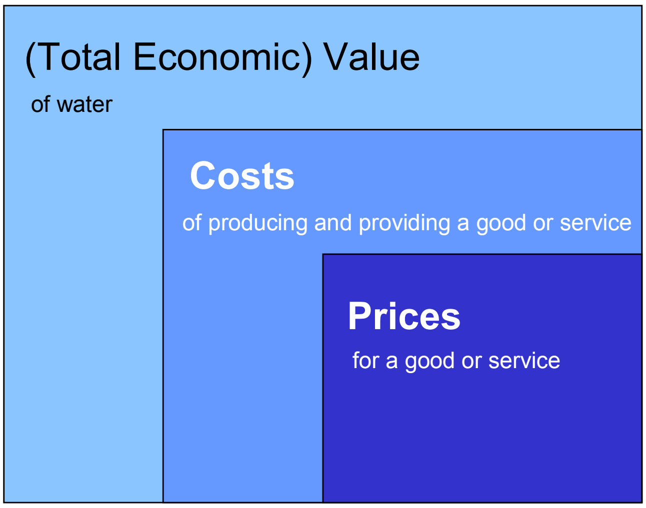
Price

Price is the assigned numerical monetary value for a good, service or asset. It is usually determined by market mechanisms taking into account supply and demand. Ideally the price should cover the production cost and reflect the value of water, hence it could give a signal for scarcity. In summary, water prices may reflect several aspects, such as

- cost coverage for a provided service
- value added contribution entailed with the use of water as a production factor
- compensation for the use of water courses for disposal of effluent.

Figure 7.1 tries to illustrate, that the price for water might sometimes only cover a small proportion of the cost and an even lower share of the value attributable to water.

Figure 7.1: Interrelation of value, cost and price



7.3 Current economic frame

7.3.1 Water pricing

Initially fixing a price for water is based on the principle of payment for use. In doing so, it aims to allocate the scarce resources among competitive uses and users. Furthermore, prices have a financing function for the supply infrastructure.

The final price can therefore comprise a variety of components, such as

- water distribution price
- sewerage price
- abstraction fee
- pollution fee
- other taxes (social fonds contribution)
- VAT

7.3.1.1 Public water services

Although the variety of tariff systems complicates a comparison, Global Water Intelligence (2005) conducted a survey on water service prices in major cities (cf. Figure 7.2). Drinking water prices range from 0.25 EUR/m³ in Bulgaria to 2.2 EUR/m³ in Denmark. Prices between 1.00 and 1.50 EUR/m³ are common in West European countries, whereas the new Member States charge on average 0.50 EUR/m³.

Wastewater prices are approximately in the same order of magnitude amounting to 0.83 EUR/m³ on average with Denmark and Germany exhibiting the highest prices again.

When drawing any conclusions from these data one has to keep in mind that the highly divergent

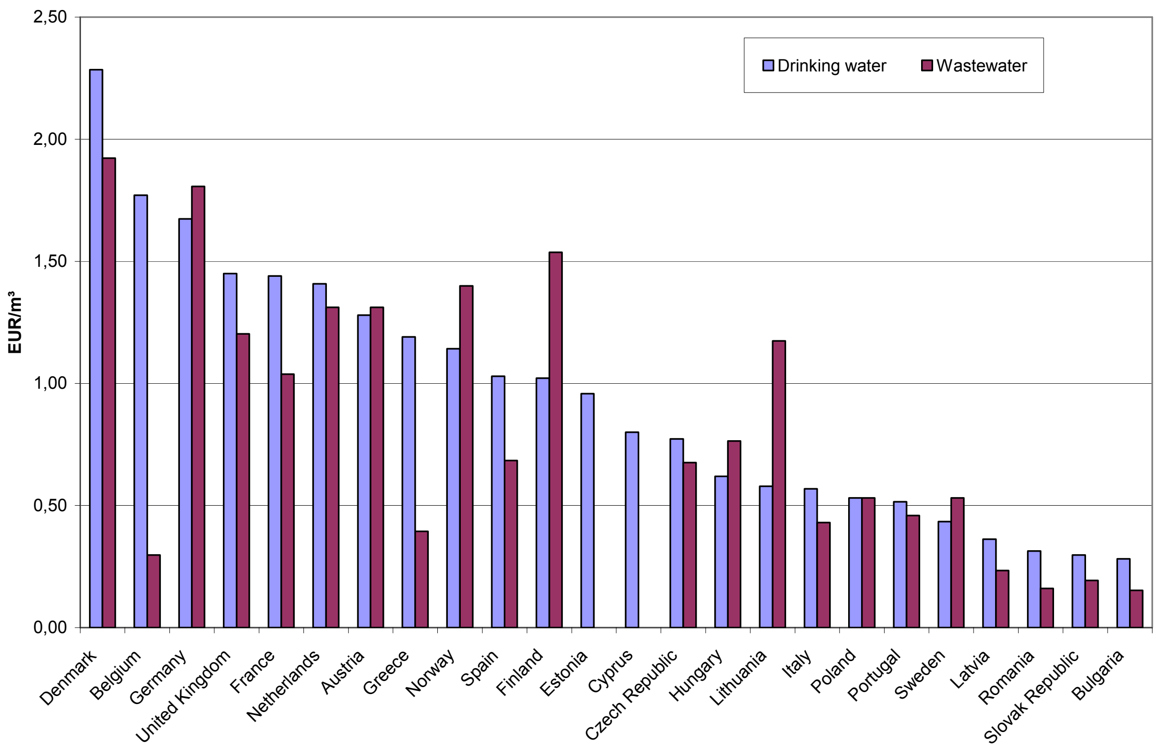
- cost recovery rates
- investment in distribution networks and treatment facilities

- service quality (e.g. reliability of supply and water quality)
- structure/size of supplied municipality

significantly determine the retail price.

Moreover, it is also part of pricing policy to restrict the social impacts when aiming for full cost recovery. The financial load of water service charges is supposed not to exceed 2% of the household income (Courtecuisse, 2005).

Figure 7.2: Prices for water services in European cities (GWI, 2005)*- domestic consumption of 15 m³/month, fixed charges added to volumetric rate on a pro-rata basis, sales taxes included - USD-EUR conversion based on exchange rate of 0.805.*



7.3.1.2 Agricultural irrigation water

Agriculture is a major water user in South European countries and also a sector absorbing most of the reclaimed water currently reused in Europe (cf. chapters 2.2.2 and 2.4.2). It is therefore worth having a look at the water prices in this sector.

It is characteristic for irrigation water that it normally stems from natural resources and does not receive substantial treatment before use. Hence the attitude to pay for it is neither well developed nor enforced by authorities. Farmers in Southern Europe either abstract water from boreholes or rivers, or are connected to a managed irrigation system. The cost to be afforded in both cases are related exclusively to the operating cost of the bulk supply system (storage and conveyance infrastructure).

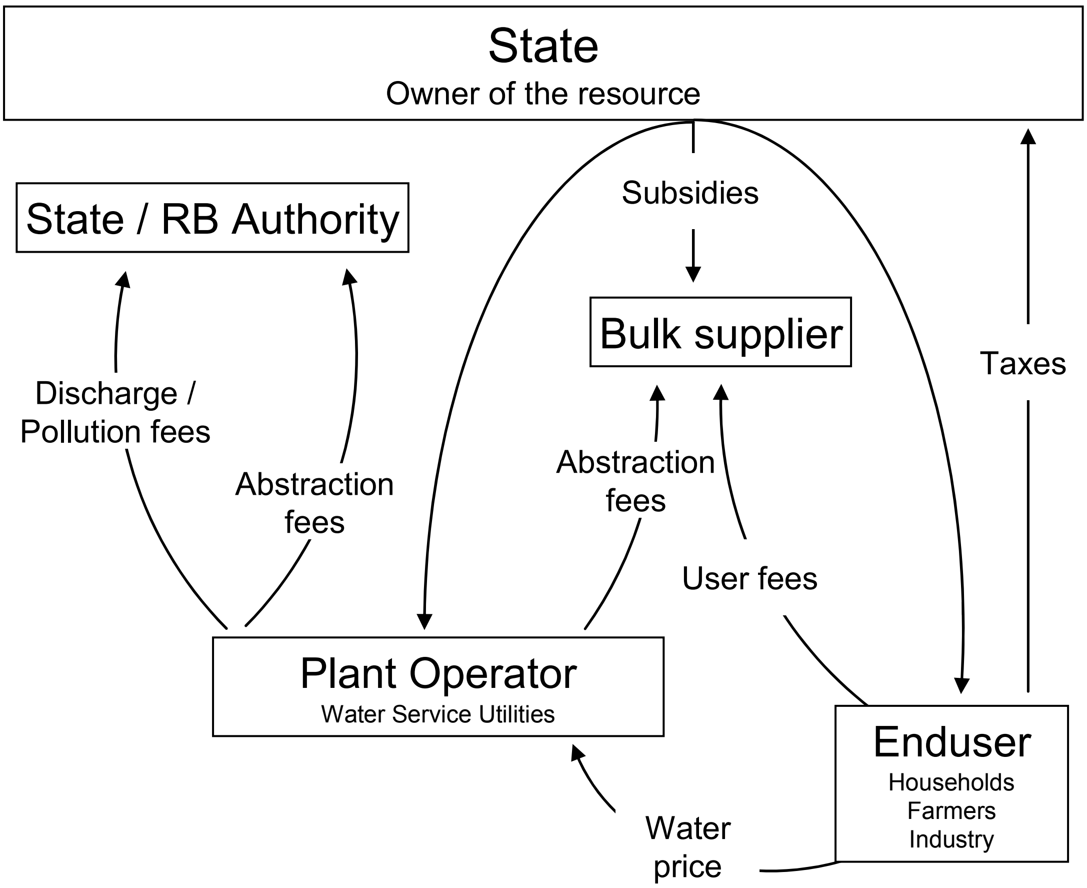
Especially in semi-arid countries, where irrigated agriculture is much more productive than rainfed one, irrigation infrastructure is massively subsidised by the government. In Greece, for example, irrigation projects are considered means for rural development in many regions and, therefore, are commonly financed by government funds. Likewise, in Spain the price of irrigation water charged by government authorities is clearly insufficient to cover operating costs (OECD, 1999). Rates paid by farmers in Spain, Southern Italy and Greece often fail to cover the operational costs of the water they receive, not to mention the even poorer coverage of the full cost of the systems (15 - 80%) (Massarutto, 2002, MOAT, 2005). For Cyprus the share of subsidies amounted to 78 % in 1999, but was progressively driven down to 62 % in 2003 by a price reform. Farmers are supposed to pay now almost twice the price of 1999, actually 0.20 EUR/m³ (Socratous, 2001).

In light of the fact that farmers obtain irrigation water at relatively low prices, there are no economic incentives to encourage them to use it efficiently. This inefficiency has resulted not only in financial costs stemming from the subsidy, but also negative environmental impacts due to overexploiting the resource.

According to Tiwari and Dinar (2001), eliminating existing subsidies and reinvesting the funds saved in technology for the efficient use of water (for example through direct grants or preferential loans) could be highly beneficial.

It is for a sure a political decision to determine how much of the cost should be subsidised or whether full-cost pricing should be applied. The aim should then be to substitute subsidies with negative effects by subsidies with positive effects that improve efficiency in the use of water. Knowledge about the less environmentally detrimental activity is a prerequisite for a founded decision. Figure 7.3 sets out the various transactions possibly included in achieving cost recovery.

Figure 7.3: Transactions along the value chain of the water sector - levels of monetary exchange (adapted and modified from Antonioli et al., 2003)
RB: River Basin Authority



7.3.2 Economic issues in the Water Framework Directive

The WFD refers to economic aspects of water management particularly in Articles 5 and 9:

Article 5 demands the economic analysis of water use which should comprise all relevant information for establishing the cost recovery principle for water services as laid down in **Article 9**. This shall take into account the environmental and resource costs associated with damage or negative impact on the aquatic environment in accordance with, in particular, the polluter-pays principle. Until 2010 pricing policy shall provide incentives to use water resources efficiently. Member States may in doing so have regard to the social, environmental and economic effects of the recovery as well as the geographic and climatic conditions of the region or regions affected. The economic analysis forms the basis for the judgement about the most cost-effective combination of measures in respect of water uses to be included in the programme of measures under Article 11 based on estimates of the potential costs of such measures.

The different terms of cost have been defined by the Working Group 2.6 for Water and Economics (WATECO) as follows:

Financial costs of water services include the costs of providing and administering these services. They include all operation and maintenance costs, and capital costs (principal and interest payment, and return on equity where appropriate)

Environmental costs "represent the costs of damage that water uses impose on the environment and ecosystems and those who use the environment (e.g. a reduction in the ecological quality of aquatic ecosystems or the salinisation and degradation of productive soils)" (WATECO, 2003)

Resource costs represents the costs of foregone opportunities which other uses suffer due to the depletion of the resource beyond its natural rate of recharge or recovery (e.g. linked to the over-abstraction of groundwater).

Figure 7.4 attributes these components to the individual steps along the anthropogenic water cycle. The picture also shows that water reuse may bypass the water environment compartment and in consequence the environmental cost to be incurred to this.

Whereas financial costs can be determined exactly, the estimate for resources and environmental costs is much more difficult. Methods to do so are currently being developed in the Common Implementation Strategy (CIS). It is of vital interest for the promotion of water reuse to put a value to these unaccounted externalities.

But the determination of the full costs is only a first step. The principle of FCR does not automatically imply to whom costs shall be assigned although an "a

7.4 Economic instruments in promoting reuse

As the analysis in Chapter 3 revealed most reuse activities are driven by water stress and scarce water resources, which in turn strives for efficiency in terms of both allocation and more rational use of water. While the use of reclaimed water is amply justified by social and environmental aspects, the reality of the situation is that its use must be encouraged in relation to the bulk of available resources. The following section discusses the possible incentives for reclaimed water as alternative resource.

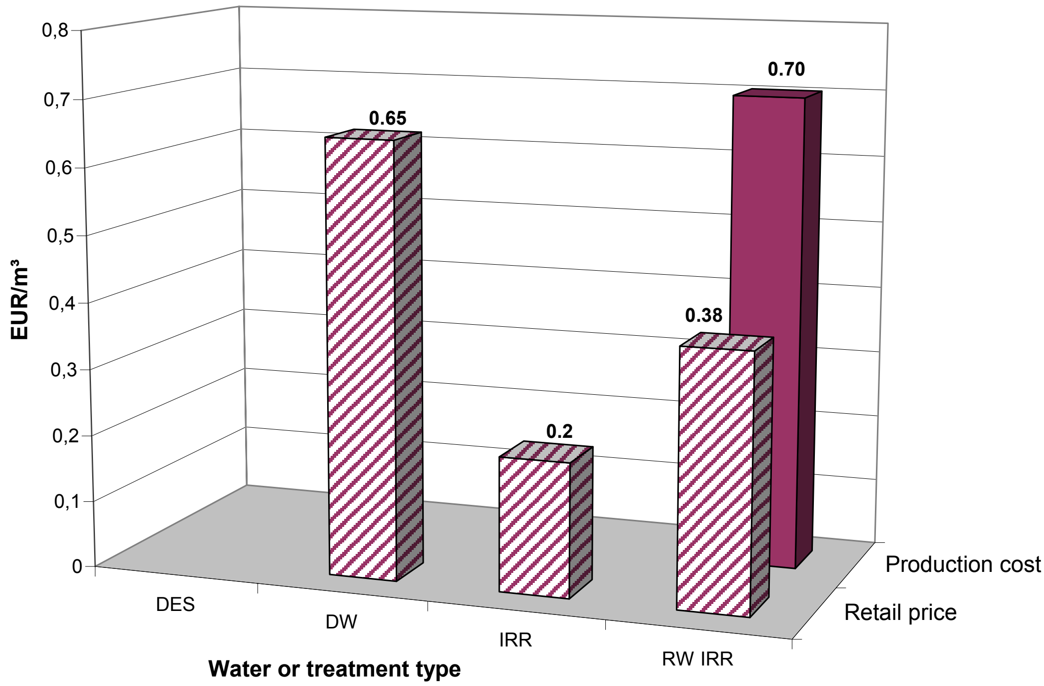
While undertaking water reutilisation projects is fully justified in terms of objectives, it is not always possible to defray its costs by charging rates. In fact, totally recovering costs by these means would imply a high willingness to pay on behalf of users, which would only be the case in regions where there are no alternative sources of water or where they are difficult to obtain.

Again a central issues arises which centres around the question of who is paying what. Is it justified that only the user of reclaimed water has to cover the costs for the upgrade and distribution? Or are rather all beneficiaries prompted to contribute to the coverage of costs. This might also include users of conventional water resources as the sustainable utilisation of these resources becomes more likely.

7.4.1 Evaluating water reuse

The evaluation of water reuse is related to questi 0 To19.ase icc611 0. sin7l. sin7l. Tc 0I8(y)-7(in)4a5-rsfc5rTJ0000024oe

Figure 7.6: Costs and prices for different water types / treatment types in Colera, Spain -
DES: desalination (no data available), DW: drinking water, IRR: irrigation water, conventional water source, RW IRR: irrigation water from reclaimed municipal wastewater

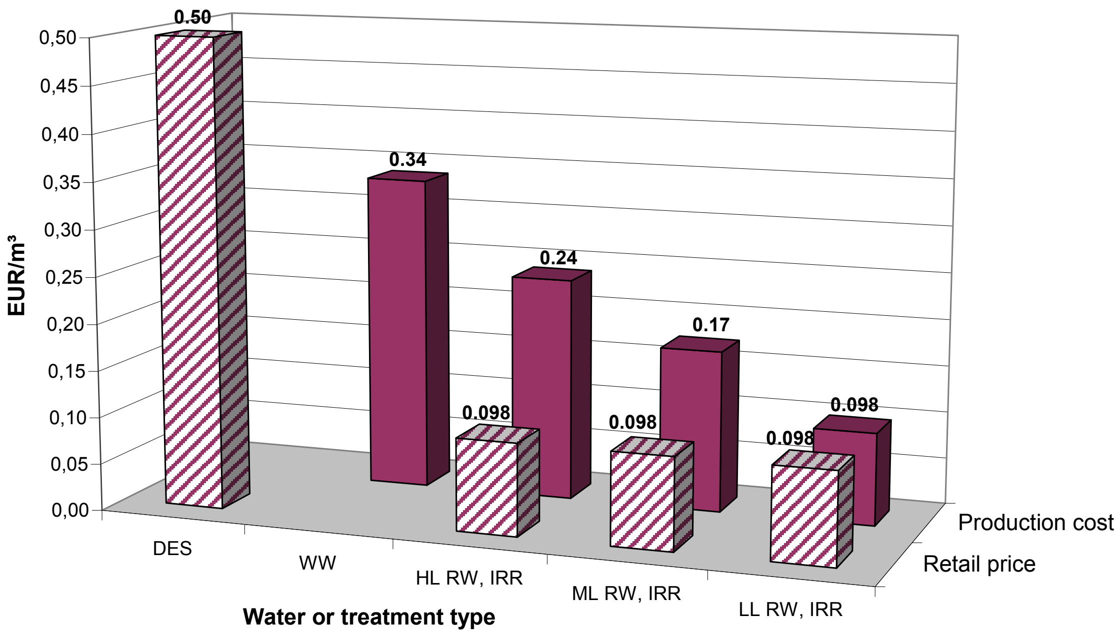


Cyprus

Drinking water in Larnaca/Cyprus is mainly produced from seawater by desalination, whereas irrigation water primarily stems from surface water reservoirs.

The production cost of reclaimed water (conventional activated sludge + sand filtration + chlorination) amounts to 0.5 EUR/m³. The retail prices are either 0.1 EUR/m³ for agricultural irrigation or 0.25 EUR/m³ for urban irrigation applications (Hidalgo, 2005) reflecting the different willingness and capability of the end users to pay (Figure 7.7). Farmers are not charged mo 0 Tw rFlecting tnga (2 Tw -21.787 vardtfl-

Figure 7.8: Costs and prices for different water types / treatment types in Israel
DES: desalination (Ashkelon plant), WW: wastewater treatment for discharge, HL RW, IRR: high level treated reclaimed water for unrestricted irrigation, ML RW, IRR: medium level treated reclaimed water for irrigation, LL RW, IRR: low level treated reclaimed water for restricted irrigation



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8 HOW TO COPE WITH RISK?

The question of managing the risks associated with water reuse is essential for sustainable and accepted water reuse development. It has often been reported that the lack of unified guidelines for water reuse in Europe with agreed criteria to assess health risks is a drawback (Marecos do Monte *et al.*, 1996, Angelakis *et al.*, 1999, Brissaud, 2006)

While chapter 5 gave an overview on the various risks of water reuse, this chapter will introduce different approaches and aspect of how to cope with risk.

One of the major concerns regarding reuse is the possible detrimental impact on human health. To minimise the health impact exerted by a product is also of high priority in the food industry. The approaches applied there can also be considered suitable for reuse activities.

In the field of food safety the concept of risk analysis has been adopted (FAM, 2003) which includes

- risk assessment
- risk management and
- risk communication

The following sections will define what these aspects could mean in the context of water reuse.

8.1 Risk assessment

A comprehensive risk management approach should address the different types of risk entailed to reuse as outlined in Chapter 5. But the safe application of wastewater reuse should particularly regard the protection of human health as its first concern. The major risks related to wastewater reuse are associated with microbial and chemical compounds of the wastewater.

The basic steps and aspects of risk assessment have been defined inter alia in the Technical Guidance Document on Risk Assessment (EC, 2003). It comprises the following four elements:

- **Hazard identification**
  which deals with the identification of cause-effect relations. It shall clarify whether a certain substance can potentially cause a detrimental effect hence analyses the pathogenic or toxic character of a substance or germ.
- **Dose-response determination**
  looks after the relationship between concentration and effect. It figures out, what is the infectious dose, hence characterises the contagious power of the pathogen or the toxicity of a substance
- **Exposure assessment**
  estimates the probability of getting into contact with a hazardous substance taking into account the concentration of pathogens or compounds, analysing the exposure routes and pattern, and appraising the amount ingested or up-taken

- **Risk characterisation**
  is the estimation of incidence and severity of adverse effects; it may include the quantification of likelihood and refers to the specific condition of a particular case

Such a quantitative risk assessment (QRA) is a demanding procedure. It requires a lot of knowledge and information about the various compounds present in wastewater and reclaimed water. In the best case, QRA can quantify the level of possible impact on the affected population and is often characterised by the number of additional illness outbreaks caused by a certain hazard. Such a number can only be the basis for the determination of tolerable risk and laying down health based targets and defining which level of risk should not be exceeded, ensured by appropriate management.

Tolerable risk and health based targets

It is recommended that the development of tolerable risk levels including health based targets for water reuse should be oriented towards established values. The tolerable risk should be comparable to those of other water exposures like drinking water or recreational water contact. (WHO, 2003; OECD, 2005; Kamizoulis, 2006). Streamlining the risk related requirements from different water uses assures equivalent health protection and incorporates water reuse in a set of consistent water regulations (Brissaud, 2006).

The US EPA sets the target risk of 1 infection in 10,000 persons per year in the Surface Water Treatment Rules (Haas, 2000). For carcinogenic chemicals in drinking water the WHO guideline defines a limit of 1 excess case of cancer in 100,000 persons. As excess burden of disease when expressed in numbers, does not directly take into account the severity of an illness or the morbidity suffered from it, the DALY concept was developed.

DALY (Disability-Adjusted Life Years)

DALYs are a measure of the global burden of disease and are the only quantitative indicator of burden of disease that reflects the total amount of healthy life lost, to all causes, whether from premature mortality of from some degree of disability during a period of time. To derive an integrated number the measure combines the years of life lost by premature mortality (YLL) with years lived with a disability (YLD). For estimating YLD, the frequency of disease, the duration and the severity are taken into account (Prüss and Havelaar, 2001)

An agreed health-based target based upon a reference level of risk of 10^{-6} DALYs could be a baseline to set specific performance targets (Kamizoulis, 2006). The limitation of particular hazardous compounds in water causing a particular loss of healthy life should then be managed in a way not to exceed this defined level of risk.

8.2 Risk management

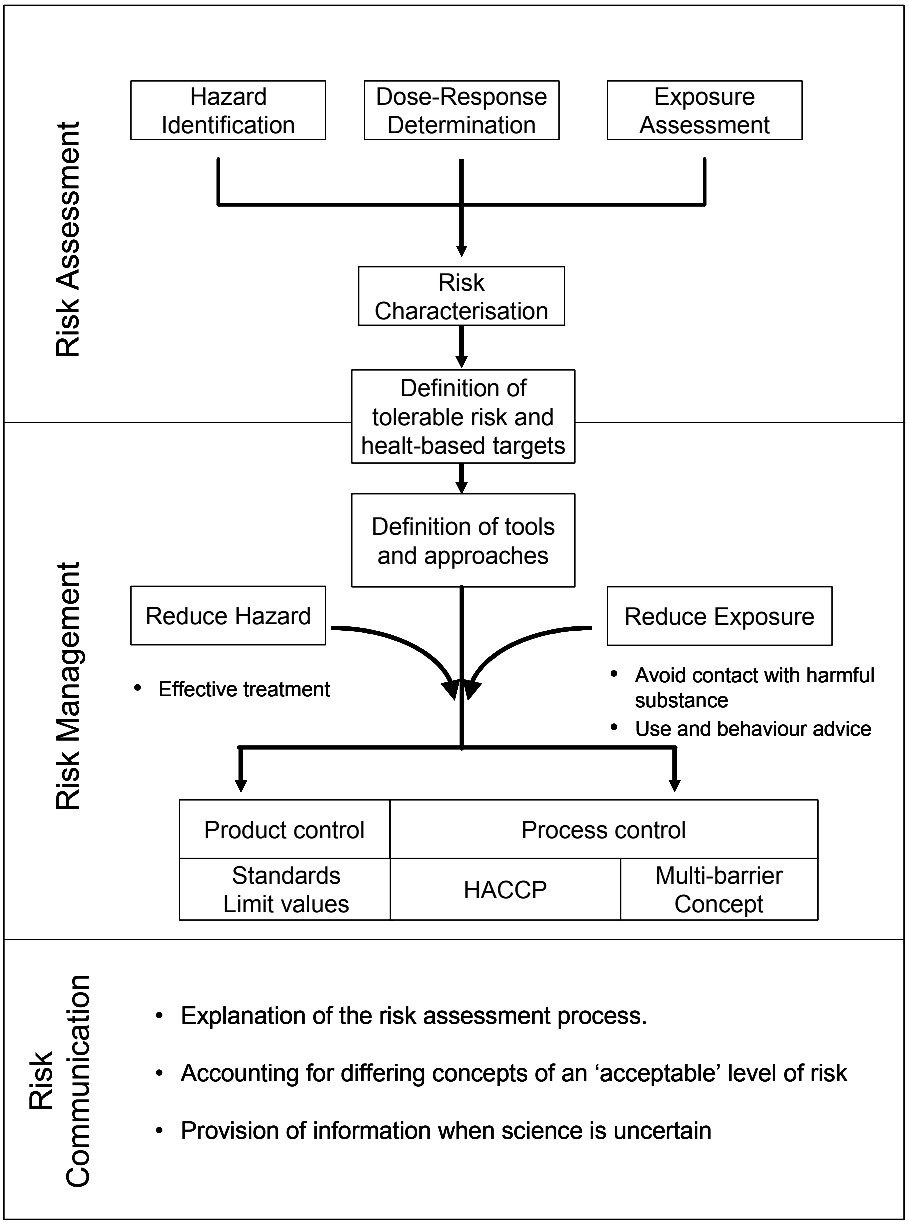
Once the desired level of protection is defined the appropriate measures to achieve and manage the installed protection aim have to be taken. According to the *Codex Alimentarius* (FAO and WHO, 2001). risk management is “the process of weighing policy alternatives in the light of the results of risk assessment and, if required, selecting and implementing appropriate **control options**, including regulatory measures. Control means prevention, elimination, or reduction of hazards and/or minimisation of risks."

These control provisions can be fixed in guidelines, regulations, handbooks or alike and may encompass a variety of elements. In general managing risk can follow two crucial principles that are logically derived from the risk assessment procedure (see Figure 8.1):

- **reduce hazard**
  avoid presence of harmful substances (source control)
  reduce presence of harmful substances (effective and reliable treatment train)
  reduce their pathogenicity → die-off
- **reduce exposure**
  avoid contact with harmful substance
  use and behaviour advice

These approaches are not mutually exclusive but can be applied complementarily to establish are comprehensive risk management system.

Figure 8.1: Flow diagram of risk analysis



The different tools applicable in this context will be described in the following paragraphs.

8.2.1 Quality standards and limit values

All existing wastewater reuse guidelines and regulations have set parametric values. They define quality standards and limit values for diverse compounds in reclaimed water, deemed a risk for human health or the environment.

Comparing different guidelines for identical uses it is striking that both the number of parameters and the limit value often vary significantly. Whereas the WHO guidelines recommend to monitors only two parameters (nematode eggs and faecal coliforms) the Italian Decree No 185 (technical norm for wastewater reuse) defines standards for 54 parameters for agricultural irrigation applications. The most quoted differences in the permissible level for faecal contamination exists between the WHO Guidelines and the California Title 22 standard (Table 8.1) representing an acceptable-risk and zero-risk approach respectively.

Table 8.1: Comparison of microbiological minimum requirements for irrigation reuse defined by the WHO and the State of California (MPN: most probable number)

	WHO	Title 22
Reuse	unrestricted irrigation	unrestricted irrigation
Microbial parameter	faecal coliforms	total coliforms
Limit value	< 1,000 number/100 mL < 200 MPN/100 mL for public lawns, (recommendation of 2003 revision) (geometric mean)	< 2.2 MPN/100 mL (7-day median)
Wastewater treatment required	a series of stabilisation ponds designed to achieve the microbiological quality indicated or equivalent treatment	secondary treatment coagulation, filtration disinfection

It is well acknowledged by the scientific community that the 'standard values that have been established are based more upon experience and philosophy than on science' (Cooper, 1998) as the whole impact of adverse effects was not yet foreseeable and risks were not yet properly assessed. This is underlined by Anderson *et al.* (2001) who identified not only the lack of knowledge but much more the lack of a unified scientific position on health and other effects as a major reason for inconsistent guidelines between and within countries. To date, limit values rather reflect a perceived risk hierarchy and are often not based on risk assessment investigations (Brissaud, 2006).

In contrast there is a uniform tendency to operate installations treating wastewater for indirect potable reuse in such a way that the effluent already matches the requirements of drinking water regulations before recharge (Mills *et al.* 1998, Dewettinck, 2001, Tsagarakis *et al.*, 2002, WHO 2003).

Moreover it is understood that the limits and target values can only be ascertained with a proper operation of the relevant treatment train, which should be an inherent component of a risk management strategy for water reuse. The concept of HACCP (Hazard Analysis and Critical Control Points) offers a tool for this purpose.

8.2.2 Hazard Analysis and Critical Control Points

A prominent example for a risk management tool is the Hazard Assessment and Critical Control Point (HACCP) system which originally was developed by the NASA space programme and has been widely adopted for the food sector. It represents a systematic approach to ascertain food (product) quality while controlling critical steps of the production process instead of relying only on end product testing (FAO/WHO 2001). In the food industry the purpose is to avoid contamination of the product with pathogenic germs or harmful substances, whereas in the context of wastewater reuse the contamination (i.e. the hazard) is already present and shall be removed or attenuated (Westrell *et al.*, 2003). But also bacteria re-growth in distribution and storage systems can be an issue.

The HACCP system consists of the following seven components:

1. Hazard analysis.
2. Determination of Critical Control Points (CCPs).
3. Establishing critical limit(s).
4. Implementation of a system to monitor control of the CCP.
5. Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.
6. Establish procedures for verification to confirm that the HACCP system is working effectively.
7. Establish documentation concerning all procedures and records appropriate to these principles and their application.

As HACCP shall support the safe operation of the installed risk reducing measures and detect any failure it has to focus on several CCPs, namely:

- Technical
  define the points of the treatment train where problems can be detected more easily.
- Sanitary
  indicate points where is more likely to generate hazards for human health (chemical and microbiological)
- Environmental
  where the main problems related to the environment can be found
- Reuse type related
  for any specific reuse, controls must extend to the related matrices, users or products (e.g. reclaimed water irrigated lettuces in the market; recharged groundwater; people eating lettuces…).

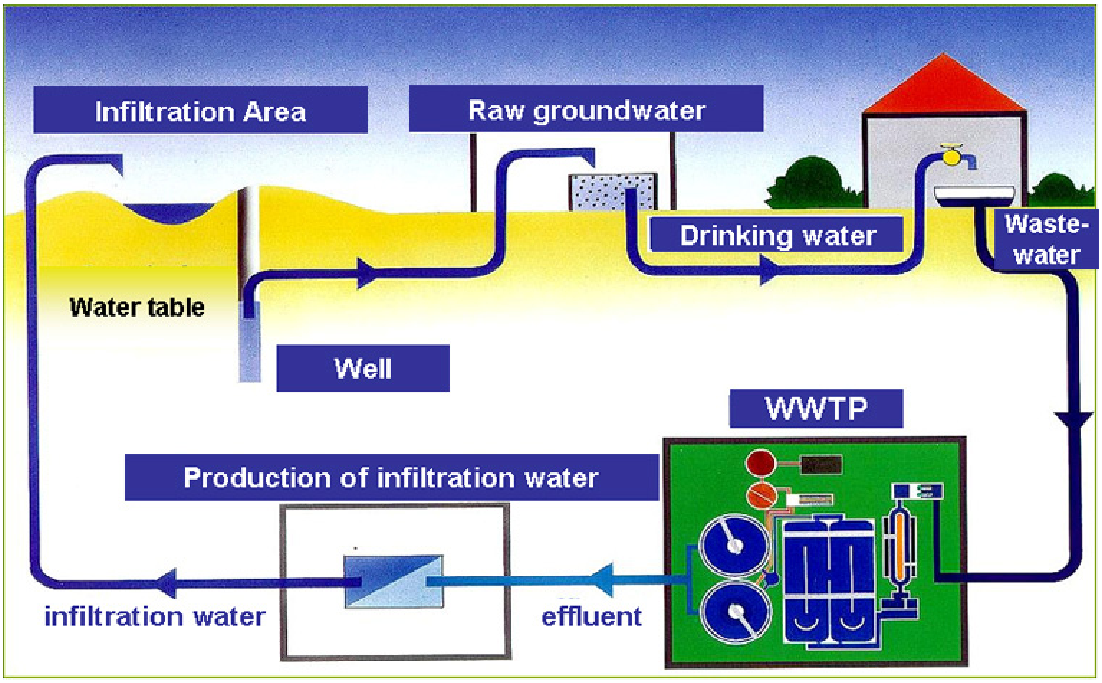
When dealing with the integrated system, several of the different types of critical points must coincide or differ. The number of CCPs must be kept reduced; otherwise the price of the controls can be unacceptably high.

8.2.2.1 EXAMPLES

Drinking water augmentation scheme Torreele, Belgium

In the western part of the Flemish coastal plain in Belgium, the Intermunicipal Water Company of Veurne-Ambacht is operating a groundwater replenishment scheme with reclaimed municipal wastewater. The region is characterised by seasonal tourism causing peak demands in the summer months. To assure a sufficient water supply it would have been necessary to increase the abstraction from the dune aquifer thus increasing the danger of saline intrusion. To prevent this, the artificial recharge with reclaimed water was set up (see Figure 8.2).

Figure 8.2: Water cycle at aquifer recharge scheme in Wulpen, Flanders (WWEE, 2001)



The effluent of the municipal wastewater treatment plant is treated with a double membrane system (microfiltration and reverse osmosis) and infiltrated into the dunes. Having regard to the well recognised hygienic hazards associated with the introduction of treated domestic wastewater into the water cycle, the concept of HACCP (Hazard Analysis and Critical Control Points) was applied to guarantee hygienically safe drinking water production. It mainly focuses on the microbial hazard and uses.

Based on literature data on pathogen concentration in effluent and the removal efficiencies of the proposed advanced treatment steps for enteric viruses and protozoa a quantitative risk assessment was performed to set quality limits. The critical control points (CCPs) were identified accordingly (Table 8.2) (Dewettinck *et al.*, 2001).

Table 8.2: Hazards, monitoring strategies and corrective actions per identified critical control points (CCP) (Dewettinck et al., 2001)

Process step	CCP	Hazard	Monitoring	Corrective action
MF	CCP1	Membrane rupture	Particle counter	Stop module
			Conductivity	Replace broken membrane
RO	CCP2	Membrane disintegration	Particle counter	Stop module
			Conductivity	Replace cartridge
UV	CCP3	Absorbance by shielding	Turbidity	Direct feedback
			UV transmittance	Check MF
		Power loss of lamp	Lamp current/lamp age	Replace lamp
Distribution net	CCP4	Recontamination	Pressure changes	Isolate part of the system, purge

Quality monitoring according to a list of parameters, i.e. performing a product and process control is already a comprehensive approach. But with a restricted number of parameters and control points, due to economic constraint, additional safety can be gained by implementing good reuse practice.

Good reuse practice (GRP) is a valuable complementary element in risk management. It is based on reasonable and responsible approaches for the operation of the whole reclamation scheme from managing the quality of raw wastewater to monitoring the effects of reclaimed water application. The specifications in GRP vary between different kinds of reuse (agriculture, urban, groundwater recharge…) but an important common element is the multi-barrier concept.

8.2.3 Multi-barrier concept

Initially, the multi-barrier concept was developed considering that every barrier should be able to reach a defined quality. In this way, using a barrier after another one or several, the final effluent quality is guaranteed nearly without any doubt. Later, the barrier concept changed and nowadays is considered as the use of several technologies or actions which imply a reduction of risks related with the use of reclaimed water. Table 8.3 gives an overview of different types of barriers and how they can be detailed in two reuse applications.

A technical barrier consisting of the wastewater treatment is indispensable. Natural barriers are optional and can constitute part of the treatment train as well. But also the natural die-off of bacteria and viruses can reduce the microbial contamination of reclaimed water even after its application in agriculture. Possible contamination on food crops are reliably reduced when a waiting period of 1-2 weeks between termination of irrigation and crop harvest is kept (Vaz *et al.*, 1996, Pfleger, 2006). Additional removal rates for bacteria, protozoa and viruses of at least 1 log in hot and sunny weather can be obtained for each day delay between wastewater application and harvest (Kamizoulis, 2006). Soil passage and adsorption processes can be very effective in reducing both some microbial and chemical compounds. Remaining levels of hazard can be coped with reducing the possible exposure so that e.g. the contamination is not transferred from the water to the crop (drip or subsoil irrigation).

The source control of raw water is a key step to avoid the input of many hazardous substances which are difficult to eliminate. A catchment pollution control plan can be implemented to exclude industrial discharges and potentially toxic compounds, unfavourably high COD/BOD ratios and poorly degradable organic substances and inorganic components. Also leakage in sewer systems can deteriorate the raw wastewater quality e.g. causing saltwater intrusion.

Table 8.3: Different types of barriers for realising a multi-barrier approach to risk management in two reuse applications

Type of barrier	**Type of application**		
		agricultural irrigation	***drinking water augmentation by groundwater recharge***
Other actions	Hazard reduction	source control of raw wastewater	source control of raw wastewater
Technical barrier		Treatment train	wastewater treatment specifications (double membranes, disinfection ...) water treatment
Natural barrier		natural, environmental post treatment, (polishing ponds, constucted wetland) adsorption, sedimentation die-off, photo-degradation	soil passage adsorption
Application barrier	Exposure reduction	waiting period between irrigation and harvest drip or subsoil irrigation, crop restriction time restriction setback distances	blending of reclaimed and natural water sufficient long detention time
Behaviour barrier		washing, cooking, processing of crops personal protection measures, hand washing	

These barriers can be used cumulative in order to minimise a risk, or they can be combined to different extents to arrive to a defined level of contamination or risk. A very efficient treatment technology will not require any application restrictions to ascertain a level of protection. But the same level may be achieved combining a less intensive treatment barrier with a more sophisticated application barrier.

Barriers can be considered as a tool box from which one can choose the appropriate instruments for health protection having regard to economic constraints and particular circumstances of the community.

8.2.3.1 EXAMPLES

Israeli barrier concept – Halperin Committee Guidelines

In this regulations the microbial criterion for unrestricted irrigation is fixed at *E. coli* contamination of <10 MPN/100mL (Aharoni and Cikurel, 2006). Reclaimed water of inferior quality can be used for restricted irrigation purposes, provided a specific number and kind of barriers is respected. Those barriers encompass (Brissaud, 2006)

- sand filtration
- long retention times in ponds and reservoirs
- effluent disinfection
- limited effluent ratio of irrigation water (dilution, blending)

- plastic mulching
- drip irrigation
- pill or shell of fruit
- vegetables only eaten cooked

Such a flexible handling of different water qualities with help of a multi-barrier concept offers much more opportunities of reusing water at affordable costs (Brissaud, 2006, Fine *et al.*, 2006).

Proposal of guidelines for Mediterranean region

Bahri and Brissaud (2002) proposed guidelines for the Mediterranean region that are oriented towards a risk management approach in wastewater reuse. The risk can be reduced either by limiting the maximum allowable microbiological content of the reclaimed water (cfu/100mL) thus reducing the potential dose during exposure or requiring no-contact application methods (drip or subsurface irrigation) which cuts the transmission path for pathogens and reduces the extent of exposure.

The Goreangab Water Reclamation project, Windhoek, Namibia

This scheme is the only direct potable reuse project world-wide. After decades of experience in potable reuse, the scheme underwent a significant refurbishment and the new Goreangab Water Reclamation project displaying a multi-barrier concept has been in operation since 2002 (City of Windhoek, 2004).

Next to catchment pollution control it is equipped with a an impressive amount of sophisticated technical barriers including pre-ozonation, coagulation, dual media filtration, main ozonation, biological activated carbon adsorption and a two-stage granular activated carbon adsorption as well as UF prior to chlorine disinfection (cf. Chapter 9.3.4). (du Pisani, 2006). The scheme has been designed to provide multiple treatment barriers for all major contaminants.

To this end the different risk management approaches should assist to

- finish the old controversy on restrictive or not so restrictive standards.
- allow qualifying a reclamation treatment depending on the quality of the water obtained.
- define the acceptable risk for a given society with its particular conditions

8.3 Risk communication

Risk communication cannot be limited to presenting and defending the established health-based targets, management approaches and compliance protocols. According to Lang "the overall goal of risk communication should not be to diffuse public concerns but should be to produce an informed public that is involved, interested, reasonable, thoughtful, solution-orientated and collaborative" (Lang *et al.*, 2001).

It has to respect that the matter of concern for the user, the consumer or in general the public is not necessarily a specific limit value defined in a guideline but the confidence and trust that the risk is negligible. Especially in the context of wastewater reuse it may be questionable whether really health safety concerns are the barrier to accepted reuse or whether it is rather the yuck factor associated to wastewater reuse. "Recycled water can't escape its past, despite stringent state regulation and assurances by officials that today's sophisticated treatment technology can scrub sewage to better-than-drinking-water standards" (LA Times, 2006).

The concepts for managing risk in planned reuse application should always take into account the reality of "managing" risks accrued with unintended indirect reuse. To communicate the real, anthropogenic water cycle to the public and to educate about the facts concerning both parts of the water cycle: from source to tap and form tap to source, constitutes a prerequisite for more acceptance and understanding (Durham *et al.*, 2005). Chapter 10 will focus on key aspects of public involvement and communication in water reuse applications.

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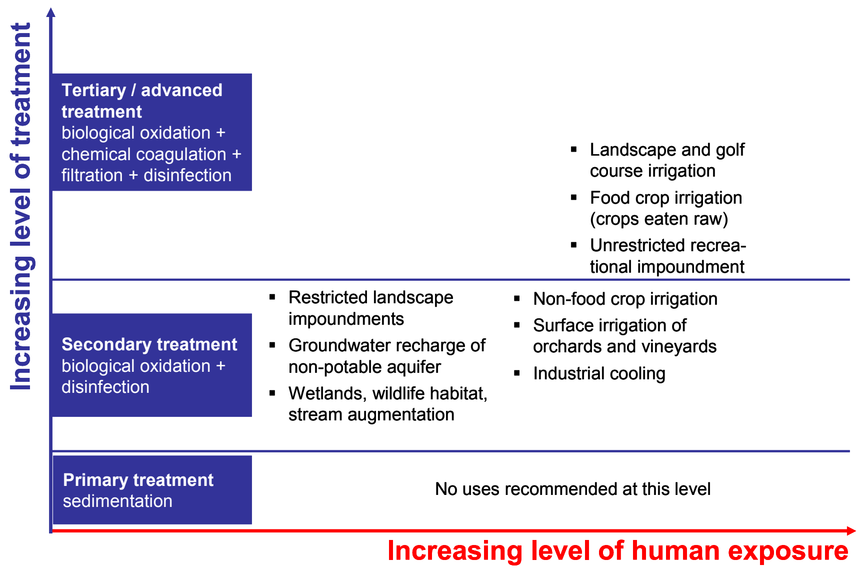
9 (BEST) AVAILABLE WATER RECLAMATION TECHNOLOGIES – WHAT IS APPROPRIATE?

Treatment technology is one of the key components of integrated water reuse concepts. Traditionally water reclamation technologies are closely connected to the water quality targets deemed appropriate for particular uses. The level of human contact has been the key factor to choose corresponding levels of appropriate treatment (see Figure 3.1).

Figure 9.1: Water recycling technologies and water quality requirements



The question of most appropriate technologies for particular local situations and water reuse purposes is of key importance for any scheme in planning and operation as well as for water recycling development as a whole. Wastewater treatment and recycling technology has developed rapidly in the last decades allowing the production of almost any water quality (even exceeding drinking water requirements) if financial and human resources are available. But this type of high-level treatment is neither required nor feasible in all circumstances. It also has to be acknowledged that the level of appropriate treatment should reflect the human health and environmental risk involved in a particular application. Locally acceptable levels of risk can vary and ways to manage risk may not only rely on water treatment but also on use practice and behavioural patterns (Kamizoulis, 2006).

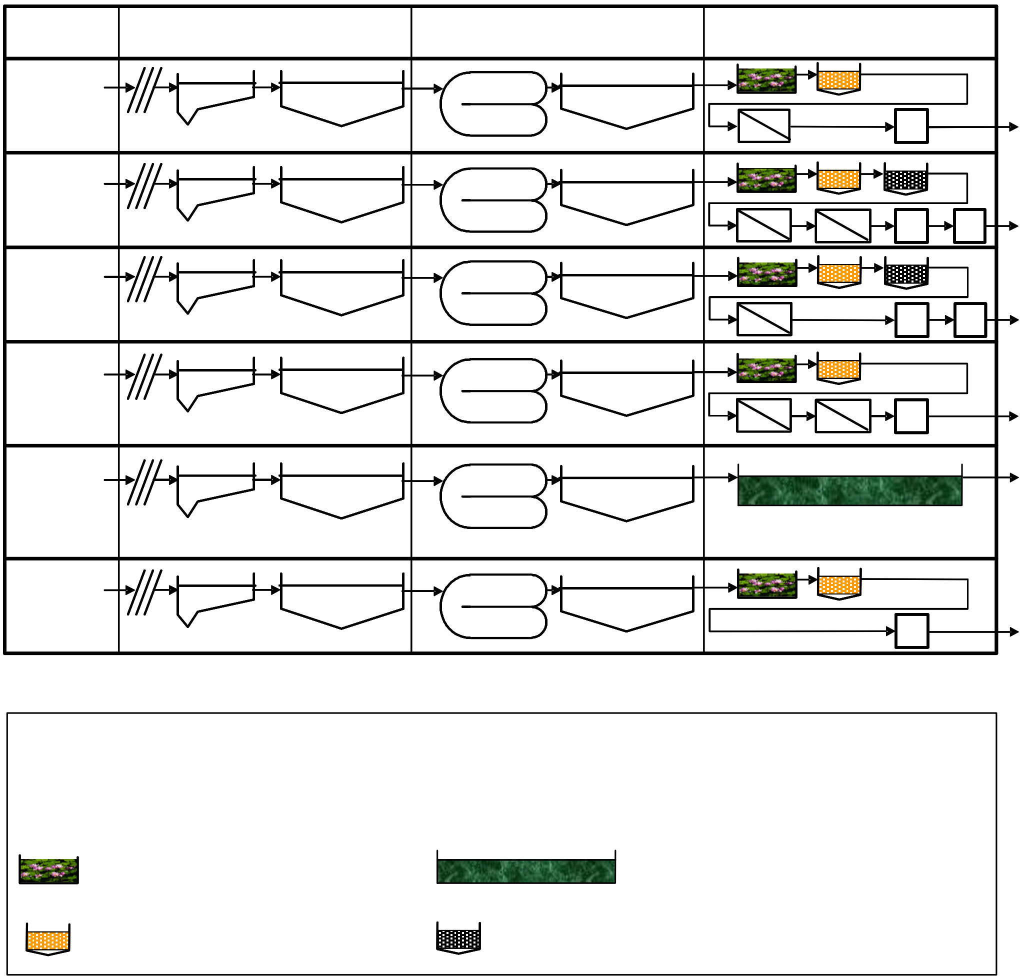
The selection of water recycling technology has always been closely connected to water quality requirements applicable for wastewater disposal as well as for the beneficial use envisaged. Factors influencing the level of appropriate technology for a particular situation are, among others:

- Wastewater quality
- Wastewater disposal requirements
- Water reuse purposes envisaged
- Water quality specifications of particular users
- Climatic conditions

- Exposure risks and risks acceptability
- Risk management approaches
- Financial resources
- Energy supply options and cost
- Constraints for sludge and concentrate disposal
- Land availability
- Geological conditions (soil and sub-soil properties)

The AQUAREC project has reviewed in detail, which treatment technologies are used in municipal wastewater recycling worldwide and collected a lot of operational knowledge (see AQUAREC Deliverables of WP6 and WP7). Also other studies have been performed to characterise treatment technologies for water recycling (Nurizzo *et al.*, 2000, Holt *et al.*, 2006, Lazarova *et al.*, 2005). It is NOT the aim of this chapter to describe and evaluate unit operations and process combinations for water recycling in detail but more generally depict the status and role of water recycling technology in integrated water reuse concepts. A wastewater treatment and water reclamation technology matrix has been developed in the AQUAREC project to illustrate possible approaches to water recycling for different applications (Figure 9.2).

Figure 9.2: Treatment Matrix AQUAREC WP7:



The treatment matrix shows which combinations of treatment processes can be regarded as suitable to upgrade different water qualities (raw wastewater, primary and secondary effluent) for different beneficial uses. These process combinations are certainly not the only technical solutions and are more dedicated to medium to large scale treatment plants than to small ones (see also chapter 9.1.2). It is obvious that the starting point for most treatment trains is the conventional secondary treatment plant concept with nutrient removal designed to fulfil the Urban Wastewater Treatment Directive (91/271/EEC) (see chapter 9.1.1).

Status and development trends with respect to municipal wastewater treatment technology will be depicted in the following chapter (9.1) as a background for the further evolution of water reuse activities. Although advanced wastewater treatment technologies become particularly suitable if there is a demand for high quality reuse (indirect potable, industrial uses, urban dual reticulation system, groundwater recharge), there are also other drivers for the application of more enhanced upgrading technologies. Among those drivers are different European water policies in place such as the Bathing Water Directive (76/160/EEC amended through 2006/7/EC and the mitigation of priority compounds according to the Water Framework Directive (2000/60/EC). These trends will be depicted in chapter 9.1.3. One of the guiding principles in setting up the water treatment matrix was to consider best available technologies, related to the definition of the Integrated Pollution Prevention and Control Directive (see chapter 9.2), which is not directly applicable in municipal wastewater reclamation, but could provide some basis to better define the “appropriateness” term as given in the Urban Wastewater Treatment Directive in respect to water reuse.

The treatment schemes in the matrix also refer to benchmark examples of water recycling schemes (see also chapter 9.3) as identified in an international survey conducted in the AQUAREC project (Bixio *et al.*, 2005). It is striking that membrane processes play a key role in most treatment schemes which serve high quality purposes (Wintgens *et al.*, 2005). But it has to be noted that also extensive or “natural” treatment processes have a role to play, particular in agricultural irrigation applications and in environmental enhancement.

While the need for “additional” treatment has long been and is probably still regarded as a costly barrier to the wider implementation of water reuse, the recent advances and different trends towards improvement of wastewater treatment technologies as well as the growing insight that certain compounds should be removed from the water cycle actually become drivers for water recycling.

Although technical solutions generally exist to achieve the desired water quality levels, research and development tasks remain to make the technologies less costly, more robust and easier to operate as well as to generate further knowledge about the impact of different technologies on an ever growing spectrum of substances of concern. These issues are addressed in chapter 9.4.

Water treatment and water reuse technologies have developed so rapidly that lacking legislative framework conditions for water recycling in Europe are anticipated as a barrier to a more widespread application of key technologies such as membrane bioreactors (MBRs) with implications for European water technology providers. The European Environmental Technologies Action Plan identifies such dependencies and seeks to mitigate barriers to the utilisation of the growth potential of water treatment technologies (European Commission, 2004).

9.1 State-of-the-art and trends in municipal wastewater treatment technology in Europe

The availability of high quality wastewater treatment plant effluent is the most important precondition to the further development of water recycling practice. This would favour stable development in Europe, where wastewater treatment standards are well defined and on the way to be enforced in the European Union through the implementation of the Urban Wastewater Treatment Directive (UWWTD) and also by the Water Framework Directive with the long term goal of achieving a good status of all water bodies. These developments have to be taken into consideration when estimating future trends in water recycling.

9.1.1 Urban Wastewater Treatment Directive compliance

Wastewater discharge has been a main polluter of surface waters. To improve freshwater quality and to prevent eutrophication of marine waters, the European Council adopted the Directive 91/271/EEC, concerning urban wastewater treatment (UWWTD) in 1991. It defines a minimum level of wastewater collection and treatment for all member states, thus promoting one prerequisite for wastewater reuse: constant availability of adequate effluents (EEC, 1991).

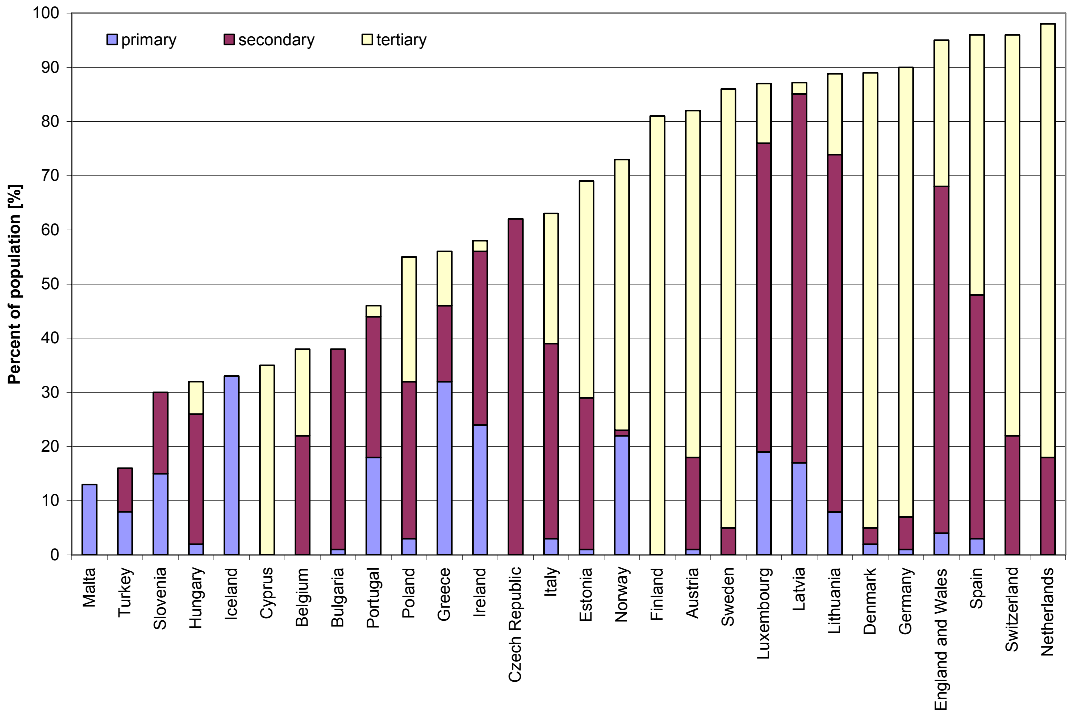
The implementation of the directive's requirements has already resulted in a steep increase of treatment capacity and treated wastewater flows in some European countries affected by water stress such as Portugal, Belgium, Spain and Greece (European Commission, 2002). In some cases the delays in installing treatment capacity may still offer the opportunity of selecting technologies that provide higher effluent quality and/or lend themselves to be combined with reclamation measures, e.g. MBR technology.

Instead of stipulating effluent quality criteria by the 'one-fits-all' principle, the distinction of sensitive, normal and less sensitive areas takes into account the ecological status and capacity of the receiving water. The measures needed depend upon the size of the agglomeration connected to a specific treatment plant. Reduction of biochemical oxygen demand is always required, whereas nutrient removal is only necessary when agglomerations over 10,000 p.e. (population equivalent) are discharged into sensitive areas.

A wide range of municipal wastewater treatment processes are used in Europe. A standard classification distinguishes primary, secondary and tertiary treatment as well as advanced or quaternary treatment. While the UWWTD defines mechanical-biological treatment with advanced nutrient removal as tertiary treatment, in the context of the AQUAREC project *tertiary treatment* is defined as a unit process or process combination following conventional biological treatment e.g. sand filtration or flocculation plus filtration. Quaternary treatment involves disinfection processes (e.g. by UV, chlorine, ozone), advanced filtration (e.g. membrane processes) or other types of treatment such as activated carbon filtration and is normally only applied if water recycling is envisaged. There are, however, a few cases of quaternary treatment prior to discharge into surface waters without direct reuse purposes (e.g. effluent disinfection with UV at the river Isar in Germany).

Figure 9.3 shows which share of the population equivalents or pollutant load respectively is currently treated with different technology levels in the EU Member States.

Figure 9.3: Levels and types of wastewater treatment in European Union Member States (according to Eurostat, 2006 and EWA, 2005)



It is obvious that many countries still have to improve the overall wastewater collection and treatment capacity. Most members states still heavily rely on secondary treatment as the standard process while tertiary treatment (which refers to plants with advanced nutrient removal including nitrogen and phosphorous elimination with biological and chemical means according to the definition of the UWWTD).

9.1.2 Extensive treatment technologies

Extensive treatment technologies are defined as those processes which generally operate at lower area or volume specific contaminant removal capacity compared to “intensive” processes. Mechanical-biological wastewater treatment including activated sludge processes in bioreactors is the benchmark standard for intensive wastewater treatment. Alternative intensive treatment processes are “biological filters” and “rotating biological contactors”. Extensive treatment processes are particularly interesting and promising when serving small and medium size communities e.g. in rural areas where the plant foot print is not a prohibitive criteria. Although examples of extensive treatment for large urban areas (e.g. Western Melbourne) exist, the plant size tends to become prohibitive when large wastewater streams have to be treated. European legislation prescribes reduced treatment standards for small treatment plants in (see UWWTD) making extensive treatment feasible for those systems. It has to be acknowledged that extensive treatment systems such as:

- constructed wetlands (horizontal and vertical flow),
- stabilisation ponds, and
- infiltration-percolation systems

can display very good treatment performance, require less energy than intensive processes, and do not demand highly trained personnel and sophisticated monitoring for operation. The International Office for Water has issued guidance notes with support of the European Commission on “Extensive wastewater treatment processes adapted to small and medium sized communities” (IOfW, 2001).

Extensive treatment processes such as polishing lagoons, constructed wetlands or soil-based processes can complement conventional secondary treatment plants and provide tertiary polishing as well as contribute to ecological enhancement of the receiving water body. Successful case studies are e.g. documented through the Waterharmonica project (Classen *et al.*, 2004).

With respect to water reclamation and reuse, an inherent advantage of these types of systems is the impact on microbiological parameters through natural attenuation effects such as filtration and degradation in the soil-root matrix or the deactivation effect through sunlight (UV) on the surface. These benefits make extensive systems attractive for small communities, helping them to meet the objectives of the UWWTD and rewarding them with opportunities for beneficial water recycling opportunities. Some case studies utilising extensive treatment technologies have been investigated in the scope of the AQUAREC project (see AQUAREC WP1 and WP7 final deliverables.)

9.1.3 Future legislative requirements and technology responses

Consequences for wastewater treatment may be expected not only from the Directive 91/271/EEC concerning urban wastewater treatment but also from the Water Framework Directive 2000/60/EC (WFD). Point sources such as wastewater treatment plants are one of the identified pressures in river basins (e.g. see Jucar Pilot River Basin Report, 2005) which might have impacts on the receiving water bodies leading to conflicts with the water quality objectives. Measures to mitigate the impact of such point sources include upgrading the wastewater treatment plants (UBA, 2005). Compared to the UWWTD, the WFD widens the spectrum of biological and chemical water quality parameters. The definition of chemical priority and hazardous priority compounds according to Annex 10 of the WFD (DECISION No 2455/2001/EC) and the subsequent establishment of environmental quality targets for these compounds (Irmer, 2005) will influence wastewater disposal technology.

The Dutch association of wastewater treatment service providers (STOWA) has reviewed the relevance of discharges from wastewater treatment plants with respect to priority compounds and an enlarged spectrum of organic compounds such as endocrine disrupting and pharmaceutically active compounds (see chapter 9.4.1). Apart from the WFD, other water quality policy documents such as the Bathing Water Directive (BWD), the Black List of the Hazardous Compounds Directive (76/464/EEC), a list of substances as prioritised by the International River Basin Management Committees for Rivers Meuse and Rhine as well as a collection of substances nominated by an STOWA expert committee have been published. Table 3.1 compares some target water quality levels to effluent concentrations measured in the Netherlands. Wastewater treatment plant discharges are relevant for a number of these substances (STOWA, 2005).

Table 9.1: Comparison of water quality targets and effluent concentrations for priority compounds (according to Stowa, 2005)

LIST OF SUBSTANCES	Bathing water Directive (CFU/100mL)	FHI avg (WFD) (µg/L)	Present in WWTP effluent 2000-2004	Max. WWTP effluent concentrations 2000-2004 (µg/L)	Relevant substance WWTP and WFD
Biological parameters					
1 Intestinal enterococci	100		+ + +	~10^5CFU/L	
2 Escherichia coli	250		+ + +	~$2*10^5$CFU/L	
3 Viruses	absent		+ + +	$1\text{-}10^3$CFU/L	
Organic Micro Pollutants					
4 Octylphenols			+ +	1.58	*5,*6
5 Nonylphenols			+	0.60	*5,*6
6 Bis(2-ethylexyl)phtalate (DEHP)		0,33	+ + +	20.00	*5
7 Benzene		16	O	0.00	
8 Benzo-a-pyrene		0.05	+ +	0.08	*5
9 Fluoranthene		0.12	+ +	0.12	*5
10 Benzo-b-fluoranthene			+ +	0.07	*5
11 Benzo-k-fluoranthene		0.005	+ +	0.04	*5
12 Benzo(g,h,i)perylene			+ +	0.06	*1,*5
13 Indeno(1,2,3-cd)pyrene			+ +	0.06	*5
14 Antracene		0.063	+ +	0.07	*5
15 Naphtalene		2.4	+ +	0.20	*5
16 Dichloromethane		8.2	O	0.00	
17 Trichloromethane		3.85	+	1.10	*1
18 1,2-dichloroethane			O	0.00	
19 Hexachlorobutadiene		0.003	O	0.00	*5
20 C10-13 – chloroalkanes			?	?	*4
21 Trichlorobenzenes		1.8	O	0.00	
22 Hexachlorobenzene		0.03	O	0.00	*5
23 Brominated diphenylethers (BDPEs)			?	?	*3,*5
Pesticides					
24 Tributyltin compounds (TBT)		1E-04	O	0.00	*5
25 Hexachlorocyclohexane / HCH / Lindane		0.042	+	0.012	*5
26 Pentachlorobenzene		0.05	O	0.00	*5
27 Pentachlorophenol (PCP)		0.1	O	0.02	*1,*5
28 Simazine			+	0.11	*1
29 Atrazine			+	0.12	
30 Diuron		0.046	+	1.40	
31 Isoproturon		0.32	O	0.00	
34 Chlorpyrifos		5E-04	O	0.00	
35 Chlorfenvinphos		0.01	O	0.00	*5
36 Trifluraline		0.03	O	0.00	*5
37 Alachlor		0.035	O	0.00	
38 Endosulfan		0.004	O	0.00	*5
Heavy metals & Others					
39 Cadmium		0.72	+ + +	0.99	*5
40 Lead		25.7	+ + +	50	*5
41 Mercury		NA	+ + +	0.14	*1.*5
42 Nickel		1.5	+ + +	36.60	*5

LIST OF SUBSTANCES	Bathing water Directive (CFU/100mL)	FHI avg (WFD) (µg/L)	Present in WWTP effluent 2000-2004	Max. WWTP effluent concentrations 2000-2004 (µg/L)	Relevant substance WWTP and WFD
Hormone disrupters & pharmaceuticals (not in Annex X of WFD)					
43 17α-ethinylestradiol			+	<0.01	
44 Bisphenol A			+ +	4.09	
45 Estrone			+ +	0.01	
46 Ibuprofen			+ + +	0.76	
47 Anhydro-erythromycine			+ + +	0.52	
48 Sulfamethoxazol			+ + +	0.13	
49 Carbamazepine			+ + +	1.00	
50 Sotalol			+ + +	1.60	
51 Amidotrizoic acid			+ + +	1.20	

LEGENDA

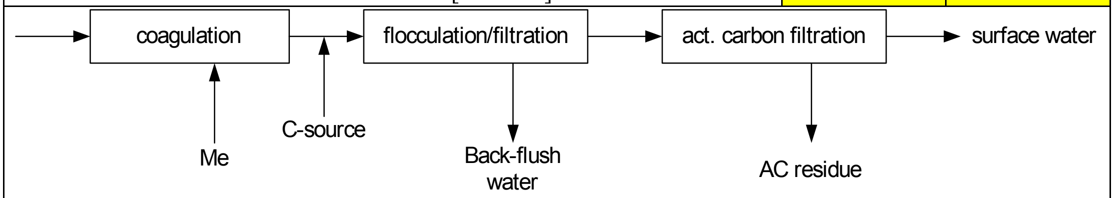
FHI avg – Yearly average standard for surface water as proposed by Fraunhofer Institute
WFD – Substance of Annex X of the European Water Framework Directive (2000/60/EC)
BATH – Parameters from the old and new Bathing Water Directive (76/160/EEG: Com 2002/581)

	Not exceeding of surface water standards
	Exceeding of surface water standards
NA	No Analysis
?	Never analysed
O	Substance is encountered in <5% of the effluent
+	Substance is encountered in >5% and <50% of all analyses in the effluent
+ +	Substance is encountered in >50% and <95% of all analyses in the effluent
+ + +	Substance is encountered in >95% of the cases
	Substance not relevant for WWTP
	Not clear whether the substance is, or is not, relevant for the WWTP
	Substance relevant for WWTP
*1	Substance is encountered in WWTP effluent, but nationally the standard is not exceeded. Locally it may be a problem.
*3	Substance was not measured in water. Substance was measured in suspended solids of WWTP effluent.
*4	There was no analytical method available to measure this substance in WWTP effluent.
*5	Apart from measured dissolved concentrations also suspended solids in the effluent play a role in the load of the surface water; log K_{ow}>3.0.
*6	No measurements available in the surface water to check.

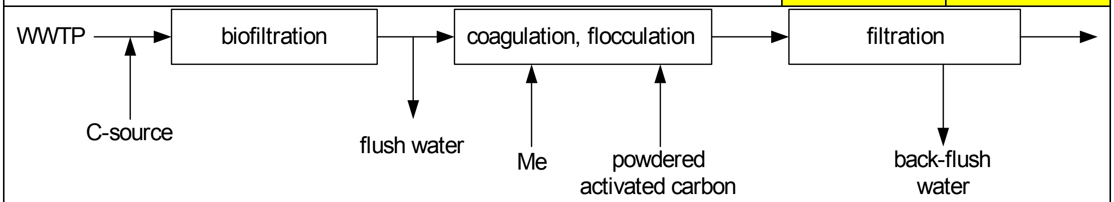
STOWA has also investigated options to extend conventional wastewater treatment to increase the removal efficiency for priority compounds. Considering both the treatment effectiveness and the additional cost for two different scenarios (20,000 and 100,000 PE treatment plants) three different multi-barrier treatment trains are recommended for a possible treatment extension (see Figure 9.3). If the local situation also requires compliance with the Bathing Water Directive additional treatment with UV radiation is recommended (STOWA, 2005).

Figure 9.4: Extended wastewater treatment options recommended for enhanced WFD compliance (modified from STOWA, 2005)

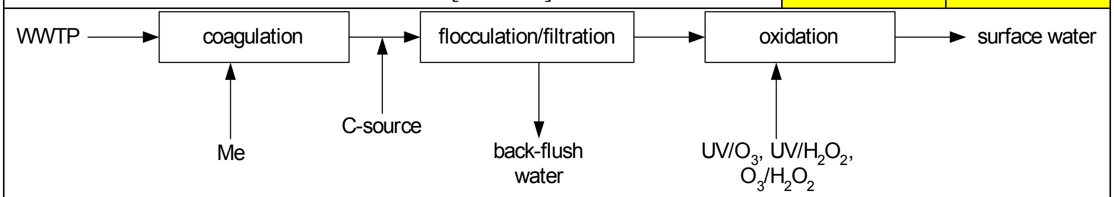
Scenario	Treatment techniques	Explanation	Cost 20,000 p.e.	Cost 100,000 p.e.
WFD 1	in line coagulation	Dosage of metal salts (Fe/Al)		
	bio / flocculation filtration	Dosage of metal salts (Fe/Al) Partial precipitation / flocculation of particles and dissolved organic macro-molecules, including (colour-) components, dissolved metal complexes		
	activated carbon filtration	Operation time of activated carbon dependent on loading with competing dissolved organic compounds external reactivation of activated carbon		
	Total treatment costs [EUR/m³]		0.35	0.17



Scenario	Treatment techniques	Explanation	Cost 20,000 p.e.	Cost 100,000 p.e.
WFD 2	biofiltration (denitrification)	Dosage of C-source (methanol, acetate etc.) Treatment of back flush water in main sludge treatment process		
	coagulation, flocculation	Dosage of metal salts (Fe/Al), powdered activated carbon (PAC) dosage (10-20 mg/L) with 20 min contact time floc. forming, adsorption of contaminants to PAC		
	flocking filtration (P-precipitation, adsorption)	Treatment of back flush water in main sludge treatment process		
	Total treatment costs [EUR/m³]		0.34	0.15



Scenario	Treatment techniques	Explanation	Cost 20,000 p.e.	Cost 100,000 p.e.
WFD 3	in line coagulation	Dosage of metal salts (Fe/Al), dosage of C-source (methanol, acetate)		
	flocculation/ filtration	(partial) removal of phosphate particles and dissolved (colour-) components. Treatment of back flushed water in sludge treatment of main process.		
	(advanced) oxidation	UV/ozone, UV/H_2O_2, ozone/H_2O_2		
	Total treatment costs [EUR/m³]		0.43	0.24



It has to be noted that those extension options cannot be regarded as a generally applicable recommendation. Potential measures have to be specific to the situation and possibilities in the particular basin or sub-basin. But the studies show clearly that the European wastewater service providers are seriously considering the future requirements and needs for action arising from the Water Framework Directive. The review also shows which treatment processes and process combinations are regarded as most promising technology responses. It is evident that such advanced wastewater treatment systems will enhance the opportunities for water reuse, as the quality obtained will be suitable for most non-potable applications, if UV disinfection is included. The local water balance and use requirements will determine whether reclamation of such a high quality effluent is beneficial. As indicated in Figure 9.3, most process combinations include coagulation, flocculation and filtration as core units to remove residual particular matter and enhance nutrient elimination as well as at least partially remove dissolved priority compounds which can bind to the removed species. Activated carbon and advanced oxidation processes are considered as removal options for dissolved compounds.

But neither advanced oxidation processes nor activated carbon adsorption can be regarded as universal processes as not all priority compounds are well adsorbable or completely removable with chemical oxidation. In the STOWA study, nanofiltration, which has indeed a more universal retention capability, has not been selected as promising option due to cost arguments and concentrate generation. The issue of universally applicable treatment options is further discussed in chapter 9.4.1.

9.2 Definition and application of best available technologies for municipal wastewater treatment

Originating from the definition in the *Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (IPPC Directive)* the term of "Best Available Technologies" has made its way into different pieces of environmental legislation in force in the European Union Member States. Chapter 9.2 depicts whether the application of such an abstract technology level will have consequences for environmental quality objectives impacts on municipal wastewater treatment and reuse technology development.

9.2.1 Best available technologies in the Integrated Pollution Prevention and Control Directive

The IPPC Directive relates primarily to industrial activities. The following definitions are used:

- **Best available techniques**: most effective and advanced stage of operation methods which indicate the practical suitability of particular techniques to prevent or reduce emissions;
- **Techniques**: Both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;
- **Available**: implementation in relevant industrial sector feasible under economically and technically viable conditions;
- **Best**: most effective in achieving a high level of protection of the environment as a whole.

To establish the desirable level of "Best Available Technologies" which serves as benchmark the general design and operation criteria contained in Annex IV of the IPPC Directive should be considered. These are:

- low-waste technology,
- use of less hazardous substances,
- recovery and recycling of substances,
- comparable processes, facilities or methods,
- consumption and nature of raw materials used,
- energy efficiency,
- technological advances and scientific knowledge,
- likely economical consequences.

Whereas water quantity is related to water use and consumption, water use intensity depends upon the substances discharged with wastewater. The main water contaminants originating from industrial activities are listed in Annex III of the IPPC Directive, as follows:

- Oxygen demanding compounds (BOD, COD)
- Eutrophicating compounds (nitrates and phosphates)
- Suspended solids
- Biocides and plant health products
- Persistent and bio-accumulable organic toxic substances
- Metals and their compounds
- Carcinogenic or mutagenic substances
- Reproduction affecting compounds (Endocrine Disrupting Chemicals)

The impact of those compounds has to be taken into account when defining best available technology standards.

9.2.2 BAT levels in industrial wastewater treatment

As part of the implementation of the IPPC Directive a number of "Best Available Technology Reference Documents" (BREF) have been issued for a range of industrial sectors, which should deal as a guidance for both industrial companies as well as permit issuing institutions. The BREFs issued by the European IPPC Bureau (http://eippcb.jrc.es) are the result of an information exchange and consultation processes going on between the Member States. Table 9.2 gives an overview on the BREF documents issued so far and under finalisation.

Table 9.2: Overview on the available IPPC BREF documents (IPPC Bureau, 2006)

Production of Iron and Steel
Ferrous Metals Processing Industry
Cement and Lime Manufacturing Industries
Non Ferrous Metals Industry
Pulp and Paper Industry
Chloro-Alkali Manufacturing Industry
Industrial Cooling Systems
General Principles of Monitoring
Tanning of Hides and Skins
Textiles Industry
Large Volume Organic Chemical Industry
Glass Manufacturing Industry
Mineral Oil and Gas Refineries
Intensive Rearing of Poultry and Pigs
Common Waste Water and Waste Gas Treatment / Management Systems in the Chemical Sector
Slaughterhouses and Animal By-products Industries
Smitheries and Foundries Industry

Apart from these documents a number of additional sectors will be published soon or are in preparation. Among those are BREFs for "Waste Incineration" and "Waste Treatment Industries". Nevertheless it is currently not intended to develop a BREF on "Municipal Wastewater Treatment". Some of the BREFs mentioned above have a strong focus on the water management in the relevant sectors and also cover industrial water recycling (e.g. for the chemical sector, EC, 2003). The BREF document for the *Industrial Cooling* sector does explicitly mention the reuse of reclaimed municipal wastewater as cooling water make-up as a best practice reference (EC, 2001).

9.2.3 Incorporation of BAT in municipal wastewater treatment on Member State and Community level

As indicated in the introduction to chapter 9.2, the term "level of best available technologies" has been introduced in different pieces of environmental legislation in force, e.g. in the German Federal Water Act ("Wasserhaushaltsgesetz"). According to § 7a of the German water law wastewater treatment has to be carried out according the level of best available technology. This phrase has complemented the former term "accepted level of technology". An adaptation to "best available technologies" would also have to be applied to water recycling practices.

There are considerations going on in different water authorities about the potential consequences of the introduction of the "BAT principle" concepts into the wastewater treatment sector (Ries *et al.*, 2005).

9.3 International benchmarking of water treatment technology

This sub-chapter provides a short overview on what could be regarded as benchmark technologies in water recycling according to full scale applications in operation. Needs for more advanced technologies from the point of new water quality parameters are considered. Studies about the application of water recycling technologies, which have been conducted in the scope of the AQAUREC project, are summarised and some examples of prominent treatment schemes are given. An overview on typical treatment cost levels for important water reclamation technology levels and water reuse types in given in Table 9.3.

Table 9.3: Typical water recycling cost for different applications (GWI, 2005)

Type of water reuse application	Typical total cost [EUR/m³]
Distributing secondary treated wastewater for restricted agricultural use near treatment plant (no additional treatment)	0.02-0.08
Tertiary treatment facility with distribution network to supply industrial and bulk municipal users within 10km (includes new tertiary treatment facility)	0.4-0.7
Groundwater recharge with quaternary treated wastewater (includes tertiary treatment facility and recharge system)	0.4-1.0
Unrestricted use dual piping systems for existing neighbourhoods (includes distribution network and tertiary treatment plant)	1.0-1.7

9.3.1 New water quality parameters of concern – a need for more advanced technology?

Conventionally treated wastewater contains a wide range of contaminants from suspended solids to the smallest of inorganic salts. Many of these are known or suspected to be detrimental to various reuse applications. A number of key contaminant categories are described in the following paragraphs.

Microorganisms represent the most common threat to the reuse of wastewater, due to the large concentration of potentially infectious species that routinely are present in the effluent from secondary treatment plants (cf. chapter 5.1) . Disinfection processes are hence one of the core elements of water reclamation technology. Traditionally chlorine and chlorine compounds have been used for pathogen inactivation (Lazarova, 2004; Salveson *et al.*, 2005). As a consequence of the debate about the formation of disinfection by-products (Mitch *et al.*, 2002), which are potentially harmful to human health and the environment, chlorination has been replaced in many cases by UV disinfection, which also has a better effectiveness on some pathogens such as protozoa and viruses (Jalali *et al.*, 2005; Lazarova *et al.*, 2005). Although ozone as well as other advanced oxidation techniques are possible alternatives, by-product formation issues and operation cost have been a competitive disadvantage. The main characteristics of the major disinfection technologies are compared in Figure 9.5

Figure 9.5: Main characteristics of different disinfection techniques (Lazarova, 2004)

Characteristics	Chlorine	Ozone	UV	MF	UF
Bactericidal action	++	++	++	+++	+++
Virucidal action	+++	+++	+	++	
Bacterial reviviscence	+	++	+	--	
Residual toxicity	++	+	-	--	
By-products	++	+	-	--	
Operating costs	+	++	++	+++	+++
Investment costs	+	+++	++	+++	+++

"-" none ; "+" low; "++" middle; "+++" high

Membranes have made their way into many advanced wastewater treatment and reuse schemes and one major objective is the retention of microorganisms. In contrast to the deactivating effect of chemical disinfection, membrane processes provide a relatively effective physical barrier for all microorganisms, including viruses. This is true even for microfiltration (MF), which by pore size alone would not retain most viruses. However, the tendency of viruses to attach to other solids, aggregate with each other and the formation of a deposit on top of the actual filter lead to reduction factors around 10^4 for bacteria and well over 10^2 for viruses.

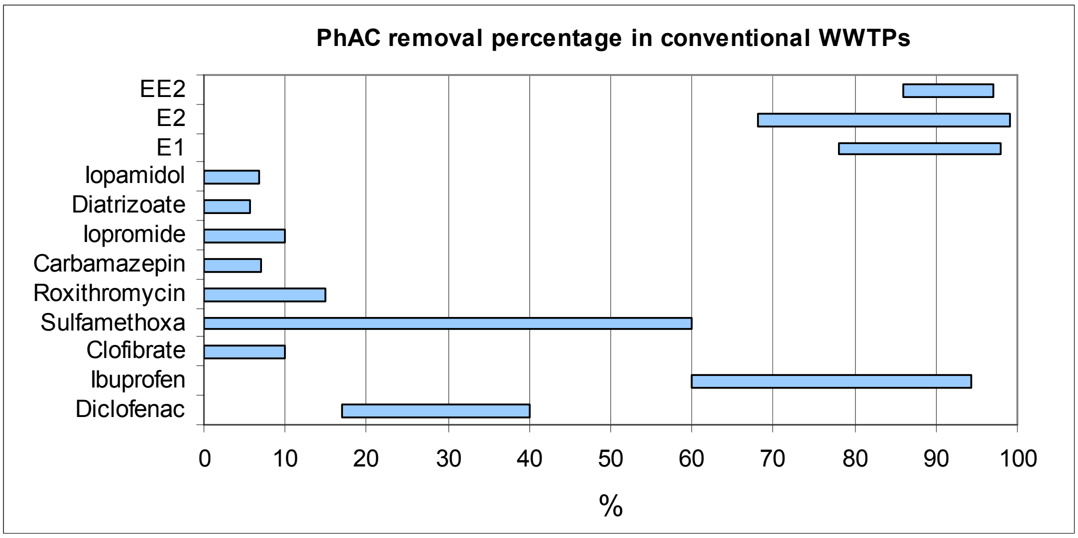
Inorganic salts such as sodium chloride and a suite of trace elements including heavy metals may be introduced to irrigated land and associated waterways via recycled water. In dry climates, much of the irrigation water evaporates and the concentration of salts in the drainage can be much higher than in the water itself, posing potential threats to groundwater quality (Bouwer, 2000). Salinity is already a major environmental problem in many parts of the world including Australia, and care must be taken not to exacerbate this problem with inadequately treated recycled water. Only dense membrane processes such as reverse osmosis and - to a somewhat lesser degree - nanofiltration are able to address this important water quality parameter.

An increasingly documented class of trace organic contaminants in wastewater are the "endocrine disrupting chemicals". Much attention has been devoted to natural and synthetic hormones, which have shown to induce biological effects on some organisms at part per trillion concentrations. Some steroidal hormones are poorly removed in conventional water treatment processes. Other chemicals exhibiting similar effects at higher concentrations that are known to be present in sewage include some plasticisers, pesticides and degradation products of some detergents. According to state of the art knowledge, these substances pose a threat primarily to aquatic organisms and would not necessitate restrictions for most reuse applications.

Further widespread attention has been given to the broad range of pharmaceutically active compounds which have been reported in municipal wastewaters in many parts of the world (Andreozzi *et al.*, 2003;

Huggett *et al.*, 2003). At this point there are no indications for limitations to water reuse caused by these compounds, although their effect is largely unknown. Figure 9.6 shows removal rates of a range of organic trace contaminants in conventional wastewater treatment plants on the basis of a broad literature survey.

Figure 9.6: General PhAC removal percentages in conventional WWTPs (Yu et al., 2005)



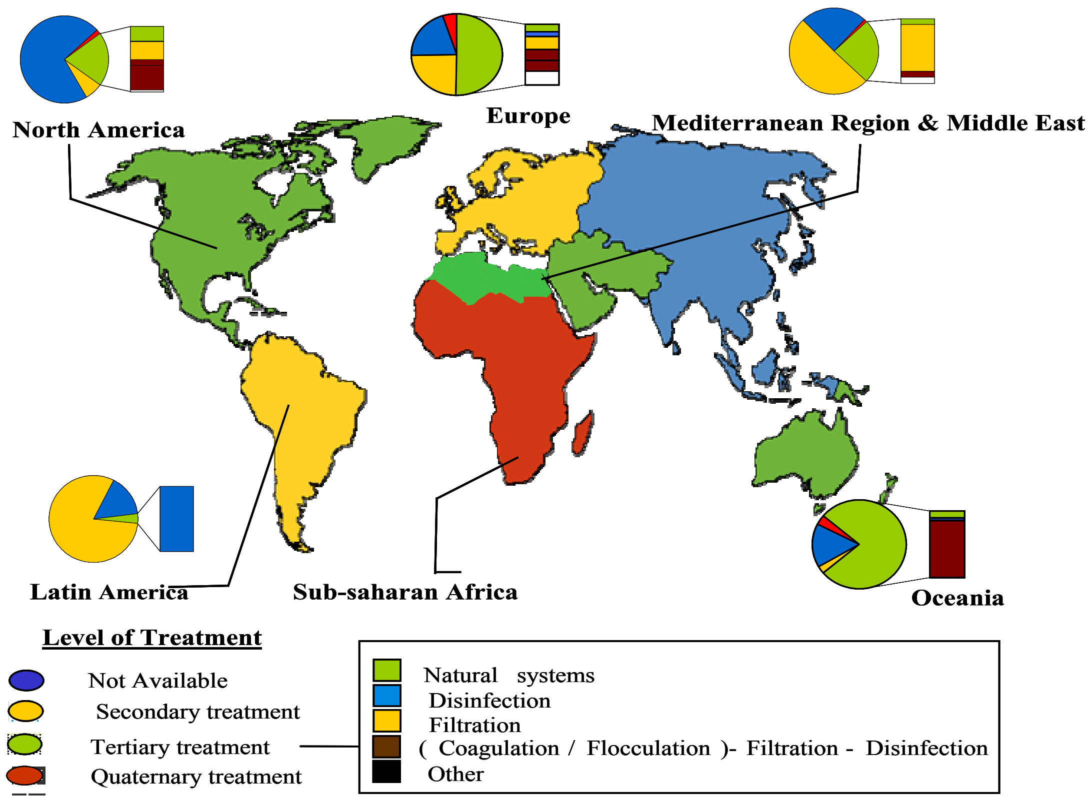
As in drinking water, by-products of disinfection processes may yet prove to be among the greatest chemical concerns in recycled water. In the USA and Canada attention has been recently given to the detection of a potent carcinogen, nitrosodimethylamine (NDMA) in chlorinated treated waste water intended for reuse. NDMA is believed to be formed as a by-product of the disinfection process and is reported to be best removed by UV catalysed oxidation (Mitch *et al.*, 2002).

It has previously been noted that we are technically capable of treating wastewater to any quality we desire simply by "filtering it through money", i.e. by applying the most sophisticated (and costly) separation technology. Membrane treatment processes present a clear example of this correlation between quality and cost. In many circumstances, the high cost associated with dense membranes will not be justifiable and porous membranes may be employed to produce reusable water of more limited quality. Furthermore, even dense membranes show limitations with regards to some contaminants (e.g. NDMA). Accordingly, the level of treatment applied will necessarily represent a compromise between the nature and concentration of contaminants and the associated treatment costs.

9.3.2 Technologies applied in state-of-the-art water treatment and recycling

The most common reclamation technologies and reuse applications in different regions of the world are illustrated in Figure 9.7. The number of water reuse schemes per field of application and the level of treatment – secondary, tertiary or quaternary – are indicated (Bixio *et al.*, 2004). Note that wastewater reclamation refers to the treatment or processing of water to make it fit for reuse, which is defined as any kind of beneficial use of reclaimed water (Lens *et al.*, 2002).

Figure 9.7: Water reuse schemes per field of application (bar-charts) and level of treatment (pie-charts with attached bar for main tertiary treatment processes) in different regions of the world (Bixio et al., 2004)

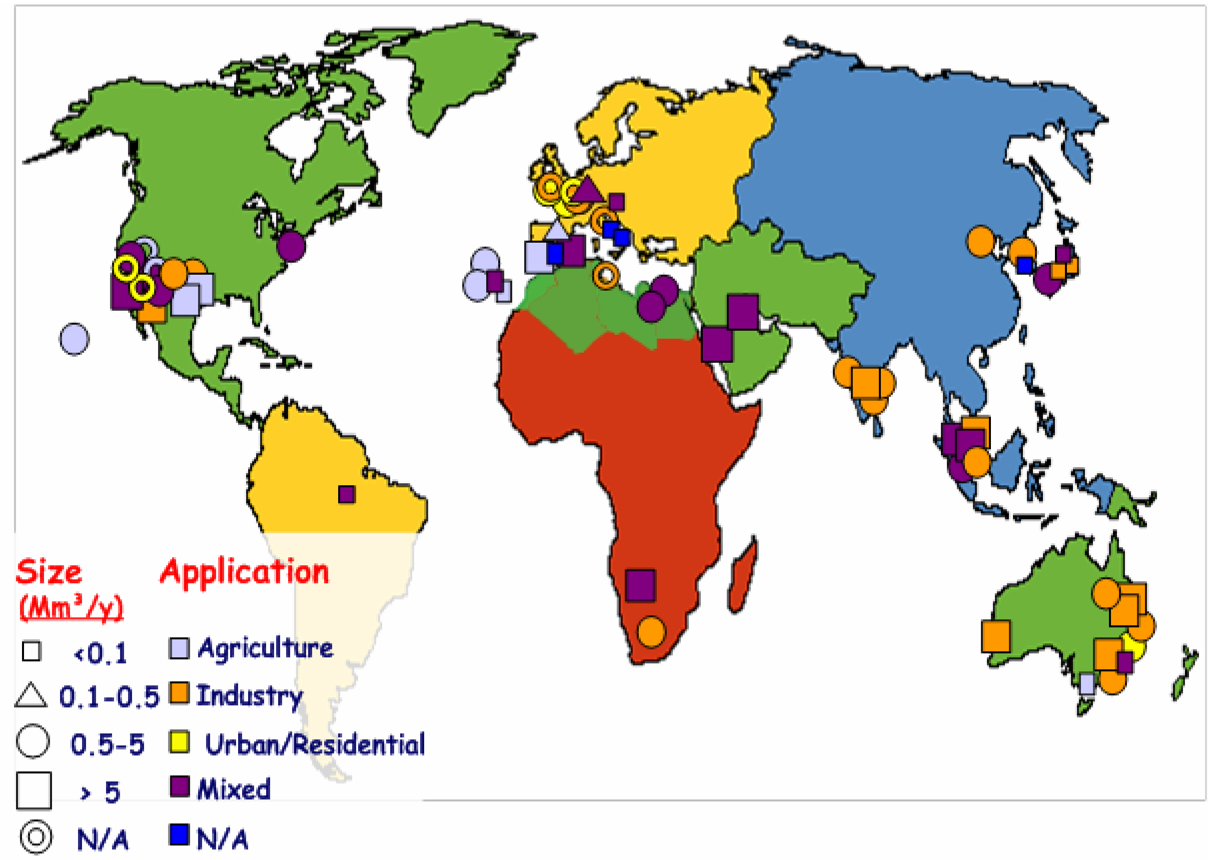


A number of definitions require further details; secondary treatment – here also including nutrient removal – is the standard for restricted agricultural irrigation (i.e. for food crops not consumed uncooked) and for some industrial applications such as industrial cooling (except for the food industry). Additional filtration/disinfection steps (tertiary treatment) are applied for unrestricted agricultural or landscape irrigation as well as for process water in some industrial applications. Quaternary treatment is defined here as a treatment producing a quality comparable to drinking water – often involving a "dual membrane" step to meet unrestricted residential uses and industrial applications requiring ultrapure water.

9.3.3 Key role of membrane processes in advanced water recycling schemes

More than any other technology, membrane processes are regarded as key elements of advanced water recycling schemes and are implemented in a number of prominent projects world-wide including artificial groundwater recharge, indirect potable reuse as well as industrial process water production. Figure 9.8 illustrates identifiable water reuse schemes using membrane technology worldwide (to date about 40 full scale installations have been recorded). The schemes are classified per size and type of beneficial use. Note that data on schemes "in planning or construction" and community facilities using membrane bioreactors (MBRs) are also available, but not reported in the Figure (Melin *et al.*, 2006).

Figure 9.8: Existing water reclamation schemes using membrane systems worldwide

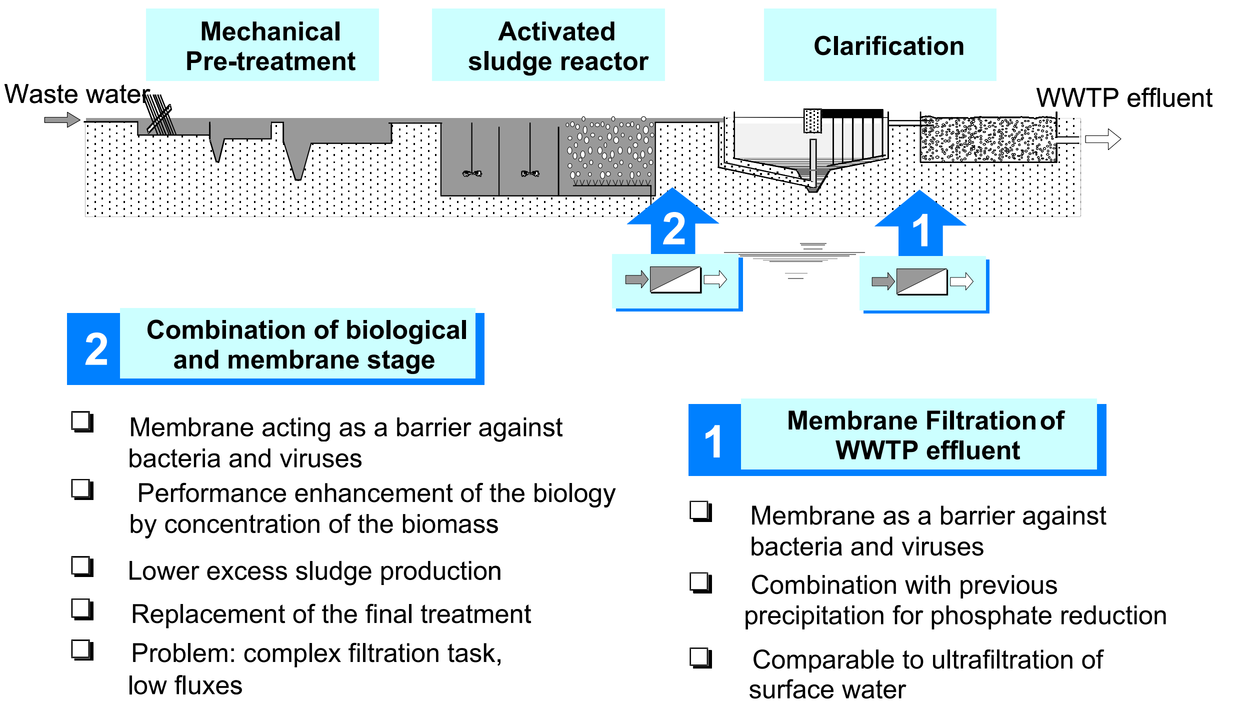


The map pictured in Figure 9.8 is destined to become outdated quickly. Many more projects are in an advanced planning phase. There is a clear trend for new larger scale plants to use dual membrane processes and MBRs.

As indicated before, membrane processes are mostly applied as effluent polishing stages of municipal wastewater treatment plants, taking a secondary or tertiary effluent as feed with rather low suspended solids content, illustrated as option 1 in Figure 9.9. An alternative to this "end-of-pipe" treatment is the application of MBRs as an integration of biological treatment processes and biomass retention by microfiltration or ultrafiltration (UF) membranes. MF and UF employed in tertiary (or quaternary) wastewater treatment are dedicated to remove suspended solids, organic matter, and microorganisms, recovering a high quality final effluent with various possible uses. MF and UF technologies both in effluent filtration and in MBRs are also suitable as pre-treatment to nanofiltration (NF) or reverse osmosis (RO). Such physical barrier-processes are attractive in wastewater treatment because any technology employed must be able to produce reclaimed water of uniform quality, regardless of the normally wide variation in the concentrations or physicochemical properties of the wastewater influent (Adin and Asano, 1998; Tschobanoglous and Burton, 1991; Alonso *et al.*, 2002) and because the absence of chemicals addition is of economic and ecological benefit.

It has been reported that microbial pollution is totally eliminated by MF and UF due to bacteria being larger than the (nominal) pore size. However, as typically designed and operated in the field of wastewater treatment, UF cannot be considered a complete barrier to microorganisms. Positive coliform results were obtained when membrane systems were operating. The passage of bacteria across membranes may be attributable to the following: fibre breakage, defects in the membrane surface; degradation of the membrane by oxidants or bacterial enzymes, or to leaking gaskets in membrane modules or elements. Another possible reason for the detection of bacteria in membrane filtrate is the introduction of bacteria from exterior sources such as contamination of the permeate tank. Since nutrients are not eliminated from the water, re-emergence is best avoided through a disinfection process (Bourgeous *et al.*, 2001).

Figure 9.9: Application options for membranes in municipal wastewater treatment



The application of UF to treat filtered secondary and tertiary effluents may (as appropriate) be considered equivalent to an oxidized, coagulated, clarified, and filtered wastewater as per Title 22 California Wastewater Reclamation Criteria (Bourgeous *et al.*, 2001).

Dense membrane processes (NF/RO) are capable of separating ions (and dissolved solids) from water. In wastewater treatment and reclamation, RO systems are typically used as polishing processes having a significant impact on bulk parameters. 65-80% and 85-99% total organic carbon (TOC) removal with NF and RO, respectively, are to be expected. RO systems have been demonstrated to be effective in removing various contaminants of concern, including neutral molecules, dissolved metals and pathogens (Adham *et al.*, 1998; Van Gauwbergen *et al.*, 1999; Levine *et al.*, 1999; Levine *et al.*, 2001).

9.3.4 Examples of technology benchmarks in water recycling schemes world-wide

Membrane bioreactors for in-house water recycling in Japan

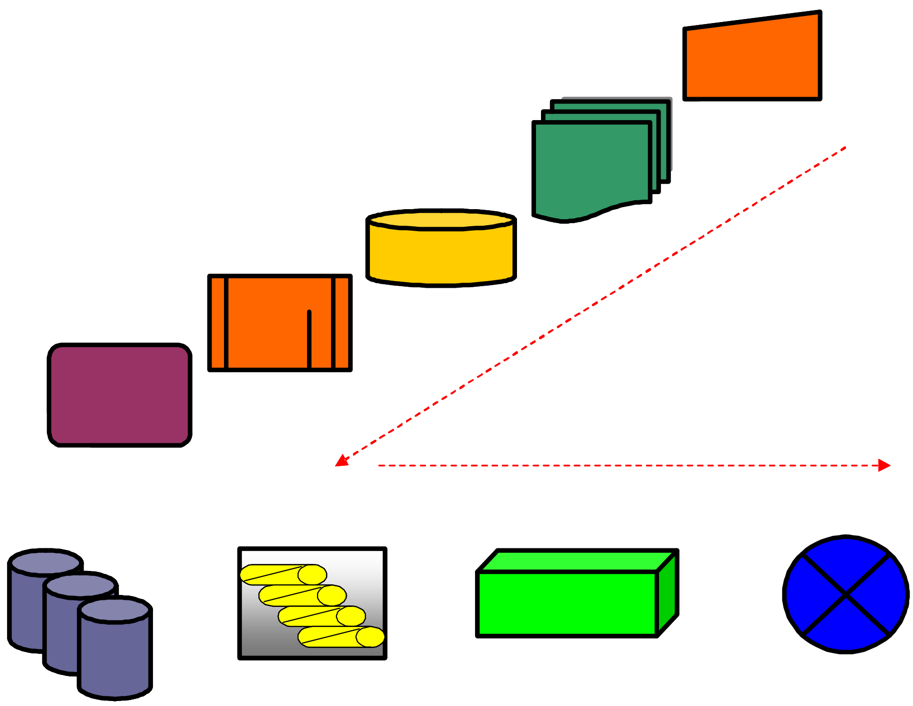
According to Stephenson *et al.* (2004), membrane bioreactor technology was proven to be very relevant in water reclamation and reuse, particularly in small-scale, decentralised applications e.g. in the densely populated urban in centres in Japan. In 1989, the Japanese Government joined with a number of large companies to promote the development of a low footprint, high product quality treatment that would be suitable for wastewater reclamation and reuse. City legislation, such as in Fukuoka, required large buildings to adopt water saving measures including rainwater harvesting and in-building grey water treatment and reuse systems. This was partly demonstrated through the Aqua Renaissance program '90 (Kimura, 1991) that led to development of systems such as the Kubota flat-sheet submerged MBR and the Mitsubishi Rayon hollow fibre submerged MBR.

Two generic types of MBR have been used for in-building grey water treatment: initially these were side stream systems, but more recently submerged systems have been introduced following their development by Japanese companies. Of the 500 operational MBRs identified by Stephenson *et al.* (2000), almost 25% were used for in-building wastewater treatment, mostly in Japan. It was found that MBRs generally provide significant advantages over alternative biological treatment processes in water recycling, particularly in terms of pathogen removal and process robustness (Jefferson *et al.*, 2001; Palmer *et al.*, 2002).

Direct potable reuse in Windhoek, Namibia

The only direct potable reuse project worldwide is operating to date in Windhoek/Namibia, one of the driest regions in Southern Africa (du Pisani, 2006). After decades of experience in potable reuse, the scheme underwent a significant refurbishment and the new Goreangab Water Reclamation project displaying a multi-barrier concept has been in operation since 2002 (City of Windhoek, 2004).

Figure 9.10: NEW GOREANGAB PROCESS TRAIN - reproduced with permission (City of Windhoek, 2004)



Within this scheme secondary effluent (21,000 m³/d) from a municipal wastewater treatment plant is reclaimed and treated to drinking water quality by a complex treatment train including pre-ozonation, coagulation, dual media filtration, main ozonation, biological activated carbon adsorption and a two-stage granular activated carbon adsorption as well as UF prior to chlorine disinfection (see Figure 9.10). This treatment not only provides high quality water, it possesses multiple barriers for most microbial and chemical contaminants of concern and reduces the potential for disinfection by-product formation. The total operation cost of the water reclamation scheme are given at 0.76 US$/$m^3$ (Lahnsteiner *et al.*, 2004). Capillary UF membranes supplied by NORIT are used in the scheme and operated in dead-end mode (inside-out) with an average permeate flux of 107 L/m^2 h at a transmembrane pressure of 0.4-0.7 bar (NORIT Membrane Technology, 2003).

Indirect potable reuse – the NEWater Project, Singapore

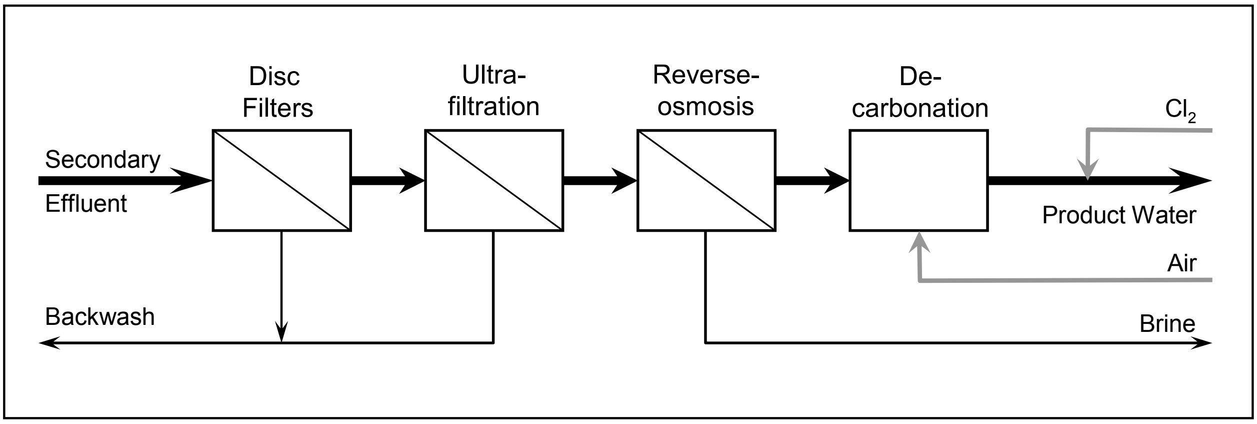
As part of the sustainable water supply programme the NEWater Project was implemented in Singapore to supplement freshwater resources used for drinking water production from reclaimed water. Since January 2004 the third water reclamation plant is in operation increasing the overall NEWater capacity to 91,000 m^3/d. The reclamation process involves a double-membrane treatment of secondary effluent with MF and RO and final disinfection by UV. Chlorine is dosed before and after the MF to control biofouling. The RO units provide an excellent product quality with TOC and total dissolved solids (TDS) removal >97% making the reclaimed water also suitable for use in the semiconductor industry (NEWater, 2004). The MF consists of a submerged hollow fibre system supplied by ZENON (Zenon, 2002). The RO units are supplied by Hydranautics (see Figure 9.11) and based on thin film composite membranes (Krüger, 2003).

Figure 9.11: Reverse Osmosis Units at the NeWater water recycling scheme in Singapore

Sulaibiya/Kuwait – the largest water reuse plant in the world

As part of a move towards integrated water resources management in Kuwait a privatised water reclamation facility was built in Sulaibiya to serve non-potable purposes. About 375,000 m^3/d highly treated municipal wastewater from Kuwait City is reclaimed. The treatment comprises conventional mechanical-biological wastewater treatment; the secondary effluent undergoes treatment in a reclamation plant including a double membrane processes with ultrafiltration (Norit X-Flow capillary membranes) and reverse osmosis (Toray). Chlorine is added to the final product to prevent microbial contamination in the distribution system. Currently the reclaimed water is reused for agricultural purposes but an aquifer recharge scheme is supposed to use up to 45,000 m³/d in the future (Widmann *et al.*, 2005; GWI, 2005).

Figure 9.12: Sulaibiya membrane treatment processes (Widmann et al., 2005)

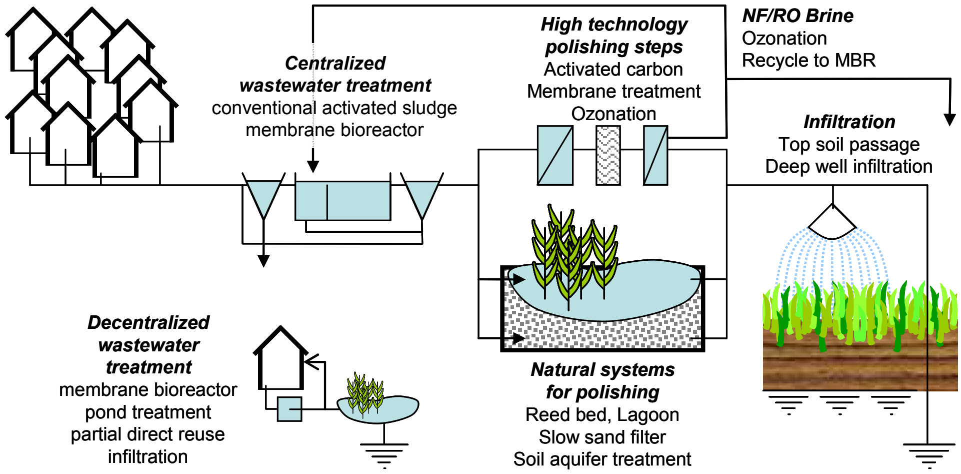


9.4 Current research and development trends in water treatment technologies

Research and development activities go on for most of the unit processes and process combinations applied for water and wastewater treatment with focus on advanced treatment options such as UV disinfection (Mofifi *et al.*, 2002), ozonation (Hiber *et al.*, 2003), advanced oxidation processes (Hoffmann *et al.*, 2003; Parson *et al.*, 2004), and different membrane processes as well as process combinations such as membranes plus activated carbon adsorption (Meier *et al.*, 2005). Also more extensive processes, e.g. constructed wetlands (Rousseau *et al.*, 2004; Huertas *et al.*, 2006) and soil based processes such as soil aquifer treatment and river bank filtration are intensively investigated (Drewes *et al.*, 2002).

The European research project RECLAIM WATER focuses on water reclamation technologies for artificial aquifer recharge and investigates the fate and transport of key contaminants in a wide range of treatment options (see Figure 9.13). One of the main aspects of the research projects is to look at the influence of water treatment technology prior to soil passage and sub-soil processes such as soil aquifer treatment (SAT), aquifer storage, transfer and recovery (ASTR). Benefits can arise from the suitable combination of reclamation technologies and different natural processes in the soil and aquifer system such as natural attenuation of contaminants. Sub-surface storage is particularly advantageous as precipitation losses, algal blooms and other surface contamination is avoided.

Figure 9.13: Technical wastewater reclamation options investigated in the RECLAIM WATER project (www.reclaim-water.org)



Another important aspect addressed in the RECLAIM WATER project relates to the concentrate disposal issues linked to the application of dense membrane processes (NF/RO) in effluent treatment. Different ways to at least reduce the organic loading of those concentrates prior to discharge into the environment are investigated; among those are activated carbon filtration, ozonation and natural treatment in reed-beds. The addition of powered activated carbon or the ozonation might also enable the re-circulation of pre-treated concentrates into the biological reactors or sludge treatment lines of the municipal wastewater treatment plants.

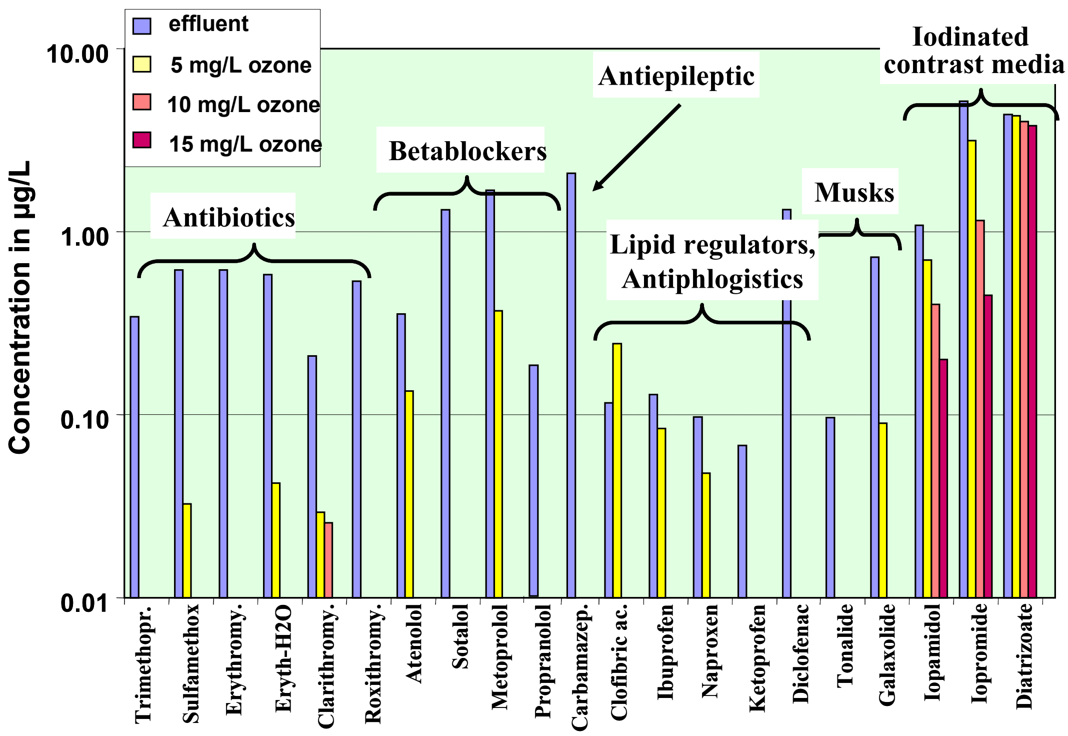
Other European Union co-funded projects, which started in late 2005 and early 2006, and deal with water treatment technologies are Gabardine, looking at sub-surface processes such as artificial recharge with reclaimed water and the MBR-technology cluster including the projects Amadeus, Eurombra, and MBR-TRAIN, which are considering membrane bioreactor technology for municipal wastewater treatment also to promote direct non-potable reuse. In the drinking water supply area technologies such as desalination through reverse osmosis and membrane distillation are currently investigated (MEDINA and MEDASOL) as well as a broader spectrum of process combinations including membranes, oxidative and adsorptive processes (www.techneau.org).

Overall it is notable that key water quality upgrade technologies applied in drinking water, process water, advanced wastewater treatment and water recycling become more and more similar and are addressing similar classes of contaminants. In water stressed areas where water resources are heavily affected by anthropogenic activities, it becomes evident that more or less closed water cycles have to be developed from a water treatment and water quality point of view.

9.4.1 How to develop treatment technologies for a large spectrum of unknown contaminants?

Considering the ever increasing knowledge about the occurrence of different classes of compounds in the water cycle it becomes almost impossible to develop, test and implement substance-specific treatment technologies for all the future “contaminants of the week” to come. Key water treatment technologies which become core elements of advanced processes in water recycling for higher quality purposes have to feature “universal effectiveness” to a certain degree. It becomes obvious from recently completed studies that some candidate technologies exist which can tackle a relatively large spectrum of compounds, particularly in the arena of organic trace contaminants, where the number of detectable compounds in wastewater is almost unlimited. Ozonation has proved to be widely effective with respect to many pharmaceutical residues, personal health care products and estrogenic compounds in doses which can also be used for disinfection (Ternes *et al.*, 2003). Some compounds such as iodinated x-ray contrast media showed high persistency in oxidation processes (see Figure 9.14), and only for a small number of compounds the intermediates generated could be identified (Mcdowell *et al.*, 2003)

Figure 9.14: Results of the Poseidon project on trace organic removal with ozone (Ternes et al., 2003)



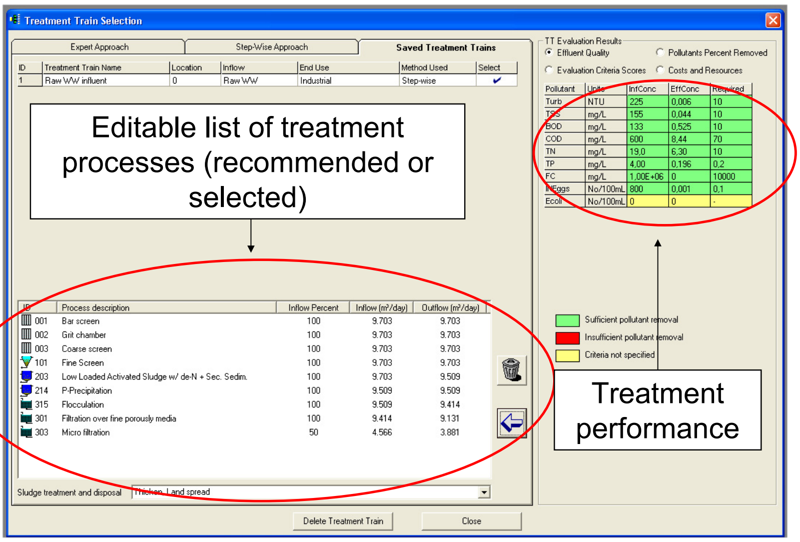
Dense membrane processes such as nanofiltration are also candidate technologies which have an impact on a large number of compounds due to molecular size exclusion and electrostatic interactions, but phase partitioning of some small molecular organic compounds into the membrane polymer matrix can decrease removal efficiency.

The effectiveness of nanofiltration membranes with respect to a wide range of organic contaminants has also been shown by numerous authors (Nghiem *et al.*, 2004; Gallenkemper *et al.*, 2002; Kimura *et al.*, 2004) with one of the most extensive carried out by Yoon *et al.* (2006). Figure 9.14 shows that for many compounds NF membranes show relatively high removal rates.

On basis of an extensive data survey generic frameworks have been defined in different studies to a priori predict the removal effectiveness on basis of limited knowledge about the properties of the contaminants and membranes in question (Lohscheid, 1999; Bellona *et al.*, 2004).

Figure 9.15: Rejection diagram for organic micropollutants in nanofiltration and ultrafiltration membranes (according to Kimura et al., 2004 and Yoon et al., 2006)

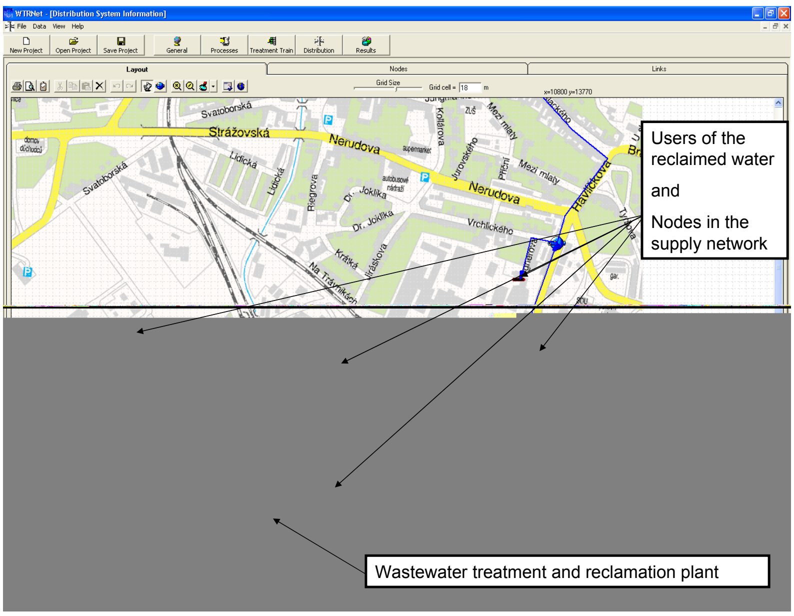
Figure 9.16: Graphical user interface of the WTRNet software (Joksimovic et al., 2006)



WTRNet stores and visualises basic information about a water reuse scheme including raw water quality, hydraulic variations in feed, climatic conditions, envisaged end-uses. The user can select default settings for treatment trains recommended for particular uses or design customized treatment options. Utilising the knowledge contained in a treatment process data base, the above mentioned evaluation criteria are assessed and displayed (Figure 9.16).

The software extends its applicability to the distribution system and evaluates the integrated scheme design. The pipeline and pumping network can be layed out and the design is supported using an optimisation algorithm (Figure 9.17).

Figure 9.17: Visualisation of a water reuse scheme utilising the WTRNet software (Joksimovic et al., 2005)



For a feasibility study example in the Czech Republic different treatment scenarios and a dual water supply system for industrial purposes has been studied (Janosova *et al.*, 2006). Key data about the different evaluated scenarios are given in Table 9.4. Tertiary treatment has been assumed to be necessary to upgrade the existing effluent for discharge into the sensitive area (UWWTD compliance). Four water reclamation scenarios have been considered which of course provide all different water qualities for potential uses in an industrial estate. This evaluation should just indicate the approximate cost relation between different scenarios. Due to the limited size of the assumed distribution system only relatively low cost are associated with the piping and pumping system. This cost category can become more prominent and more complex urban distribution systems.

Table 9.4: Cost calculation for advanced wastewater treatment and reuse options evaluated in an AQUAREC feasibility study

Project components	Investment cost [€]	Operation cost [€/a]
Conventional secondray wastewater treatment plant (ca. 10.000 m³/d)	*6000000*	*450000*
Tertiary Treatment (full flow)		
Phosphor precipitation	40000	15000
Flocculation	150000	30000
Sand filtration	600000	32000
Water reclamation and distribution system		
Treatment Scenario 1: Constructed wetland as polishing (full flow) and UV disinfection (800 m³/d)	220000	15000
Treatment Scenario 2: Nanofiltration (10% of the effluent = 800 m³/d Permeate)	280000	38000
Treatment Scenario 3: Ozonation and Granular Activated Carbon Adsorption (800 m³/d Permeate)	570000	60000
Treatment Scenario 4: Microfiltration and Reverse Osmosis (800 m³/d Permeate)	630000	72000
Distribution system (ca. 2.5 km) + pumping station + storage	700000	17000
	Total yearly cost [€/a]	**Specific cost [€/m³]**
Constructed wetlands and UV disinfection	56000	0,20
Nanofiltration	83000	0,30
Ozonation and Granular Activated Carbon	160000	0,57
Microfiltration and Reverse Osmosis	180000	0,64
Distribution system	82000	0,29

9.4.3 How to increase cost-effectiveness and minimise environmental impact of treatment technologies?

Increasing cost-effectiveness of water reclamation technologies is certainly one of the major goals of further development if high reclaimed water quality is to be available in a larger number of schemes. Large growth potential is expected in water reuse for aquifer recharge and urban applications, where under most circumstances desalination techniques will come into play (see also the case study section above). Hence, the evolution of treatment cost of membrane systems for effluent desalination is of crucial importance for the further development.

Figure 9.18: Cost curves for membrane systems for water reclamation (Adham et al., 2005)

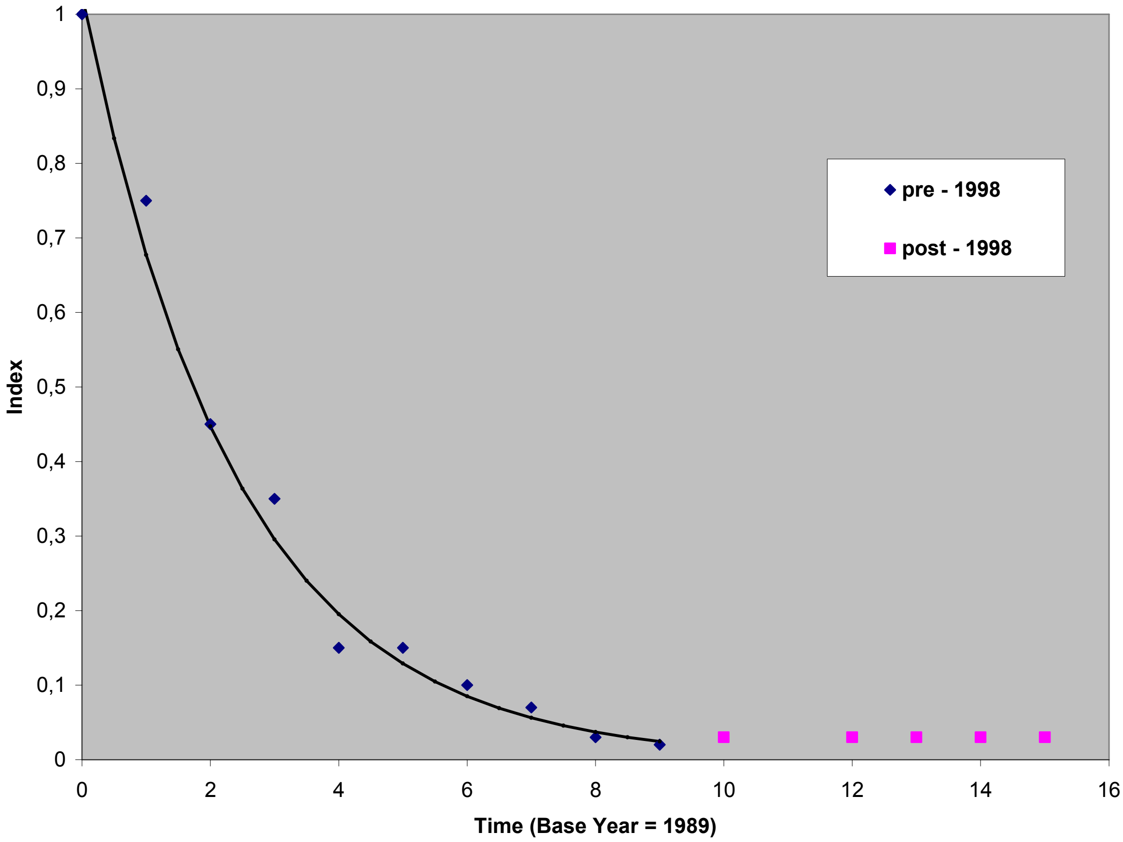
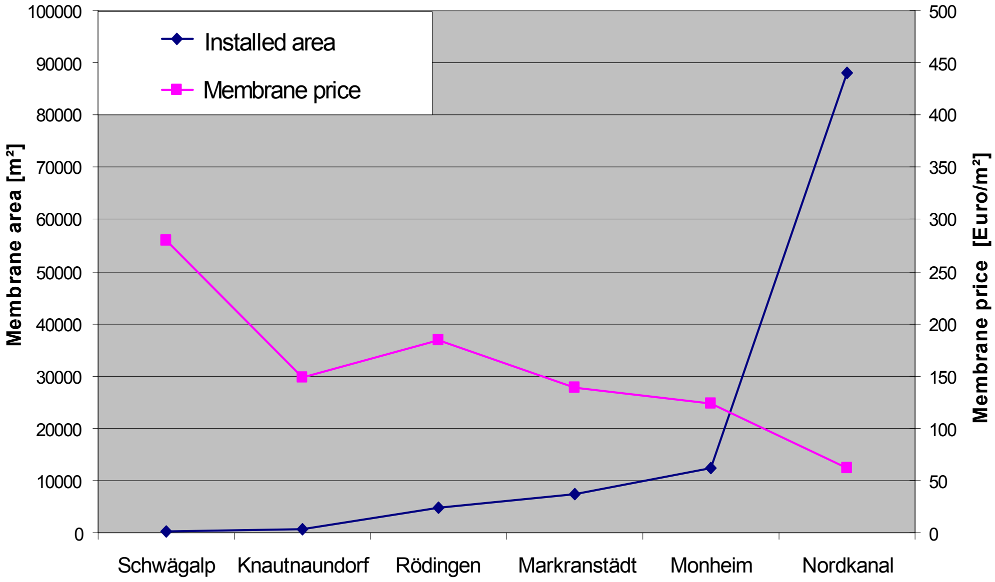


Figure 9.18 shows the dramatic decrease in the cost index for micro- and ultrafiltration membranes for water reclamation from 1990 to 1998. From 1998 onwards the cost index has stabilised on a rather low level.

Even for membrane based treatment plants economy of scale effects are important as shown in Figure 9.19 where membrane prices for municipal membrane bioreactors implemented in full scale in Germany are given (non of these projects is currently reusing the effluent). This indicates quite clearly that cost advantages exist for large systems.

Figure 9.19: Membrane prices for municipal MBRs in Germany (Wintgens, 2005)



9.4.4 How to explain sophisticated treatment technologies to the public and gain trust?

Apart from all the different tangible factors influencing the decision about treatment technologies, the stakeholder perception and understanding is an important aspect in applying sound techniques successfully. The NEWater Visitor's Centre in Singapore and the Advanced Water Recycling Demonstration Plant (AWRDP) in Queensland, Australia are two initiatives to convey information about water reclamation technologies to the public in two different scales. The AWRDP was a relatively small scheme with a full range of pilot-scale treatment units which have been used both for scientific investigations (Gibson *et al.*, 2001; Khan *et al.*, 2005) as well to explain treatment technologies to a broad public audience (Figure 9.20).

Figure 9.20: Advanced Water Recycling Demonstration Plant in Queensland/Australia (Queensland Environment Agency)

The NEWater scheme is doing that on a much larger scale with a permanent exhibition including displays and professional guidance around issues of integrated water resources management, water recycling and treatment technologies (Figure 9.21). Similar initiatives are not known in Europe and certainly show the lack in public consultation activity in the sector of water recycling.

Figure 9.21: NEWater Visitor's Centre in Singapore (Public Utility Board Singapore)

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10 COMMUNICATION AND PUBLIC INVOLVEMENT STRATEGIES

10.1 Why get involved in participatory planning?

There are three categories of incentive for wider participation in water recycling projects. The first derives from principles of fairness and justice: that people who may be affected by a project should be consulted and have some influence over its development. Participation, alongside representation and accountability, is seen as an essential part of a healthy democracy.

Second are regulatory obligations. Many regional, national and international bodies have introduced requirements for planners and project developers to consult with the public and key actors at various stages of a development process. In Europe, for example, the Water Framework Directive contains a requirement (under Article 14) that:

'Member States shall encourage the active involvement of all interested parties in the implementation of this Directive, in particular in the production, review and updating of the river basin management plans.'

Third, beyond a justification in terms of democratic principles and of legislated requirements for consultation, we can point to a number of potential benefits – particularly if, as we advocate, the process starts early and gives genuine flexibility and scope for participants to shape the outcomes. Such benefits include;

- Help identify acceptable and achievable goals and solutions
- Encourage consensus on the benefits and value of a project, a sense of involvement and control, and a commitment to its successful implementation and operation
- Prompt people to suggest new ideas and approaches
- Reduce the time and effort spent dealing with individual objections and requests for information
- Advise users about appropriate practices and precautions, and generate commitment to good practice
- Promote integrity and trust between parties, and reassure users and the wider public of the accountability and trustworthiness of scheme developers
- Provide scheme designers with knowledge of local operating conditions and the practices of users
- Improve understanding of concerns and their social / cultural basis

However, just as there are many reasons to see participatory planning as beneficial, there are a number of objections that may be stated;

- The planning process becomes too reactive and inefficient, and decisions and actions are delayed
- Participatory processes are expensive and resource-intensive
- Expert advice and decisions may be overridden
- The people who get involved may not be representative of the wider population

- The decisions or compromises that the process leads to may not be appropriate
- People may become sensitised to issues they would not have worried about otherwise, and rather than producing consensus the whole process may increase antagonism and distrust
- Participatory processes may raise unrealistic expectations
- They undermine the role and authority of elected representatives – in particular local councils

There are clearly some important concerns underlying these objections. They point to a need, however, not to avoid engagement, but to take the process and its requirements seriously.

10.1.1 Guiding principles of communication and engagement

The selection and presentation of material in this handbook are guided by a number of principles, perhaps best described in terms of three ideal characteristics of participatory processes: procedural justice, inclusiveness, and knowledge-sharing.

Procedural justice

People often object when they feel that the distribution of a resource between recipients is unfair or inequitable. Such objections can equally be made when the process by which a decision is made about resource use and distribution is seen as unfair. 'Procedural justice' is achieved where all parties acknowledge that the method by which decisions are reached is fair, even if they disagree with the outcome itself.

Inclusiveness

For participatory processes to be effective, they require a degree of openness and transparency that is often missing from commercial-public relationships. By 'openness', we mean that involvement should be accessible to all concerned parties. By 'transparency' we mean that the workings of the process should be clear to all and understood by all. Information used should come from reliable and auditable sources, and should be explained and translated in a variety of formats for different groups. The extent to which information is uncertain, unreliable or unknown must be acknowledged fully and honestly.

Knowledge sharing

Constructive debate can not be achieved without the different parties to the process learning from each other ¬(though not necessarily learning in the academic sense). Sharing experiences, understandings, skills, insights, ideas and information between parties will result in wider understanding, not only of the characteristics of the project, but of other parties' views.

10.1.2 Tools & techniques

This section reviews the various elements of a participatory planning process and provides a critical appraisal of candidate tools and techniques. Inclusion of a participation mechanism in this section does not imply endorsement – the aim is to describe a range of options rather than promote any particular one. Participation exercises require a combination of techniques. The combination, and how the elements should fit together, may depend on:

- the objectives for the exercise;
- the stage at which participants are being involved – early in a water planning exercise, or later to seek endorsement of a specific scheme – and the extent of their input into decision-making;
- local circumstances and history, for example as they might bear on relations between the developer and public, or latent conflict arising from other planning issues;
- the preferences of participants themselves for the design of the procedure.

What is required in any local consultation will of course depend on how much discussion and education has been undertaken at a national or regional level. We stress the need to identify and understand any existing conflict in the community; it may point to quite different techniques for consultation – and in some cases to a need for negotiation or mediation before any productive discussion can be achieved.

Serious consideration should be given to placing the organisation and conduct of participatory processes in the hands of professional facilitators or similarly skilled people. There are, of course, consultancies that specialise in organising and facilitating participatory planning. Even if the work could be done by the developing organisation, it will often be more appropriate to use an independent facilitator so that the process is more credible.

10.2 General principles of participatory planning

Those responsible for initiating or driving the project need to consider carefully and honestly their motives and goals for the participation exercise, to understand the local context and identify the groups which will be affected. Subsequently, a decision needs to be made on what sort of participation is to be supported. All parties have to accept that an effective participation process will require significant resources. It may take considerable time to identify participants and cultivate contacts, to agree on a suitable process, to allow people's understanding to develop, and for them to come to informed and reasoned judgements.

Early contact among participants in the planning and management process is clearly preferable to a late, perhaps merely symbolic, exercise. It enables those leading a participatory planning exercise to take the initiative and provides an opportunity to explain concerns. It allows time for productive relationships to develop. Hearing others' positions and responses at an early stage leaves more time for sharing knowledge, developing understanding and building consensus. If dialogue is delayed, actors may feel that they are being faced with a fait accompli and suspect that consultation is merely a public relations exercise.

It is important to set clear objectives for the participation process and to evaluate it candidly, not only at its conclusion but also at appropriate intermediate points so that the process can be revised in the light of experience. This evaluation should include feedback from all participants – indeed they will almost certainly provide it whether or not they are asked.

10.2.1 Who should participate

Who should be included in a participatory planning exercise? The principle to follow here is inclusiveness: the mix of participants should be as representative as possible of interested parties in the community. The opportunity to participate should not be denied to any individual or organisation. Different groups may need to be engaged in different ways, reflecting their needs, traditions and cultures. It may also be important to identify not only formal leaders and representatives, but other local figures who are respected, who are opinion leaders, or who may expect to be consulted. As a starting point, it is useful to consider targeting the following groups with information on participation opportunities.

- Residents
- Families
- Schools
- Local and national government representatives
- Religious groups & leaders
- Care professionals
- Hospital & clinic workers
- Scientists
- Journalists
- Local community groups
- Landowners
- Property developers
- Lawyers
- Local businesses
- Relevant trade associations or industry groups
- Trade unions
- Conservation & wildlife groups
- National NGOs

Difficult questions may still arise about how representative the individuals are who become involved – whether they are invited or put themselves forward for an active role. There may also be concerns that some views are being given a disproportionate weight, particularly when disagreements emerge. Facilitators may have to give much more attention and time to the most vocal participants, and it may be sensible to anticipate who will be most concerned and affected by a proposal and target them early with special opportunities for interaction.

10.2.2 Tools and techniques to support participatory planning

Designing and managing a participatory planning process for water recycling is not a simple or straightforward exercise. The good news is that there is a wide variety of techniques and tools that can be used to help structure and manage the process, and a wealth of experience to draw on.

Table 10.1 presents a list of the major types of tool and technique – in no particular order – which can be used as part of a participatory planning process. A short description of each one is provided, with up to four purposes or advantages and four limitations or problems. Although each tool or technique has particular objectives and characteristics, there are a number of considerations common to all. Primary among these is that participants should be informed why they are being asked to contribute, what is expected of them, and how their contribution will be used.

Table 10.1: Types of tool and techniques to support participatory planning

Technique & description	Purposes & advantages	Problems & limitations
Open / public meeting		
Widely advertised and free access event lasting perhaps two hours. Various formats possible but should include short presentations and opportunities for questions.	• Provides opportunities for comments and questions. • Requires no special training to implement (although professional facilitators may be used). • Are highly visible if well publicised. • Encourages discussion and flows of information.	• People attending may not be drawn from or representative of local population. • Contributions may be limited by a lack of knowledge and lack of interest. • Event may be stage-managed by organisers or dominated by conflict without means of resolution. • Contributions may be dominated by particular individuals or by local, topical or personal concerns.
Face-to-face interview		
Typically one-on-one session lasting up to an hour. Used to explore views on prepared agenda of issues.	• Can elicit views from individuals excluded or discouraged from other consultation mechanisms. • Can explore extent of understanding and basis of interviewees' beliefs and responses. • Generates more detailed feedback than from group discussion. • Allows investigation of sensitive or personal issues.	• Interviewers need to be well trained, and credible and legitimate to interviewees. • Results cannot be taken as representative of group or community. • Detailed analysis is resource-intensive. • Access to some types of respondents can be difficult.
Citizens' jury or panel		
Group of perhaps 10-15 citizens or institutional representatives asked to consider proposal or set of issues and tasked with reaching recommendation or shortlist of options. Intensive one-off process over several days. Jury hears or reads evidence from expert witnesses and can question them. Outputs feed into other participation mechanisms.	• Allows participants to select and pursue own lines of enquiry, and interact with experts and proposer. • Supports detailed and critical consideration of key issues and may identify areas of agreement or disagreement. • Can help identify relative influence of different types of argument, evidence and information on beliefs and responses. • Jury members usually value opportunity to make significant contribution to deliberation process.	• Expensive to organise and run. • Requires significant time commitment from jury members and expert witnesses. • May develop unrealistic expectations if role and terms of reference are not agreed and clear. • May produce confrontational environment, not conducive to building trust and promoting consensus.

Technique & description	Purposes & advantages	Problems & limitations
Community liaison / Project reference group		
Group comprising representatives of key interests meeting regularly throughout project planning, implementation and operation. Reviews progress and problems. Offers, and responds to requests for, advice and information for developer and authorities. May organise or contribute to wider participatory activities including information provision.	• Provides continuing feedback as project develops and circumstances change. • Helps ensure inclusion of diverse interests. • Provides variety of perspectives and expertise, and allows interaction. • Develops group with continuity and substantial understanding, and may help generate consensus around solutions.	• Requires significant time commitment from members. • Attendance may lapse or lack continuity during protracted planning and development process. • Representatives may not communicate adequately with constituencies, or continue to represent their views. • May develop unrealistic expectations if role and terms of reference are not agreed and clear.
Focus group		
Small group meeting (up to 8, randomly selected from relevant population) with facilitator to discuss set of issues. Group responds to set of topics or questions, but responses are open-ended and setting permits interaction. Ideally group meets several times to allow rapport, provision of information and development of views.	• Allows interaction and collective generation of understanding, ideas and concerns. • Can explore extent of understanding and basis of interviewees' responses. • Generates more detailed feedback than surveys and allows probing of initial responses. • Can show how understanding and views change over time and in response to information and interaction, and help identify relative influence of different types of argument, evidence and information.	• Detailed analysis is resource-intensive. • Without good facilitation group dynamics may allow domination by individuals or diversion from topic. • Awareness and understanding of issues may vary greatly among participants. • Should not be relied on as sole point of contact with community or seen as necessarily representative.
Questionnaire-based surveys		
Administered or self-completed. Conducted face-to-face or via post, phone, email or internet. Elicits responses from representative sample of larger population. Needs to be designed to suit stage of consultation and information provision.	• Can provide statistically valid and representative information on opinions. • Allows responses from people who might not normally attend meetings. • Can be used to introduce and gather views on project options and choices. • Detailed analysis may allow correlation of support with social characteristics and identification of profile of supporters and opponents.	• Provides only snapshot of opinions, heavily dependent on level of information and opportunities for deliberation. • Costly to conduct additional surveys so that changes can be tracked as information is provided. • Poor or manipulative design can bias responses and allow misleading interpretations. • May be difficult to get reasonable sample size and access to some groups

Technique & description	Purposes & advantages	Problems & limitations
Ballot / referendum / deliberative poll		
Formatted as for/against vote or choice of options. May elicit immediate reactions or be preceded by provision of information. Deliberative polling compares reactions before and after opportunity to discuss issue or proposal. Conducted via post, phone, email or internet.	• Straightforward and easily interpreted results. • Allows variety of means of communication. • Can provide opportunity for extensive debate and information-sharing in advance. • Large sample size extends involvement and can provide legitimacy to outcome.	• Does not provide information on reasons for choice. • Result can be significantly influenced by volume, quality and balance of information provided. • Low turnout may damage credibility of result.
Written submissions		
Open or targeted invitation to comment in written submission on proposal. Usually preceded by provision of information.	• Provides opportunity to distribute detailed, comprehensive information. • Allows respondents to work together to formulate response. • Responses likely to be considered, comprehensive and measured, and provide insights from local expertise. • Fits existing planning procedures in many jurisdictions.	• Response rates vary greatly by demographic characteristics. • Cost of printing and distributing documents can be significant. • May require more time than other methods, and analysis can be prolonged and resource-intensive. • Without adequate and detailed response from commissioning authority, often seen as wasted effort.
Open day / road show / exhibition		
Open event with displays, presentations and opportunities to talk with proposer or authorities. May include other techniques such as small discussion groups.	• Can use variety of presentation and communication media. • Provides informal and unthreatening environment to encourage contributions. • Allows flexibility in attendance. • Provides opportunity for participation in communities remote or difficult to access.	• Those attending are not necessarily representative. • Preparation of display material can be expensive. • May require extensive promotion to encourage attendance. • Responses to material may be difficult to assess.

10.2.3 Providing information and promoting understanding

People's understanding of the issues surrounding a water recycling project, and their views on them, develop during a participation process as they get to grips with information and arguments. Consequently, snapshots of people's 'attitudes' only make sense in the context of the stage of this process.

We should recognise that any of the consultation activities listed in Table 2 are inevitably also exercises in providing information and helping participants develop their understanding. Different forms of information will be required at appropriate stages in any sequence of activities, and the conduct and success of each stage will depend on how well prior information has been prepared by the facilitators and processed by the participants.

Obviously all information needs to be as accurate and clear as possible. For many audiences complex technical matters will need to be simplified and presented with a minimum of jargon. The purpose, meaning and significance of quantitative information should also be explained. However, presentations should not be condescending. It is worth thinking carefully, and seeking advice, about how best to present information, explain concepts and issues, and stimulate discussion on them. Well designed diagrams, pictures, video clips and charts can all be helpful.

Experiences from the field of risk communication point to further considerations. First, we should be careful not to impose specific value judgements in the guise of neutral information. For example, it is misleading to assert that a particular level of contaminant is 'safe' without making clear what criteria we are using. Second, what information is provided and what issues are on the agenda for discussion should be determined as much by the participants as by the organisers and information providers. Third, concerns should be addressed in terms that the audience is familiar with, rather than impose what we assume is a rational agenda and framework for discussion but which marginalises or excludes other ways of approaching the issues.

All audiences are likely to place great emphasis on the impartiality and credibility of information, and to be suspicious of information provided by parties with a clear interest in a particular outcome. It may be necessary for materials to be prepared by, or filtered through, a group with the required expertise but with no links to the project.

We can certainly expect people's views to change significantly in response to information and opportunities for discussion. We should not assume, however, that their evaluation will, or should, eventually come to correspond to that of the developer or experts, nor that they will reach consensus on every contentious matter.

10.2.4 Understanding responses to water recycling projects

As early as possible, developers, authorities and consultation facilitators need to develop an initial picture both of potential users' and others' responses towards a possible scheme. We emphasise the need for locally specific studies. Findings from surveys are rarely generalisable, and so far attempts to correlate views with demographic variables have produced largely inconsistent and contentious results. The key determinants of people's initial responses may be local. A variety of issues and events, some not directly connected to water, may influence their stance.

As we have stressed, people's views are likely to develop rapidly as they learn more about the issues, and start to think about something they may not have considered before. Studies of opinions and attitudes should accept that responses are inevitably dependent on opportunities to obtain information and develop understanding. So while a survey might indicate a certain level of public support for water recycling, we cannot assume that the response is necessarily robust.

Scheme developers and authorities will probably undertake a formal risk assessment to assess the potential for undesirable impacts from a proposed recycling scheme. The aims of such an activity will be to understand the hazards better, inform decisions on hazard management and on effective points of intervention, and help develop contingency plans. Such risk assessments are not only essential to managing hazards, but also an important form of information for consultation with users and the public. As we have pointed out before, however, it is important that presentations of risk acknowledge the uncertainties and value judgements involved in the exercise..

Participants will have access to a variety of sources of information about the risks, will evaluate the risks in different ways, and may come to different conclusions even on the same evidence. We can expect people's judgement of the risks to change as they are given more information and develop a better understanding of the issues.

Beyond concern with possible health hazards, the acceptability of a project will depend on many factors to do with its benefits and costs and their distribution, the organisations involved, the context, and the degree of influence people are given over decisions and operations. In the face of uncertainties, people are likely to place great weight on the trustworthiness of project developers, authorities and information providers, and on the transparency of the consultation process

10.3 References

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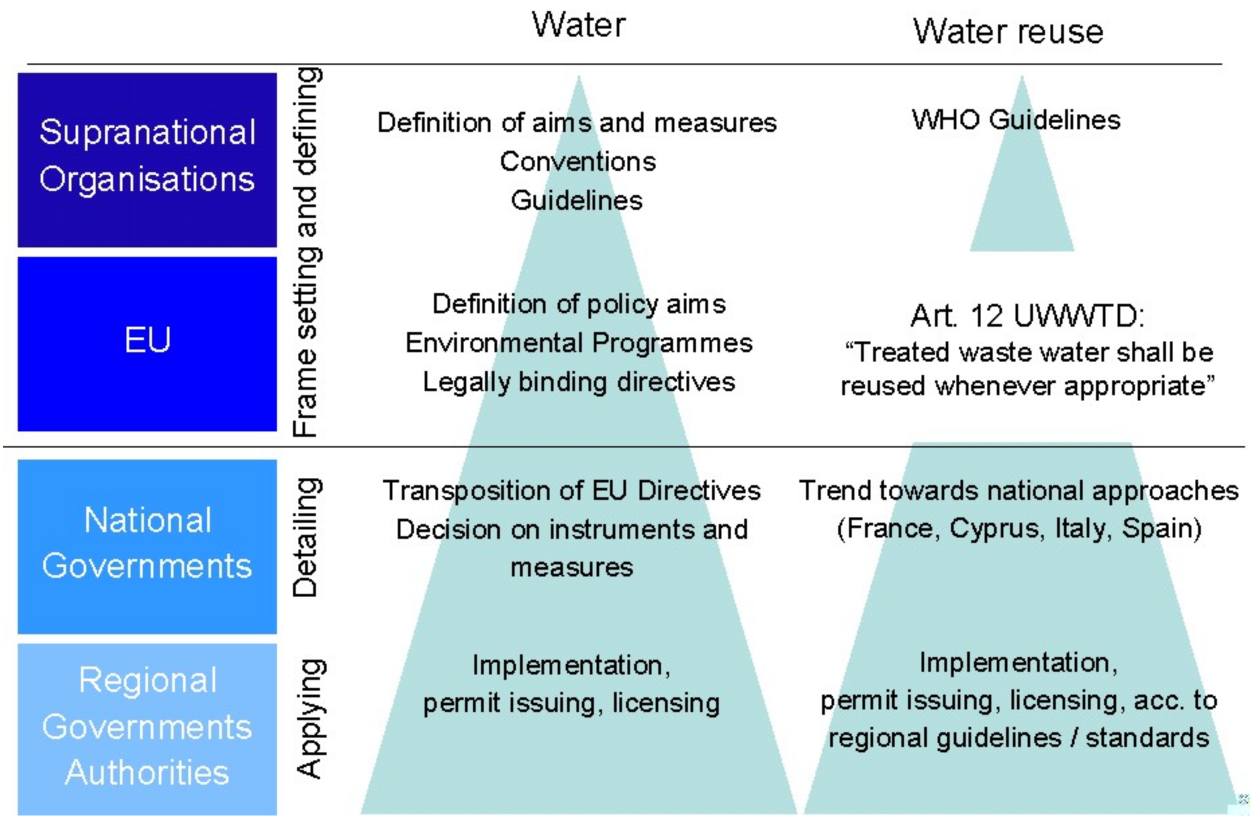
11 TOWARDS A EUROPEAN WATER RECYCLING POLICY

11.1 Policy options to frame water reuse development

Water reuse is not a new science or policy field, as the findings in the previous chapter showed. Water reuse is rather an interdisciplinary and intersectorial undertaking which calls for consideration in integrated approaches.

Figure 11.1 depicts the regulative involvement of policy makers on different levels in the water and water reuse field. The competence for setting the boundary conditions on the supranational and pan-European level is fully developed in the water sector, for which a series of conventions, policy aims and legally binding directives are adopted (cf. also Chapter 6.2.1). The national and regional governments or authorities assume the task of detailing and applying the agreed concepts when transposing them into national governance structures.

Figure 11.1: Regulative involvement at different levels



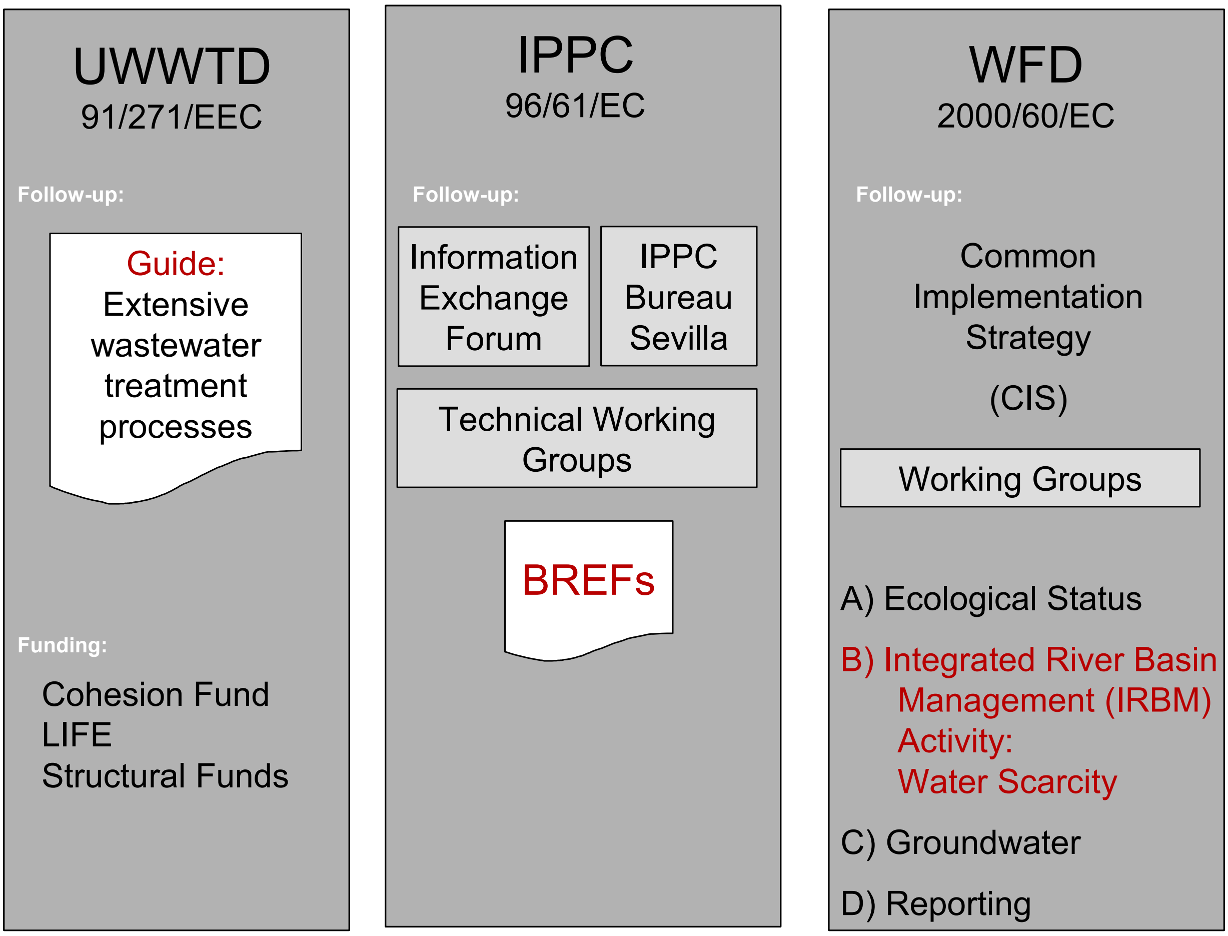
For the water reuse side the actual implementation of projects is often based on regional guidelines, even though there is a trend to establish national standards on water reuse, too. On a supranational level, the WHO has issued Guidelines for the use of reclaimed water in agriculture, but there is a gap on EU level, addressing reuse solely with a one-sentence-statement in the Urban Waste Water Treatment Directive: "Treated waste water shall be reused whenever appropriate". In fact reuse could be readily considered in many ongoing implementation activities.

11.2 Former, ongoing and future activities

The transposition of European environmental legislation into Member State law and its implementation have experienced different degrees of community support. The approaches and types of assistance will be addressed in the next sections (see also Figure 11.2).

It is striking that with increasing complexity of the protection aim of the legislation the supportive frame is becoming more comprehensive, too. The demand to tackle environmental protection in an integrated way - across the borders of environmental compartments or even territories - calls for a likewise integrated and broad approach to find solutions.

Figure 11.2: Overview of different follow-up activities for the implementation of European directives in the environmental sector

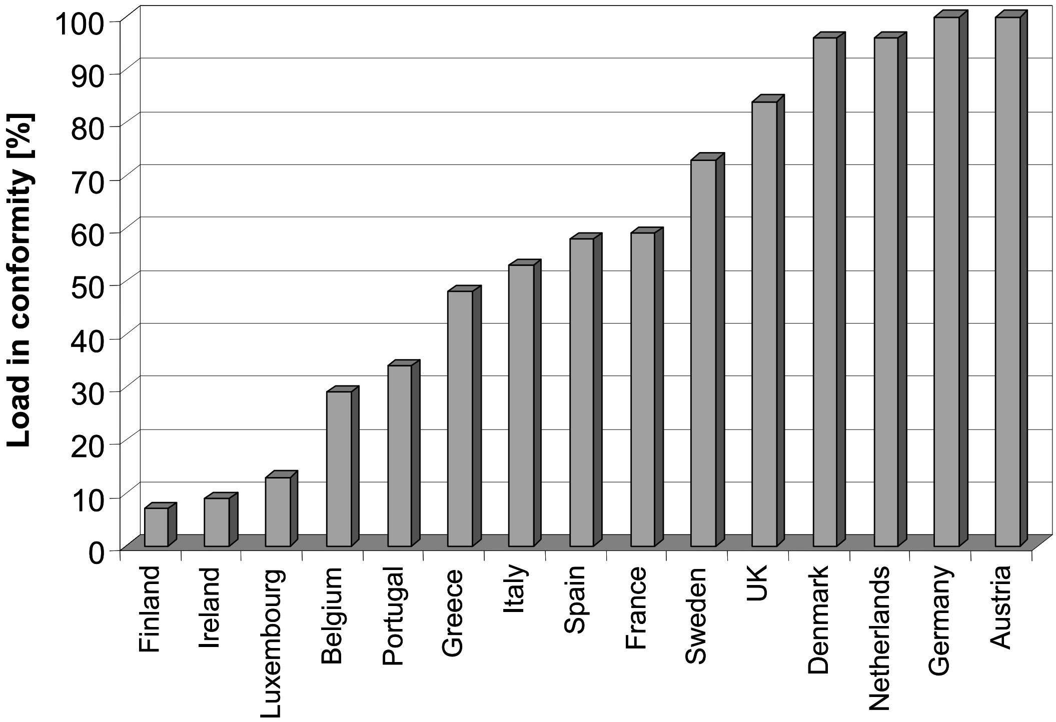


11.2.1 Urban Wastewater Treatment Directive (UWWTD)

Since entering into force in 1991 the UWWTD has caused considerable efforts of Member States to improve the status of their wastewater systems (sewerage network and treatment plants) in terms of increasing connection rates and installed treatment capacities. Initiatives and ways of implementation were primarily considered a national task although financial support was provided by the Communities Cohesion Fund (5 billion EUR per year (EC, 2004)).

The latest report of the European Commission concerning the implementation status of the Urban Wastewater Treatment Directive (EC, 2004) revealed that the aims set are not complied with in many of the member states (see Figure 11.3). Non-conformity may be caused by insufficient treatment capacity or inappropriate treatment level, i.e. lack of full nutrient removal of effluent discharged into sensitive areas. Sometimes there are even opposing opinions about the sensitivity of a receiving water between Commission and Member States.

Figure 11.3: State of implementation of the Urban Wastewater Treatment Directive



It is striking that countries with full-cost recovering water prices like Denmark, The Netherlands and Germany are the model pupils. On the other hand Belgium, Portugal, Greece, Italy, Spain and France do not yet provide sufficient treatment, with only 28 % to 58 % of the load being in conformity. These figures represent the status by the end of 2002 and although Article 12 of the UWWTD mentions the possibility or even the call to reuse treated waste water whenever appropriate the implementation of reuse scheme has not always been foreseen in the planning and design phases of treatment facilities.

As the implementation is still ongoing the Commission itself acknowledges the possible role of reuse stating "waste water treatment, as well as waste water re-use in order to ensure human health and protect the environment will receive further importance due to increased floods and droughts as a consequence of climate change" (EC, 2004)

As many of the countries lagging behind can no longer rely on financial support of the European Union Cohesion funds in future, funding will become a more prominent issue with a focus on cost-effectiveness. Measures of pollution prevention at source are recommendable (industrial water saving and wastewater treatment technologies) in order to reduce the flow to municipal treatment plant (EEA, 2005).

The implementation of the UWWTD has not been particularly guided on a European level, with regard to follow-up documents. Only for wastewater treatment in agglomerations of 500 - 5,000 inhabitant equivalents a guide on extensive processes has been published with support of DG Environment (IOfW, 2001). The purpose was to support the distribution of less intensive purifying processes via the development of technical exchanges and advisories (see also chapter 9). The guide drew on the particular experience with these concepts in France. Such a **bottom-up approach** could be envisaged for water reuse applications as well. The Handbook of Best Management Practices (AQUAREC WP6, Deliverable D13) could be considered a first step in this direction.

11.2.2 Integrated Pollution Prevention and Control Directive

As part of the implementation of the Directive 96/61/EC concerning integrated pollution prevention and control (the IPPC Directive) a number of "Best Available Technology Reference Documents" (BREF) have been issued for a range of industrial sectors, which should deal as a guidance for both industrial companies as well as permit issuing institutions.

The BREFs issued by the European IPPC Bureau (http://eippcb.jrc.es) are the result of an information exchange and consultation processes going on between the Member States. BREFs for waste treatment and industrial wastewater treatment are issued but not for municipal wastewater treatment.

Although the process of producing reclaimed municipal water is not described under the BAT aspect (see chapter 9), the use of reclaimed water in some industries is and could be further enhanced. The BREF document for the *Industrial Cooling* sector does explicitly mention the reuse of reclaimed municipal wastewater as cooling water make-up as a best practice reference (EC, 2001).

11.2.3 Water Framework Directive (WFD)

The implementation of the Water Framework Directive is accompanied by the so called Common Implementation Strategy (CIS), which should support a coherent and harmonious implementation of the directive in the individual Member States. With shared river basins crossing administrative and territorial borders, a common understanding and approach is of paramount importance for successful and effective implementation process. "The aim (of the CIS) is to clarify and develop, where appropriate, supporting technical and scientific information to assist in the practical implementation of the Directive. Guidance documents, providing advice on operational methods and other supporting documents may be developed for this purpose." (N.N., 2001)

In doing so, a number of Working Groups have been established focussing on different aspect of the WFD implementation. The main characteristic of the process is that information and competencies existing on national level will be shared and made available for all parties (N.N. 2003).

In particular the Working Group B - Integrated River Basin Management (IRBM) aims at:

- identifying key issues of integrated river basin management,
- exchanging information and highlight best practices on key issues,
- gaining practical experiences through testing of conceptual approaches in pilot river basins,
- pointing out links to funding instruments,

integrating research results and other initiatives on IRBM outside the WFD CIS process (N.N., 2005).

Especially the dedicated activity on "Water Scarcity", led by France and Italy, offers a suitable forum to address water reuse issues in the context of improving drought preparedness and balancing demand and supply under exacerbating climatic conditions.

Many of the guidance documents have already been tested in Pilot River Basins or on national initiative. The German Federal Environment Agency has contracted a project about Basic principles for selecting the most cost-effective combinations of measures which resulted in a handbook (UBA, 2004). Taking into account the identified pressures, which primarily stem from diffuse pollution, the catalogue of measure does not address water reuse as an option. But in a different environment with other identified pressures, water reuse should always be included in the catalogue of optional measures.

Recently Spain, France, Portugal, Italy, Greece, Malta, Cyprus and Slovenia handed in a drought petition (March 9, 2006) which requests a Community strategy to manage drought and palliate its effects by supporting actions on local, regional and national scale.

11.3 Other policy motivation

Next to the activities in course of the implementation of distinctive legislation, the overall policy orientation and action programmes on EU or Member State level offer lots of opportunities to launch and promote water reuse.

11.3.1 European Environmental Technology Action Plan (ETAP)

The review of the Environmental Technologies Action Plans (CEC, 2005) suggests (although not explicitly referring to water reuse) an implementation strategy that builds on the experiences and initiatives in member states. It is intended to draw from experiences made on member state level in identifying best practices to set up a consolidated roadmap at EU level. The approach to a European wide promotion of reuse could be designed similarly.

With reference to water reuse the experiences gained in Spain and other EU countries with a variety of reuse schemes of different technological design constitute a valuable basis for contemplating such a roadmap for the reuse sector. Moreover experiences from around the world where reuse is a common consideration in integrated water management (USA, Israel, Australia) should be utilised.

Additionally the ETAP potentially supports reuse activities as it

- identifies priority technologies for water sector (MBR, reed-bed/extensive treatment processes in remote small areas),
- sees regulation as a main driver for the application of advanced treatment technologies and best management practices,
- favours the promotion of best available technology.

Especially the Water Supply and Sanitation Technology Platform - WSSTP- (stakeholders involved in European water supply and sanitation and major end-user groups) has set up a relevant strategic research agenda listing the increased use of recycled water among the prioritised aims (WSSTP, 2005).

11.3.2 Policies on water reuse in different Member States

A political commitment is indispensable for the promotion of water reuse and a strategic approach to develop the full potential benefits.

Spain, which thus far has been leading in European reuse activities and which is the country with the highest future potential (according to the model appraisal presented in this report) has taken the initiative to substantially enhance the reuse practice.

The program **A.G.U.A.** (Actuaciones para la Gestión y la Utilización del Agua - Actions for management and utilisation of water) reflects the reorientation of the Spanish water policy towards guaranteeing availability and good quality of water in all river basins, to gain independence from the climatic situation (MMA, 2006). In a first stage from 2004-2008 a number of activities are foreseen for the river basins bordering the Mediterranean coast line.

The activities in A.G.U.A include

- optimisation of infrastructure (irrigation schemes and water supply infrastructure)
- improvement of water treatment and reuse
- desalination

The tapping of alternative water resources is an issue of paramount importance in this program. 14 new, large-scale water reclamation and reuse projects, ranging from agricultural irrigation for conservation of groundwater resources for high-grade uses to nature enhancement are foreseen (MMA, 2006).

11.4 Summary and conclusion – major barriers and drivers for the future development

If the European water reuse potential is to be tapped to the fullest, a variety of issues will have to be tackled first. A preliminary evaluation of a large number of European water reuse projects that have been screened by the AQUAREC project indicates that several common issues exist. Some of these issues are briefly described in the following paragraphs (Aquarec, 2004).

Re-orientation of the water governance towards integrated water management

While in several Member States integrated water resources management is still at its infancy, the implementation of the Water Framework Directive is progressing and will provide a basis for further steps in integrated water resources management on catchment scale. The WFD is a soft legal document, i.e. it sets forth the principles to achieve sustainable water governance, but not the means. In developing the appropriate means at local level there is a need to go wider in thinking and to gain a good balance between disciplinary expertise and interdisciplinary understanding. Too often in stakeholders consultations water reuse is excluded from the possible integrated water management scenarios and often regardless whether water reuse is or not a realistic alternative.

The challenge for the water reuse specialists here is to educate and re-orient their own institutions to more conscious and sustainable practices by bridging the tight but artificial compartments of water supply and sanitation.

Need to strengthen cooperation among stakeholders

The tight compartmentalisation of water supply and sanitation resulted in poor institutional arrangements on the water cycle management in general and water reuse in particular. This is a factor that produced a considerable time lag between the feasibility study related to many reuse options and their realisation in practice, especially (but not only) for those regions where water and sanitation services are run by different entities.

There is a lot of discussion on how water reuse projects should be managed, in particular who should take the leadership and how the responsibilities/liabilities should be divided.

Establishment of guidelines or criteria for wastewater reclamation and reuse

Once convinced of the need of water reuse at local level, it is not always easy to obtain a permit for the reuse of reclaimed water and this despite the European Union wide encouragement to reuse the wastewater treatment effluent. One of the major problems in Europe is the lack of clear criteria on when to reuse and on quality standards for different reuse purposes.

In the past, due to the lack of water reuse criteria the public administration bodies had to rely on conservative assumptions. This led to various types of misunderstandings and misjudgements. An extreme example is an agricultural reuse project where the wastewater treatment plant effluent complied with the strict standards for unrestricted agricultural irrigation, but the public administration released a permit basically referring to the WHO's recommendations on irrigation with raw wastewater. Although this is an extreme case, it illustrates quite well how urgent the need is for the establishment of water reuse guidelines.

Despite the fact that no guidelines or regulations yet exist at European Union level several countries or federal regions have published their own standards or regulations (see Table 6.3).

Targeted use of economic instruments

Financing is perhaps the major barrier to a wider use of reclaimed wastewater. In the EU, financing of up-front costs was originally provided by (local) government grants while revenue programmes were financed by the end users i.e. on a commercial basis. Recent trends are that only a portion of the up-front cost is paid through grants (generally up to 50% of the approved cost) and that the water reuse project has to provide the balance.

For the demand and supply prices to match, targeted, time-bound subsidies are important and necessary. The subsidy is generally aimed at allowing the project to operate on a commercial basis while reaching a certain public programme objective. Often water supply benefits alone cannot cover the project costs. One of the reasons is that there still exist distortions of the water supply market. Since the Dublin conference in 1992, the full cost recovery principle is becoming more widespread in the provision of water supply. However, even when the cost recovery principle is applied, externalities such as for instance the scarcity of water and the marginal cost of new sustainable sources of water, e.g., where existing sources are at - or beyond - their sustainable limit, are rarely accounted for. Similarly the financial, social and environmental burdens of effluent disposal to the environment are rarely considered in the economic analysis.

Subsidies cover a number of areas, predominantly: planning, technical assistance and research (pilot studies, etc.), construction costs, actions contributing to regional objectives which are not locally cost-effective and pay-for-performance incentives. Subsidies do not cover (or will no longer cover) operation and maintenance costs.

Water reclamation projects have also benefited from several types of specific financial incentives, although to a lesser extent. Some examples include a recent regulation allowing exemption of the user tax for reclaimed water in Costa Brava, Spain (Mujeriego *et al.*, 2000). The EU does not have specific subsidies to encourage water reuse but EU financial institutions play a key role in favouring water reuse schemes. On a case-by-case basis several schemes have benefited from EU subsidies. The predominant programme objective is the creation of a framework that supports innovation and competition.

The current transitional phase of the European water management represents a unique opportunity to correct market distortions while providing, together with water reclamation, a cheaper alternative to applications not requiring drinking water quality. EU Member States will have to promote cost recovery policies ensuring adequate incentives for users to exploit water resources efficiently by 2010 (European Union, 2000).

Cost-benefit comparisons should be made that compare total cost for integrated water resources management alternatives, rather than considering simply cost before and after the project. Moreover, as the costs and benefits of a project are shared among different groups, there is a need for clearer institutional arrangements for the distribution of the effects of the projects. It is not ethically and economically possible that the water reuse consumers have to bear all the costs for the benefits generated by the project.

Building trust, credibility and confidence

Even if the authorities will favour the application of all the sustainability principles, no rules and no incentives will work without a general acceptance of the stakeholders, i.e. the water and sanitation urban and semi-urban areas in Europe surface or ground waters (still) have bacterial quality worse than that of a secondary-treated wastewater. In many existing urbanized catchments the water cycles actually include indirect, unplanned and uncontrolled reuse of - sometimes even untreated - wastewater.

However, facts and figures might inflame rather than convince. The acceptance of water recycling is a social factor with a high emotive content. In some cases the involvement of local NGO's and environmental associations was a critical success factor, as the Empuriabrava project in Spain, clearly demonstrated (Sala, 2004). Their involvement in building up credibility, trust and confidence is often underestimated.

As a basis for building the trust between stakeholders there is a need to convey simple, clear and reliable information. The establishment of a best management practice framework to provide a basis for structure and transparency in the management and companies, the community and the consumers alike. Otherwise even basic sustainability principles may be disregarded. Take the cost recovery rule imposed by the WFD: in a water scarce area for instance, the regional environmental ministry now imposes a water tariff in accordance to the cost recovery principle while the agricultural ministry supports farmers in the form of subsidy to compensate increased water cost. This approach maintains the situation with water resources management in the region - including the attractiveness of water reuse - practically unchanged.

A sub-optimally managed project may result in adverse health, environmental or financial outcomes that may quickly reduce enthusiasm for water reclamation, hindering its development in the region. In case of failure one might not get a second chance! For example in the Netherlands dual reticulation systems are banned altogether because of one negative experience of cross-connections with the drinking water supply. This need for a best management practice framework is well acknowledged within the European Union according to a recent survey undertaken by the EUREAU Water Reuse Group. The AQUAREC project made an effort to firmly anchor the best management practice framework to reality. Plenty of information on water reclamation and reuse practices is now available.

Of particular importance are the management practices to reduce and communicate the risk of human exposure. Management practices of quality control and failure management vary considerably from region to region and even from project to project. A common trend in process operation and risk management of the surveyed projects was the adoption of extensive quality control practices and in particular the widespread use of instrumentation, control and automation. On the other hand, despite the fact that procedures such as Hazard Analysis and Critical Control Points (HACCP) are increasingly used to direct efforts in process control and monitoring to guarantee hygienically safe reclaimed water, very few surveyed projects have used them (Dewettinck *et al.*, 2001; Salgot *et al.*, 2002). Another interesting point is that very few projects seem concerned about emerging issues such as trace organic contamination.

Final Conclusions

In Europe the last decade witnessed growing acceptance of water reuse practices, with now more than 200 municipal water reuse projects available.

The results of the AQUAREC project however indicate that only a limited fraction of the water reuse potential is actually exploited.

The results do raise and leave open the question on how to accompany the realisation of this massive potential from a regulatory point of view and how to shape an appropriate framework of incentives and implementation support measures. The potential utilisation shall not contradict the "whenever appropriate" claim of the Urban Wastewater Treatment Directive, thus demanding the determination of appropriateness.

These aspects will be of paramount importance for the wastewater potential realisation in applications that could absorb huge volumes of water but are at the same time sensitive to health objections, as for example groundwater recharge. In other cases, switching from conventional water resources to reclaimed wastewater is primarily hindered by cost arguments. This would demand the establishment of water prices that reflect the full-cost recovery principle on the one hand, and the monetarisation of the potential environmental benefits of wastewater reuse, on the other.

The production of a best management practice framework and increasing public awareness of the water cycle are other two very important aspect to be considered in promoting water reuse projects which have been addressed by AQUAREC.

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