Detailed report, related to overall project duration

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1. BACKGROUND

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.

Different climate zones and uneven distribution of precipitation causes a variety of water availabilities in European countries. The annual renewable freshwater resources average to 87,000 Mm³/a including extremes such as 51 Mm³/a in Malta and 382,000 Mm³/a in Norway. In terms of water abstraction characteristic use pattern can be identified each emphasizing a different sectoral use (Figure 1.1). At present, agriculture is the predominant water use in all Mediterranean countries (except Malta), whereas Western and Northern countries use the highest share of abstracted water for electricity production or industrial purposes, as do the Baltic and Central European states. Denmark, Luxembourg, the Czech Republic and Malta supply most of abstracted water by the public network.

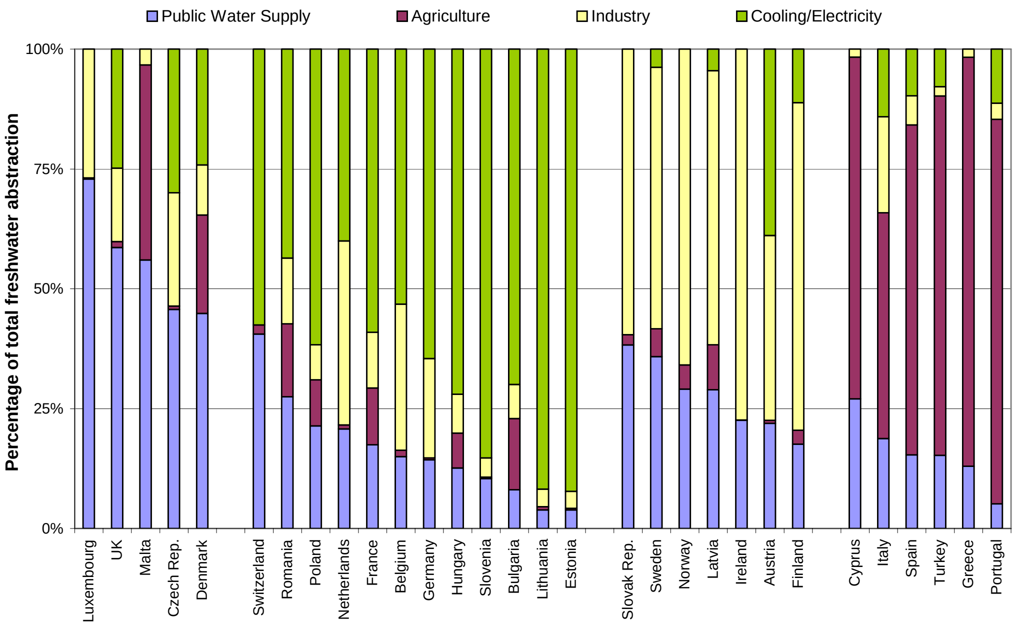


Figure 1.1: Sectoral water use in Europe

The classification of water stress is assessed as the water exploitation index. It identifies the degree of water use intensity as the ratio of water abstraction to available water resources. Israel, Cyprus, Malta, Belgium and Bulgaria rank highest with a water use intensity of > 40%. The other Mediterranean countries exhibit a less severe water stress with indices between 10 % and 30 %. But also Poland, the Czech Republic, Denmark, France and Germany fall into this category.

A survey conducted as part of the AQUAREC project revealed that approximately half of all European countries, representing almost 70% of the population, are facing water stress. Figure 1.2 ranks European countries according to their water stress index. The water stress index serves as a rough indicator of the pressure exerted on water resources (note however that different water uses have variable influences on water stress). Water Stress Index values of less than 10% are considered to be low. A ratio in the range of 10 % to 20 % indicates that water availability is becoming a constraint on development and that significant investments are needed to provide adequate supplies. A water stress index above 20 % necessitates comprehensive management efforts to balance supply and demand, and actions to resolve conflicts among competing uses[1]. These data are on a country-level and do not reflect the fact that water stress often appears at the regional scale. Uneven spatial distribution and seasonal variations in water resource availability and demand make the semi-arid coastal areas as well as highly urbanised areas particularly susceptible to water stress. Changing global weather patterns can only make the situation worse, in particular for those Southern European countries which are prone to drought conditions.

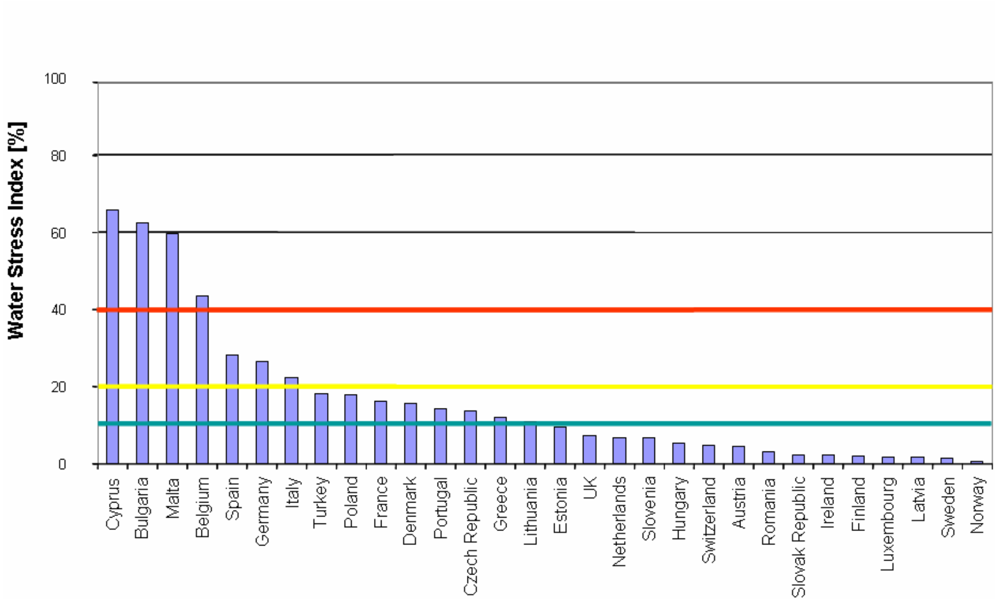


Figure 1.2: Water Stress Index for the European countries (Data sources: ltaa availability data from EUROSTAT; water abstraction mainly from EUROSTAT and national Environmental Reports)

Increasing uncertainty of water availability places many municipalities in a precarious position, especially in the face of increasing water demand, increasing water supply costs and increasing competition (e.g. between industry, agriculture, tourism, etc.) for good quality fresh water resources.

Forthcoming legislative constraints will exert institutional pressure to conserve water resources and identify sustainable management practices. In 2000, as an acknowledgement of deteriorated water resources and fragmented water related legislation, the European Union adopted the Water Framework Directive establishing a framework for the Community action in the field of water policy (WFD)[2]. It is expected that the promotion of an integrated approach to water resources management as spelled out in the WFD will favour wider application of municipal wastewater reclamation and reuse projects , for both augmenting water supply and decreasing the impact of human activities on the environment. Note that in 1991, the Urban Wastewater Treatment Directive (91/271/EC – UWWTD) already urged member states to reuse treated wastewater "whenever appropriate"[3]. But a legal definition of the legally undefined term "appropriateness" is still pending.

Furthermore, a review of the state of wastewater treatment comprising percentages of population connected to sewerage systems and treatment plants, treatment plant capacity and volume of treated effluent is necessary to depict the most relevant background factors (Figure 1.3). Even though the

[1] Organisation for Economic Co-operation and Development (Eds), Water – Performance and challenges in the OECD countries, Environmental Performance Reviews; 2003.

[2] European Union. Council Directive establishing a Framework for Community action in the field of water policy. 2000/60/EC of October 23; 2000, OJ L 327 of December 22, 2000.

[3] European Union. Council Directive concerning urban wastewater treatment. 91/271/EC of May 21, 1991, OJ L135/40 of May 30, 1991.

European legislation enacted The Directive of Urban Wastewater Treatment in 1991, which clearly defines minimum treatment requirements, quality and level of sewerage service vary markedly throughout Europe. The countries lagging behind the most are the Accession Countries but as well Spain, Portugal and Belgium with connection rates of currently below 60 %. Apart from the share of population connected to wastewater treatment plants the specific wastewater flow per person determines the wastewater volume.

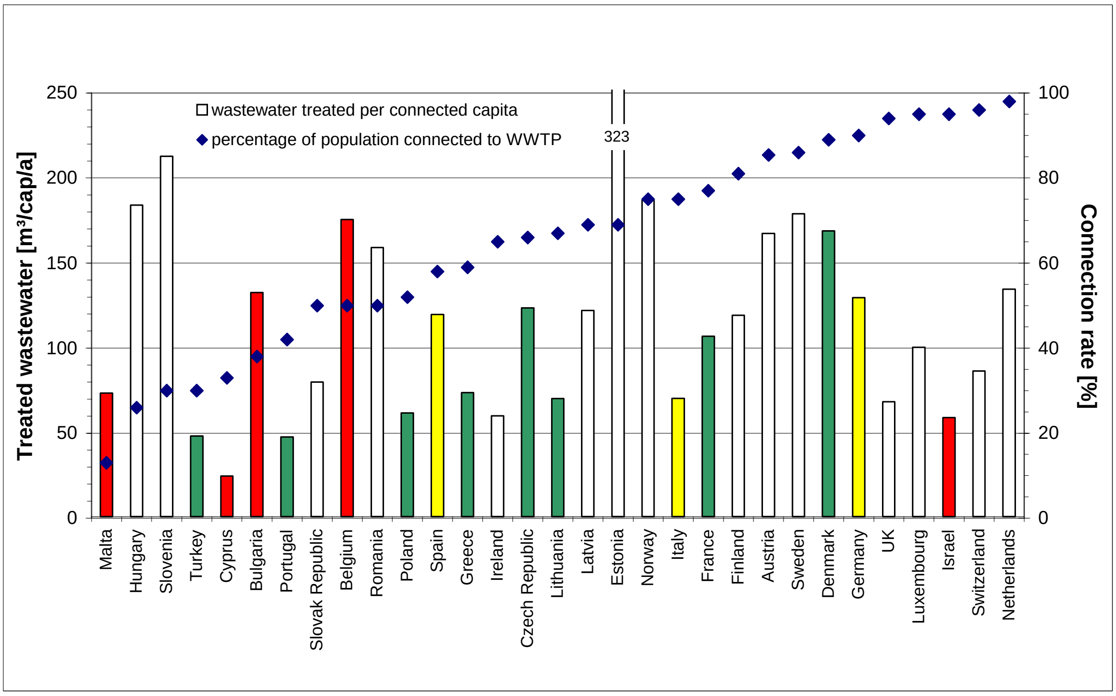


Figure 1.3: Connection rates to wastewater treatment plants and sewage collected per capita (coloured columns represent the country's water stress index:
low water stress medium-high water stress high water stress)

The availability of good quality effluent is one of the pre-suppositions for water recycling and hence the implementation of the UWWTD is one of the major constraints for the further development of water reuse in Europe.

2. SCIENTIFIC/TECHNOLOGICAL AND SOCIO-ECONOMIC OBJECTIVES

The general objective of the AQUAREC project is to provide knowledge to support rational strategies for municipal wastewater reclamation and reuse as a major component of sustainable water management practices. The approach is interdisciplinary and broad, addressing issues of strategy, management and technology. The project aims to define criteria to assess the appropriateness of wastewater reuse concepts in particular cases and to identify the potential role of wastewater reuse in the context of European water resources management. The project provides guidance for end-users facing decisions in the planning, implementation and operation of wastewater reuse schemes as well as for public institutions at various levels. Figure 2.1 illustrates the different project levels and the assessment criteria which should be utilised to evaluate the appropriateness of water reuse schemes in the agricultural, peri-urban (e.g. industrial) and urban sector which are all within the scope of the AQUAREC project.

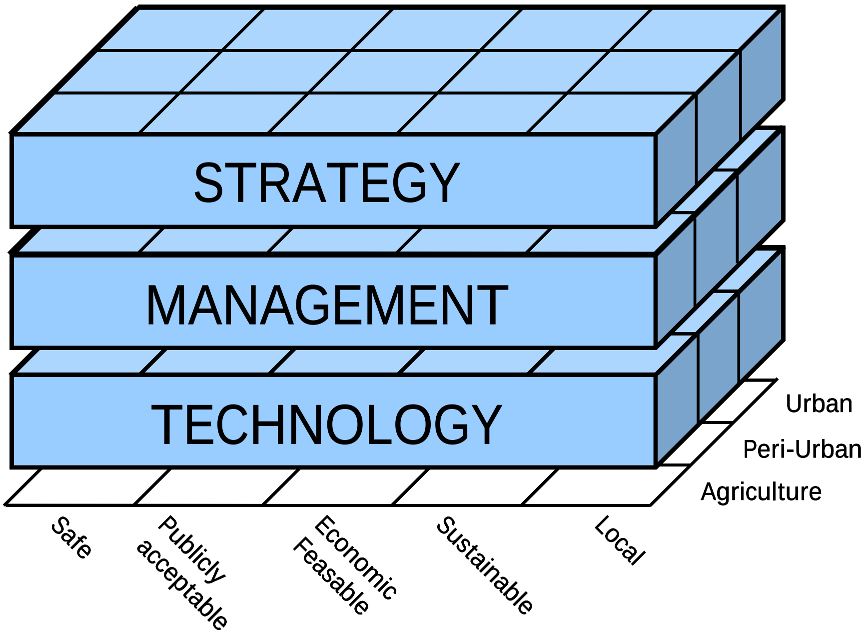


Figure 2.1: AQUAREC Project structure, scope and assessment criteria

On the strategic level, the project intends to provide policy guidelines and water quality standards for wastewater reuse in Europe. Within integrated water management concepts, reuse should become a standard option to balance water supply and demand in regions where natural water resources are highly stressed.

From a water management point of view, the objectives include the collection and validation of best management practices to ensure safe, publicly acceptable, economically favourable and sustainable reuse. Areas to be addressed are feasibility and cost / effect assessment, marketing, funding, engineering and operation of wastewater reuse as well as distribution systems. Handbooks for the pre-implementation phase, as well as, for the implementation and operation phase have been developed as reference manuals and as step by step guides for future end users. Topics covered include feasibility and public acceptance studies, design, operation, maintenance and quality control of water reuse systems.

The main technological objective is the evaluation, selection and standardisation of concepts and components for upgrading wastewater to a range of quality levels corresponding to regional demand situations. The focus of the studies undertaken is on the assessment of process combinations. Figure 2.2 gives an overview on the scientific work packages (WP) of the AQUAREC project on the different project levels.

Figure 2.2: Scientific AQUAREC Work packages (WP) on the different project levels

The scientific objectives during the full duration of the different work packages in the AQUAREC project are:

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

The basic concept of this work package has been to analyse the European water market, including the main water supply and water demand related data, key water quality parameters, socio-economic and environmental indicators. Specific objectives have been:

- Application of Geographic Information Systems (GIS) in water/wastewater related data visualisation and the development of thematic data layers. Geographical Information Systems provided a mean of handling, integrating as well as visualising supply and demand related digital spatial data at various scales. The spatial distributions of parameters such as water charges and water consumption have been illustrated in a trans-European context. GIS was also used to support activities in other work packages. Freely available statistical data have been compiled and the datasets have been analysed with standard built-in GIS tools.

- *Development of water demand and supply indicators*. The examination of the European water market incorporated a core set of socio-economic and environmental indicators to quantify large-scale effects as well as potential scenarios involving water supply and demand descriptors. The main water uses/functions (drinking water supply, bathing/recreational water use, industry, fish farming, irrigation, ecological functioning and sustainability of aquatic ecosystems) have been analysed to assess economical requirements, risks and environmental restrictions under the framework conditions of European water policies.

- *Overview on European wastewater treatment status.* Based on the analysis of water supply & demand, the wastewater treatment status in Europe has been assessed taking the water management situation and targets into account. The project partners believe that the results of the GIS analysis and the corresponding visual representations will help to identify regions, where the increased use of upgraded wastewater should to be promoted.

- Development of Cost Margins for particular reuse applications and regions using a strict economical approach, covering all possible alternatives of water supply and demand with the intention of allocating the sources to the users in the most cost effective way.

WP2: Definition of key objectives for water reuse concepts

This workpackage has the objective to define water quality parameters for reuse. The standards and criteria for reuse will be adjusted to the specific purposes of reuse. All potential uses: agricultural and other irrigation ones, aquifer recharge, industrial cooling, cleaning and process water, and even human consumption, are considered in this project. Further objectives of WP2 have been:

- To study different water quality parameters related to European guidelines and their analytical procedures to reuse reclaimed water.
- Risk evaluation (chemical and microbiological parameters) in relation with wastewater reclamation and reuse is one of the goals of WP2 in order to establish relationships between reclaimed water quality and the health hazards associated to the practice of reuse.

WP3: Development of integrated water reuse strategies

- The potential for the development of water reclamation and reuse in Europe should be assessed on a quantative basis through a scenario analysis considering different important influencing factors.
- Building on the methodology for the water reuse potential assessment a sensitivity analysis should be conducted to depict the influence of a range of variables such as water resources availability, seasonal fluctuations in demand as well as to depict the relevance of different regulative framework conditions.
- To support the exchange of information on water reclamation and reuse within the project and with the interested public the knowledge network "Wastewater Reuse" should be established.
- This work package had the objective to support continuous communication with external entities which focus on the water reuse development in Europe. Close ties have been established with the Eureau Water Reuse Group which has a major interest in fostering the further development of water reuse in Europe.
- A baseline concept for the development of a European Strategy on Water Recycling should be derived on basis of an integration of the analysis of the current water resources situation, the potential estimation as well as recommendations derived for the water reuse practice in the different other work packages.

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

- The compilation and evaluation of feasibility studies in water reuse had to be carried out. A standard structure and methodology to develop this type of studies had to be prepared.
- Extent and methodology of input data collection had to be defined. Moreover, the different issues to be considered in a water reuse feasibility study, as for example, size, water quality,

upgrading technology, cost, financing and logistics should be developed. In this phase GIS tools had to be studied as a useful technology for data collection as well as for performing water reuse ecological effect/ risk assessment.

- Different key indicators for social, economic and environmental to assess, calculate and compare the effects of the different considered options had to be identified and developed. Criteria and methods to assess socio-economic and ecological effects of water reuse had to be worked out.
- Other useful methodologies in the evaluation of the feasibility of a water reuse project had to be taken into consideration and integrated into the final handbook on water reuse feasibility studies, as for example ecological integrity methodology and data envelopment analysis (DEA) models.
- It was very important in order to validate and test the developed methods to execute different real feasibility study examples in areas of potential water reuse application.

WP5: Methodologies for public acceptance studies and consultation

- Consultation with project partners and water reuse experts to identify information requirements for each WP objective.
- Conduct a literature study (including ‘grey’ literature such as reports and information from electronic sources) on stakeholder and institutional perceptions of water reuse and participative planning models.
- Organise and report on a session at an International Conference on the human dimensions of water recycling projects. The session should focus on practical examples, encourage a diversity of perspectives and ask contributors to draw conclusions from their own experiences.
- Conduct fieldwork activities to improve our understanding of consumer attitudes towards water reuse and the management of participative planning processes for water reuse schemes.
- Author and disseminate a set of guidelines on participative planning for water reuse projects. Draft versions to be sent out for comment to professional and lay groups.
- Conduct visits to operating reuse projects across Europe, the Middle East, Australia and Africa to compare and contrast the design and management of stakeholder engagement processes.
- The guidelines on participative planning for water reuse projects will be translated into French & Spanish and made available in a variety of formats.

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

- Review management practices for water reuse systems. Many water reuse schemes and experience already exist throughout the world, yet the information available is very dispersed or open to misinterpretation. Instead of producing new evidence, this work package had the task to compile knowledge.
- Mapping study of water reuse schemes to see where present practice lies in relation to what is deemed to be best practice.

- To compile a water reuse system management manual in order to share and promote best practice at European level through providing a single source of information on management practices for the implementation and operation of water reclamation schemes that are suitable to the European context.

WP7: Characterisation and assessment of technology in water reuse cycles

- Compile an inventory and description of unit operations for water reclamation. Biological, physico-chemical and advanced treatment processes as well as disinfection processes are part of the inventory. The inventory and descriptions are based on an extensive literature survey
- Compile a of water treatment matrix in which (standard) treatment schemes are defined on the basis of the raw (waste)water quality and reuse requirements
- Select typical treatment trains for wastewater reclamation based on a world wide inventory of existing reuse schemes. To illustrate the typical treatment schemes case studies are selected. For each typical scheme at least one case study has been selected.
- Provide information to WP8 for the validation and calibration of the decision support model which is developed as objective of WP8
- On the long term, schemes alternative to the traditional chain can become feasible options. Therefore innovative technologies for water treatment are reviewed and described. The description is focussed on direct membrane filtration and advanced oxidation processes.
- Besides the development of new technologies the regulations for the discharge of treated wastewater become more and more stringent. This means that assessing the standard group of parameters will be not longer sufficient. Up to now non-standard parameters (heavy metals and organic micro pollutants) are only measured occasionally. A literature review is conducted into the removal of non-standard substances in traditional and advanced (wastewater) treatment processes.

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

- Reclaimed water projects typically include construction of new or upgrades to a municipality's treatment systems, to treat wastewater to the required quality level, and construction of distribution systems for reclaimed water.
- A water reuse system is likely to have many possible design options: type and degree of treatment, number and location of treatment plants, number and location of pumps/pumping stations, number, size and location of storage tanks, layout and size of distribution pipe network, as well as a large number of potential end-users of reclaimed water.
- The complexity associated with planning of water reuse schemes is therefore very high due to a very large number of design combinations possible, and establishes the need for use of decision support systems (DSS) to aid in the planning process.
- The objective of this work package was to develop and validate system design principles for water reuse systems. In order to achieve this objective, a DSS called WTRNet was developed first, which consisted of simulation and optimisation components that enabled efficient evaluation of a large number of design options.

- The developed DSS was applied to two case studies, and several design principles were developed with regards to both the treatment and distribution aspects of water reuse. In addition, the WTRNet software was made available as a stand-alone application that could be used in the future for integrated evaluation of planned water reuse schemes.

3. APPLIED METHODOLOGY, SCIENTIFIC ACHIEVEMENTS AND MAIN DELIVERABLES

The major project methodology included reviews of the existing experiences of water reuse practices all over the world through literature reviews, questionnaires and surveys dedicated both to water reuse practitioners, different focus groups and the general public. Data has been collected from various sources such as databases and reports as well as full and pilot scale reuse schemes. In the technical work packages a limited number of experiments have been conducted to gather more data on the effectiveness of different treatment technologies. The following table 3.1 gives an overview on the deliverables accomplished in the project.

Table 3.1 Deliverable list of the AQUAREC project

Deliverable No.	Deliverable title
1	WP2: Report on the definition of key quality parameters
2	WP4: Report on the survey on conducted feasibility
3	WP1: General maps on water supply & demand
4	WP5: Conference proceedings on public consultation
5	WP3: Knowledge Network "Wastewater Reuse"
6	WP7: Report on water treatment matrix of current
7	WP8: Simulation software for reuse systems
8	WP9 Draft of Technology Implementation Plan
9	WP5: First draft of guidelines
10	WP6: Review report on water management survey
11	WP8: Report on validation of simulation software
12	WP1: Report on the water supply & demand indicators
13	WP6: Water reuse system management manual
14	WP8: Design support software for water reuse
15	WP2: Guideline for quality standards for water reuse in
16	WP4: Handbook on feasibility studies for water reuse
17	WP7: Proposal of standard treatment in water reuse
18	WP5: Published guidelines on stakeholder engagement
19	WP3: Report on integrated water reuse concepts
20	WP9: Final project report
21	WP9: Technology Implementation Plan

The methodology applied in the different scientific work packages and the major deliverables obtained are described below.

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

Following the definition of project scales and scopes of GIS application in Aquarec base maps of Europe were completed and finalised – containing the vector map of Europe with the administrative boundaries, capitals, main surface waters, moreover several water related environmental indicators, economic and statistical data. The most important water demand and supply indicators were selected and integrated in the system. Thematic maps were developed to describe the water sources, water abstraction or for example the sectoral distribution of water demands. The maps and data behind the maps show absolute quantities, relative values and spatial differences caused by climate, population density or type of an economic activity. The developed GIS tool is fully accessible via the official website of the project. The GIS tool was developed, and is being operated by GEONARDO Ltd. By the application of this tool, end-users and interested people can access the maps without the need of purchasing special GIS software. The online tool offers basic GIS functions (zoom, search, show the legend, etc.), while the chosen map can be printed as well. The GIS tool contains the attribute data (e.g. the above mentioned indicators) connected to the spatial data. These attributes can be viewed by clicking on a certain geographic location. The online GIS tool has a simple but robust structure: five main categories contain the different maps.

Regional data collection and processing received increased attention during the second part of the project. WP1 started analysing the water market at European, national and (in some cases) at regional level. The status of wastewater treatment was analysed across Europe according to the most important aspects. Firstly, the origin of wastewater was analysed followed by the analysis of infrastructural issues (capacity and treatment level) as well as the examination of effluent quality. The outcome of this analysis was the availability of treated wastewater to reuse. This work was supplemented by an overview on the water related environmental policies, examining the EU environmental legislation up to the Water Framework Directive. The new aspects of the water pricing received much attention as it will become the most important legislative tool in the future.

WP1 also developed a set of indicators describing the local water market aimed at revelation of the additional water resource that can be supplied from treatment plants and the potential water demand for the adequate purposes. A total of 31 demand and 34 supply indicators were defined for the market analysis, which culminated in the development of a Cost Margin theory for wastewater reuse applying a strict economical approach. Cost margins have been defined as a methodology to compare the cost of water reclaimed in relation to the cost of other water sources, for example, freshwater in a given area. It is also related to water prices and political incentives to water reuse. This methodology theoretically allows achieving an indicative measure of the potentiality of water reuse in the selected test areas, but also providing qualitative indicators for Europe as a whole. The functionality of the developed linear model covers all possible alternatives of water supply and demand. The purpose is to allocate the sources to the users in the most cost effective way.

Three test areas were selected for regional analysis representing four levels of assessment according to various details: Catalonia (Spain) was found suitable for examine the role of water reuse for generating additional water resource in peak demand periods. Thessaloniki (Greece) is an example for a municipal area, where reclaimed municipal wastewater and pollution reduction of coastal waters can be surveyed. Moravia (Czech Republic) is a more complex area, where municipal, industrial and agricultural sites have been reviewed.

WP2: Definition of key objectives for water reuse concepts

During project, the water reuse related rules and regulations changed, form a standards-based law to a more comprehensive approach.

The shift has been in the sense of using new tools, risk-related, and considering reclamation as a classical industrial activity. In this way, industrial quality management has been applied to the reclaimed water manufacturing.

HACCP (Hazard Assessment and Critical Control Points) and GRP (Good Reuse Practices); usual quality assurance systems in the industry (e.g. agro-food) have been applied to reuse practices. QMRA (Quantitative Microbial Risk Assessment) has also been considered.

Consequently, the outputs of the WP2 have been re-oriented to fulfil the current trends in the reclamation and reuse (recycling) field. Three main lines were developed with respect to water quality criteria:

- microbiological
- chemical
- biological

Pathogens presence (microbiological approach) is the present basis for the DALY (Disability Adjusted Life Years) calculations, and several exercises on it are described in the WP2 deliverable. Chemicals contaminant occurrence in reclaimed effluents was also discussed in the sense of a quantative risk assement. The possibility to use biological indexes for the establishment of risks related to reuse was the third approach.

Considering the three approaches, a suggestion was made to develop new regulations or recommendations in the near future, although it seems clear that further work is needed on the chemicals side, new indicators are to be implemented both for chemicals and pathogens, and biological indexes are suitable for environmental applications only.

The practical application of the theories developed show that the barrier approach, the DALY calculations and the application of GRP are to be implemented together to obtain a safe non-conventional water resource utilisation.

WP3: Development of integrated water reuse strategies

This strategic work package included different tasks which required the adaptation of a range of methodologies.

- Assessment of European water reuse potential

The estimation of water reuse potential in Europe carried out in AQUAREC project is based on a mathematical representation of that share of water demand and supply which can be covered by reclaimed wastewater.

Modelling approach

The model is based on a straightforward 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 equal the amount reused while covering a particular fraction of total demand. If wastewater is reused in different sectors like agriculture, domestic uses or industry, these segments can be regarded separately. The basic model equation for the assumption of reuse in different sectors is structured as follows:

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

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

The intention is to combine various general water management data and the currently verifiable status of wastewater reclamation and reuse in Europe as a basis to calculate reclamation and reuse-factors which describe the main influencing parameters on further development.

Determination of variables

To calculate a change in the total wastewater reuse volume during a time interval, the current wastewater treatment capacity, the fraction reclaimed and reused as well as the sectoral water demand have to be known. For the purposes of demonstration, these data were extracted from the EUROSTAT database, the FAO AQUASTAT database and various national statistics. Information on wastewater reclamation and reuse is based on literature survey and the compilation of installations conducted by Bixio *et al.* (2003)[4]. For a first projection horizon, set for the year 2025, the assumptions for the variables were made as follows:

WWTP Effluent E. Several factors influencing the amount of wastewater generated, collected and finally treated have to be taken into account for future estimation. The amount of wastewater treatment plant effluent generated is significantly determined by the proportion of population connected to sewers and treatment plants. For many European countries this share is already very high (> 85%; Austria, Germany, Netherlands, Denmark) whereas others are still in the process of improving their sanitary systems. For some Member States of the European Union the Urban Wastewater Treatment Directive (UWWTD) has triggered an enormous effort to enlarge the wastewater treatment systems (Spain, Greece, Portugal, Italy, Belgium). The treatment capacities supposed to be installed in Member States pursuant to the objectives of the Directive form a good data base for future effluent flow estimations. For the purposes of the study in the AQUAREC project wastewater volumes had to be derived from other parameters like design capacity.

Water demand U. The future water demand was appraised for each sector separately. When available, estimates for future water demand in national hydrological planning documents were referred to. For the share of public water supply, future withdrawals were estimated based on the actual per capita abstraction taking into account population development. Future water withdrawal for irrigation is rather difficult to assess as irrigation needs vary notably with the meteorological characteristic of a year. If nothing contrary was reported, the extent of irrigation practice was assumed to be stable in both area and intensity. Literature statements on additional irrigable areas in Italy were considered. Nonetheless for future estimation a moderate economic growth of 1% was assumed resulting in an equivalent increase in industrial water use and electricity production.

Wastewater reclamation factor η. It is a major challenge to estimate this parameter. Although the present value can be calculated for many countries, no quantitative correlation between this factor and

[4] Bixio D., de Heyder, B., Joksimonovic, D., Chikurel, H., Miska, V., Muston, M. and Thoeye, C. (2003). Municipal wastewater reclamation: Where do we stand? An overview of treatment technology and management practice. Water Supply, Vol. 5, No. 1, pp 77–85

other water management indicators has ever been derived. The factor has to include the need to change the water management pattern and turn towards alternative water sources. As water stress due to limited water availability is regarded as a main driving mechanism behind wastewater reclamation and reuse, the correlation of η to water stress indicators was investigated. The measure of 'water use intensity' that relates total water abstraction to the total renewable freshwater resources of a country was chosen. Taking into account a country's water use profile, this index was modified by weighting the water abstractions of each sector according to their consumptive characters. This is to emphasise how much water, abstracted for a certain use, is 'lost'. For example, the index for irrigation water use is set to 0.77 as much of the applied water leaves the liquid water cycle by transpiration and evaporation or is incorporated into biomass. Based on the general trends observed, a correlation between consumptive water use intensity *A'* and the wastewater 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 relationship. The model equation has the following structure:

$$\eta(A') = \frac{1}{\left(1 + \exp(k_1 \cdot (1 - A') + k_2\right)} + k_3 \qquad \text{(Equation 2)}$$

The parameters k_1, k_2, and k_3 were adjusted by a least-square-error-minimisation method to fit the curve with the considered data.

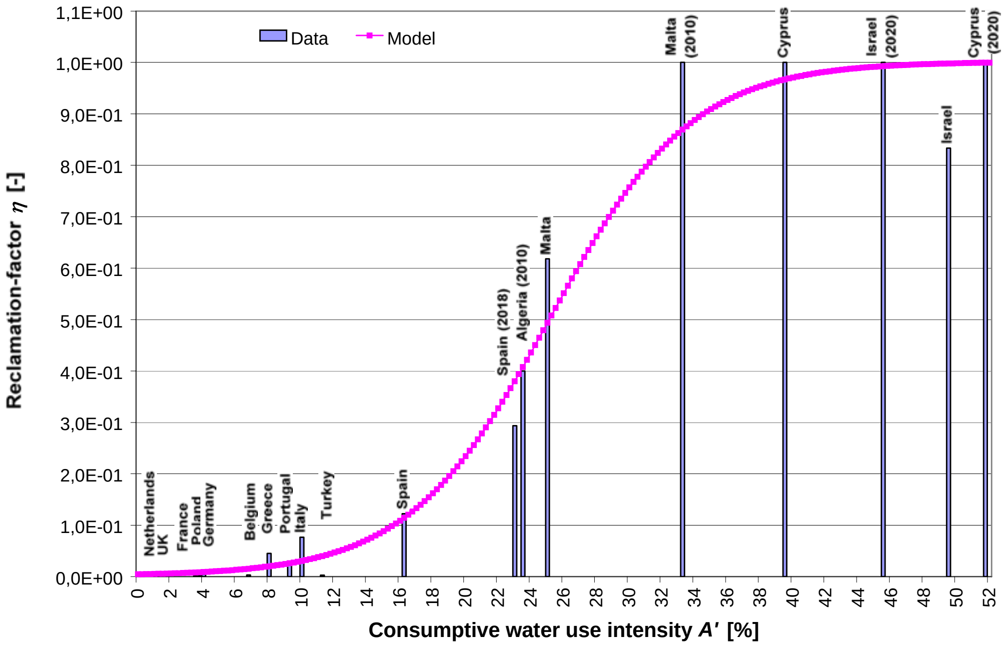


Figure 3.1: Reclamation-factor η as a function of consumptive water use intensity

Figure 3.1 depicts the comparison of the model output and wastewater reuse data for some countries of consideration. The gap between data and model e.g. in case of Israel is expected to be closed in the future, while Cyprus already displays an extraordinary high level of water reuse application.

Wastewater reuse-factor ϕ.: Analogue to the procedure for the estimation of the reclamation-factor and based on the same mathematical correlation as presented in Equation 2 the reuse-factor ϕ was quantified 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 3.2):

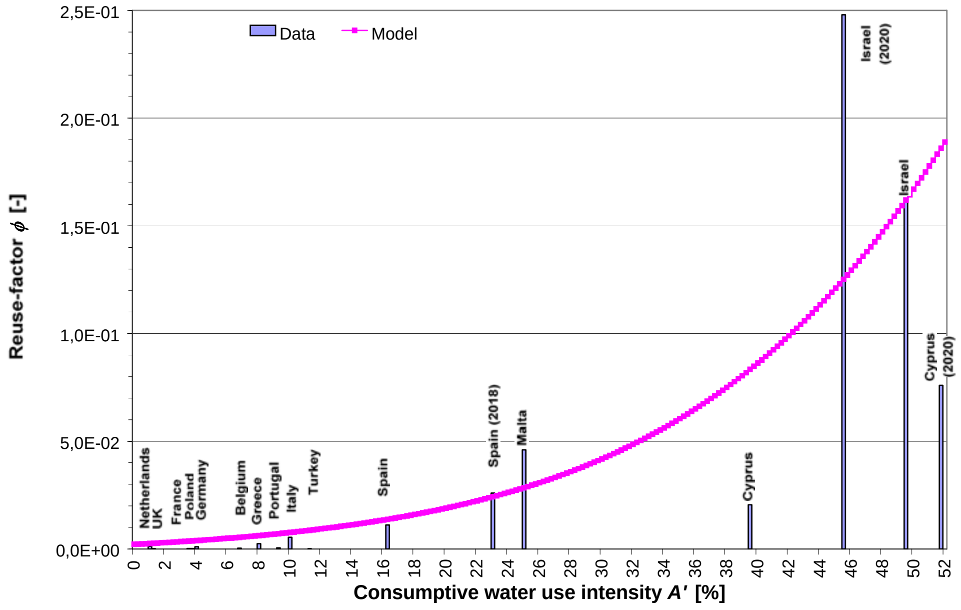


Figure 1.2: Reuse-factor ϕ as a function of consumptive water use intensity

Water stress (expressed e.g. as consumptive water use intensity) for itself does not automatically incite the reuse of wastewater but requires accompanying demand managing instruments like water abstraction restriction to exert requisite pressure. Hence, the correlation established here is only a first attempt in estimating the dimension of ϕ.

Results of the potential estimation

For the computation of a first rough estimate of the water reuse potential in European countries and Israel Equation 1 is used with the corresponding data for time-discrete points (t(0)=2000; Δt=2025) and with parameters calculated according to the presented correlations.

Figure 3.3 depicts the wastewater reuse potential for most European countries according to the model calculation. Spain shows by far the highest reuse potential, which is supposed to exceed 1,200 Mm^3/a. Israel and Italy exhibit estimated reuse potentials of 463 Mm^3/a and 418 Mm^3/a respectively. Wastewater reuse appraisals for Turkey amount to 234 Mm^3/a whereas Germany and France are supposed to reuse 126 and 102 Mm^3/a respectively. Bulgaria and Portugal account for reuse potentials of less than 100 Mm^3/a (74 and 64 Mm^3/a). On the whole the estimate predicts a wastewater reuse volume of 2,979 Mm^3/a.

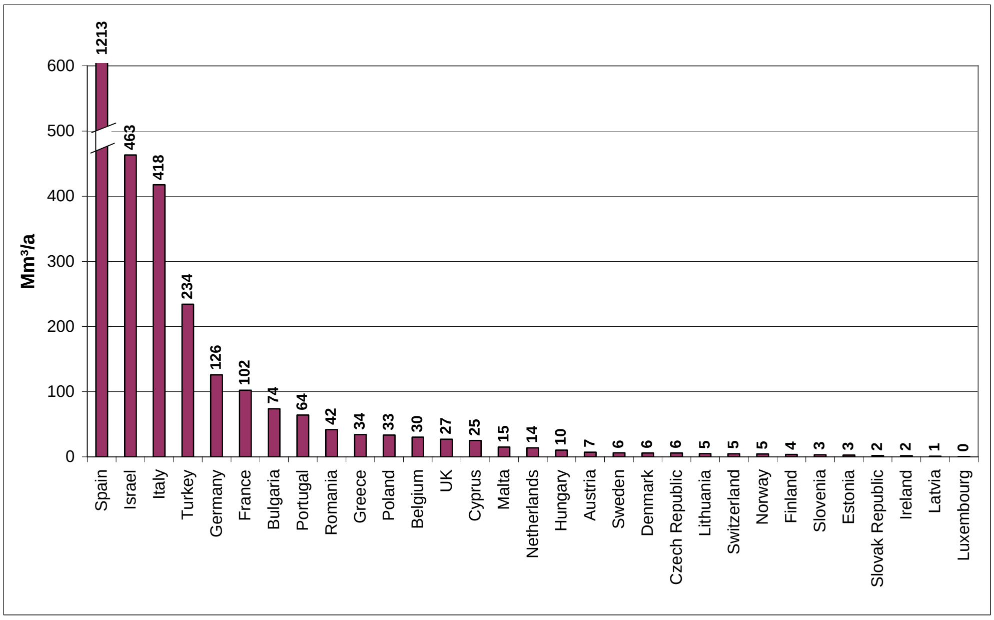


Figure 3.3: Model output for wastewater reuse potential of European countries; projection horizon 2025

As expected, for most Nordic or small countries, the estimated reuse potential is low in both absolute volumes reused (≤ 7 Mm³/a) and relative to the country's total water demand. On a European level, the reused wastewater volume would save 0.9 % of the total water abstraction in the year 2025. While for most countries the substitution potential is less than 0.5 %, Malta, Cyprus, Israel and Spain could cover up 26 %, 7.6 %, 18 % and 3 % of their future water demand respectively.

- Scenario analysis: impact of different influence on water reuse potential

The established model for the water reuse potential estimation implies that any deterioration of water availability or increase in water demand will enforce a change of the consumptive water use intensity, that on itself modifies both the wastewater reclamation- and reuse-factor, hence the reused wastewater flow *Q*. In order to depict the impact of decreasing water availability and increasing water demand different scenarios were tested. The assumptions for each scenario are summarised in Table 3.2.

In the scope of the sensitivity analyis, the possible decline of water availability due to climate change was appraised referring to the results of the EuroWasser model by Lehner et al. (2001)[5]. This model is forecasting the impact of climate change on water availability in Europe for the time horizons 2020s and 2070s. Due to their calculations 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. The First European Climate Assessment[6] came to similar conclusions predicting a reduction of the mean annual flow in Portuguese river basins of 10 % to 20 %. Hence the reductions of water availability for the water shortage scenarios III and IV were based on assumptions in these orders of magnitude.

[5] B. Lehner, T. Henrichs, P. Döll, J. Alcamo, EuroWasser – Model-based assessment of European water resources and hydrology in the face of global change. Kassel World, (Water Series 5, Center for Environmental Systems Research, University of Kassel, Germany 2001)

[6] EEA (Ed.) Water resources problems in southern Europe – An overview report, Kopenhagen, Denmark(1996)

Changes in water demand were estimated to the following premises. As, in general, irrigated agriculture is much more productive than rain fed cultivation[7] the resumption and enforcement of irrigation practice in most of the eastern European countries was assumed. In addition, planned extensions of irrigated land in Spain and Portugal were taken into account[8].

Table 3.2: Different scenarios and underlying basic conditions

Scenario	I	II	III	IV
Projection year	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

The scenarios have been evaluated with respect to the impact on the water reuse potential[9].

- Development of an integrated water reuse strategy – the legislative framework

WP3 has particularly addressed the relation between the European environmental legislation in force and a potential framework for a European Strategy on Water Recycling. Within the existing regulatory frame, some of the concerns relevant to wastewater reuse applications have already been addressed by separate directives. Table 3.3 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 microorganisms are explicitly addressed in the Bathing Water Directive and the Drinking Water Directive. Whereas the former has

[7] INAG Plano Nacional da Água. Instituto da Água. Lisbon, Portugal (2002).

[8] Ministerio de Medio Ambiente (MMA). Libro Blanco del agua en Espana., Madrid, Spain, 2000

Kamizoulas, G., Bahri, A., Brissaud, F., Angelakis, A.N. (2003). Wastewater recycling and reuse practices in Mediterranean region: Recommended guidelines. Published on www.med-reunet.com

[9] R. Hochstrat, Thomas Wintgens, Thomas Melin, Paul Jeffrey. Assessing the European wastewater reclamation and reuse potential - a scenario analysis. Desalination 188 (2006) 1-8

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.

Table 3.3: Outline of correlation of reuse applications and effected compartments regulated under European law

Reuse application	Major concern	Related directive							
		A	B	C *	D	E	F *	G *	H *
Agricultural irrigation	*Contamination of soil, groundwater and produce with chemical and/or biological hazardous substances* Health risk for workers and consumer	x	x	x	x				
Groundwater recharge	Health concerns if potable reuse is intended		x	x	x				
Urban applications	Health concerns regarding exposed persons								
Indirect potable reuse	Health concerns			x	x		x		
Recreational water use	Health concerns, infections risks for exposed persons					x			
Environmental enhancement	Detrimental effects on the biocoenosis						x	x	
Aquaculture	Contamination of water and produce with chemical and/or biological hazardous substances							x	x

Where:

A Sewage Sludge Directive; 86/278/EEC
B Nitrate Directive; 91/676/EEC
C Groundwater Directive; 80/68/EEC
D Drinking Water Directive; 98/83/EC
E Bathing Water Directive; 76/160/EEC
F Surface Water Directive; 75/440/EEC
G Freshwater Fish Directive; 78/659/EEC
H Shellfish Water Directive;79/923/EEC

* to be repealed by regulations under the Water Framework Directive latest by 2013

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. Their legal status ranges from provisional standards (Cyprus) over guidelines (France) to technical norms fixed as Ministerial Decree (Italy). 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). Some basic consideration about a potential legal framework for water reuse in Europe is outlined in the final Deliverable of Work Package 3 on "Integrated Strategies for Water Reuse".

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

Water reuse accomplishes two fundamental functions: the treated effluent is used as a water resource for a beneficial purpose and the effluent is kept out of streams, lakes, and beaches thus reducing pollution of surface water and groundwater. In addition to the economic savings, valuable substances and heat recovery can be achieved by water recycling favouring a zero emission process.

One fundamental advantage of water reuse is the fact that in many cases the resource employed is available in the vicinity of its prospective new use, i.e. urban agglomerations and industrial sites. The limiting factor for water reuse can in many circumstances be the quality of the water available linked to the treatment processes (technology) and potential hazards for secondary users.

The practise of wastewater reuse is increasing greatly within the EU, mostly to alleviate the lack of water resources in certain regions, such as in Southern European countries, but also to protect the environment especially in coastal waters by removing all discharges into fragile receiving waters. In this sense, the full implementation of the Urban Waste Water Treatment Directive (91/271/EEC) in Europe will contribute to obtain treated wastewaters of quite high quality available for reuse.

Water reuse has to be considered in the first stages of an Integrated Water Resources Management Project. To examine its economic viability, a careful cost-benefit analysis for the various parties involved needs to be carried out regarding mainly technology aspects. But some water reuse implementation projects have failed because some other key factors, such as social awareness or associated ecological effects, were not accounted for. Thus, the consideration of regulatory, economic, technological, social and environmental factors seems essential to successfully accomplish a reclaimed water reuse project.

Feasibility studies can contribute to obtain successfully completed water reuse projects. A feasibility study is defined as an evaluation or analysis of the potential impact of a proposed project or program and is conducted to assist decision–makers in determining whether or not to implement a particular project or program. It is based on extensive research on the current practices and the proposed project / program and its potential impact. Accordingly, it will contain extensive data related to financial and operational impact and will include advantages and disadvantages of both, the current situation and the proposed plan.

Within of WP4 of the AQUAREC project, a water reuse feasibility study methodology – summarised in Figure 3.4 - has been developed considering regulatory, economic, technological, social and environmental factors. This methodology is publicly available through the “AQUAREC Handbook on feasibility studies for water reuse systems”. The aim of this handbook is to offer a useful methodology to assist the different stakeholders (administration, engineering companies, water management bodies, etc.) involved in the implementation of a water reuse programme in a specific area and to provide the needed tools to address a water reuse feasibility study for a specific purpose.

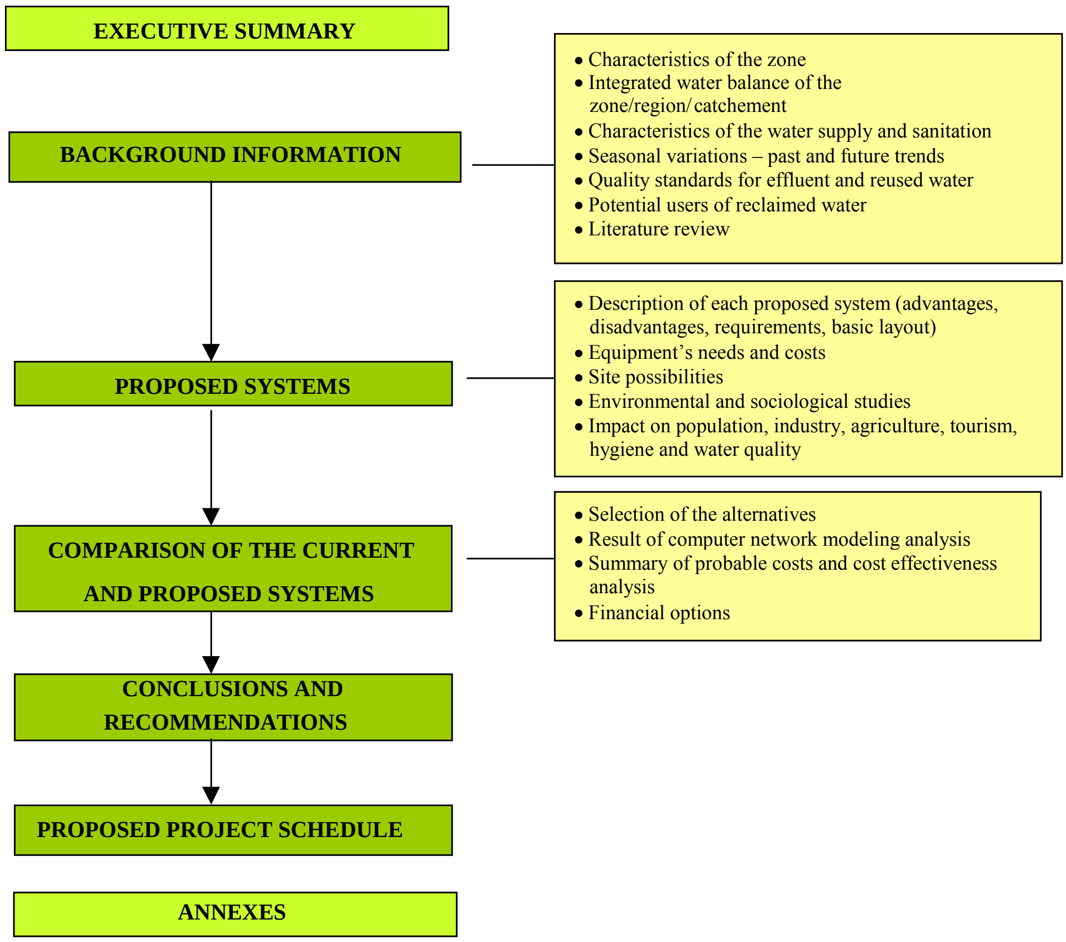


Figure 3.4: General structure of a water reuse feasibility study

Information collection

When facing a feasibility study it is fundamental to count on different reliable data sources, indicators or information of very different nature. Some basic records to be collected include:

- Water supply and demand (local and seasonal),
- Water and wastewater management agencies in the area,
- Regional water and wastewater facilities (in operation and planned),
- Water cost and quality requirements,
- Environmental setting (climate, geography and topography, water resources –surface and groundwater),
- Land use and population (current state and projections),
- Structure and location of potential users,
- Ecological and hydro-geological boundary conditions,
- Water related socio-economic facts (water supply restrictions on domestic, industrial and/or irrigation uses),

- Status of public acceptance of water reuse.

To obtain this information it is necessary to contact the main stakeholders (different water-related institutions, organisations and associations) in the evaluated zone such as water and wastewater agencies, regional environmental agencies, councils and regional governments (land and population projections, funding options…), farmers associations, end-users associations, etc.

Moreover, different maps (boundaries, location of water and wastewater facilities, location of water sources, zones of land uses, possible users of the reclaimed water and population zones, geological zones…) should also be compiled. The location of the water supply and wastewater facilities is crucial. In addition, the correct identification/location of its users and the reclaimed water flow and quality demands will also be key factors as they will condition the treatment, storage, piping and distribution needs, being one of the most relevant items to consider in the economical evaluation of the proposal. In Annex I of the Deliverable D16 a complete table with the type of information to obtain and main sources where more information can be obtained is enclosed.

Socio-economic facts and other data like water supply restrictions on domestic, industrial and irrigational uses or cost and prices for water supply and sewerage might be compiled too. The data scope should generally cover a wide period of time (from 20 to at least 5 years) so as to predict and consider the trend of each parameter (rainfall, temperature, water resources, water demand, population, land uses, wastewater quality, water prices and so on).

The implementation of a water reuse project will certainly alter existing planning concepts, especially the potable water supply and distribution systems which are usually foreseen for a long time. Moreover, wastewater treatment plants are usually planned to operate for at least 20 years so as the quality of the reclaimed water will depend on the treatment itself these forecasts should be accounted for. Lastly, other civil works such as piping, storage tanks, etc. must be correctly sized to fulfil with the future needs (10-20 years). In summary, the executed projections must be realistic cover a wide period of time.

The public acceptance of water reuse is another important issue that needs consideration. In fact, many water reuse projects have not succeeded due to a lack of considering the public opinion with regard to the project or over estimate the acceptance of the final users. Public acceptance can change depending on the water reuse application. For instance, water reuse for landscape irrigation, agricultural uses and industrial applications are usually well or relatively well accepted whereas reuse for indirect potable uses is not well considered. Moreover educational (unknown effectiveness, potential risks…) and socio-economic considerations (perception of water as an unlimited cheap resource…) as well as religious issues should also be considered.

In order to improve the public acceptance of water reuse, information about its benefits (environmental, economic, etc.) together with a training session on the key terms (water, wastewater, reclaimed water, water treatment, water quality, etc) should be promoted. Direct information has proved to have a positive influence in users' willingness and a higher level of income and education are positively correlated with a respondent's willingness to use recycled water. In any case, cost and risks are usually the main aspects to determine public acceptance.

Proposed water reuse options

The choice of the right wastewater treatment technology is a major step in planning a water reuse system because it is the key means of decreasing its potential risk including environmental, technical, social and economical risks as shown in Figure 3.5. Amongst the risks linked to reclaimed water use, the possible transmission of infectious diseases by pathogens is the most important concern.

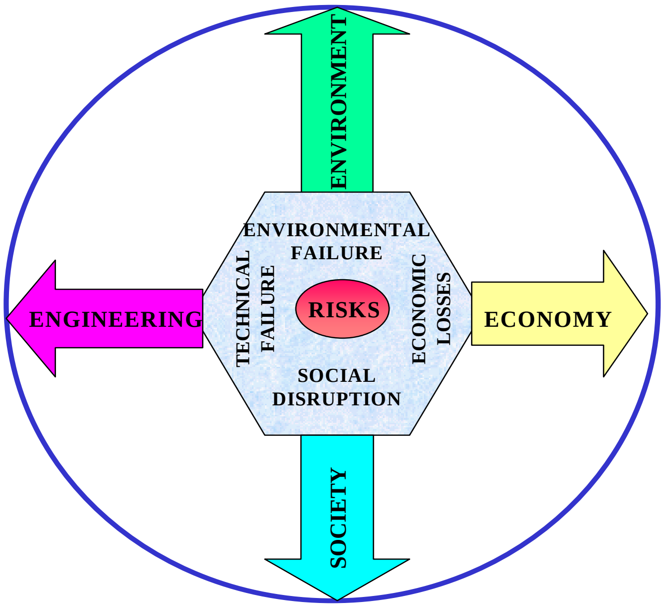


Figure 3.5: Risks and objectives for sustainable water reuse

The environmental impact assessment (EIA) of a water reuse project may address the following groups of risk:

1. Substantial alteration of land use,
2. Conflict with the land use plans or policies regulations,
3. Impact on wetlands,
4. Affection of endangered species or their habitat,
5. Populations displacement or alteration of existing residential areas,
6. Anthagonistic effects on a flood-plain or important farmlands,
7. Effect on parklands, preserves, or other public lands designated to be of scenic, recreational, archaeological, or historical value,
8. Significant contradictory impact upon ambient air quality, noise levels, surface or groundwater quality or quantity,
9. Substantial adverse impacts on water supply, fish, shellfish, wildlife, and their actual habitats.

The accomplishment of an **environmental impact assessment** of the considered solutions compared to the situation at present is a compulsory requirement to fulfil when implementing any water reuse project. In many cases a water reuse project will exceed positive impacts in the mentioned categories (e.g. environmental enhancement projects). In the Deliverable D16 an Environmental Impact Assessment Multiple-Level (**EIAML**) approach and its multidisciplinary application for a water reuse feasibility studies have been developed. This systematic analysis, covering social, cultural, economic and ecological constraints, supports ecologically sustainable water management using the best practicable techniques of decision-making processes addressed to environmental effects of a project. Basic strengths of the EIA procedures have been proposed, by reflecting both the application of the procedures laid down by the current legislation and the potential application of best practices by individual Member States that could be adopted in their own guidance on screening, scoping, reviewing and cumulative impact assessment.

The main supportive **procedures and tools** for developing a **Decision Support Systems (DSS)** and determination of all EIA components in the **feasibility and operational phases** of the project have been analysed as follows:

(1) Hazard Analysis and Critical Control Points **(HACCP) system –** with an analysis and definition of major requirements of water reuse projects including environmental values to be protected;

(2) Driving Force – Pressure – State – Impact –Response **(DPSIR) system** focusing on the formal optimisation of the relationships between various sectors of human activity and the environment as causal chains.

(3) Strategic Environmental Appraisal **(SEA) supportive framework** aiming at making explicit the cause-effect relationships between interacting components of complex social, economic and environmental systems and at organising the effective information flow between its parts.

Water reuse costs and financing

A common misconception in planning water reclamation and reuse is that reclaimed water represents a low-cost new water supply. This assumption is generally true only when water reclamation facilities are conveniently located near large (e.g. agricultural or industrial) users and when no additional treatment is required beyond the existing water pollution control facilities from which reclaimed water is delivered. The conveyance and distribution systems for reclaimed water represent the principal cost of most water reuse projects.

The different water reuse options should be compared with the conventional non-reuse alternative. In most cases there is not a single most suitable option. Two or more different types of treatments and water reuse applications are often recommended. Different **assessment methodologies** and **computer network modelling analysis approaches** have been considered. In fact, **probable costs** (cost of reclaimed water reuse, price of reclaimed water…) and **cost-effectiveness analysis** of the different proposed options must be conducted.

Investment costs account for 45% to 75% of the total cost of a water reuse project. Comparison of reclaimed water costs with a similar compilation of costs for a freshwater supply system provides a measure of cost-effectiveness of a reuse project. The cost effectiveness of reuse projects is directly related to the volume of reclaimed water used: the more water utilised, the more cost-effective the project. However, reuse costs should also integrate external costs of an environmental or social nature usually not considered.

Accordingly, funding and management of a water reuse system is a key element for a feasible implementation. The funding mechanisms can be split in two related categories:

1. Financing of up-front costs (i.e. initial capital investment)
2. Financing of ongoing operating costs (i.e. revenue programmes during the operation to cover debt service and operation and maintenance costs).

The EU does not have specific subsidies to encourage water reuse. Basically there are six European programmes or organisations that are likely to finance water recycling projects: European Investment Bank (EIB), Short and Medium-term Priority Environmental Action Programme (SMAP), Financial Instrument for the Environment (LIFE), Community Initiative of the European Regional Development Fund (especially, Urban II), Structural Funds (FEDER) and Cohesion Fund. Alternatively, the Interreg Programme is also available.

Integrated project assessment

Using reclaimed water in place of fresh water for existing uses can free up existing water supply system capacity to cater for new water needs. This results in cost savings for developing new water sources, water transfers and treatment and distribution systems. It can also result in significant improvements in downstream river water quality.

Additionally, **public acceptance** to water reuse and a **public participatory plan** are two other important issues also covered in the prepared handbook. A public participatory plan is needed in order to get the public acceptance of the considered water reuse project and consequently the approval of the final users and consumers of the reclaimed water. In this sense, several water reuse projects have not succeeded due to the over-estimation of the potential users of the obtained water.

This thorough analysis will lead to the choice of the most suitable alternative. The last sections in a feasibility analysis performance are those related to the **main conclusions** of the whole feasibility study, the proposed **recommendations**, the foreseen **schedule for the implementation plan**, including possible demonstration projects, and **other issues** such as needed agreements, contracts and responsibilities of the different involved partners.

Feasibility case study examples

The developed feasibility study methodology has been validated by performing three different case studies on water reuse feasibility studies (Annexe IV).

The first feasibility study has been carried out in the **Moravia region (Czech Republic)**. Two zones with different characteristics and wastewater reuse possibilities have been identified, which are Znojmo and Kyjov. For the first one agricultural wastewater reuse has been considered as the most suitable option and for the second one industrial wastewater reuse has been selected. In the zone of Kyjov, six different companies have been identified as possible users of the reclaimed water. These companies are high water flow demanders and important water polluters too. Internal and external water reuse in these companies has been considered. Water reuse in this zone would suppose a sustainable solution to solve water quantity and quality problems.

The design of the distribution system for the reclaimed water has been carried out. Estimation o f the costs for the four considered options for Kyjov city has been developed. After the evaluation of all the proposed options it can be stated that the best solution for wastewater reclamation is to start reclamation with the secondary effluent from the WWTP in Kyjov. The best tertiary technology that should be used next is P-precipitation and then Ultrafiltration or Nanofiltration.

The second feasibility study corresponds to the water reuse of the technological wastewaters (7% of the total flow) produced in the drinking water plant of Rosu in **Bucharest (Romania)**.

The sources of technological wastewater in drinking water plants are: discharge of surpluses of raw water captured at the water intake, water from the reagents preparation, water with sludge from the settling equipment, water from washing of the filters and other water types (technological washing).

The developed project has focused on the water discharged out of the settling equipment and the water resulting from the washing of the filters. Currently these waters are collected and sent to the clarifying ponds (ANAR).

Four different treatment processes have been evaluated for a flow of 1,500 m^3h^{-1}:

V1 - Natural sedimentation + platform for sludge drying

V2 - Natural sedimentation + clarification+platforms for sludge drying

V3 - Natural sedimentation + centrifugal clarifier

V4 - Natural sedimentation +clarification + centrifugal clarifier

Advantages and disadvantages of each option have been described, and laboratory and pilot plant researches and characterisations have been carried out. The evaluation and selection of the best option was based on technico-chemical efficiency.

The obtained result has been that the optimal solution is Version 4 (Natural sedimentation +clarification + centrifugal clarifier).

Possible users have been identified. Due to the high quality of the obtained water, it could be used in thermal power stations.

The third feasibility study has been carried out in **Magosliget (Hungary)**. The objective of this study has been to solve an environmental problem together with the increase of the water resources in one of the most underdeveloped regions of Hungary (Magosliget). This zone faces water scarcity and increased water availability will contribute to the economical development of this zone.

The selected option for the municipal wastewaters treatment has been by root matrix technology for different reasons: cost, variability, easy to construction, labour, etc.

Four different alternatives for the reuse of the treated water have been examined considering economic, environmental and social aspects and the most suitable one has been considered the reuse for irrigation land and fish breeding.

WP5: Methodologies for public acceptance studies and consultation

This WP involved four primary activities.

- A literature review of public & institutional perceptions of water reuse projects
- A study of consumer perceptions of water reuse for irrigation
- An analysis of the consistency of stakeholder group attitudes towards water reuse issues
- Development of a set of guidelines on participative planning for water reuse schemes

Conclusions from the literature review of public & institutional perceptions of water reuse projects

The potential for reuse in Europe is considerable. A decrease in urban water requirements would lead to a significant decrease in total water demand, particularly in highly urbanised states. Those countries which have been slow to exploit the potential for reuse are responding to real barriers. For example, economic incentives (in the absence of direct governmental intervention) are poorly understood and not immediately attractive, the impact of climate change and demographic change are yet to provide a significant challenge to water resource planners, and there are more cost and resource effective options available to balance local (both temporal and geographic) water supply shortfalls.

Furthermore, progress in many countries is hampered by the presence of effective regulation and quality standards. The development of reuse quality criteria is hampered by two primary issues;

- A lack of any empirical data upon which quantitative models of risk can be based (see below)
- An apparent unwillingness of any regulatory or governmental body to take responsibility for setting (and monitoring) standards

The risks associated with using recycled water are both context and scale specific. Appropriate standards might therefore also be made dependent upon the scale of application. We would caution that standards impact on several aspects of the potential for water recycling. For example, there is a clear relationship between the severity of standards for a particular application, and the cost of supplying water of appropriate quality. If set too severely, standards could effectively repress the financial motivation for recycling. It is also worth noting that standards aimed at prescribing particular treatment processes could serve to inhibit innovation in a field where there is still a great deal of opportunity for technology and technique development.

These standards need not be legislative. They could come from an independent regulatory body or, indeed, from a coalition of concerned and responsible stakeholders. They must, however, be credible, comprehensive and inclusive (i.e. have the agreement of all relevant bodies). Standards should also be backed up by a rigorous and dependable monitoring programme executed by a trusted organisation or trusted organisations. In very simple terms, it is difficult to design recycling systems without some guidance on what is an acceptable water quality for specific applications (e.g. toilet flushing or garden irrigation). Commercial organisations are generally (and quite understandably) not prepared to make estimations or conjecture on this point. In the absence of official guidelines or criteria, many organisations are waiting for the first legal challenge to the use of recycled water (which could be used as precedent) before strategically committing themselves to water recycling.

We would note that a further, but less obvious, constraint on more extensive use of water recycling is the existence of a deep-seated familiarity with the current water distribution arrangements. The population of many European countries are accustomed to having access to as much high quality water as they require, when they require it. Furthermore, water providers are accustomed to (and it must be said amongst the best in the world at) supplying the resource on demand. During our work we have often been dismayed at the lack of imagination and creative thinking displayed by major water sector organisations. A shift from a single product production mind set to a multiple product service mind set would go a long way towards creating conducive conditions for the exploitation of recycling opportunities.

It should be recognised that not all recycling opportunities will become commercially viable at the same time. Niche markets will be exposed as the configuration of motivations and constraints are modified. Our work leads us to believe that the following applications are worthy of monitoring as potential future niche contexts.

- Isolated buildings or remote communities
- Households or communities with private supplies

- Buildings located adjacent to sites which have additional recycled water use potential.
- Building with un-adopted sewers

The business conditions under which water recycling becomes commercially attractive can change rapidly. Water utilities should maintain their knowledge base and skills in this area through research and training.

Commercial viability is a pre-requisite for large scale application of recycling schemes (although we do recognise that subsidies can be used to make schemes profitable as is the case in Germany). A variety of opportunities exist for commercial exploitation, although we would point out that selling the treated effluent by volume does not appear to be attractive. Alternative arrangements whereby customers pay for regular maintenance (crucial to the reliability of most systems) and quality monitoring may be considered. Likewise, design, build and operate, projects at larger scales may be profitable depending upon the value of the recycled water to the client.

Recycling and reuse technologies can make a contribution to the continuity of availability of water within a sustainable eco-economic context at the level of the consumer or groups of diverse consumers. At smaller spatial scales, there are a number of candidate technologies which can be used to provide water treatment to match typical effluent – reuse opportunities. Whilst many of the associated engineering design considerations have been addressed over the past decade, the attribute set that defines this design space needs to be extended to include the receptivity of diverse consumer groups and a quantitative assessment of the additional risk posed by the use of recycling systems.

As a general conclusion to this project, we could do little better than strongly support the statement contained within the introduction to the UK Water Advisory Scheme's paper on water recycling.

'*Due to a lack of straightforward, factual information about costs, reliability and control of hazards there has been little enthusiasm to install reclaimed water systems. The adoption of reclaimed water systems is strongly influenced by user perceptions and economic benefit, but once installed, reclaimed water systems should not be allowed to fall into a state of disrepair or disuse and attention is drawn to the importance of prompt investigation and resolution of problems.*'

The variety of water treatments required to match the patchwork of recycling opportunities means that developing the potential to exploit this opportunity space will involve high-tech as well as low-tech applications. Unfortunately, this variety of contexts also means that the motivations for technology adoption and the reasons for successful operation are complex enough to constitute a real difficulty for policy and programme implementation.

Water reuse is still in its infancy in the UK, but rapidly catching up. In Germany, many buildings use communal grey water or rainwater systems. However, they are not common in Germany due to divided opinions on potential risks. Other European countries are also developing reuse systems and as social acceptance of reuse increases then they may become more common. It is necessary to develop new ideas regarding methods for public and stakeholder involvements that are sensitive to all the cultural and historical variations that are encountered. The 'perception spectrum' with regard to water conservation is wide; from countries such as the UK, who are frequently flooded by heavy winter rainfall and have difficulty in perceiving a need for it, to the active involvement of consumers in Australia where the shortage of rainfall is more obvious.

Gaining public acceptance and support for water reuse is paramount to their success. Reuse projects, especially those for more personal usage such as potable reuse have a greater chance of failure if confronted with strong public opposition. How you achieve and maintain support for reuse projects through inclusion and integration of certain parties, alongside the structure and education required to drive the decision making process, needs further investigation so that we can gain a better understanding of the intricate components of the whole process.

We conclude by emphasising the need for an integrated approach to sustainable water management in general and recycling projects in particular. Without such cross-fertilization of engineering, behavioural, economic and environmental knowledge, policy makers will never understand the extent and relatedness of phenomena they need to consider when planning and managing sustainable water management systems.

Conclusions from a study of consumer perceptions of water reuse for irrigation

In exploring opportunities and developing options for water recycling schemes, policy makers, planners and system designers face a number of problems which do not have simple technological or legislative remedies. For example, whilst the development of suitable technologies which provide opportunities for agricultural water recycling has moved on apace over the past decade, successful employment of preferred strategies and technologies will require an understanding of the social environment in which they are to be applied. With specific regard to the study reported here, it is inadequate to assume that levels of project awareness and understanding (a critical element in promoting public support) are consistent across a culturally heterogeneous community. We report the findings of a survey of over 300 respondents from Israel which explores how reuse scheme endorsement and agricultural produce consumption behaviour varies as a function of ethnic and cultural background. We also present data which illustrates the extent to which these two dependent variables are correlated with awareness and understanding of a reuse scheme's design and configuration (i.e. source water, treatment train, distribution system, quality control). Our conclusions relate primarily to the implications for design of public education programmes. Example results from the survey are provided below.

Table 3.4: Questionnaire results

Question	Is there significant variation in responses dependent on		
	Gender	Immigrant / Sabra	Urban / rural
To your knowledge, are some of the fruits and vegetables for sale in supermarkets in Israel irrigated during dry weather ?	X	X	X
Have you ever heard of the 'Shafdan project' ?	X	X	X
If you knew that fruit and vegetable are irrigated with purified wastewater, which are in high quality, will you still consume them ?	X	X	X
If you knew that purified wastewater used for irrigation, contains essential components for agriculture crops and there is no danger for population, will you change your mind ?	X	X	X

An analysis of the consistency of stakeholder group attitudes towards water reuse issues

Whilst the argument for extending the constituency of consultees is now widely accepted, further understanding is required of how the process of participatory planning and management can best be structured and facilitated. In particular, the who, when, how and not least, 'what' of participative planning cannot be effectively facilitated unless a broad picture of the various interest groups' existing opinions and attitudes can be ascertained. Identifying the issues pertinent to each stakeholder group involved in a particular project and then assessing and distinguishing where the similarities and variations lie between the groups on those issues could be beneficial to the planning and implementation of a scheme. The identification of commonly held salient beliefs on water management could supply topics for initial discussion, which in turn could provide the basis for further discourse on areas of dispute or issues that need further input or elaboration. Such an approach could lead to a more robust participatory framework by improving the quality of discussion and decisions.

The research reported here addresses an important feature of the debates abridged above: to what extent do the views of stakeholder groups on significant features of participative planning processes and water management issues actually vary? Furthermore, can we associate a consistent view on any particular issue with particular stakeholder groups? It should be noted that we make no value judgment about the costs or benefits of conflicting views in a participatory process; we are simply interested to explore the coherence of the 'stakeholder' construct in the context of dialogue and debate.

Our sample population for this study comprised members of four widely distinguished stakeholder groups from the water sector; regulators, researchers, water managers, and the general public. A multi-modal elicitation strategy was used for collecting survey data. However, a dedicated web page was the primary elicitation vehicle chosen for the survey. Whilst the internet can be a useful tool for conducting a survey, one should be aware that it can result in the obvious exclusion of those who do not have access to a computer or the internet. In comparison to other data collection methods online surveys do have some advantages such as, low implementation costs, short response times and researcher control of the sample. Web based surveys have also been reported as having fewer missing values than the more traditional pen and paper data collection methods.

Launch of the website and requests for hot links to the survey site were promoted to a wide base of water sector organisations that were likely to be in contact with the four main response groups. The questionnaire was made available on request as an MS Word document for those organisations that preferred to issue it to their members via company email. Paper copies were also distributed at relevant conferences and meetings along with pre-paid return envelopes. Survey responses were transcribed and stored in MS Excel. Ethical research practice was adhered to throughout the survey. The survey start date was 12th of July 2004, terminating on 31st of December 2004.

Respondents were grouped via a self classification system, into one of four classes of stakeholder, namely (figures given in parenthesis represent the number of respondents in each group): Regulator (17), Manager (37), Researcher (57), Customer (42). The number of self classification responses within the regulator group is low when compared to the other three groups. However, the proportion of regulators within the water sector is likely to be lower than that of other respondent groups.

The results presented in the following section are organised around three thematic sets of questions posed in the survey questionnaire. These related to:

- preferences for different water policy mechanisms
- preferences for different forms of participative planning
- attitudes towards information or knowledge sources

Questions relating to project type

A few respondents commented that the choice of water conservation option was situation dependent. This is an important and valid point; however the reasoning behind this question was to identify the basic preferences of each respondent group, as the questionnaire was not aimed at any particular project. The fundamental conclusions that can be drawn from the results on the responses to the two questions relating to project type are that:

- None of the four groups object to the abstract concept, or principle, underlying the adoption of water reuse as a conservation option.
- There are differences however between the four groups regarding how they think water conservation should be encouraged or regulated. For instance, of the options given, 47.2% of water managers chose ‘pricing’, whereas only 11.9% of customers chose that option. Conversely, 52.4% of customers chose the ‘adoption of sustainable or alternative technologies’ option in comparison to only 22.2% of water managers.
- The least frequent conservation option chosen across all groups was ‘imposing restrictions’.

Questions relating to participative planning

Based on the four respondent groups’ views on whether the public should be involved during different stages of a project:

- It appears that comparable outlooks are held by the four groups regarding inclusion of the public during the scoping, planning, construction and operational stages.
- Statistical differences do however lie between the four respondent groups with regard to the question of public inclusion during the monitoring stage of a project and during shut down.
- The researcher respondent group was found to be the respondent group most in favour of inclusion of the public for all of the six stages.
- Similar views were also held by the respondents regarding how the public should be included. The means all four respondent groups lie between the two options ‘make some of the decisions’ (option two) and ‘be consulted’ (option three).
- Regarding protection of interests, lower levels of trust in other stakeholder groups was detected in some of the respondent groups. In this situation, transparent trust building interactions could help to better define collaborative goals in relation to individual group interests.

Question relating to information or knowledge sources

Analysis of the ANOVA and multiple comparison test results show that some respondent groups’ opinions and expectations differ when considering the characteristics of certain information sources, which are:

- Managers and Customers on the levels of impartiality and knowledge of NGOs
- Regulators and Customers regarding the levels of impartiality of NGOs
- Managers and Customers regarding the orientation of academic researchers

- Regulators and Managers regarding levels of impartiality shown by regulators
- Managers and Researchers on the orientation and knowledge levels of academic researchers
- Managers and Researchers on the orientation of NGOs

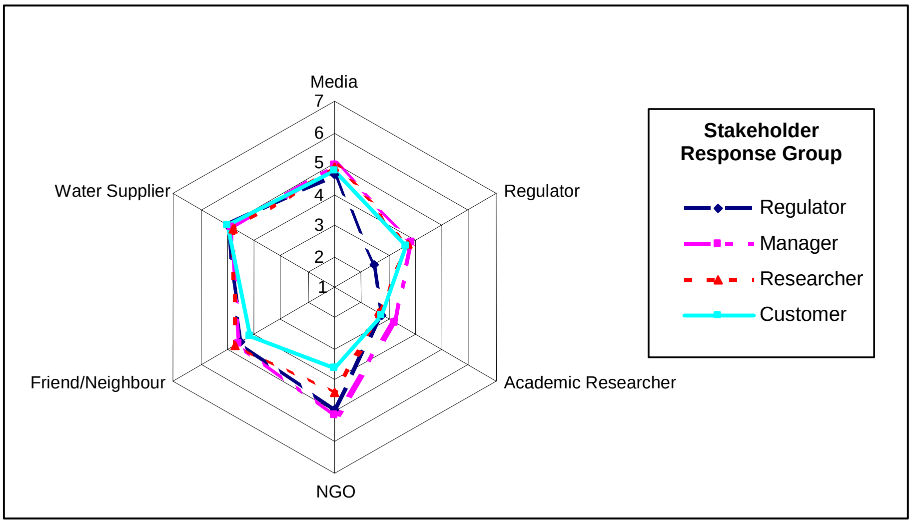


Figure 3.7: Extent to which sources are considered Impartial (1) or Biased (7)

The results of ranking the same data (Figure 3.7) show that:

- Customers give regulators and NGOs a similar high rating in their estimation of them as knowledge or information sources in six out of eight word pairs.
- Of all the knowledge sources both researchers and customers view NGOs as the most people orientated of the sources.
- Both regulators and managers view NGOs as highly biased in comparison to the other sources.

Development of a set of guidelines on participative planning for water reuse schemes

The supply of sufficient and safe water supplies for human and environmental needs is a significant and difficult challenge in many parts of the world. To manage water resources in an effective and sustainable way, a wide range of approaches are required. Water recycling is an increasingly important element of sustainable water management strategies in both water-poor and water-rich regions.

Successful design, implementation and management of many types of industrial or public infrastructure project are now recognised as being strongly dependent on the involvement of those institutions, businesses and communities that may be affected. A participatory planning approach is particularly relevant to water recycling projects where the size and spread of costs, risks and benefits depend on how the venture is planned and managed.

Ideally, participatory planning and management of a water recycling project will be just one element of a broader consultation process on integrated water resources management (IWRM). Whether and how water recycling plays a role, and how it is combined with other measures like stormwater control and demand management, should be assessed according to local circumstances and needs. Similarly, we should stress the need for a national or regional discussion on recycling and its place in water management. Broad public debate in advance of specific water recycling initiatives, or in parallel with them, clearly puts all participants in a more informed position.

So while these guidelines are meant primarily to support dialogue on recycling proposals, we trust they will also be useful for the broader and longer-term relationships that we regard as essential for effective and equitable water resource management.

The aim of the guidelines is to encourage wider and more informed participation in the planning and management of water recycling projects. Our objectives in support of this aim are:

- to review the motivations for and principles of participatory planning and management;
- to describe the types of tools and techniques which can be used to support participatory planning; and
- to provide an illustrative protocol for a participatory planning exercise in water recycling.

The handbook (the front cover of which is illustrated in Figure 3.8) is designed for use by individuals, organisations and communities that wish to plan and manage water recycling projects collaboratively. However, we hope that those involved in other types of project will also find it useful.

Many of the available guidelines and reference materials on participatory planning and public engagement are written from the viewpoint of a single interest (e.g. NGOs or water supply companies). Such perspectives promote an unfortunate 'us and them' approach to participation. This handbook is based on the principle that participatory planning is a learning process for all – not just an exercise in educating one group. Importantly, such a perspective accepts that there is a wide range of technical and management choices that public input can help to shape.

Our intention is therefore to provide information and advice for all participants. Moreover, we have set out to write it in a way that neither values the contribution of one type of actor above that of others, nor assumes that any one type of actor should have control over the participation process. Thus we hope to provide a common reference point for good practice and process design. We believe that such an approach can turn cooperation (working together for individual benefit) into collaboration (working together for mutual benefit).

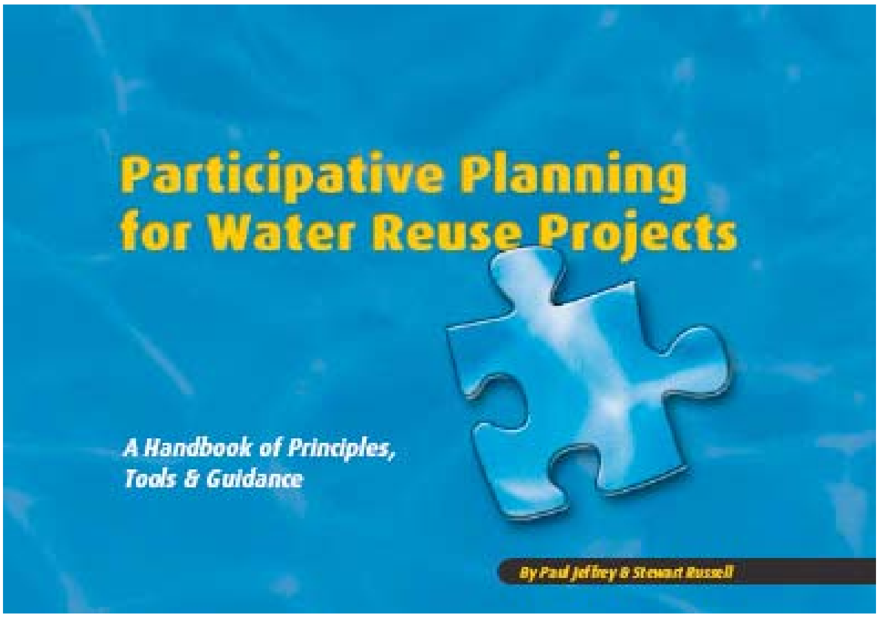


Figure 3.8: Front cover of guidelines booklet

Participatory planning and stakeholder engagement generally take two forms: (i) long term relationships between interested parties involving regular meetings and events, and (ii) participatory processes focused on a specific project or plan. This handbook is relevant to both, though it should be particularly useful for the latter.

The information and advice in these guidelines is neither comprehensive nor exhaustive. We have had to be selective in the material we have included, and we do not claim that the techniques we list and the illustrative protocol presented later will be applicable in all circumstances. Our aim is to provide simple but not simplistic advice in an accessible form.

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

This management work package was focussing on the compilation of a Management Practice Manual. The manual was built upon four major milestones:

1. **A mapping study** to identify reference structural requirements for different types of direct non-potable reuse applications.

   A database of municipal reuse schemes containing basic system data such as field(s) of application, process train, size, years in operation and possible relevant public documentation attached to it was compiled. Data were collected from regional databases, national experts and literature. Seven geographical regions were analysed: 1) Europe, 2) Mediterranean Region and Middle East, 3) Oceania, 4) North and 5) Latin America, 6) Sub-Saharan Africa and 7) Japan and Singapore.

2. **A literature review on management practices** attached to the implementation and operation of water reuse schemes was conducted.

   The European Union and overseas experience, existent and latent problems, and factors promoting successful management of water reuse projects were reviewed through a desk study covering implementation and operational aspects such as type of ownership and financing, cost optimisation, process operation, maintenance and quality control, failure and failure management. Specific maintenance and quality control procedures for the reference water reclamation process trains identified in the mapping studies were also sought.

3. An **international workshop** of water reuse professionals to share insights and, especially, discuss gaps on information acquired through the desk study.

   The International Workshop on Implementation and Operation of Municipal Wastewater Reuse Plants was held in Thessaloniki, Greece on 11-12 March 2004. The workshop was co-organised with EUREAU, an organisation that represents the national associations of water suppliers and wastewater services in Europe. The outcome report of the workshop is publicly accessible from the Aquarec website.

4. An **e-enquiry to managers** of medium- to large-scale water reclamation facilities, to determine where present-day practice lies in relation to what is seen as best practice.

   A Microsoft Word self-compile questionnaire has been developed and sent to targeted water reuse facilities representatives to determine the range of management practices attached to each organisation and just how these practices are undertaken in terms of efficiency and effectiveness. The questionnaire has been produced in a short and in a long version, and is available in English, Italian and French.

5. In the end, the manual went through an extended peer review process, in the first place to guarantee the quality of the output, but also, to include the insight and know-how of a larger number of professionals from water reuse utilities, manufacturers, consultants and research institutions.

1. Mapping study

Over 3,300 water reclamation facilities were identified, mostly in Japan and the USA, but also in Australia and the EU, with now an abundance of over 450 and 230 projects, respectively (Bixio et al., 2005). The distribution of the projects, sorted per type of reuse activity, is shown in Fig. 3.9. Reuse activities are consolidated in four categories: 1) agricultural irrigation; 2) aquifer recharge, urban, recreational and environmental uses; 3) process water for industry including cooling and 4) combinations of the above (multipurpose schemes).

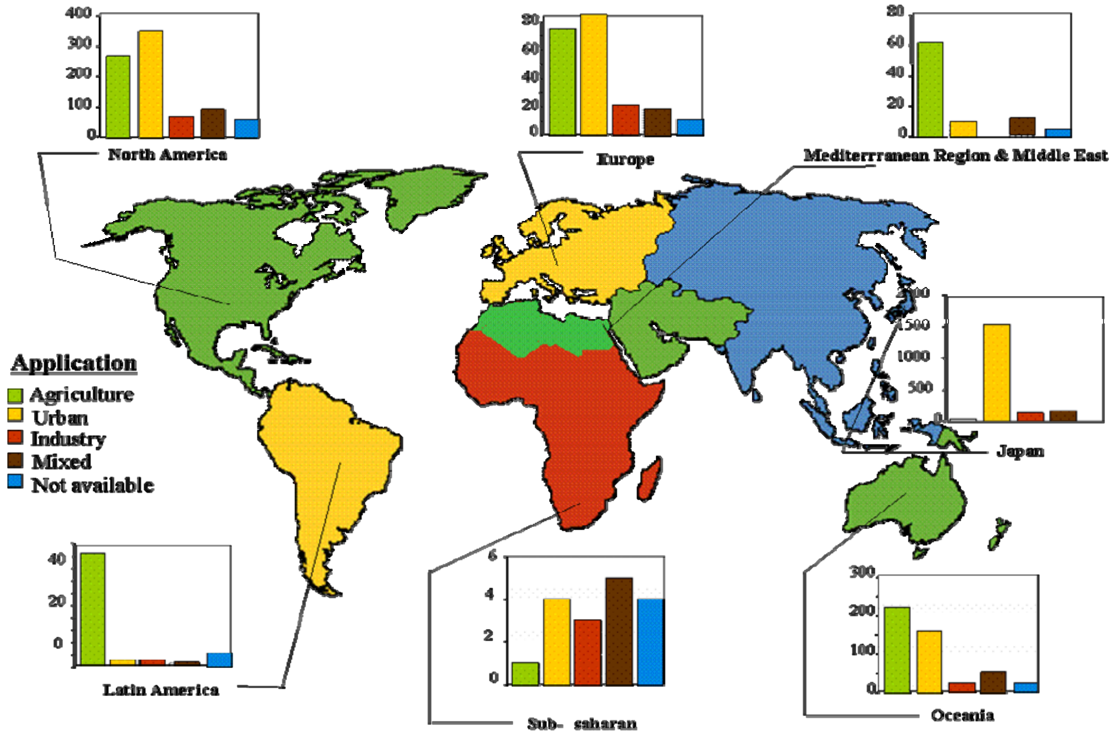


Figure 3.9: Number of identified municipal water reuse schemes per field of application in seven regions of the world

In Europe, water reuse is becoming a well-established water resources management option in many water-stressed regions. While in the beginning of the 1990s wastewater reclamation and reuse was limited to a few local cases, in 2004 more than 200 sites were operational and many others were in an advanced planning phase. Most of the projects are located along coastlines, on islands off the semi-arid Southern regions, and in the highly urbanised areas of Northern and Central Europe (Fig. 3.10). Spain is by far the largest European Country. In 2004, over 30% of the produced wastewater seemed to be reclaimed.

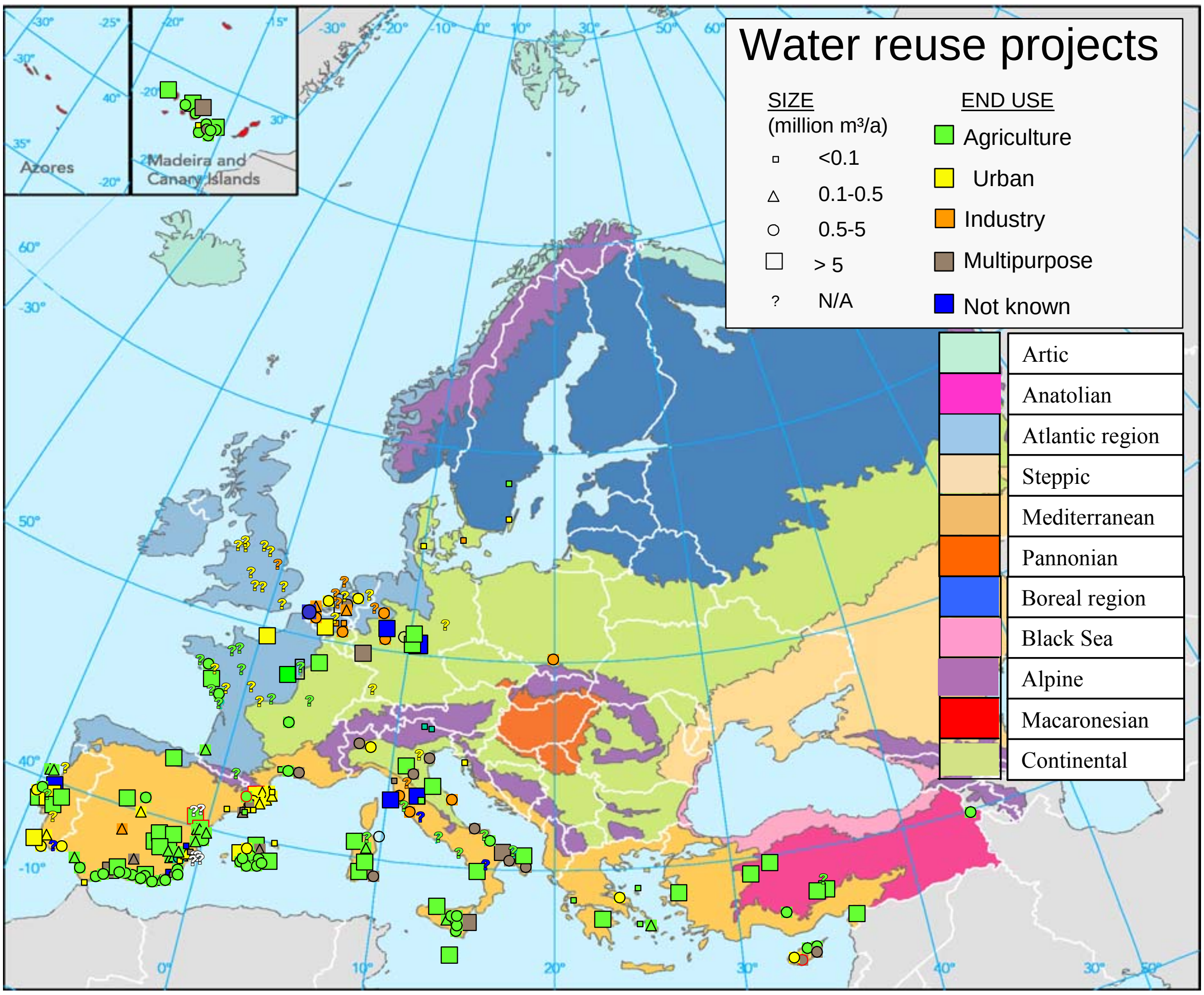


Figure 3.10: Geographic distribution of water reuse schemes sorted per size and field of sectoral water uses

From the map, it is clear that in the European Union usually high infrastructural requirements are needed, with the reclamation technology having the same components as conventional water and sanitation treatment:

- Disinfection - many techniques have been applied. Reference techniques are chlorination, UV irradiation and Ozonation (and combinations hereof).
- Filtration – disinfection is often preceded by a filtration step. This has been crystallised in the Title 22 Californian regulation, where a coagulation/flocculation, sedimentation, filtration and disinfection step are required as benchmark technology for unrestricted irrigation purposes. Actually, Title 22 allows filtration without flocculation if the effluent turbidity before filtration is less than 5 NTU. This benchmark technology is now considered the yardstick for unrestricted irrigation against which all the other systems are evaluated because of its long history of successful case practices (more than 400 in the sole United States and one third of the water reuse schemes in the European Union).
- Membrane processes – are progressively replacing conventional filtration, especially for applications requiring high water quality. Today, membrane processes can considered the yardstick for many high-grade applications including groundwater recharge, direct / indirect potable reuse, and high-grade process water applications (such as for instance for microelectronics and boiler feed water).

- Maturation ponds – are used to achieve the water quality requirements of the 1989 WHO guidelines for unrestricted agricultural irrigation with reclaimed water (< 1000 FC/100 mL; < 1 helm. egg/L). Surface-flow tertiary constructed wetlands, especially in combination with maturation ponds, have found wide application in polishing conventionally treated wastewater to meet quality requirements for recreational and environmental uses, including habitat creation, restoration and/or enhancement.

The level of wastewater treatment that was applied in the mapped projects is illustrated in Figure 3.11. Secondary treatment – also including nutrient removal – is characteristic of 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 are applied for unrestricted agricultural or landscape irrigation as well as for process water in some industrial applications (tertiary treatment). Quaternary treatment - indicative of production for quality comparable to drinking water - involves a "double membrane" step to meet unrestricted residential uses and industrial applications requiring ultra-pure water.

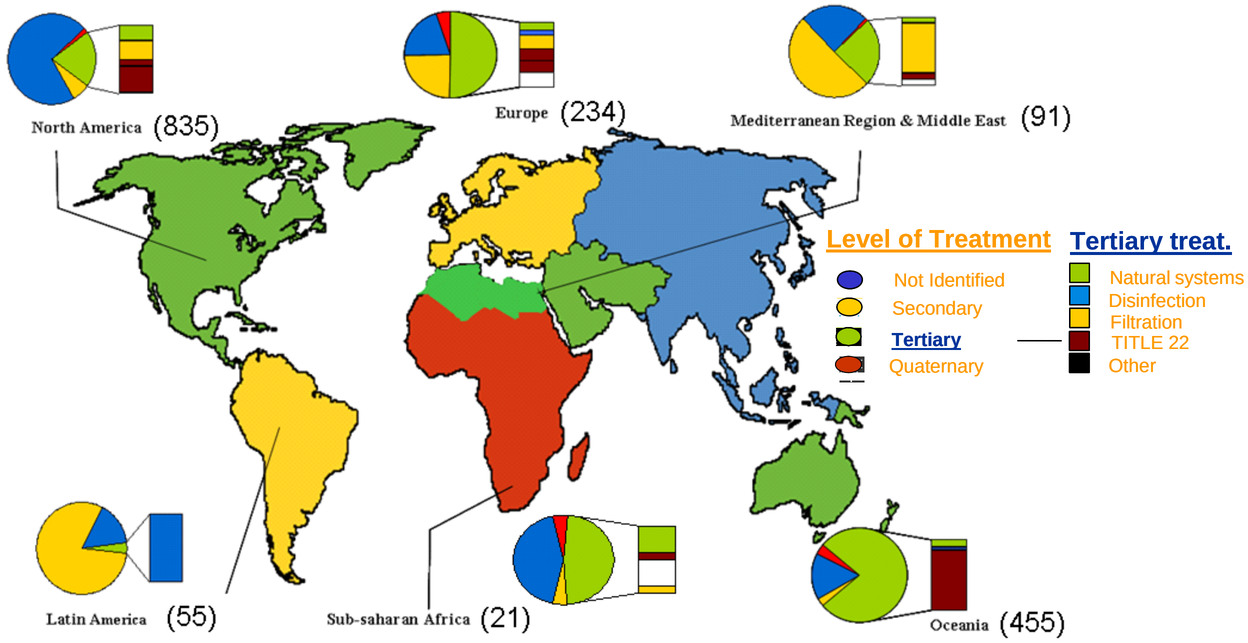


Figure 3.11: Distribution of level of treatment and tertiary water reclamation technology in six world regions (adapted from Bixio et al., 2005)

2. Literature study

More than 200 documents have been screened on structural, non-structural and managerial aspects of implementing and operating water reuse schemes.

Structural and non-structural practices were limited to the water reclamation benchmark technologies identified in the mapping study. Much full-scale experience is available for these technologies on life-cycle costs, process performance, ease of maintenance and operational needs, including specific quality control and failure management procedures.

The same cannot be said about effective and practicable managerial practices. For several aspects there has been a number of different guidelines, each being useful but none entirely satisfactory because of the wide variability in field conditions.

Any managerial action that is deemed to be sustainable, effective and practicable needs to include detailed considerations about the local water supply market structure, the structure of the water sector, reclaimed water costs compared to the costs of conventional water and sanitation projects and the timing and investment cycles. These aspects have been investigated with particular emphasis to the European Union, Israel and Australia.

3. International workshop on management practices

The workshop was a forum for frank exchange of valuable information on the key international issues and experience with respect to commercial, environmental and social aspects of reuse schemes as well as operation and maintenance experience including experience from system failures. In total 77 professionals and experts from 5 continents/24 Countries participated to the event. Some undeniable issues were identified and discussed:

- Many of the funding sources for water and wastewater projects are not structured in a way that encourages reuse.
- Similarly, the split in responsibility between different authorities for water supply and wastewater disposal in many urban areas is an institutional barrier to reuse as the responsibilities, costs and liabilities associated with reuse are not clearly defined.
- The issue of transparency and trust, together with leadership, is crucial for the community acceptance of reuse schemes. The need for honesty by water companies is seen to be important for the development of community confidence. The perception of a cover-up will invariably result in a more prominent and less favourable reporting in the media and within the community, compared to situations where adequate information is made available by the appropriate authorities.
- There is a need for flexibility in the development of guidelines to allow for the differing circumstances in each country and region.

4. E-questionnaires and interviews

Forty questionnaires have been returned, namely: 20 from Europe, 10 from Australia, 9 from the Middle East (Israel) and 1 from Asia (Singapore). The survey provided valuable insight into current management practices attached to the sampled schemes.

The main conclusion is that there is no ‘one size-fits-all’ formula to implement and operate water reuse schemes. The adoption of the suitable management practices for the project seems to be all a question of local circumstances, political will, legislation, institutional structure and regulation. These factors diverge from Member State to Member State and sometimes even within Member States. Nevertheless, some general conclusions could also be derived. These include:

- Mainly because of the market distortions of the water supply services, water supply benefits alone are often insufficient to carry the investment costs of improving the effluent. Only in Portugal the public funding was mobilized as a part of a water reuse regional program, while for the other projects the grants were provided on the basis of for instance technical innovation (e.g. EC LIFE grants) or as a help to structural development (e.g. EC cohesion fund or other regional subsidies).

- The enquiry highlighted that the way in which the water and wastewater market in some European regions is structured today collaboration between different entities is far from evident. Institutional impediments were in some cases the only reason for delaying the project.
- The question of ownership seems not to be a problem per se rather it is tied to that of legal responsibility, access and above all financing and cost allocation.
- The social aspects were often noted as a problematic area (except for the industrial and institutional reuse applications). Several projects were delayed or are running at a lower yield as a result of the public and other stakeholders' resistance to the project. It is important noting that the perception revealed by the European survey is that, in the view of some public administrations and of the civil population, treated wastewater basically still remains wastewater. The involvement of local NGO's and environmental associations in building up credibility, trust and confidence was an essential ingredient for a successful and sustainable project implementation.
- Lack of national quality standards and the inadequate training of public administrations led in some cases to the setting of questionable permits.
- For none of the respondents the technological aspects scored as a problematic area. This does not mean however that no technical effort is required, on the contrary! All the interviewees stressed the importance of extensive pilot testing to assess technical and health risks, which are very much project-specific. Moreover, the respondents did not seem concerned about emerging issues such as trace organic contamination (as they are not taken on in guidelines of good operation, permits or regulation).
- The degree of reliability of the water reclamation systems seems very high. In the analysed sample of projects no documented public health problems occurred. The percent of end – users affected by interruption of reclaimed water distribution was around 1% and the duration of the interruptions were from a few hours to 24 hrs and almost no major power failures were reported. It is worth noting however that several respondents have been quite reticent to answer on the failure and failure management questions. The main failure types seemed to be associated with the distribution system (leakage, biofilm clogging) and with chlorinators or other disinfection system failure.
- A common trait in process operation and risk management of the surveyed projects is the adoption of extensive quality control practices and in particular the widespread use of instrumentation, control and automation. Contrarily to the common perception that sensors are one of the weakest points in on-line monitoring and control, the respondents have expressed quite a high degree of satisfaction with the performance and reliability of many types of monitoring equipment. Because of the preventive measures that are generally in place (including a multi-barrier protection of the intended reclaimed water use), monitoring of delivered water quality is simply verification that the preventative measures are effective, and often variables that can be monitored instantaneously can give a higher level of confidence in safety of supply and at less cost than analysing for an expanding number of chemicals. Sensors that are available in almost all the water reclamation schemes in order to identify and halt the use of unacceptable reclaimed water quality are conductance meters and turbido-meters (high levels of turbidity can protect micro-organisms from the effects of disinfection, stimulate the growth of bacteria, and exert a higher chlorine demand for disinfection).

WP7: Characterisation and assessment of technology in water reuse cycles

One of the objectives of work package 7 is the definition of a wastewater treatment matrix (WWTM) for water reuse (especially municipal wastewater), in which wastewater treatment process schemes are:

- categorised as a function of the raw wastewater quality and the reuse application and
- further characterised with respect to costs and operational critical control points.

Different water reuse options require different kinds of water qualities. For each quality several treatment schemes can be applied. Treatment schemes are composed of several kinds of wastewater treatment unit operations. The considered wastewater treatment unit operations are given in table 3.5.

The starting point for building a water treatment matrix is the definition of the conceivable reuse applications. Municipal wastewater can be reused for industrial, domestic (household/irrigation), natural and agricultural purposes. These reuse options require different kinds of water qualities which can be achieved by using of specific levels of treatment (see Figure 3.12). In most situations, a series of treatment processes is needed to achieve the required water quality for reuse.

As a first step all realistic processes involved in these treatment schemes were described and investigated. Special attention is given to the efficiency of removing constituents to meet the water quality for various reuse applications. A clear distinction has been made between primary, secondary and advanced treatment processes, which include both conventional and innovative options. Detailed information is provided in the Aquarec report "Deliverable D6: Review report on wastewater treatment unit operations"; the review of processes is mainly based on recent literature.

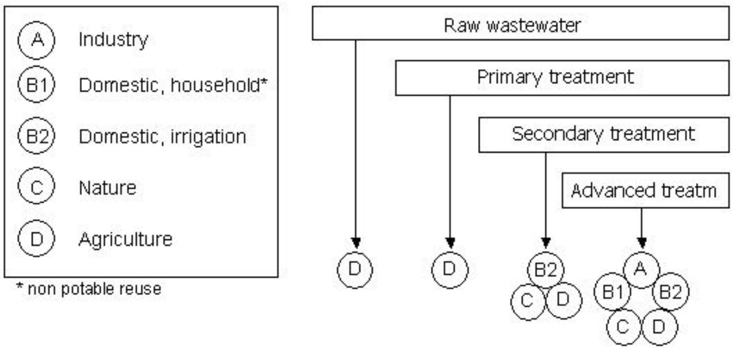


Figure 3.12: Reuse aims with their corresponding levels of treatment.

The treatment matrix is also an input for WP 8. In this workpackage the matrix is one of the approaches for constructing a full treatment scheme in the design and simulation software tool.

<u>Global water treatment matrix</u>

With the different primary, secondary and tertiary treatment processes numerous different treatment trains or schemes can be constructed. The possibilities of water reuse greatly depend on the requirements set up for the various applications. In fact, for each reuse application, there are a large number of possible combinations of treatment processes to meet the water quality requirements.

<u>Selection of standard treatment trains</u>

The global matrix is not very simple for the user of a design and simulation software tool. Therefore a selection has to be made among the schemes leading to the Reuse Matrix with standard treatment trains. From basic considerations a set of logical limitations can be deducted.

- Primary treatment level
  - Many processes can lead to comparable process results; so not all primary processes should be evaluated further.
  - Processes based on the solubilization of constituents have to be followed by biological secondary processes.
  - Total removal of particles can be realised by (a combination of) primary processes.
- Secondary treatment level
  - Biological processes can handle effectively the dissolved organic constituents (soluble COD).
  - Many biological processes lead to comparable results.
  - Nitrogen can be removed almost completely by application of nitrification/denitrification.
  - Advanced particle removal in the primary treatment step only gives limited advantages in the secondary step.
  - Removal of BOD, COD, N and P, if necessary, should be preferably done in the secondary treatment step.
  - Membrane bioreactors include some of the tertiary process effects (e.g. residual particle removal).
- Advanced treatment level
  - Porous media filtration is a common step for pretreatment when other tertiary processes are applied.
  - Advanced treatment processes are very specific for certain components.
- As to all processes
  - The sludge produced in the primary and secondary processes requires further and extensive treatment.

The next step, after building the treatment schemes, is the construction of the Reuse Matrix. This Reuse Matrix greatly depends on the existing wastewater treatment infrastructure and the possible applications. So it is a very specific instrument that can vary from case to case. An example of the Reuse Matrix is given in Figure 3.13.

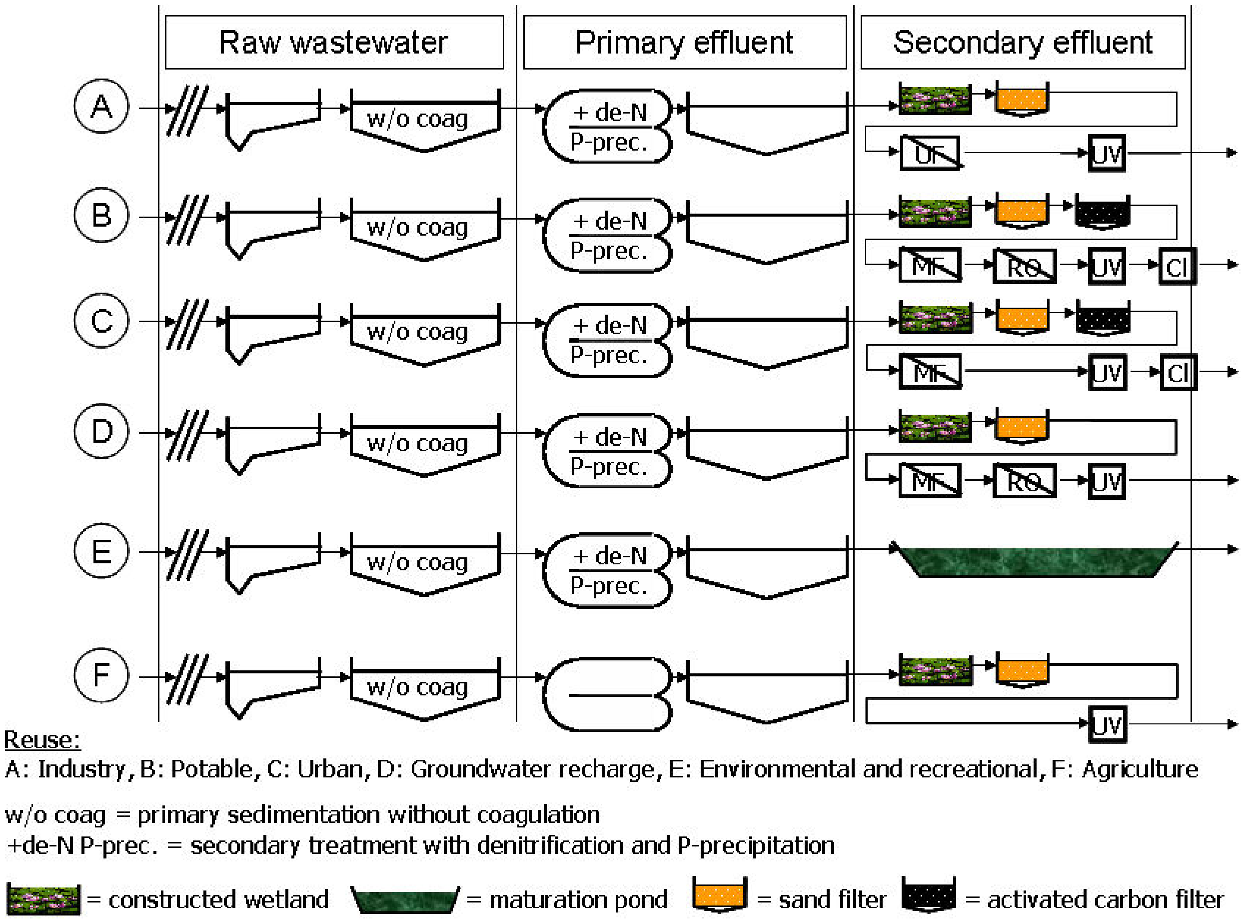


Figure 3.13: An example of the Reuse Matrix

Standard treatment schemes for wastewater reuse

In the process of collecting information and comparing different treatment schemes, some observations have been made which are highlighted below.

1 The actual knowledge on municipal wastewater treatment is definitely well consolidated up to and including secondary treatment which includes biological and physical/chemical nutrient removal. Processes and schemes are well known and planning and management are reliable. These processes can provide a satisfactory effluent quality for parameters such as BOD, COD, SS, N, P, which are still the basis of the EU standards for effluent discharge. Nevertheless, in some cases, the actual wastewater treatment plants need upgrades and renewals in order to satisfy the new directives.

2 The upgrade of the effluent of secondary treatment is accomplished through more advanced techniques. Nowadays, rapid filtration and disinfection are regarded as traditional and common in practice, while other processes such as membrane filtration are applied less frequently. What makes the advanced treatment ‘different’ is the specificity of the treatment, which has to be calibrated based on the water quality requirements. As such preliminary experimentation becomes of major importance for good planning as each and every case is unique.

3 The EU directives discharge limits should be the starting point for further treatment for municipal wastewater for reuse. Many countries will indeed strive to meet these standards in the near future. Therefore effluent will be the main primary source for wastewater reclamation in the short term.

On the opposite, schemes alternative to the traditional chain can be a feasible option only in the long term.

Typical or standard schemes

Based on the previous matrix and comments, a set of typical or standard schemes was developed. These schemes have their own strength, are related to specific reuse applications and are mostly represented by many examples in practice. Without excluding any other possibilities these schemes seem to be representative for the majority of the possibilities in the Reuse Matrix. Shortly these schemes are:

Effluent filtration and disinfection

The process typically consists of conventional wastewater treatment, including P- and N-removal, followed by dual media filtration and disinfection by UV or chlorine. The reuse varies from urban applications, unrestricted irrigation, green landscaping to industrial usage. This concept exists as standard in the USA.

High quality / double membrane

Conventional wastewater treatment, including P- and N-removal, followed by double membrane filtration (MF or UF followed by RO) and final disinfection by UV; eventually other processes such as advanced oxidation and activated carbon adsorption can also be applied. The treated water is of such a high quality that many applications (industrial, households, etc.) are possible. Examples of this concept are Water Factory 21, Sydney Olympic park and Torreele (Belgium).

Only disinfection

Conventional wastewater treatment, followed by chlorination, enables the reuse of the treated water for irrigation under restricted conditions. Many examples are available all over Europe.

Local Membrane Bioreactor (MBR)

Small scale treatment of wastewater using a package MBR system with reuse of the water in the direct neighbourhood (e.g. as toilet flush water). Typical solution for Japanese office buildings which is introduced in some Europeans sites now.

Soil aquifer treatment

Conventional wastewater treatment, including P- and N-removal, followed by infiltration through large ground areas; the extracted water can be reused for unrestricted irrigation. Examples are present in the Mediterranean region (e.g. Israel).

Wetlands

Conventional wastewater treatment, including P- and N-removal, followed by constructed wetlands as a natural polishing step is an extensive treatment solution. The treated effluent can be reused for nature conservation or agriculture. Applications are present in Northern Europe (Netherlands) as well as Southern Europe (Spain).

Lagoons or Pond systems

Treatment of wastewater by lagoons (several types in series), occasionally followed by chlorination; reuse of the effluent only for (very) restricted irrigation. This is typical application for Mediterranean countries with moderate treatment facilities.

To illustrate each of the standard schemes at least one case study for each scheme is described in the final WP7 Deliverable.

Water recycling technology development

On the long term, schemes alternative to the traditional chain (i.e. secondary treatment including nutrient removal) can become feasible options. One of the innovating technologies is Direct Membrane Filtration (DMF) of raw wastewater. This is a purely physical process by which particles (including micro organisms) are removed from the wastewater by membrane filtration (UF). To remove large particles from the wastewater simple pre-treatments such as screening, sedimentation or Dissolved Air Flotation (DAF) can be applied. The effluent of this process is particle free water rich in dissolved components (e.g. nutrients). Possible applications of this new concept can be found in agriculture. DMF is investigated in several places (Netherlands, China, Israel).

Other innovating technologies are advanced oxidation processes. These processes become more and more important since substances such as pesticides, endocrine disrupters, etc. are given priority. Some of these substances cannot be degraded biologically. Advanced oxidation processes are capable to destroy most organic compounds at least partially.

Besides the development of new technologies the regulations for the discharge of treated wastewater become more and more stringent. This means that measuring the standard group of parameters (BOD, COD, nitrate-N, nitrite-N Kjeldahl-N, total-N, ortho-P, total-P, suspended solids) will be not longer sufficient. Up to now heavy metals and organic micro pollutants, the so-called non-standard parameters, are only measured occasionally. The discussion of new and emerging parameters will dominate the further technology selection process.

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

The bulk of the effort in this work package was concentrated on the development of a decision support system (DSS) for integrated water reuse projects, which was then validated and used in the development and validation of system design principles.

Modelling approach

The development of WTRNet aimed at incorporating both the process synthesis and water distribution aspects of reuse schemes in an integrated DSS, and overcoming some of the limitations that appear in currently available decision support tools. Some specific objectives set out in the development of the software were:

- Provide a completely open modelling environment that will allow users flexibility in terms of editing and adding information to the software knowledge base (e.g. unit processes and their characteristics, pollutants to be considered, use types and quality requirements, rules for combining unit processes in a treatment train, etc.),
- Provide suggestions for complete treatment trains based on the influent quality (or current level of treatment provided in the case of existing wastewater treatment facilities) and quality requirements for "standard" end uses of reclaimed water,
- Include the distribution system in the reuse scheme evaluation, by allowing users to specify the locations of pumping, transmission and storage facilities and providing a least-cost preliminary sizing of the distribution system that meets all operational requirements.

The software includes a knowledge base, a control module which contains the graphical user interface (GUI), and three computational modules for evaluation of treatment performance, sizing of the distribution system and optimisation. Each of these components is described briefly below.

Knowledge base

The knowledge base contains the following information: water quality requirements for different types of end uses of reclaimed water, design and costing information on unit processes, suggestions for treatment trains that could be used for influent quality / end use combinations, rules for combining unit processes, and the design and costing information for the distribution system components. There are 44 unit processes currently included in the knowledge base, ranging from preliminary treatment to disinfection, as listed in Table 3.5.

Table 3.5: Unit processes included in the model knowledge base

Category	Unit Processes
Preliminary	Bar Screen Grit Chamber Coarse Screen
Primary	Fine Screen Sedimentation w/o Coagulant Sedimentation w/ Coagulant DAF w/ Coagulant Membrane Filtration Actiflo®
Secondary	High Loaded Activated Sludge + Secondary Sedimentation Low Loaded Activated Sludge w/o de-N + Secondary Sedimentation Low Loaded Activated Sludge w/ de-N + Secondary Sedimentation Trickling Filter + Secondary Sedimentation RBC Submerged Aerated Filter Stabilization Pond Constructed wetland Membrane bioreactor EBPR P-Precipitation
Tertiary	Filtration over fine porous media Surface filtration Microfiltration Ultrafiltration Nanofiltration Reverse osmosis GAC PAC Ion exchange Advanced oxidation SAT Maturation pond Constructed wetland - polishing Flocculation
Disinfection	Ozone Paracetic acid Chlorine dioxide Chlorine gas UV radiation

For each of the unit processes, the following information was assembled: maximum allowable influent pollutant concentrations, design criteria for sizing, process efficiencies for a series of pollutants, land

and labour requirements, sludge and concentrates production, cost estimates and preference scores on qualitative evaluation criteria. All of this information is displayed to the user in a series of editable forms, which allow the user to review all the information and alter the expressions used in the calculation to suit local conditions.

Treatment performance module

The treatment performance has been developed with functionality to perform the evaluation of user-selected combinations of unit processes in a treatment train. The evaluation of treatment train performance and the display of treatment train evaluation results are carried out as changes to the treatment train are made. Since the evaluation results in a large output, the calculated data is displayed through four separate frames on the form: effluent quality, pollutant percent removed, evaluation criteria scores and costs and resources.

Distribution system sizing module

The distribution system performance computational module is used to optimally size the distribution system elements based on a pre-determined branched layout and preferences of the user for locating the pumping and storage facilities. The method used is a two-step procedure that first determines the optimal allocation of reclaimed water (along with optimal sizes of seasonal storage), followed by the sizing of pipes and pumping stations.

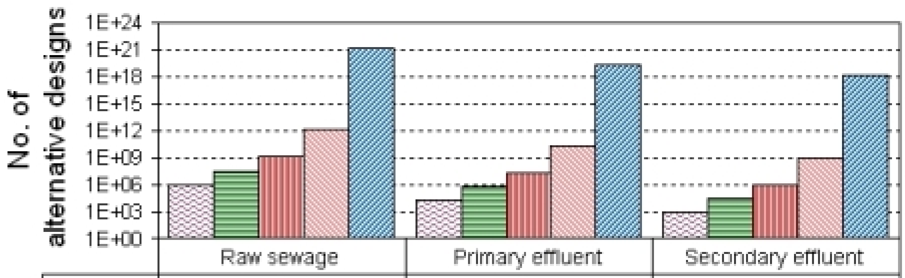
The problem of optimal allocation of reclaimed water is solved as a minimum cost flow problem following an approach. The solution of the minimum cost flow problem determines the flows in real parts of the network (pipes) and conceptual flows (storage carryover arcs) over twelve monthly intervals and fixed locations of storage facilities. Output from this optimisation algorithm is used in three ways: 1) the optimal operating policy identifies volumes of reclaimed water transferred to each user, 2) maximum monthly flows in the real part of the network are used to calculate the pipe head losses for the optimal sizing of pipes and pumping stations, and 3) the maximum storage carryover arcs are used to size and cost the seasonal storage elements of the distribution network.

The least-cost sizing of pipes and pumping facilities is then carried out using a linear programming (LP) algorithm, which uses the information on standard pipe sizes and pumping station costs contained in the model knowledge base. The model is limited to branched distribution networks, typical in water reuse schemes and appropriate at the planning level of analysis, and uses standard representation of the network in the form of links and nodes.

Optimisation module

As indicated above, the knowledge base included in WTRNet covers 44 treatment unit processes. Evaluating all possible combinations of these unit processes (i.e. without any rules for combining them in a meaningful way) yields the number of total possible combinations as $1.76*10^{13}$. However, the analyses of water reuse options can be conducted in situations where some treatment of wastewater is already provided. In addition, rules incorporated in WTRNet for assembling treatment trains further restrict the search space.

The combined effect of introducing treatment train rules and restricting the starting unit process according to the influent quality on the possible number of ways in which the unit processes could be combined to form a treatment train was analysed. The results of this analysis, shown in Fig. 3.14, indicate that the number of possible treatment trains is drastically reduced if treatment train assembly rules are considered. The same figure has additional results showing the number of possible design alternatives for various numbers of potential end-users and influent quality. In the case of raw sewage influent, the total number of design alternatives for any number of end-users requires that a formalised optimisation approach be applied. The situation is similar if primary effluent is used as a source in a system incorporating several potential end-users. If secondary effluent is used as a source and only several potential end-users are considered, an exhaustive search could potentially be used to identify the least-cost alternative.



	Raw sewage	Primary effluent	Secondary effluent
1 user	1.21E+06	19,608	1,139
5 users	3.74E+07	607,848	35,309
10 users	1.24E+09	2.01E+07	1.17E+06
20 users	1.27E+12	2.06E+10	1.19E+09
50 users	1.36E+21	2.21E+19	1.28E+18

Figure 3.14: Number of design alternatives

In order to accommodate the wide range of the number of possible design alternatives, three algorithms are incorporated in the optimisation module. If the secondary effluent is to be reclaimed and the number of potential customers is not large, exhaustive enumeration is used to determine the least-cost design alternatives for all combinations of end-users. If the secondary effluent is to be reclaimed for a (potentially) large number of end-users, a simple Genetic Algorithm (GA) is used for optimal user selection. Finally, if the source of water is raw sewage or primary effluent, the optimisation algorithm used is a GA with customised operators. The algorithm conducts a simultaneous search of least-cost design alternatives and the best selection of customers, and uses the project Net Present Value (NPV) as the evaluation criteria.

Software Validation

The software validation was carried out by comparing its output with values recorded at Wulpen WWTP. In addition, the software evaluation results were compared with values reported in the scientific and technical literature for a theoretical study of process cost estimation and comparison of various wastewater treatment schemes, a full-scale MBR facility, and a demonstration scale MBR/RO facility.

Concentration of several pollutants measured at WWTP Wulpen was compared with the results obtained from WTRNet simulation software. Overall, the comparison indicated that the software is generally functioning as intended, meaning that the calculations produce a gradual removal of pollutants through each of the unit processes in the treatment train.

The first comparison with literature values, conducted using Cote et al.[10] as the source of information, was on a theoretical study of process cost estimation and comparison of various wastewater treatment schemes, based mainly on proprietary software owned by the Zenon company. The comparison regarding costs and energy requirements suggests that reliable estimates are obtained from WTRNet.

The last technical report used for validation is from a study involving demonstration scale testing of an integrated MBR/RO treatment train to reclaim municipal wastewater in the city of McAllen, Texas, for use as a new drinking water supply[11]. Detailed available capital and O&M cost estimates for a plant with a capacity of 26,000 m^3/d of treated water were compared with WTRNet predictions. The O&M cost estimates obtained by WTRNet are very close to the estimates provided by organizations with well known involvement and expertise in water and wastewater treatment. Capital cost estimates are again here reasonable with the exception of the MBR-RO process where the WTRNet estimate is higher.

System design principles

In order to develop the system design principles, the WTRNet software has been applied in the study of industrial water reuse options in the city of Kyjov, located in the South Moravia area of the Czech Republic. Six industries were identified as potential end-users of upgraded wastewater from the Kyjov WWTP. Table 3.6 displays the details of these industries, along with their estimated quantity requirements for reclaimed water. The total reclaimed water demand estimated for these users represents less than 10% of the current plant average flow. Nevertheless, an assumption was made that 10% of the effluent from the WWTP would need to receive additional treatment in order to satisfy both the quantity and quality requirements of these potential users.

Table 3.6: Potential users of reclaimed water in Kyjov

Company	Industry Type	Estimated Water Demand (m^3/d)
Sebesta spol. s r.o.	Manufacturing of packaged wastewater treatment plants	23
KM Beta a.s.	Manufacturing of building and roofing products	35
Sroubarna Kyjov spol. s r.o	Manufacturing of fasteners	122
EKOR s.r.o	Waste management	9
Mlekarna Kyjov, a.s.	Dairy works	74
Vetropack Moravia Glass a.s	Glass manufacturer	297
Total		600

Investigation of wastewater reuse opportunities in Kyjov was carried out using WTRNet. The Kyjov WWTP effluent quantity and quality was used as the source of reclaimed water, and a preliminary layout of the distribution system was implemented. The distribution system modelled consists of a single pumping station and 10,000 m^3 of operational storage, both located at the WWTP, in addition to the piping required to deliver the reclaimed water to the potential end-users.

[10] P. Cote, M. Masini and D. Mourato. Comparison of membrane options for wastewater reuse and reclamation. Desalination 167 (2004) 1-12.

[11] J. C. Lozier and A. M. Fernandez, Demonstration Testing of ZenoGem and Reverse Osmosis for Indirect Potable Reuse, , U.S. Department of Interior, Bureau of Reclamation, City of MsAllen, Texas, 2002.

The results of applying the exhaustive enumeration optimisation methodology are shown in Fig. 3.15. The six potential end-users produced 64 different combinations. The first remark that is made on the results of evaluation is that the variability in overall water reclamation system costs is due primarily to the varying costs of the distribution system as different sets of potential end-users were selected. The treatment costs, although not linear, are in proportion to the percent demand satisfied (volume) and do not exhibit such variation, potentially due to the assumption that the potential end-users in this case study require the same quality of water. Nevertheless, the importance of evaluating water reuse systems in an integral manner is clearly demonstrated.

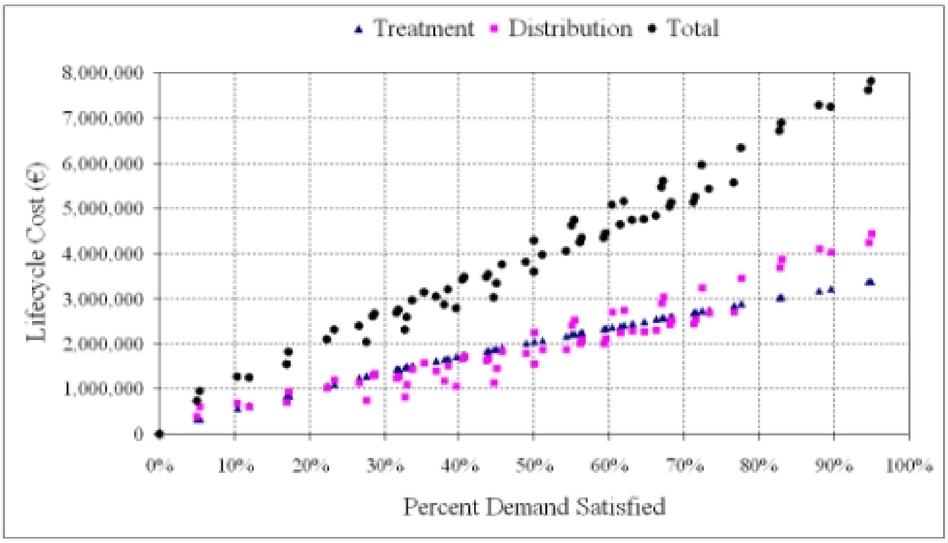


Figure 3.15: Results of evaluation of water reuse options in Kyjov

The application of WTRNet is illustrated in a case study of water reuse options in the city of Kyjov, on a relatively small scale with few potential end-users. The application allowed for the following design principles to be derived by analysing the optimisation results:

- The variability in lifecycle cost of water reuse schemes is a direct result of the distribution system costs, while treatment costs are relatively proportional to the volumes of water treated.
- Costs of distributing reclaimed water can comprise a significant portion of the total scheme lifecycle cost, and have to be included in the evaluation.
- Patterns have been observed in the selection of least-cost treatment trains as a function of both the reclaimed water end use type and the size of the scheme.
- A fixed investment (life-cycle) cost can result in satisfying a relatively wide range of the percentage of projected demands.

4. CONCLUSIONS INCLUDING SOCIO-ECONOMIC RELEVANCE, STRATEGIC ASPECTS AND POLICY IMPLICATIONS

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 indicate that several common issues exist. Some of these issues are briefly described in the following paragraphs[12].

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.

12 AQUAREC, D. Bixio, H. Chikurel, J. De Koning, D. Savic and M. Muston. Management review report Deliverable D10, 2004.

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 (Table 4.1).

Table 4.1: Existing country/regional water reuse criteria within the European Union

Country/Region	Type of criteria	Comment
Belgium: Flemish Regional Authority	Aquafin Proposal to the Regional Government (2003)	Based on Australian EPA guidelines
Cyprus	Provisional standards, 1997	Quality criteria for irrigation stricter than WHO standards but less than Californian Title 22 (TC < 50/100 mL in 80% of the cases on a monthly basis and < 100/100 mL always)
France	Art. 24 décret 94/469 3 juin 1994 Circulaire DGS/SD1.D./91/n°5 1	Both refer to water reuse for agricultural purposes. Essentially follow the WHO standards, with the addition of restrictions for irrigation techniques and set back distances between irrigation sites and residential areas and roadways
Italy	Decree of Environmental Ministry 185/2003	Quality requirements are required for the three water reuse categories defined: agriculture, non-potable urban and industrial. Possibility for the Regional Authorities to change some parameters or implement stricter regional norms
Regional authorities: Sicily, Emilia Romagna and Puglia	Guidelines	The proposed microbiological standards are similar to those of the Title 22 regulation for Puglia and Emilia Romagna and to WHO standards for Sicily
Spain	Law 29/1985, BOE n.189, 08/08/85 Royal Decree 2473/1985	In 1985 the Government indicated water reuse as a possibility, but no specific regulation followed. A draft legislation has been issued in 1999, with a set of standard for 14 possible applications of treated water. The proposed microbiological standards range is similar to those of the Title 22 regulations in terms of defined use categories but not as to the standards set for each category.
Regional authorities: Andalucia, Balearic Is. and Catalonia	Guidelines from the Regional Health Authorities	Developed their own guidelines concerning wastewater recycling, in particular in the field of the irrigation, based on the WHO guidelines of 1989

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[13]. 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[14].

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[15]. Their involvement in building up credibility, trust and confidence is often underestimated.

[13] Mujeriego R., Serra M. and L. Sala (2000) Ten Years of Planned Wastewater Reclamation and Reuse in Costa Brava, Spain. In: Proc. Water Reuse 2000 Conf.; San Antonio (USA), 31 Jan - 3 Feb 2000

[14] European Union. Council Directive establishing a Framework for Community action in the field of water policy. 2000/60/EC of October 23; 2000, OJ L 327 of December 22, 2000.

[15] L. Sala. Operational experience with constructed wetlands in Costa Brava. In Proc. Intl Workshop on Implementation and Operation of Municipal Wastewater Reuse Plants; Thessaloniki, Greece; 11-12 March 2004.

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[16]. 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

[16] T. Dewettinck , E.Van Houtte , D. Geenens , K. Van Hege and W. Verstraete HACCP to guarantee safe water reuse and drinking water production – A case study. Wat.Sci.Tech.43 (12): 31–38, 2001

M. Salgot C. Vergés and A.N. Angelakis. Risk Assessment for Wastewater Recycling and Reuse, Proc. IWA Regional Symposium on Water Recycling in the Mediterranean Region Iraklio, Greece September 2002.

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.

5. DISSEMINATION AND EXPLOITATION OF THE RESULTS

The AQUAREC project has made extensive effort to engage with the wider scientific and practioner audience on water reuse and integrated water resources management. Project partners have issued more than 50 publications including journal papers and presentations on international conferences. Articles about the AQUAREC project have been published in wide spread journals such as Water 21. Through its web site www.aquarec.org and a publicly accessible "Knowlegde Network Water Reuse" the consortium has spread information about the AQUAREC project and the water recycling issue in general. The website and the Knowledge Network will still be maintained after the project termination.

One of the major dissemination activities has been in a successful number of public events, namely a Workshop on Water Reuse System Management Practice in March 2004 in Thessaloniki/Greece. A workshop on participative planning of water reuse schemes as part of the IWA World Water Congress in Marrakech/Morocco in September 2004. The International Conference on Integrated Concepts for Water Recycling was held in February 2005 in Wollongong/Australia. The Workshop on Water Reuse was organised in September 2005 in Valencia/Spain with participation of the Spanish Federal Environmental Minister. The final Conference on Integrated Concepts for Reuse of Upgraded Wastewater has been hold in February 2006 in Barcelona/Spain.

The AQUAREC project has actively fed in project results in ongoing initiatives to promote water reuse such as the Eureau Water Reuse Group, the Global Water Research Coalition and to communicate to a large number of individual stakeholders.

Final project results will primarily published through main dissemination channels such as the European Commission Publication Services, or publishers as well as the internet. Many project results will be used in other ongoing EU co-funded research projects such as AQUASTRESS and RECLAIM WATER. The dissemination activities can be summarised as follows:

- Web site: www.aquarec.org
- Publications (see publication list on the web site)
- Workshop on Management Practices in Thessaloniki in March 2004
- Workshop on "Participative Planning of Water Reuse Schemes" in Marrakech in September 2004
- Conference on Integrated Concepts for Water Recycling in Wollongong in February 2005
- Workshop on Water Reuse in Valencia in September 2005
- Final Conference on "Integrated Concepts for Water Reuse" in Barcelona in February 2006

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