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Wastewater reuse in Europe

D. Bixio[a*], C. Thoeye[a], J. De Koning[b], D. Joksimovic[b], D. Savic[c], T. Wintgens[d], T. Melin[d]

[a]Aquafin NV, Dijkstraat 8, Aartselaar 2630, Belgium
email: davide.bixio@aquafin.be
[b]Sanitation Engineering Departmen, Delft University of Technology, Stevinweg 1, PO Box 5048, GA Delft 2600, The Netherlands
[c]Center for Water Systems, Exeter University, Harrison Building, North Park Road, EX4 4QF Exeter, UK
[d]Chemical Engineering Department, RWTH Aachen University, Turmstrasse 46, Aachen 52056, Germany

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Abstract

In Europe the last two decades has witnessed growing water stress, both in terms of water scarcity and quality deterioration, which has prompted many municipalities to look for a more efficient use of water resources, including a more widespread acceptance of water reuse practices. This paper reviews European water reuse practices and sets out the map of the water reclamation technologies and reuse applications. The data are based on a conventional literature survey, on the preliminary evaluation of an in-depth survey of a large number of European water reuse projects and on the findings of a dedicated international workshop. The preliminary evaluation indicates that for an increased utilisation of reclaimed wastewater, clearer institutional arrangements, more dedicated economic instruments and the set-up of water reuse guidelines are needed. Technological innovation and the establishment of a best practice framework will help, but even more, a change is needed in the underlying stakeholders' perception of the water cycle.

Keywords: Wastewater reclamation; Water reuse; Water management; European Union

1. Drivers for water reuse

Europe has plenty of water resources compared to other regions of the world, and water has long been considered as an inexhaustible public commodity. This position has, however, been challenged in the last decades by growing water stress, both in terms of water scarcity and quality deterioration. Approximately half of the European countries, representing almost 70% of the population, are facing water stress issues today [1]. Fig. 1 ranks the countries according to their water stress index.

*Corresponding author.

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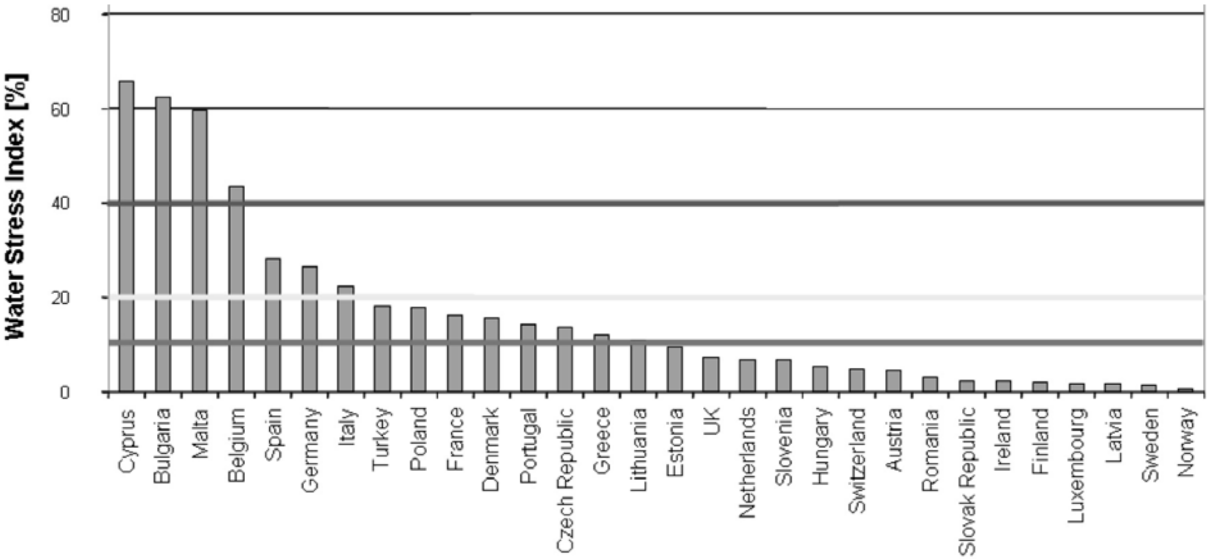

Fig. 1. Water stress index for the European countries. Annual abstractions for the year 2000 (or latest available data) are divided by the long-term annual average availability [1].

The water stress index — the ratio of a country's total water withdrawal to its total renewable freshwater resources — serves as a rough indicator for the pressure exerted on water resources (note, however, that not all water uses are causing comparable stress). With values of less than 10%, water stress is considered low. A ratio in the range of 10–20% 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% is supposed to necessitate comprehensive management efforts to balance supply and demand, and actions to resolve conflicts among competing uses [2].

These data are on a country level and do not reflect the fact that water stress often appears on a regional scale. Uneven distribution and seasonal variations of water resources make the semi-arid coastal areas and the highly urbanised areas particularly affected by water stress. Changing global weather patterns will make the situation worse, in particular for the southern European countries, more susceptible to drought conditions that can be cause of major environmental, social and economic problems.

Such a situation places many municipalities in a precarious position, especially in the face of increasing water demand, increasing water supply costs and increasing competition (industry, agriculture, tourism, etc.) for good-quality fresh water reserves. The European Union and its member states have successively over the last three decades implemented European Union wide and national measures to ensure a sustainable water management process, an important outcome of which is the Water Framework Directive (WFD) [3].

It is expected that the promotion of an integrated approach to water resources management as it is spelled out in the WFD will favour municipal wastewater reclamation and reuse to be implemented on a larger scale, for both augmenting water supply and decreasing the impact of human activities on the environment. Take the example of the Nete River catchment, Belgium. The nitrogen discharge to the river is shown in Fig. 2.

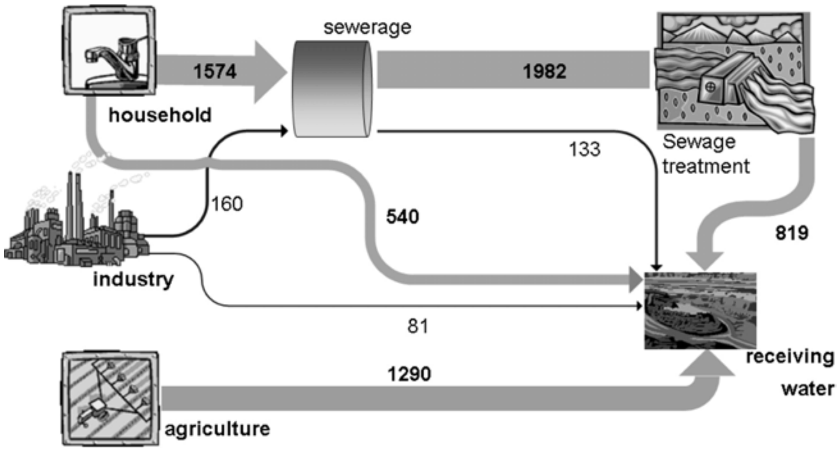

Fig. 2. Total nitrogen contribution, expressed in ton TN /year, to the Nete River, Belgium.

With a traditional approach to pollution abatement, i.e., the approach followed in the Urban Wastewater Treatment Directive (UWWTD) [4], one will have to: (1) implement decentralised treatment to reduce the pollution from households in remote areas (540 t TN/y), (2) apply a more stringent consent on the municipal wastewater treat-ment plants' effluent (note that all WWTPs >10,000 PE already comply with a nutrient removal consent of 10 (15) mg TN/L for agglomeration larger (smaller) than 100,000 PE) and if still necessary, (3) reduce the diffuse pollution from agriculture (which would directly touch at the agriculture stakeholders' interests, and therefore, this is an option that today is not politically possible).

Considering the holistic approach introduced by the WFD, on the other hand, it might be more sustainable (and cheaper) to obtain a similar level of nitrogen removal by just reclaiming the municipal WWTP effluent and reusing it, for example, in agriculture, or for parkland irrigation/creation. This would achieve protection of the water quality while reducing the water (and fertiliser) demand from fresh water reserves.

Note that in 1991, the UWWTD already urged the member states to reuse treated water "whenever appropriate". But a legal definition of the term "appropriateness" is still pending in the context of wastewater reuse.

2. Reuse of municipal wastewater in Europe — status

The study identified more than 200 water reuse projects as well as many others in an advanced planning phase. This is a particularly large figure considering that in the early 1990s municipal water reuse was limited to a few cases, mostly incidental, i.e., related to the proximity of the wastewater treatment plant to the point of use.

Fig. 3 shows the geographic distribution of the identifiable water reuse projects, including their size and intended use. In Fig. 3 the areas of application are split into four categories: (1) agriculture; (2) industry; (3) urban, recreational and environmental uses, including aquifer recharge; and (4) combinations of the above (mixed uses). The scale of the projects is also split into four classes: very small (<0.1 GL/y), small (0.1–0.5 GL/y), medium (0.5–5 GL/y) and large (>5 GL/y).

Much of the development occurred in the coastline and islands of the semi-arid southern

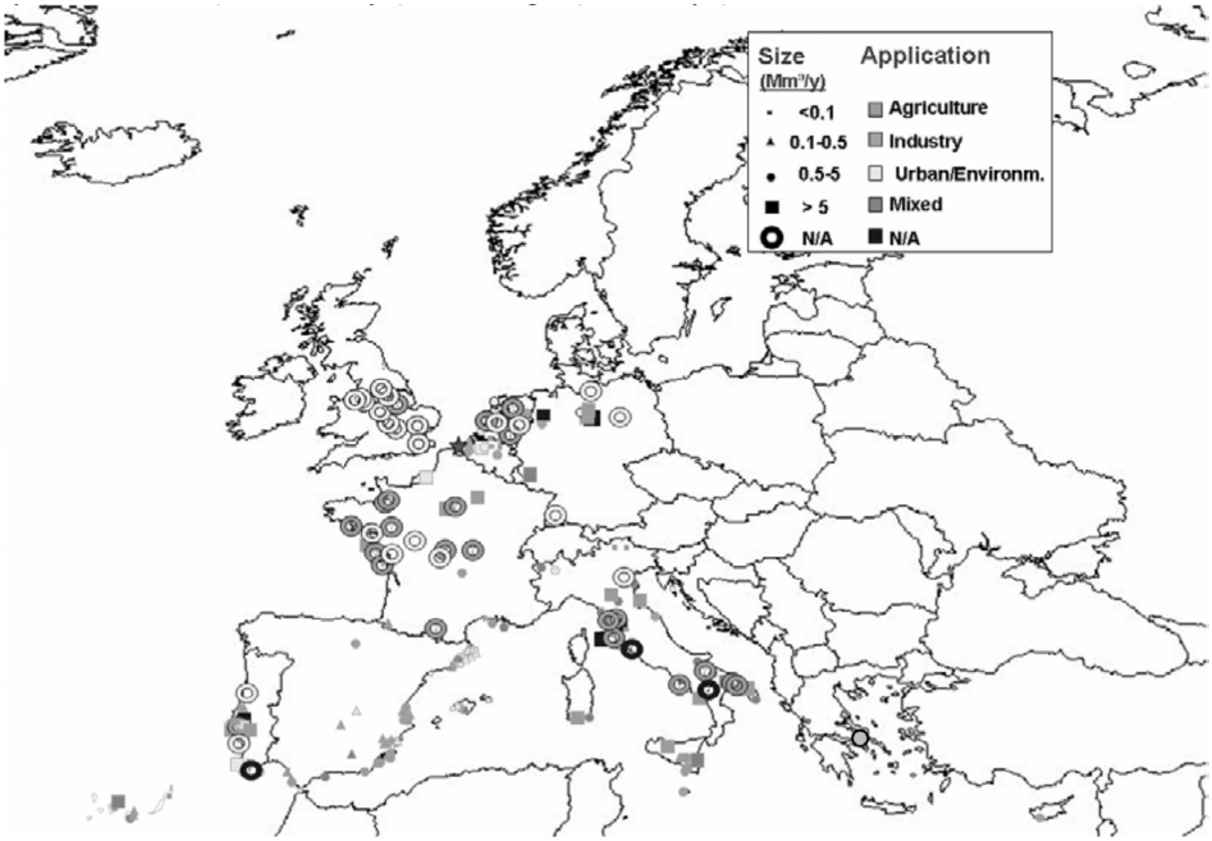

Fig. 3. Identifiable water reuse projects in Europe, including their size and intended use.

regions, and in the highly urbanised areas of the wetter northern regions. Fig. 3 shows that the use of reclaimed water is quite different between those two regions: in southern Europe, reclaimed wastewater is reused predominantly for agricultural irrigation (44% of the projects) and for urban or environmental applications (37% of the projects); in northern Europe, the uses are mainly for urban or environmental applications (51% of the projects) or industrial (33% of the projects).

The project distribution reflects quite well the sectoral water use of the different countries (Fig. 4), with the exception of France. This exception can be explained by the fact that France has published guidelines only for agricultural irrigation.

Only one water reuse project has been identified for potable water production. The project was set up to reduce the extraction of natural groundwater for potable water production and to hold back the saline intrusion at the Flemish coast of Belgium. On the other hand, indirect or even unplanned potable reuse occurs in most of the major European cities.

In Europe there is an escalating interest for artificial groundwater recharge with reclaimed wastewater to hold back saline intrusion in coastal aquifers. This can be seen by the involvement of the WHO regional office for Europe in addressing the specific health risks of this practice [6]. Two large-scale projects, one in the Barcelona area and one in the north of London,

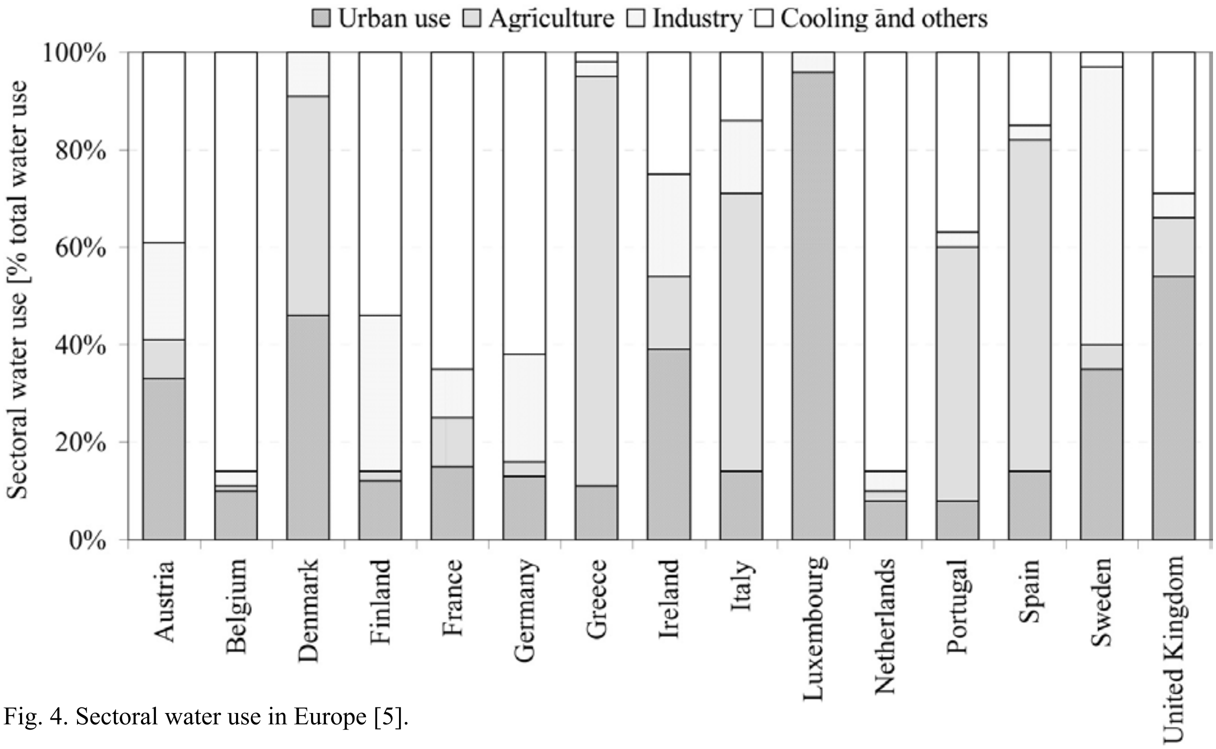

Fig. 4. Sectoral water use in Europe [5].

and several other medium-sized projects already exist.

3. Water reclamation technology — status and trends

Almost all medium- and large-scale schemes have been designed as add-on technology to conventional secondary treatment processes. Note that secondary treatment (including nutrient removal in areas sensitive to eutrophication) is the mandated basic wastewater treatment for discharge to fresh water [4].

3.1. Secondary treatment

Over one-third of the water reclamation schemes rely on secondary treatment. This level of treatment is characteristic for restricted agricultural irrigation applications (i.e., for food crops not consumed uncooked) and for some industrial applications such as industrial cooling (except for the food industry). A separate reference ought to be provided to membrane bioreactors (MBR). MBR is the only treatment process that is not designed as add-on technology to conventional secondary treatment processes, but rather replaces conventional secondary treatment processes in order to match new stricter effluent standards.

There are significant expectations for the application of MBR in water reuse projects, either as pre-treatment of nanofiltration or reverse osmosis (quaternary treatment), or with the effluent directly reused for unrestricted irrigation, as the full-scale experience of the Schilde WWTP, Belgium, indicates. Long-term effluent results for a broad range of water reuse parameters demonstrate the suitability of the MBR technology to meet unrestricted irrigation standards. The MBR effluent complies with the faecal coliforms WHO guideline limit for using treated water in agriculture. Concerning the stricter State of California Title 22 water recycling criteria, no straightforward evaluation could be made because of the differing sampling procedures [7]. Out of the 24 effluent samples so far measured for total coliforms, 18 were <240/100 ml, 9 were <23/100 ml and 5 were <2.2/100 ml.

The first series of MBRs for municipal wastewater treatment in Europe was commissioned in 1998. In the first years, MBRs were typically applied for small-scale decentralised treatment (<100 m^3/h), with several examples available in the UK, Germany and Italy. The uptake of membrane bioreactors for large/medium-scale municipal facilities has been slow, but some large/medium-sized applications already exist and many other are under construction. Examples are the Empoli facility in Italy for industrial water supply and the Villafranque facility in France for agricultural irrigation.

3.2. Tertiary treatment

To meet the standards for unrestricted irrigation, conventional secondary treatment requires supplemental treatment (filtration and/or disinfection). These standards are valid for agricultural and landscape irrigation, recreational and environmental uses as well as for process water in some industrial applications.

In Europe there are no technology-based regulations or guidelines such as, for instance, the Californian Title 22 regulation (which imposes coagulation/flocculation, sedimentation, filtration and disinfection of secondary effluent to strive for a 0-FC/100 ml limit). The European water industry could benefit from the experience gained by the implementation of the Title 22 concept. In the EU–Mediterranean countries, aiming at the 10 FC/100 ml limit (Spain, Greece, Italy, Portugal and Cyprus), the most common process is coagulation–flocculation and direct (or contact) filtration followed by disinfection. Only a limited number of installations apply the full Title 22 concept. Note that the Californian Title 22 allows filtration without flocculation if the effluent turbidity before filtration is less than 5 NTU. As the effluent of a well designed and operated activated sludge plant achieves that limit, several unrestricted reuse applications require thus only filtration (no flocculation) and disinfection steps, whereas the coagulation–flocculation step may serve as a back-up.

Constructed wetlands filtration (and disinfection) is also quite commonly used, especially for small-scale projects. Medium- to large-scale applications are found in the Netherlands [8] and in Belgium. Medium- to large-scale applications are generally used for habitat creation, restoration or enhancement and provision of additional treatment prior to discharge. This has led to many demonstrated benefits such as, for instance, a remarkable reduction in the pathogenic strength of the discharged water, which is particularly important when the discharge is in proximity of beaches.

Disinfection is still carried out mainly though chlorination. The trend is, however, to move to ultraviolet irradiation (UV). Disinfection techniques other than chlorination and UV are rarely applied. Full-scale examples using ozone or peracetic acid are found for an industrial application in Belgium and for indirect agricultural irrigation in Italy.

3.3. Quaternary treatment

Microbial retention can also be achieved by microfiltration (MF) and ultrafiltration (UF). MF and UF are employed as preferred pre-treatment processes for nanofiltration (NF) or reverse osmosis (RO), i.e., the quaternary treatment step which is able to generate drinking or ultrapure process water quality [9]. This “double membrane” treatment concept plays a major role in water reclamation schemes that are aimed at advanced levels of purification. Applications include several aquifer recharge projects (one even for indirect potable reuse), dual-water systems in households and industrial process water [10,11,12], or for mixed urban and agricultural uses [13,14].

In indirect potable reuse applications the secondary effluent is reclaimed by MF, cartridge filtration, RO and UV. The produced RO filtrate is reconditioned to match the natural salt content in the dune water, blended in the water supply aquifer, recaptured after a minimum residence time of 40 days and repurified in the drinking water production facility. The drinking water quality standards are met; the recharge system performs as expected and after one and an half years of operation, the results are softer drinking water, adding to the comfort of the customers [15].

4. Reclamation and reuse of municipal wastewater — challenges

Despite the fact that water reuse is already becoming an essential and reliable water supply option for many municipalities, there is still significant potential for an increased utilisation of reclaimed wastewater [16]. A preliminary evaluation of a large number of European water reuse projects indicates that there are a number of common issues that will have to be tackled if the water reuse potential is to be tapped to the fullest. Some of these issues are briefly described in the following paragraphs.

4.1. Re-orientation of the water governance towards integrated water management

In many regions integrated water resources management is still at its infancy. At the time of writing most of the member states have yet to adopt national legislation to comply even with the Water Framework Directive. Moreover, 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 is 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.

4.2. 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 of water reuse and putting the results into practice, especially (but not only) for those regions where water and sanitation services are run by different entities.

There is much discussion on how water reuse projects should be managed, in particular who should take the leadership and how the responsibilities/liabilities should be divided. This was investigated through an international survey that covered four types of ownership structures: (1) where water and sewerage management is the responsibility of a single corporate entity, where (2) the water or (3) the wastewater company managed the water reclamation project, or (4) where *ad hoc* project-related structures were set up [17]. The survey indicates that the adoption of the suitable ownership structure for the project is all a question of local circumstances, political will, legislation, institutional structure and regulation. On the other hand, successful case studies hint that ownership is not the real issue, rather is that of tied liability, and above all access to financing and cost allocation. An example in point is the Tilburg water reuse project in the Netherlands where the water supply and the wastewater services joined together to set up an *ad hoc* water reuse company under an administrative and legal framework that has tax advantages while at the same time having the ability to allocate funds at the lowest interest rate.

Another preliminary conclusion of the survey is that the communication/collaboration between the water and the wastewater sector is always desirable. The Tilburg project, for instance, could also benefit in full the technical capacities of the two companies, namely: the wastewater treatment company for the management of the water reclamation scheme and the drinking water company for the distribution system and for the customer relations. This is a clear case where the whole is more than the sum of the parts.

4.3. Establishment of guidelines or criteria for wastewater reclamation and reuse

Once convinced of the need of water reuse, it is not always easy to obtain a permit for the reuse of reclaimed water, and this despite the European Union's wide encouragement to reuse wastewater treatment effluent. For several member states one of the major problems is the lack of clear criteria on when to reuse and on quality standards.

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 strict standards for unrestricted agricultural irrigation, but the public administration released a permit basically referring to the WHO's recommendations on irrigation with raw wastewater. Although this is an extreme case, it illustrates quite well how urgent the need is for the establishment of water reuse guidelines.

Despite the fact that no guidelines or regulations yet exist at the European Union level, several member states or autonomy regions have now published their own standards or regulations (Table 1). The EU-funded RTD project AQUAREC [18] is making an effort to harmonise the various approaches at the European level.

4.4. Economic instruments

Financing is perhaps the major barrier to wider use of treated wastewater. In the EU financing of up-front costs was originally provided by (local) government grants while revenue programmes were financed by 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. One of the reasons why water supply benefits alone cannot cover the project costs 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

Table 1
Existing water reuse criteria within the European Union

Member state	Type of criteria	Comment
Belgium: Flemish Regional Authority	Aquafin proposal to the 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 1994 Circulaire DGS/SD1.D./91/n°51	Both refer as 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 and implement stricter 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 strongly similar to those of the Title 22 regulations
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

incentives. Subsidies do not cover (or will no longer cover) operation and maintenance costs.

Water reuse 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 [19]. 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. It is worth noting that EU member states will have to promote cost recovery policies ensuring adequate incentives for users to exploit water resources efficiently by 2010 [3].

Cost-benefit comparisons should be made that compare total cost for integrated water resources management alternatives, rather than considering simply for 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 (externalities) of the projects. Take as an example the possible pollution abatement solutions for the Nete River catchment: the water reuse option may be (much) cheaper when looked at from an holistic point of view, still the sharing of benefits and cost among the stakeholders is very different than with the conventional option. It is not ethically and economically possible that water reuse consumers have to bear all the costs for the benefits generated by the project.

4.5. Building trust, credibility and confidence

Even if the authorities 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 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 subsidies to to compensate for increased water costs. This approach maintains the situation with water resources management in the region — including the attractiveness of water reuse — practically unchanged.

It is important to note that the perception revealed by the European survey is that, in the view of some public administrations and of the population, treated wastewater still remains basically wastewater. It is not widely known that in many 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 NGOs and environmental associations was a critical success factor, as the Empuriabrava project in Spain, clearly demonstrated [20]. Their involvement in building up credibility, trust and confidence is often underestimated.

As a basis for building the trust between stakeholders, there is a need to convey simple, clear and reliable information. The establishment of a best management practice framework to provide a basis for structure and transparency in the management and decision processes is very much needed. 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.

The need for a best management practice framework is well acknowledged within the EU according to a recent survey undertaken by the EUREAU Water Reuse Group. This is another important objective of the EU–RTD AQUAREC project [18]. Plenty of information on water reclamation and reuse practices is already available but is often fragmented and open to misinterpretation.

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 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. On the other hand, despite the fact that procedures such as Hazard Analysis and Critical Control Points are increasingly used to direct efforts in process control and monitoring to guarantee hygienically safe reclaimed water [21,22], very few surveyed projects have used them. Another interesting point is that very few projects seem concerned about emerging issues such as trace organic contamination.

5. Research on municipal water reuse at the European Union level

The vital importance of wastewater reclamation and reuse of municipal wastewater for water management in Europe has been acknowledged by the Commission of the European Communities through its General Directorate Research through a support of a comprehensive set of research projects. Table 2 summarises the EU-funded projects in the Fourth (1994–1998) and Fifth (1999–2002) Framework Programme on Community activities in the field of research,

Table 2
EU funded RTD projects concerning municipal water reuse in the last decade

Acronym	Title	Project URL
FP5 (1999–2002)		
CORETECH	Development of cost-effective reclamation technologies for domestic wastewater and the appropriate agricultural use of the treated effluent under (semi-) arid climate conditions	
POSEIDON	Assessment of technologies for the removal of pharmaceuticals and personal care products in sewage and drinking water facilities to improve the indirect potable water reuse	www.eu-poseidon.com
MBR-RECYCLING	Water Recycling and Reuse by Application of Membrane Bioreactors: Textile and Municipal Wastewater as Examples	
WAM-ME	Water Resources Management under Drought Conditions: Criteria and Tools for Conjunctive Use of Conventional and Marginal Waters in Mediterranean Regions	www.dica.unict.it/users/fvaglias/Wam-meWeb/
AQUAREC	Integrated concepts for reuse of upgraded wastewater	www.aquarec.org
P-THREE	Removal of persistent polar pollutants through improved treatment of wastewater effluents	www.pthree.de
MEDWATER POLICY	Policy initiative to overcome water competition between the vital economic sectors of agriculture and tourism in the Mediterranean	www.medwater.de
SWIMED	Sustainable water management in Mediterranean coastal aquifers: recharge assessment and modelling issues	www.crs4.it/EIS/SWIMED/
FP4 (1994–1998)		
COLD WSPS	Development of low-cost methods for treatment and reuse of drainage and urban wastewater by adaptation of waste stabilitation ponds for extreme continental climates (cold wsps)	
CATCHWATER	Enhancement of integrated water management strategies with water reuse at catchment scale	
	Utilisation of groundwater desalination and wastewater reuse in the water supply of seasonally stressed regions	
BIOWATSYST	A system approach to wastewater biotreatment for the protection of Mediterranean coastal areas	

technological development and demonstration (RTD).

As illustrated in Table 2, various issues including technology, water quality and integrated water management aspects, were addressed in the research projects. In the still ongoing Sixth Framework Programme, the activities on wastewater reuse will be continued, e.g., as part of an integrated project on water stress mitigation called AQUASTRESS, where the utilisation of alternative water sources will be considered as one component in a comprehensive set of options to achieve more sustainable water management patterns.

6. Conclusions

The water sector in Europe is in a transitional phase with unique opportunities for water reuse to be implemented on a larger scale as a sustainable practice within a framework of integrated water management. Success of integrated water management policy depends on individual, local communities and companies as much as on centralised rules and regulations. In order fully to tap the significant potential for water reuse, clearer institutional arrangements, economic instruments and water reuse guidelines are very much needed (top-down approach), technological innovation and the establishment of a best practice framework will help, but there can be few more pressing and critical goals than to produce a change in the underlying stakeholders' perception of the water cycle (bottom-up approach).

As the Danish poet Esther Gress expressed it:

"*If you want to change the world*
You must change man
If you want to change man
You must make him want to change"

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