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COST ASPECTS OF WASTEWATER TREATMENT

In cooperation with

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EXECUTIVE SUMMARY

Over the last few years, the World Water Vision has shifted drastically following recognition of the multiple values of water in terms of sustainable development and the need for legislation and economic incentives to improve global water management. In addition, it has been recognized that the supply of water without adequate sanitation could have strong negative impacts on public health and the environment. Consequently, the treatment and reuse of wastewater could be one of the great challenges of the 21st century.

In general, the lack of funding greatly constricts the implementation of adequate wastewater treatment. Economic and financial constraints have an even greater impact on water reuse. Therefore, the majority of water reuse project developments have depended on subsidies and grants because the benefits of water reuse are underestimated.

It is worth noting that a lot of uncertainties exist in the micro-economic evaluation of wastewater treatment, particularly in water reuse schemes. Capital costs are characterized by high variations, depending on the type of treatment and local specific conditions. Very little information exists on wastewater treatment operating costs, which is a serious obstacle for the establishment of adequate wastewater treatment and reuse charges. Therefore, the cost evaluation of wastewater treatment and reuse remains one of the greatest challenges confronting water professionals and decision-makers. In this context, the main objective of this document is to present and discuss the financial aspects of the operation of wastewater treatment plants. The most important outcome will be the definition of a methodology for O&M cost estimation and, subsequently, a basis for the evaluation of a minimum water reuse price that will encompass O&M costs.

A comprehensive questionnaire has been prepared and circulated throughout the Mediterranean countries by mail, web sites, international organizations, as well as distribution during several conferences and seminars. Unfortunately, very few countries and institutions have responded to our request. Complementary information has been obtained by direct contact with plant operators, equipment suppliers and visits to selected wastewater treatment plants. Special efforts have been made to collect more information on non-monetary data such as man hours, energy demand, chemical consumption, specific charge for sludge disposal, etc. A literature review on the economic aspects of wastewater treatment and reuse has also been carried out with the aim of completing this information.

Direct cost comparison of wastewater treatment capital and operating costs is characterized by great uncertainty and imprecision because of the strong influence of technical and local conditions, various patterns of fund granting, different treatment targets and large variations in plant size. The most important specificity of wastewater treatment costs is that over the operational lifetime of the given sewage treatment plant, the operating and maintenance costs (O&M costs) may be as high, or even higher, than the cost of construction.

Analysis of the survey data showed that average annual capital costs related to design capacity of large wastewater treatment works with nutrient removal, vary from 16 to 60 €/p.e., with maximum values observed in Northern European countries that have more stringent discharge standards. Significantly lower costs are required for conventional activated sludge treatment, as illustrated by the average values in Greece and Spain of 16 and 23 €/p.e., respectively. Calculated per unit of treated volume, the total average cost of wastewater treatment in Northern European countries is about of 1 €/m^3, which is almost double that of the lower costs of approximately 0.6 €/m^3 in Italy and the Netherlands. The Average treatment costs of conventional activated sludge is almost 2-3-times lower in Southern EU countries, such as Greece and Spain, *i.e.* 0.3-0.35 €/m^3. Wastewater treatment costs are higher by +50 to +100% for medium size works (<50,000 p.e.) and significantly higher +200 to +500% for small-scale plants (<2000 p.e.). In addition to the influence of plant capacity, specific capital costs increase by +50 to +250% with the increase in treatment level from conventional activated sludge treatment to full nutrient removal and disinfection.

The contribution of operating costs varies from 41 to 75% of the total annual costs. According to these data, average operating costs in European countries are in the range of 56±12% (conventional activated sludge systems).

Specific O&M costs vary from 0.1 to 24 €/p.e./year. Typical net operating costs are about 5 to 10 €/p.e./year for plant size of 20,000 to 1,000,000 p.e. Higher costs are characteristic for the countries from North Europe with high level of nutrient removal (N and P). In the Mediterranean region, specific operating costs are higher for plants with tertiary treatment and reuse, *i.e.* 5 to 16 €/p.e./year.

Small plants have significantly higher operating costs of 10 to 100 €/p.e./year.

About 70% of the operating costs are for labour and energy. In general, the contribution of energy and labour is lower by 40 to 50% for large activated sludge plants, mainly because the high expenses for sludge treatment (chemicals) and disposal.

The major portion of operating costs of wastewater treatment in Europe is labour for operation, maintenance and administration, which accounts for 25 to 70% of the total operating costs (repair and maintenance included). A typical value is 45±5%. Labour costs vary from 1 to 15€/p.e./year depending on plant size, load variations, treatment technology and automation.

Energy consumption is the second largest component with values from 12 to 29% of total operating costs. For plant capacities over 10,000 p.e., specific energy costs vary from 1 to 4.7 €/p.e./yr with a typical value of 2.5±0.5 €/p.e./yr. Plant size has no significant influence on conventional activated sludge treatment with a typical energy consumption of 25±5 kWh/p.e. Extended aeration requires about 20% less energy. Advanced treatment processes and disinfection involve a higher consumption of energy of up to 45 to 100 kWh/p.e.

The cost of sludge disposal in EU countries varies from 0.06 to 5.82 €/p.e./year with typical values of 1 to 3 €/p.e./year. Depending on the route of sludge disposal, unit costs per ton of dry matter (DM) vary from 8 to over 90 €/t DM, with lower values for land spreading and the highest values for incineration. The influence of scale is not significant. With the implementation of the EU Sludge Directive 86/278/EEC, significant increase in sludge disposal costs is expected to 110-160 €/t DM for land spreading and up to 260-350 €/t DM for incineration.

It should be stressed that the reported costs are illustrative only and cannot be applied to other projects due to the strong influence of local factors and the use of different cost estimation methodologies.

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1. CONTEXT AND OBJECTIVES

1.1. Introduction

Over the last few years, the World Water Vision has shifted drastically. The most significant milestone of the 20^{th} century is certainly recognition of the multiple values of water in terms of sustainable development. The Dublin and Rio principles (1992) on sustainable use of water resources have been adopted internationally andcompleted with new initiatives proposed during the World Water Forums in Marrakech (1997) and The Hague (2000). These new initiatives include economic actions, such as a move to full-cost pricing of water services for all human uses and a massive increase in investments in water.

The second most important milestone is the recognition of sanitation as an important element of sustainable human development, as stated in the recommended targets of the World Summit on Sustainable Development in Johannesburg (2 002). It has been recognized that water supply without adequate sanitation could have strong negative impacts on public health and the environment. Consequently, the treatment and reuse of wastewater could be one of the greatest challenges of the 21^{st} century.

Historically, the objective of wastewater treatment has been to protect human health by implementation of centralized sewerage systems and large treatment works. Nowadays, these objectives still remain relevant, but the protection of public health is being accomplished by safeguarding the entire ecosystem and its inhabitants. In addition to the protection of natural water resources and the environment, the 21^{st} century is characterized by some new challenges in wastewater management including cost recovery, integrated basin management and water recycling.

It is important to stress that even now, the notion of integrated resource management does not include systematically improved wastewater management. Nevertheless, there is no doubt that without adequate sanitation and wastewater treatment, the objectives to protect of human health and the environment cannot be achieved. Moreover, once treated to appropriate quality level, wastewater effluents become an alternative resource that must not be considered as a waste product. With the threat of increasing water scarcity, population growth and fast urbanisation, water recycling becomes a vital alternative resource that will enable acceleration of the natural water cycle on a small and large scale.

The driving force today for developing water reuse in Europe is the need for alternative resources and increasingly stringent wastewater quality discharge rules and requirements for environmental protection. Hence, water reuse is growing steadily not only in water deficient areas in Southern countries, such as France, Greece, Italy, Portugal, and Spain, but also in highly populated Northern European states, such as Belgium, England and Germany. In the Mediterranean region, water reuse is a cost competitive vital resource for all tourist and coastal areas, as well as for islands.

The integration of treated wastewater reuse in the existing water management master plans was essentially geared towards irrigation. Irrigation of golf courses is the fastest growing reuse application because of the high water consumption and of the increasing surface application. The areas where reclamation and reuse are most operated at present are the Balearic Islands (golf courses, urban parks and groundwater recharge), the Canary Islands (golf courses and agriculture), Noirmoutier Island (agriculture), Sicily and Sardinia (agriculture) and the entire Mediterranean coastline (Tunisia, Morocco).

Crucial analysis of existing reuse practices and future needs for enhanced water resource management, demonstrates that management of the integrated water cycle could be the only strategy that can provide a sound, cost-competitive and sustainable solution for areas with water scarcity (EU project CatchWater, 2001). Consequently, water reuse projects should be considered as a part of the global cycle management.

Having a clear vision of the possibilities offered by water reuse to water resource management is a prerequisite to any project planning and design. Water reuse can serve several objectives:

1) Alternative water supply

- Alternative resource to generate regional economic development, particularly in water scarce areas (chronic water scarcity or droughts);
- Augmentation of water supply to displace the need for other sources of water, generating financial and non-financial benefits; and
- Additional water supply for environmental enhancement (wetlands restoration, beautification of cities, protection of sensitive zones, etc.).

2) Pollution control and environmental protection

- Cost-effective means of environmentally sound treatment and disposal of wastewater; and
- Secondary benefits to the disposal of wastewater, for example crop production by irrigation with effluent or golf course irrigation.

3) Sustainable development

- Long-term availability of water resources and ability to satisfy population growth and economic activities in arid and semi-arid regions; and
- Increased independence of water supply the event of droughts and chronic water shortages, ensuring constant economic revenue for industry, trading, tourism, etc.

Distinguishing between these three objectives is not always easy. Supplying an additional water source is the first objective of most water reuse projects. Nevertheless, protection of the environment (mainly sensitive water bodies) is the crucial element of more and more new projects, which are being implemented in regions that cannot be considered as short of water resources. In all cases, a multi-criteria evaluation of possible water management scenarios must be applied, including cost-benefit analysis and assessment of social and environmental impacts and benefits.

1.2. Objectives of the survey on wastewater treatment costs

In general, the lack of funding restricts the implementation of adequate wastewater treatment and reuse practices. Therefore, most of the water reuse projects have depended on subsidies and grants. As a rule, the benefits of water reuse are underestimated because of the lack of an adequate approach to macro-economic evaluation.

Many uncertainties still exist in the micro-economic evaluation of wastewater treatment and reuse. Capital costs are characterised by high variations, depending on the type of treatment and specific local conditions. Very little information exists on wastewater treatment operating costs, which is a serious obstacle for the establishment of adequate charges for wastewater treatment and reuse. Therefore, the cost evaluation of wastewater treatment and reuse remains one of the greatest challenges of water professionals and decision-makers.

The main objective of this document is to present and discuss the cost aspects of operating wastewater treatment plants. The most important results will be the definition of a methodology for O&M cost estimation and, subsequently, a basis for the evaluation of a minimum water reuse price that will encompass O&M costs.

The reported costs are illustrative only and cannot be applied to other projects due to the strong influence of local factors and the use of different cost estimation methodologies (cost estimation and determination of prices are very context specific).

1.3. Work methodology

This survey commenced in September 2004 and was completed in February 2005.

A comprehensive questionnaire (Appendix 1) has been prepared and circulated to all institutions involved in wastewater treatment throughout the Mediterranean countries by mailing, selected web-sites, international organizations (ASTEE, Eureau), as well as by distribution during the IWA World Water Congress in Marrakech (September 2004), IWA Specialised conferences on natural wastewater treatment in Avignon (September 2004) and the ONAS Seminar on Wastewater Treatment and Reuse in Tunis (December 2004).

The information requested in the questionnaire covers the following topics:

- General information on the name, location and contact details of the wastewater treatment plant (WWTP);
- Main characteristics of the WWTP, including design parameters, actual loading rates, treatment trains (water and sludge);
- Required level of treatment with information on discharge or reuse options;
- Capital and O&M costs with specific information on labour, energy and chemical costs, as well as cost of repair and maintenance, sludge discharge, pumping and administrative costs;
- Common operating concerns; and
- Annual life cycle costs.

Unfortunately, very few countries and institutions responded to the above for information. Complementary information was obtained through direct contact with plant operators, equipment suppliers and visits to selected wastewater treatment plants. Special efforts have been made to collect more information on non-monetary data, such as man hours, energy demand, chemical consumption, specific charge for sludge disposal, etc. A literature review on the economic aspects of wastewater treatment and reuse was also carried out in an effort to complete the information.

1.4. Data sources

This document has been compiled using the following data sources:

1. MED POL/WHO survey, 2004: Greece, Slovenia, France (Lyonnaise des Eaux), Spain (Canal de Isabel II, Searsa, Consorci de la Costa Brava)
2. Survey of French wastewater treatment works (Alexandre *et al.*, 1998)
3. EU survey on 34 large wastewater treatment up to 300,000 p.e. in 6 EU countries (Bode and Grünebaum, 2000)
4. Survey of wastewater treatment plants in Greece (Tsagarakis *et al.*, 2003)
5. Survey of 20 wastewater treatment plants (7000 to 650,000 p.e.) in Sweden (Balmer and Mattson, 1994)
6. Survey of 14 wastewater treatment plants (12,500 to 100,000 p.e.) in Austria (Nowak, 2000)
7. Survey of small-scale treatment plants in Flanders (Geenens and Thoeye, 2000)

2. MAIN SPECIFICITIES OF COST ESTIMATION IN WASTEWATER TREATMENT

Cost estimation and comparison of wastewater treatment on a national, regional or international scale is a difficult and challenging task. A direct cost comparison is characterized by great uncertainty and imprecision because of the strong influence of technical and local conditions on capital and operating costs, various patterns of fund granting, different treatment targets and large variations in plant size.

To establish a valid cost comparison, it is necessary to include both the investment and operating expenses and this within the scope of the overall annual costs.

The most important specificity of wastewater treatment costs is that over the operational lifetime of the given sewage treatment plant, operating and maintenance costs (O&M costs) may be as high, or even higher than construction costs.

Cost estimation becomes more complicated when dealing with water recycling. The cost evaluation of a recycling scheme depends on the purpose of the analysis, whether for example the purpose is to determine overall financial feasibility, to determine charges to water users, to determine the need for funding, or whether the purpose is to assess the wider economic performance of the investment, including the value of any environmental impacts.

Unfortunately, the benefits of water reuse, including environmental conservation and protection, local economic development, improvement on reliable water supply, protection of public health and other factors, are not easily quantified by traditional cost-benefit analysis. Unquantified benefits are treated as “zero” in spite of their importance when considered on a regional or global scale. Water reuse projects are often undervalued when compared to other water projects, and significant benefits of water reuse are lost.

2.1. Main components of wastewater treatment costs

In the field of wastewater treatment and reuse, cost estimation includes the following elements: capital costs, annual fixed costs, annual operating costs and total average annual costs (life cycle costs).

As a rule, land costs are not included in wastewater treatment costs and are not, therefore, considered in this study. It should be stressed, however, that land costs are not negligible even in North African countries and vary from country to country and also within each community. In the case of non-conventional wastewater treatment, land costs are an important factor in the choice of treatment scheme.' See p8 - 2.1 Main components of wastewater treatment costs.

In the case of water reuse, storage reservoirs need to be provided, particularly for irrigation purposes. However, specific supplementary costs are not considered in this study because of the great discrepancy in funding of storage facilities between countries and even between the municipalities of each country.

2.1.1 Capital costs

The capital or investment costs of wastewater treatment plants include the cost of land, design, supervision, and works including earthworks, civil engineering (canals, pipes and buildings), electricity supply, treatment and pumping installations, control gear, workshop and office equipment, communications and vehicles.

As a rule, construction costs are classified into three major cost categories:

- Civil engineering (civil works);
- Mechanical engineering (equipment); and
- Electrical engineering, including instrumentation and control.

The cost distribution between these main categories may vary considerably and depends on the treatment process. For example, the major part of an investment for advanced treatment processes is dedicated to equipment plus control and instrumentation, while conventional processes require more significant expenses for civil works.

In many cases, subsidies and grants may be available to reduce the capital costs borne by the investor.

Capital items provide services over the life of the project, although some, such as pump equipment, will require replacement at regular intervals. Replacement costs need to be identified over the project life, where the latter is taken to be the economic life (depreciation period) of the major investment items such as the civil and mechanical engineering works. The commonly used values for depreciation periods are 20 to 30 years for civil works and 10 to 15 years for mechanical equipment. The lifetime of the Network is higher - at least 50 years.

The main factors that influence the capital costs of wastewater treatment plants are as follows:

- Plant size;
- Water quality standards (treatment targets and discharge consents);
- Type of treatment processes;
- Site-specific constraints;
- Market constraints influencing the sale prices of equipments and civil works; and
- Specific constraints related to sewage treatment and safety measures.

2.1.2 Fixed annual costs

Initial capital costs determine the fixed annual costs, which arise as debt service with depreciation and interest and apply for many years to follow.

Fixed annual costs are derived by calculating an amortization cost for each capital item, in accordance with the following the equation:

$$A = P(1/\sum_{n=1}^{n=20}(1/(1+r)^{n})) \qquad (1)$$

Where A is the annual amortization payment (which includes both depreciation and charges for interest on capital),
P is the capital investment,
r is the annual rate of interest as a decimal paid on borrowed funds,
n is the life of the particular capital item (20 in the example of civil works and 10 or 15 for

mechanical equipment).

Aggregation of these items provides an estimate of average annual fixed costs (€/year). It is probably best to assume that capital items are depreciated and, therefore, have zero remaining values.

By definition, fixed costs are fixed in the short term during which the basic infrastructure and management regime of the treatment plant cannot be changed. Thus, amortization costs are unavoidable in the short term; they have to be paid even if the plant is not in operation.

There may be some other unavoidable costs that are not directly linked to the degree of use. These include the co st of routine site maintenance, licenses, inspection, security and insurance.

The estimate of fixed cost per year for a given treatment plant can be expressed per unit of output of treated water in €/m^3. For a given plant size, fixed costs €/m^3 will be lowest when the plan is operating at full capacity and full time. If for example, wastewater treatment is operated only during few months per year, which is often the case of wastewater disinfection and water reuse, annual fixed costs will be much higher compared with an annual operation.

2.1.3 Operating and maintenance costs

The operating expenses of wastewater treatment plants (WWTP) are defined as being all costs incurred within the site boundaries of the treatment plant.

The main operating components and maintenance costs are influenced by different factors, similar to capital costs, and may vary between treatment facilities and countries. In addition to the size of plant, local sewage and site-specific conditions and market constraints have also to be considered.

It should be noted, however, that the degree of plant utilization in terms of the ratio between the real loads and design capacity, is of much greater importance.

As a rule, the O&M costs include the following components:

- Repairs, renewal and maintenance costs: high variations depending on the treatment train;
- Labour and management: high variations from country to country and strong influence of treatment processes;
- Energy and fuel: high variations from country to country and strong influence of treatment processes. In some cases of power generation using biogas, net savings are added to power consumption;
- Chemical costs;
- Charges for sludge or bio-solid waste disposal: strongly influenced by local conditions;
- Internal and external laboratory costs: depend hugely on the requirements of the local authorities, higher for water reuse systems; and
- Other (as a rule, minor or case-specific expenses):
  - Sewer systems and external pumping stations that are sometimes operated by the WWTP staff
  - Rents and tenancy - in the event that the WWTP is not the owner of the land and buildings

- Annual charges for interest payment on loans, as well as subsidies and taxes
- Administrative costs, including insurance (if not paid centrally by the municipality)
- Water charges: licenses or charges for water supply or abstraction, if charged to the WWTP (sometimes covered by the municipality)
- Communication and marketing costs, more specific to water reuse projects
- Water charges: licenses or charges for water supply or abstraction, if charged to the WWTP (sometimes covered by the municipality).

Major operating costs are likely to be those of energy for water lifting, repairs to treatment equipment and labour.

Operating costs by definition vary in total according to the throughput of the plant, although they may be reasonably constant per unit of output (expressed in €/m^3).

It should be stressed that the more stringent the requirements for water quality and reliable plant operation, the higher the associated O&M costs. The main challenge for water professionals is to minimize the risk of failure of wastewater treatment plants by maintaining acceptable operating and maintenance costs.

2.1.4 Total annual costs

Total average annual costs are the sum of annual fixed and total annual operating costs.

Total annual wastewater costs also include life-cycle costs and are calculated using the following equation:

$$\text{Total annual cost} = \frac{\left(\sum_{j=1}^{m} \text{loans in capital investment}_j \times \text{charge ratio}_j\right) \times \text{capital recovery factor} + \text{annual O\&M cost}}{\text{Annual water volume}}$$

$$\text{Capital recovery factor} = \frac{i(1+i)^n}{(1+i)^n - 1}$$

Where, i: interest rate, typically 6 to 10%; n: years of payment (commonly 10 to 20 years).

Wastewater services are generally characterized by relatively high capital investment costs, which means that fixed costs account for a relatively high proportion of total average costs (€/m^3). This is a significant feature. It means that investments of this kind usually have a relatively long economic life (>20 years), over which capital costs need to be recovered. They are relatively inflexible in their costs structure in that a large proportion of the cost is unavoidable and relatively long-term investment funding is needed.

For these reasons, without guaranteed demand for treated water or assistance with funding, such investments may be regarded as risky by many private investors. This is especially applicable to water reuse projects.

The structure of costs does mean that once a treatment plant has been constructed, a large part of the costs are ‘sunk’ and non-recoverable, regardless of whether or not the treatment plant continues to operate. In the short term, this might justify the operation of existing plants at charges which at least recover operating costs, even though they fail to recover the full average total costs. However, in the absence of subsidies to make good the deficit, failure to recover full costs in the longer term will lead to plant closure.

Table 1 provides a simple example of the derivation of an average cost (€/m^3) of treated wastewater (Morris *et al.*, 2005).

Depending on the level of treatment, plant size and equipment, typical wastewater treatment costs are in the range of 0.05 to 0.6 €/m^3 (Lazarova, 2001) and depend on treatment trains. Typical costs of conventional activated sludge with nitrogen removal are in the range of 0.28 to 0.4 €/m^3 and increase from 0.05 to 0.20 €/m^3 when adding tertiary treatment by filtration and disinfection.

Table 1

Illustration of the costing methodology for wastewater treatment

Parameter	Capital costs, Million €	Life (years)	Amortization factor at 10%	Annual costs[a] Million €
Reservoir and civil engineering	5	20	0.1175	0.59
Treatment equipment	1.8	10	0.1627	0.29
Sub total				0.88
Operation and maintenance				0.5
Total annual cost				1.38

Effluent volume, million m^3/year	4.0
Average wastewater treatment cost[a], €/m^3	0.35

Source: Adapted from Morris *et al.*, 2005
[a]Constant 2004 values, indirect costs not included, conventional activated sludge treatment

2.2. Evolution of water and sewerage tariffs

According to a recent WHO report (WHO, 2000), there was remarkably little variation in the median unit production cost of water between developing regions of the world, although the variation was greater between sub-regions (Figure 1) and between countries. Nevertheless, it was demonstrated that more than half the countries of each region (except for Europe and Northern America) charge an urban water tariff that is less than the unit cost of production of the water.

The highest regional median tariff for water is found in Europe and the lowest in Asia. Between these two extremes the other regions show remarkably little variation compared to the variation between individual countries within each region.

Sewerage tariffs are lower than water tariffs even when the construction and operating costs of sewers and sewage treatment plants are very high. Analysis of available information in the WHO report (2000) leads to the conclusion that water and sewerage tariffs do not cover the full cost of the services provided.

In Europe, the EU Water Framework Directive requires EU Member States to ensure that by 2010, water-pricing policies will provide adequate incentives for the efficient use water resources and recovery of the true costs of water services in an equitable manner. Most countries are progressing towards water pricing systems. Investing in water supply and sanitation has produced benefits far greater than those directly related to the cost of treating water-related diseases (UNEP, 2005).

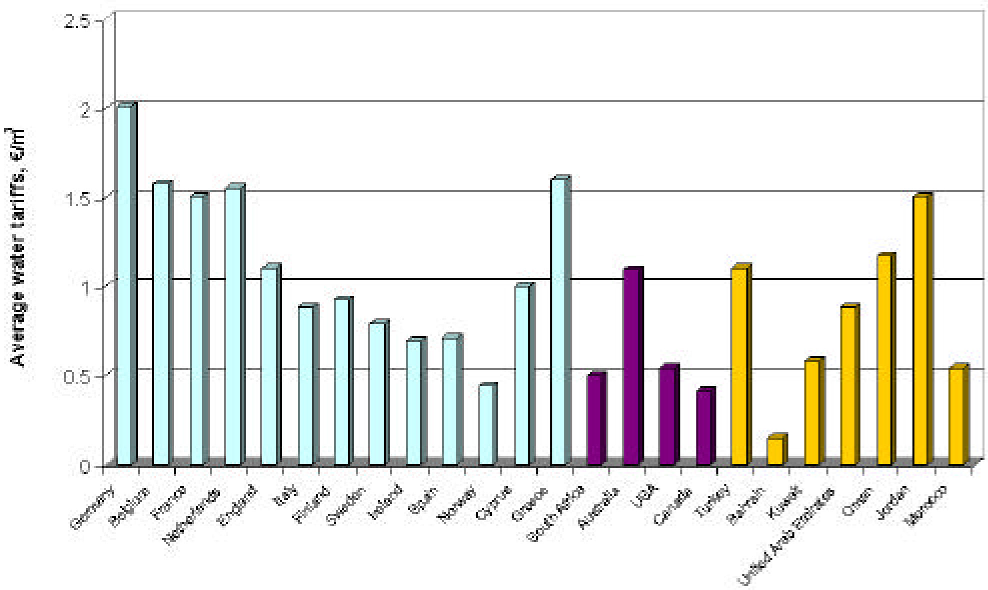


Figure 1 Comparison of average water tariffs in some countries in Europe, the Middle East and the world (1990-2000)

While there has been a general trend towards higher water prices throughout Europe, prices still vary considerably from 0.1 to 2.3€/m^3 and above. Many of the capitals and major cities in Mediterranean countries have below average prices, as do cities in countries with abundant water supplies. In contrast, water prices are highest in northern and western European cities.

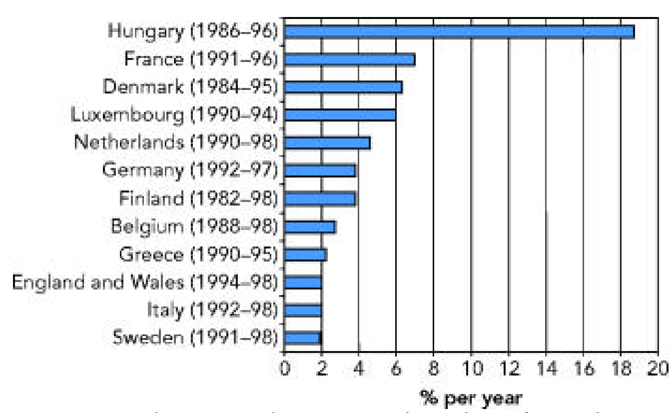


Figure 2 Average increase in water prices in selected European countries

The general trend in Europe and worldwide is a steady increase in water prices (Figure 2) with annual variations between 2 to 7% (EAA, 2005). A higher increase in water prices (up to 18%), is observed in new EU member states, such as Hungary, It is important to note that specific local water costs could be significantly higher than the reported average values.

2.3. Evaluation of costs, prices and benefits of recycled water

The immense difficulty in estimating wastewater treatment costs has had a direct impact on the determination of water reuse costs. In addition to this constraint, water reuse pricing is strongly challenged by the low water prices that are, as a rule, subsidized or do not include all incurrent expenses.

Consequently, the main economic challenges of water reuse are:

- Good determination of the components that must be included in the costs of recycling water;
- Evaluation of macro-economic benefits of water reuse; and
- Water reuse pricing that enables the recovery of, at least, O&M costs with a final objective of full cost recovery.

2.3.1 Main constraints in water reuse pricing

There is a wide variation in the unit pricing of recycled water, ranging from 0 to 0.52 US$/m^3 depending upon the type of reuse, flow rates and local conditions, and also upon the quality of recycled water and specific conditions. Almost 50% of 34 reuse projects recently assessed by WERF (Mantovani *et al*., 2001) ranged from 0.15 to 0.52 US$/m^3. Among existing water reuse projects, the prices of recycled water appear consistently lower than those of potable water with almost all international reuse projects ranging from zero to 25% of potable water rates and only 5 US projects achieving 75 to 100% of potable water rates.

Consequently, although the revenue from recycled water appears to recover operating costs, in most cases total recovery of costs is dependent on some degree of subsidy. As a rule, water reuse pricing is driven by the need to offer a discount on recycled water to either encourage its use or make it competitive against other sources (many of which are also subsidized). It is worth noting that end-users expect to pay no more for recycled water than for an alternative supply of water of at least the same quality and security.

Table 1 shows the price of recycled water as a function of the price of potable water supply in some large water reuse projects in California, USA (Lindow and Newby, 1998, Mantovani *et al.*, 2001). The price differentials are apparent: few recycled water charges are similar to potable water prices with the lowest values observed for agricultural irrigation (0 to 25%). Table 2 presents some examples of recycled water prices mainly for non-potable reuse applications.

Table 1

Examples of recycled water sale prices in California

Water reuse project	Water reuse price as % of water rates
City of Long Beach (landscape irrigation)	53
Marin Municipal Water District (landscape and agricultural irrigation) City of Milpitas (landscape irrigation)	56 80
Orange County Water District (indirect potable reuse)	80
San Jose Water Company (agricultural and landscape irrigation, industry)	85
Irvine Ranch Water District (agricultural and landscape irrigation - 90% of uses, toilet flushing, industry)	90
North Coty, San Diego (landscape irrigation)	90
Carlsbad Municipal Water District	100
East Bay Municipal Utility District (landscape irrigation, industrial uses)	100
Otay Water District	100
West Basin Municipal Water District (urban and industrial uses, aquifer recharge)	80 (53 to 90%)

Source: Adapted from Morris *et al.* (2005) and Lindow and Newby (1998)

Table 2

Examples of user fees for recycled water in the USA

Type of rate	Number of utilities	Range of recycled water charges for end-users
Monthly flat residential charge	3	\$7.00 (limited to 0.4 ha), unlimited use: \$7.50 or 8.00 St. Petersburg, Florida: (not metered) \$10.36 for the first acre (0.4 ha), \$5.92 for each additional 0.4 ha; Cocoa Beach, Florida: residential (not metered) \$8.00 per 0.4 ha (acre)
Commodity based rate generally for commercial and industrial uses, landscape irrigation	8	0.08 \$/m^3 to 0.45 \$/m^3; St. Petersburg, Florida: few metered large users: 0.08 \$/m^3 (\$10.36 per month minimum) Cocoa Beach, Florida: commercial (metered) 0.07 \$/m^3 Henderson, Nevada: 0.19 \$/m^3; Wheaton, Illinois: 0.05 \$/m^3 County of Maui, Hawaii: major agriculture 0.026 \$/m^3, agriculture, golf courses 0.05 \$/m^3, other 0.15 \$/m^3, South Bay (California): 0.04 \$/m^3 for agricultural irrigation; 0.4 \$/m^3 for urban irrigation San Diego-North city, California (90% of drinking water): 0.51 \$/m^3
Base charge plus volume charge	1	3.25 \$ + 0.03 \$/m^3
Seasonal rate	2	low: 0.27 \$/m^3 - 0.43 \$/m^3; medium: 0.32 \$/m^3; high: 0.42 \$/m^3 - 0.53 \$/m^3
Declining Block Rate encourages large industrial users such as industry, water supply augmentation	2	first block: 0.13 \$/m^3; second block: 0.05\$/m^3; third block: 0.03 \$/m^3 South Bay (California): 0.23 \$/m^3 (up to 31,000 m^3/month; 0.21 \$/m^3 (31,000-62,000 m^3/month; 0.196 \$/m^3 (62,000-123,000 m^3/month; 0.18 \$/m^3 (123,000-246,000 m^3/month; 0.16 \$/m^3 (over 246,000 m^3/month) West Basin, California (encourage large industrial users):

		a) Title 22 effluent - 0.23 $/m^3 (up to 31,000 m^3/month; 0.21 $/m^3 (31,000-62,000 m^3/month; 0.19 $/m^3 (62,000-123,000 m^3/month; 0.18 $/m^3 (123,000-246,000 m^3/month; 0.16 $/m^3 (over 246,000 m^3/month) b) 0.35 $/m^3 with declining block pricing
Inverted block rate encourages conservation: landscape irrigation	2	First block: 0.16 $/m^3; second block: 0.21$/m^3; third block: 0.42 $/m^3; fourth block: 0.84 $/m^3; fifth block: 1.67 $/m^3 Irvine Ranch, California (90% of potable water rates): 0.20 $/m^3 (0-100% of base volume; 0.40 $/m^3 (100-150%); 0.81 $/m^3 (150-200%), 1.78 $/m^3 (over 200%) San Rafael, California: 0.71 $/m^3 (0-100% of water budget); 1.37 $/m^3 (100-150%); 2.7 $/m^3 (over 150%);
Time of day rate (agricultural uses)	1	Total average daily demand from 21h to 6h: 0.03 $/m^3; total average daily demand occurring at a continuous, constant level over a 24-hour period: 0.31 $/m^3

Source: Adapted from Morris *et al.* (2005) and Mantovani *et al.* (2001)

2.3.2 Main components of recycled water costs

The cost of recycled water may only include marginal costs of wastewater recycling in terms of additional treatment, storage and distribution, excluding the cost of wastewater collection and treatment. However, such distinction is not common in the Mediterranean countries where the costs of tertiary wastewater treatment for reuse purposes are included in the overall wastewater treatment costs.

Similar to the wastewater treatment costs, the distribution of capital and O&M costs varies from one project to another and depends on the type of the applied treatment processes. These costs are also highly influenced by local constraints, such as price of the building site, distance between the production site and end-users, and need to install a dual distribution system or retrofitting.

The latter two constraints are significant as in many projects, the main capital investment concerns the distribution system (+70 to 300% compared to water recycling treatment costs). New distribution systems have lower expenses compared with the retrofitting of existing networks: 0.06 €/m^3 in Jubail, Saudi Arabia (Al-A'ama and Nakhla, 1995), 0.14 and 0.36 €/m^3 in the Dan Region and Jerusalem, Israel respectively (Shelef, 1991).

2.3.3 Evaluation of water reuse benefits

A water reuse project generates both monetary and non-monetary benefits. As a result, water reuse projects are often under evaluated when compared to other projects and significant opportunities for beneficial reuse are lost (Sheikh *et al.*, 1998). The non-monetary benefits consist of improvement of the environment and public health, reduction in discharge of nutrients in receiving water, reduction in cost of drinking water treatment, safeguarding recreational use and tourism.

Typical benefits for the wastewater agency and local authorities include:

(1) Reduction of effluent discharge and preservation of discharge capacity;
(2) Elimination of certain treatment processes to meet mass limits (for nutriments, for example);
(3) Reduction or elimination of major sewers through construction of satellite water reclamation plants; and
(4) Sale of recycled water.

It is should be noted that between the reported costs and benefits of 54 international reuse projects analysed by a recent WERF study (Mantovani *et al.*, 2001), some important economic benefits have been identified, such as savings in water treatment, storage and transportation, savings in new water resource development, reduction in the costs of required fertilisers for irrigation and new revenues from sales of reclaimed water.

2.3.4 Comparison of water recycling costs with other alternative water resources

More and more countries, in particular countries of the Arabian Peninsula (Saudi Arabia, Kuwait, Bahrain, Qatar), rely heavily on large-scale desalination plants to satisfy between 50% to 95% (Kuwait, Qatar) of the urban water demand, with overall combined capacity of 1863 million m^3 in 1990 (Abdulrazzak, 1995). This figure almost tripled in 2000, reaching 5830 million m^3. In Europe, the overall installed desalination capacity in 2000 was 3500 million m^3 (Wagnick, 2002). The main trend in the desalination market is the augmentation of maximum desalination plant capacity up to 150,000-330,000 m^3/d and the implementation of membrane processes (reverse osmosis).

The large number of small desalination plants makes desalination an expensive alternative. Moreover, the high salinity of the Red Sea leads to higher desalination costs: from 2.5 to 10 €/m^3 (Abdulrazzak and Khan, 1990) compared to reported costs in the USA in the range of 0.43 to 2.6 €/m^3. It is noteworthy, however, that during the past 20 years, desalination costs have decreased to a more affordable level. According to recent publications (UN report, 2001), average costs of desalination may range from 0.75 to 1.5 €/m^3 for seawater in large plants, while for small works typical values are 2-3 €/m^3 (Figure 3). Lower costs from 0.4 to 1.5 €/m^3 are common for brackish water desalination.

Even though the cost of desalination has shown a clear downward trend over the last few years (Arlosoroff, 1996 reported lower values for the reverse osmosis costs in Israel in the range of 0.7 to 1.1 €/m^3), direct comparison of this data remains difficult due to lack of information as to whether or not the cost of transportation is included, power costs and also because the reported costs are not revised for inflation.

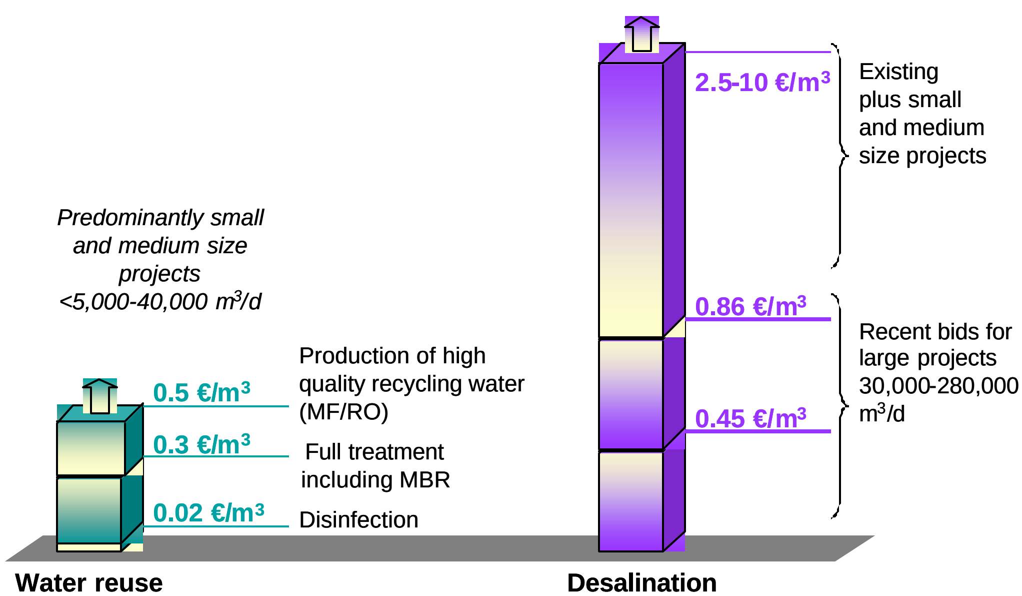


Figure 3 Comparison of water recycling and desalination costs (Source: Lazarova, 2004)

Figure 3 (Lazarova, 2004) tentatively compares the cost of recycled water with desalination. In view of the high real cost of potable water in the Middle East which is not subsidized by the state, 20 €/m^3 in Qatar, for example (Ahmad, 1988), seawater desalination remains a viable solution. However, recycled water, even after intensive treatment up to the stringent Title 22 standard, appears to be the lower cost alternative. Additional post-treatment leads to a 30-100% increase in the costs required for secondary treatment.

In general, desalination costs include the following elements: 38% for capital investment, 21% for energy, 21% for labour, 16% for maintenance and 4% for chemicals.

In addition to the variations due to plant capacity, desalination costs vary depending on the type of desalination technology used, as well as whether brackish or seawater is used for water production.

Compared to desalination costs, wastewater treatment and reuse costs are characterised by the greatest range of variation, mainly depending on plant size. For example, in Gulf countries wastewater treatment costs range from 0.26 to 0.63 €/m^3 for plant capacity of 10,000 p.e., while for an average capacity of 100,000 p.e., the range of variation is from 0.16 to 0.44 €/m^3 (UN report, 2001).

Wastewater treatment costs increase substantially as the level of treatment becomes high in order to meet stringent environmental or reuse standards.

3. MAIN FACTORS INFLUENCING WASTEWATER TREATMENT COSTS

It is well known that wastewater treatment costs vary from region to region and country to country. Direct comparison of published or communicated unit and/or average costs is difficult because of the lack of a common basis for benchmarking. Very often, no information exists on the main components of the reported costs, such as sludge disposal, laboratory monitoring costs, storm water treatment, storage, and in some cases, sewage collection and pumping, which can also be included in the overall wastewater treatment costs.

3.1. Status of municipal wastewater treatment in Europe

One of the most important factors influencing wastewater treatment costs is wastewater treatment requirements. Significantly higher expenses are needed for advanced nutrient removal and disinfection requirements in sensitive areas. Some Northern countries have defined large areas as “sensitive”. For example, almost the whole of Germany has been defined as a sensitive area.

Figure 4 illustrates this trend, showing the different levels of treatment and sewerage coverage from Northern and Southern European countries (EEA, 2005). This figure only includes countries that have data for all periods (number of countries in brackets). The Northern countries include Iceland, Norway, Sweden and Finland. The Western countries include Austria, Ireland, United Kingdom, Luxembourg, the Netherlands, Germany and Denmark. The Southern countries include Greece and Spain.

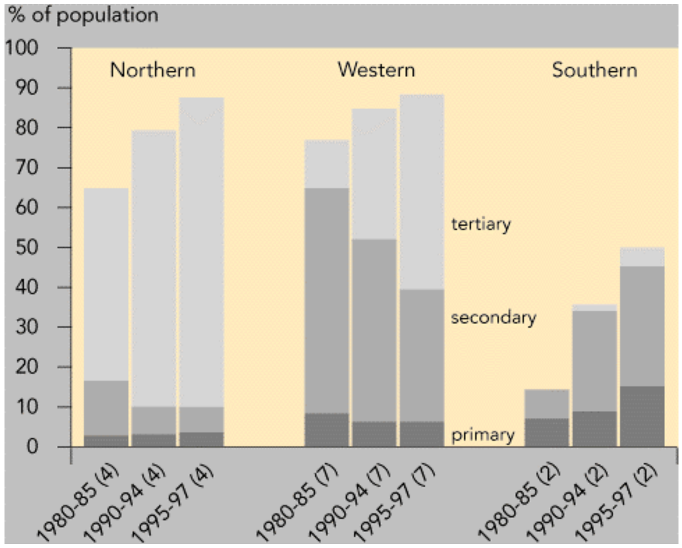


Figure 4 Distribution and evolution of wastewater treatment in Europe by regions (Source: EEA, 2005)

Primary wastewater treatment removes part of the suspended solids, but no ammonium. Secondary (biological) treatment uses aerobic or anaerobic micro-organisms allowing retention of 20% to 30% of the nutrients and removal of approximately 75% of ammonium. Tertiary treatment includes phosphorus precipitation and, in some cases, complementary nitrogen removal.

The EU Directive sets out which type of treatment systems (primary, secondary and tertiary) are required in different situations. For example, making secondary treatment systems, which use biological processes to break down organic material, essential wherever discharges flow directly into fresh waters or estuaries. The Directive has resulted in increased treatment capacity in all EU countries except Sweden, Finland and the Netherlands, where it was already sufficient.

The largest increase can be seen in southern Europe and Ireland. As a result, the EU collection and treatment systems should be able to cope with all organic discharges from most Member States by 2005, further reducing pollution from nutrient and organic matter. The most significant improvements are expected to be seen in levels of phosphorous and biochemical oxygen demand in southern Europe. The highest growth of water reuse is observed in Spain and Cyprus.

In Cyprus, the wastewater generated by the main cities, about 25 Mm^3/yr, is planned to be collected and used for irrigation after tertiary treatment. Because of high transportation costs, it is anticipated that most of the recycled water, about 55 to 60%, will be used for amenity purposes (hotel gardens, parks, golf courses, etc.). A net of about 10 Mm3 is conservatively estimated to be available for agricultural irrigation. The cost of recycled water is low, about 0.07€/m3. This will reportedly allow irrigated agriculture to be expanded by 8-10% while conserving an equivalent amount of water for other sectors (Papadopoulos, 1995).

A recent survey of Italian treatment plants estimated the total treated effluent flow at 2400 Mm^3/yr of usable water (Barbagallo *et al.*, 2001). This gives an estimate of the potential resource available for reuse. In view of the regulatory obligation to achieve a high level of treatment, medium to large-sized plants (>100,000 p.e. served), which account for approximately 60% of urban wastewater flow, can provide recycled effluents with a favourable cost/benefit ratio.

During the last decade, significant advance has been made in the implementation of wastewater treatment in Greece and Portugal. In 2000, almost 60% of the Greek population was connected to 270 wastewater treatment plants with a total capacity of 1.3 Mm^3/d. Over 15 of these plants are planning to reuse their effluents for agricultural irrigation. In Portugal, according to Plano nacional da Agua (2002), the treated wastewater volume in 2001 was 201 Mm^3/yr. Water reuse with tertiary treated wastewater is planned in four large wastewater treatment plants in the area of great Lisbon for agriculture (1000 ha) and golf course irrigation.

In Turkey, a recent survey (1996) indicated that 75% of the urban population is covered from sewers producing 1608 Mm^3/year of wastewater from which only 12% (193 Mm^3/year) is treated in municipal wastewater treatment plants (57% of activated sludge).

Concerning the countries of North Africa, Israel and Tunisia, all have proven water reuse experience, especially for irrigation. Significant efforts should be made in Algeria, Egypt, Morocco and Turkey to improve coverage of sanitation and wastewater treatment (including rural communities).

Tunisia has proven experience in wastewater treatment and reuse (Bahri, 2000). Most residents of large urban centres have access to various adequate sanitation systems and wastewater treatment facilities (78% versus 61% for all the population and 40% in rural areas). Of the 237 Mm^3 of wastewater discharged annually, 138 Mm^3 are treated in 52 treatment plants. The wastewater reuse policy launched at the beginning of the 1980s favoured the planned water reuse for agricultural and landscape irrigation. About 35 Mm^3 of reclaimed water are allocated annually for irrigation but only 80% (approximately 20% of the treated effluent) is being reused. In some areas, irrigation with effluents is well established and most of the allocated volume is being used, while in new areas where irrigation is just beginning, the reclaimed water usage rate is slowly increasing. The annual volume of reclaimed water is expected to reach 290 Mm^3 in the year 2020. The expected amount of reclaimed water will then be approximately equal to 18% of the available groundwater resources and could be used to replace groundwater currently being used for irrigation in areas where excessive groundwater mining is causing salt water intrusion in coastal aquifers.

In Israel, the acute shortage of fresh water throughout most of the land has promoted the development of a nation-wide integrated water management scheme. This approach to water reclamation and water conservation strategies has played a key role in the increase of available resources. In 1994, water reuse represented 20% of Israel's total water supply (Lazarova, 2001). Nearly 70% of the wastewater collected in sewers was treated and reused for agricultural purposes. Israel's objective is to treat and reuse most of its wastewater by 2010, which should represent 400 Mm^3 per year and will account for 15% of total water resources. This additional resource will be used for the irrigation of crops and animal fodder in accordance with permits issued by the Ministry of Health. The two largest reuse schemes in Israel are the *Dan Region Reclamation Scheme* and the *Kishon Scheme*, also known as the Haifa Project. The first employs subsurface storage in a sandy aquifer, while the second is based on two-stage stabilization reservoirs. The Dan region reclamation scheme serves the Tel Aviv Metropolitan Area and five satellite communities. The total population served by this project is over 1.7 million and the flow is over 95 Mm^3/year (Kanarek and Michail, 1996, Lazarova 2001). The plant is designed to process about 120 Mm^3/year of wastewater. The total investment cost of the Soreq activated sludge plant amounts to 170 M$US. The O&M costs are 0.083 $US/m^3 and 0.136 $US/m^3 for the pumping and conveyance systems. If the investment capital recovery for each item were to be included in the estimated value, the life cost of the respective items becomes 0.22 and 0.233 $US/m^3, respectively. After biological treatment, the wastewater is polished via recharge basins and stored in the aquifer. A network of observation wells surrounding the recharge area monitors the quality and also checks that the treated water does not flow towards fresh water wells beyond the confined recharge area.

Most Moroccan towns are equipped with sewerage networks, also frequently collecting industrial effluent. The volumes of wastewater collected were estimated at 500 Mm^3/year in 1993 and are expected to reach 700 Mm^3/year in 2020. For Casablanca alone, the annual production of wastewater was estimated at 250 Mm^3/year in 1991, with forecasts of around 350 Mm^3 in 2010. However, out of the 60 largest towns only 7 have treatment plants, and both their design and operation are considered insufficient. As a consequence, most of the wastewater produced by the inland towns is used to irrigate about 8,000 ha of crops after insufficient or no treatment at all. A high proportion of the remaining water is discharged into the sea.

In Egypt, actual wastewater production is estimated at 4930 Mm^3/year from which about 33% (1640 Mm^3/year) are treated in 212 municipal wastewater treatment plants. A total of 42,000 ha of agricultural land are irrigated with treated wastewater, mainly near Greater Cairo, Alexandria and other large cities.

3.2. Influence of treatment requirements on wastewater treatment costs

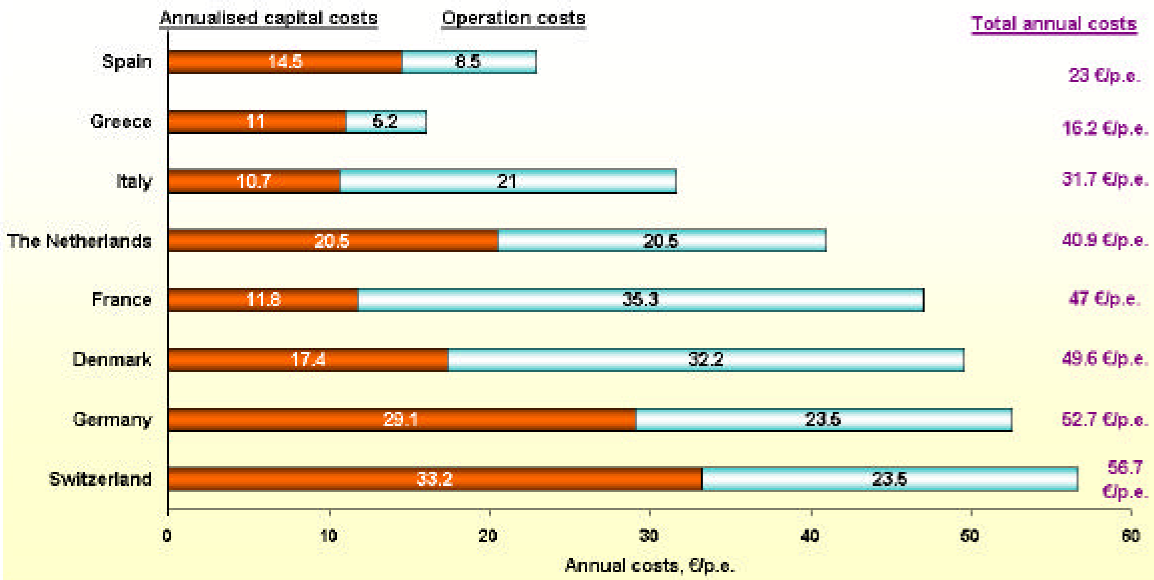
Analysis of the data from the MED POL/WHO survey (2004) and recent surveys of 34 European large wastewater treatment plants (Bode and Grünebaum, 2000) and wastewater treatment works in Greece (Tsagarakis *et al.*, 2003), illustrates the difficulty in comparing cost data.

As illustrated in Figure 5, average annual capital costs related to design capacity of large wastewater treatment works, vary from 16 to 60 €/p.e./year with maximum values observed in Switzerland and Denmark and lower values in Italy and the Netherlands. This difference could be attributed to the stringent standards for nitrogen and phosphorus removal (physical-chemical phosphorus removal) in Northern European countries (see Figure 4), that, consequently, are associated with higher treatment costs. Significantly lower expenses are needed for conventional activated sludge treatment in Greece and Spain of 16 and 23 €/p.e./year, respectively.

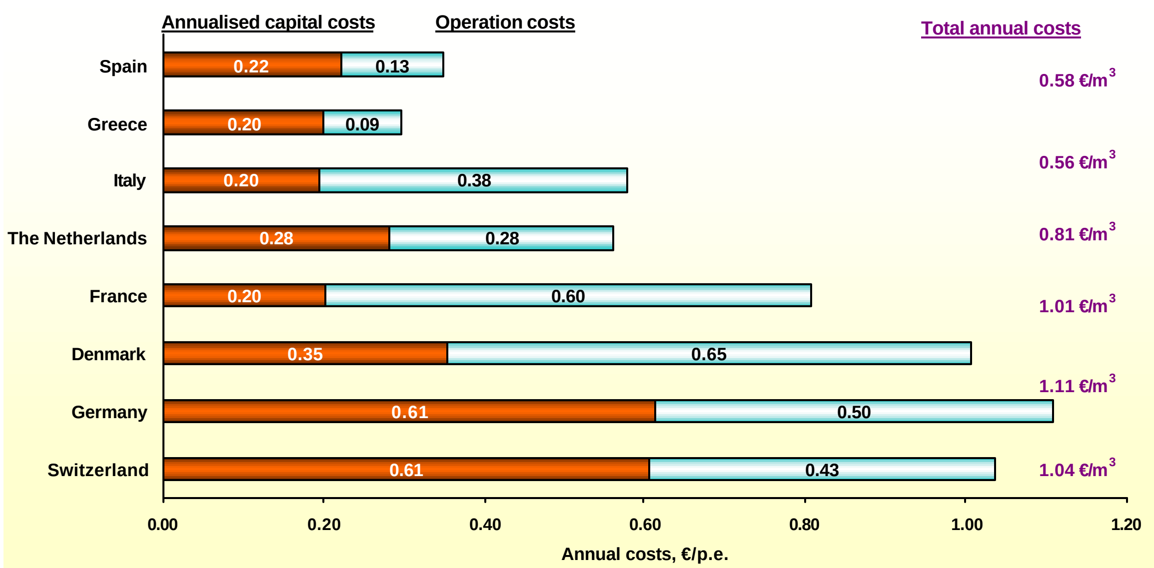
The total average wastewater treatment cost in Northern European countries, calculated per unit treated volume, is about 1€/m^3, which is almost double compared to the lower values of about 0.6 €/m^3 reported in Italy and the Netherlands. Average wastewater treatment costs are almost 2-3-times lower in Southern EU countries, *i.e.* 0.3-0.35 €/m^3.

Wastewater treatment costs are higher from +50 to +100% for medium size works (<50,000 p.e.) and significantly higher from +200 to +500% and more for small-scale plants (<2000 p.e.).

A very significant difference has also been observed in the percentage of operating costs. The contribution of operating costs to the total annual wastewater treatment costs may vary from 41 to 75% (Figure 6). No significant difference has been observed between Northern and Southern EU countries.



a) annual wastewater treatment costs calculated per capita equivalent



b) annual wastewater treatment costs calculated per cubic meter of treated wastewater

Figure 5 Average wastewater treatment costs in European countries (biological treatment with nutrient removal, including biological or physical-chemical phosphorus removal)

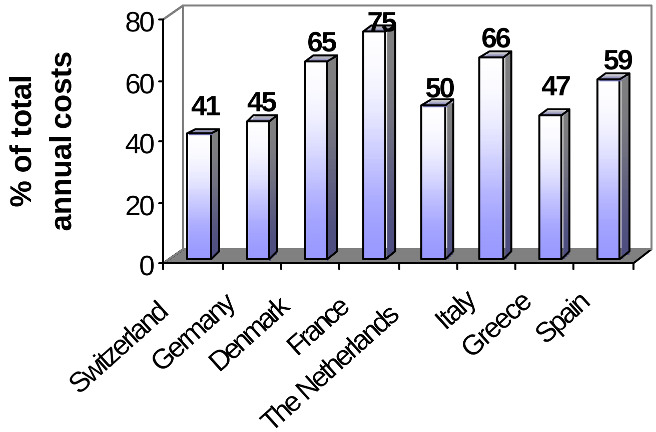


Figure 6 Comparison of operating costs of activated sludge plants as % of the total annual wastewater treatment costs in Europe (information was not provided for other Mediterranean countries)

According to these data, average operating costs in European countries are in the range of 56±12% (conventional activated sludge systems for carbon and nitrogen removal).

3.3. Influence of plant capacity on wastewater treatment costs

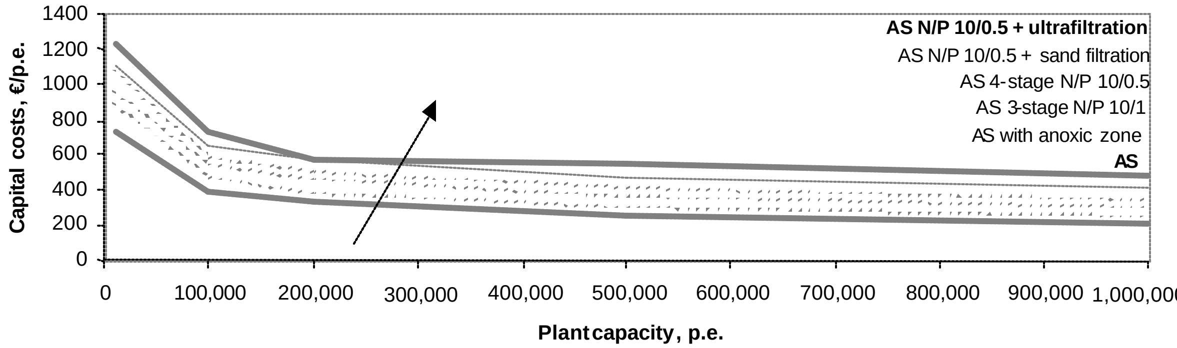
Plant capacity has a strong influence on capital costs of wastewater treatment. Figure 7 illustrates average annualised capital wastewater treatment costs in Europe and North America as a function of plant size and level of treatment.

The lower limit corresponds to conventional activated sludge systems designed for carbon and nitrogen removal and the dashed lines reflect the costs of two-stage activated sludge with anoxic zone, tri-and four-stage activated sludge for total nitrogen removal, as well as physical-chemical phosphorus removal.

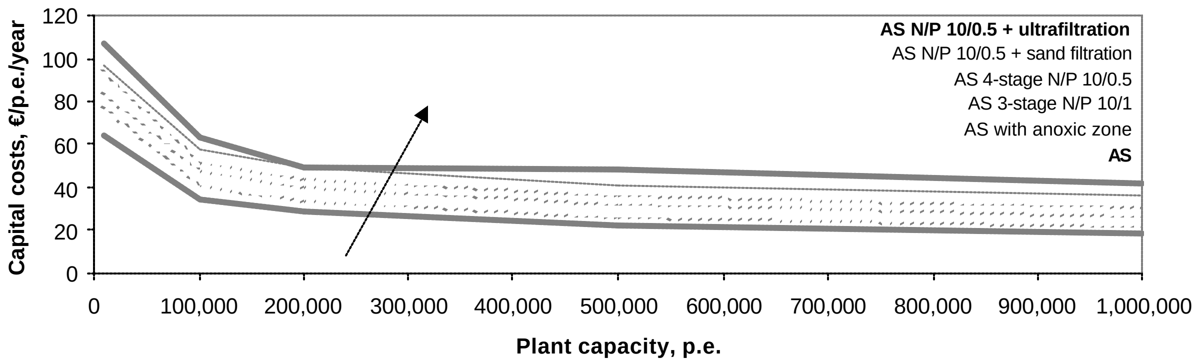
The upper limit indicates the costs of full biological treatment with N and P removal, followed by ultra filtration for the production of high-quality recycled water.

Analysis of the data shown in Figure 7 clearly demonstrates the significant economy of scale that can be achieved: specific capital costs are doubled for a decrease in plant capacity from 1,000,000 to 100,000 p.e., and are doubled again for small works of about 10,000 p.e.

In addition to the influence of plant capacity, specific capital costs increase from +50 to +250% with the increase of the treatment level from conventional carbon removal to full nutrient removal and disinfection. The needed investment for full biological treatment and disinfection for the production of high-quality recycled water may be more than double compared to conventional activated sludge. For example, for plant capacity of 200,000 to 1,000,000 p.e., the average annualised capital costs of full treatment and disinfection are 45±3 €/p.e./year compared to 24±5 €/p.e./year for conventional activated sludge. The overall capital costs are respectively 525±40 €/p.e versus 270±60 €/p.e.



a) Overall capital costs, €/p.e.



b) Annualised capital costs, €/p.e./year

Figure 7 Influence of plant capacity on capital costs of wastewater treatment to different water quality levels (capital costs are amortised for 20 years at a return rate of 6%)

The effect of scale depends strongly upon treatment technology. As a rule, high influence of scale is reported for tertiary treatment processes as demonstrated in Figure 8 (Richards *et al.* 1993).

As shown in Figure 8, capital costs for tertiary filtration and disinfection and for full Title 22 treatment (coagulation/flocculation, filtration and disinfection) did not exceed 30-40% of the investment for secondary treatment. However, significantly higher expenses are involved for activated carbon filters (GAC) and reverse osmosis (RO) to produce high-purity recycled water for industrial and indirect potable reuse purposes.

On the basis of the experience in the USA (Figure 9), the life cycle costs for the treatment of raw sewage to produce recycled water suitable for unrestricted irrigation vary from 0.43 to 1.10 US$/$m^3$.

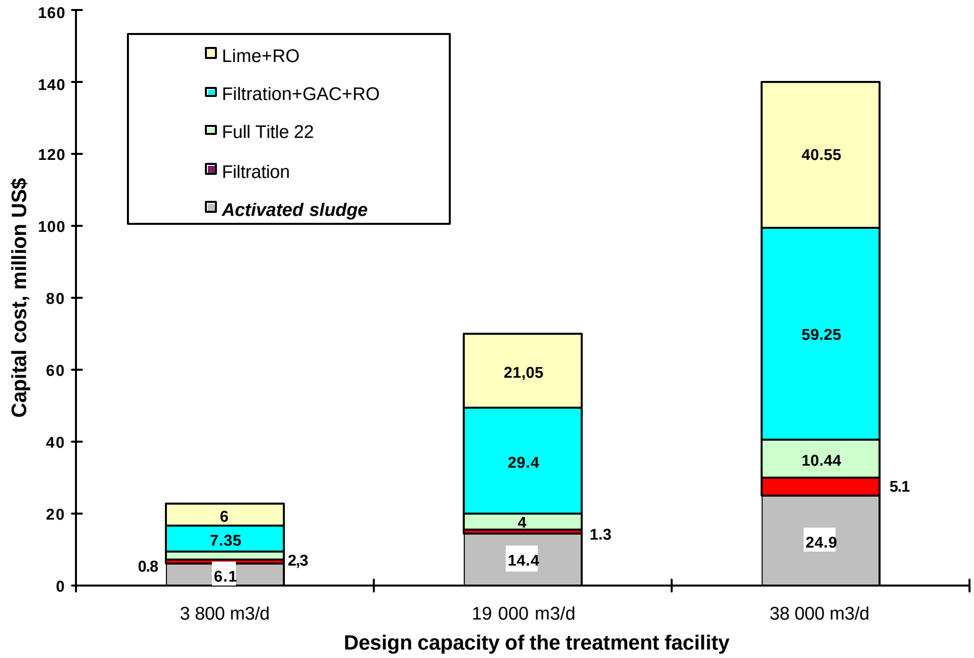


Figure 8 Estimated capital costs of reclamation treatment facilities in the USA (adapted from Richards *et al.*, 1993)

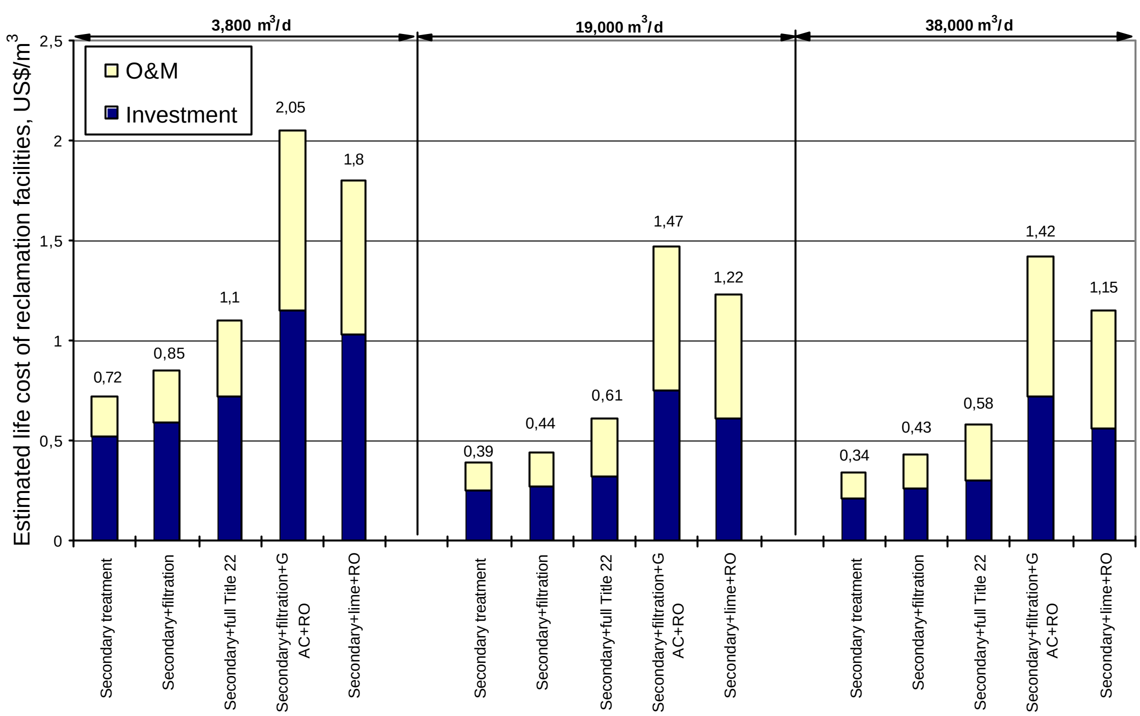


Figure 9 Estimated life-costs of reclamation treatment facilities in the USA: capital costs are amortised for 20 years at a return rate of 10% (adapted from Richards *et al.*, 1993)

O&M costs, compared to capital amortisation in the total cost, depends on treatment technology and is higher for the high-tech processes of GAC and RO than secondary treatment with or without tertiary filtration and disinfection.

Similar to secondary treatment, significant economy in scale may be achieved for large reclamation facilities: the life cycle cost could be halved when the plant capacity increases from 4,000 to 20,000 m^3/d or from 50,000 to 200,000 m^3/d, respectively.

It should be emphasized that these costs are reported solely for the purpose of illustrating the influence of plant size on treatment costs. The costs values can not be extrapolated to other countries because the unit cost of reclaimed wastewater depends not only on the plant size and the treatment chain, but also on wastewater composition, water quality requirements and other local conditions (energy costs, labour, etc.). Moreover, the main components of recycled water costs are not the same from one plant or country to another.

3.4. Specificities of wastewater treatment costs of small-scale works

This survey demonstrated that 60 to 85% of centralized sewage facilities in different European countries are small-scale wastewater treatment works with treatment capacities of 100 to 2000 p.e. (maximum 5000-10,000 p.e.). With the application of the European Directive for Urban Wastewater Treatment (91/271/EEC, 1991), it is expected that the number of small works will increase. In addition, new requirements for stringent discharge consents will be applied to sensitive areas.

The predominant treatment technology at small-scale works in almost all EU countries, is extended aeration (oxidation ditches, package plants, conventional activated sludge). In Southern Europe, waste stabilization ponds (lagooning) have a relatively large application, as shown in Figure 10: the technology breakdown for small works in Greece (Tsagarakis *et al.*, 2000). Infiltration-percolation and reed beds are becoming the preferred treatment option for an increasing number of small works in Spain and France. Reed beds are increasingly recommended for very small works in Belgium and the Netherlands. Trickling filters and biological rotating contactors (RBC) are the preferred options in the UK.

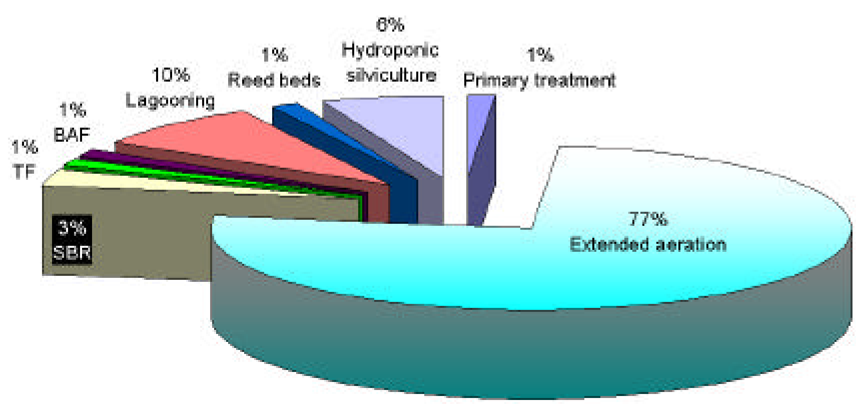


Figure 10 Breakdown of small-scale wastewater treatment works in Greece (adapted from Tsagarakis *et al.*, 2000)

Compared to large wastewater treatment plants, the effect of size on capital and operating costs for small works is quite significant (2000 to <100 p.e.). Capital costs, for example, decrease 10-fold from 2000 to 200 €/p.e. as population served increases from 100 to 2000 p.e. (Figure 11). For a given plant capacity, capital costs vary in wide range depending on the type of treatment train and specific local conditions.

It is very important to underline that in addition to plant capacity, wastewater treatment costs of small works depend heavily on local situation (type of soil, water table, pumping, pre-treatment, etc.).

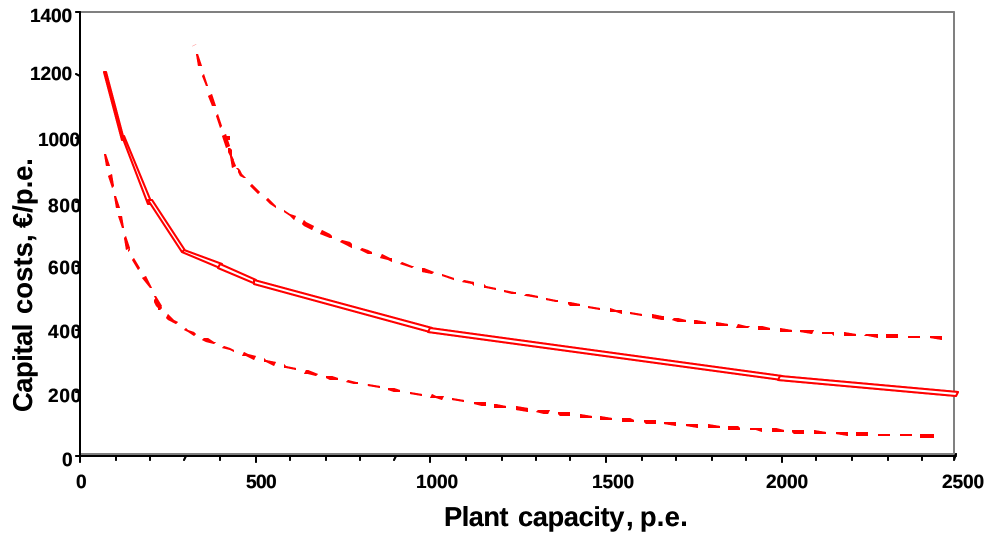


Figure 11 Influence of plant capacity on capital costs for small sewage works (theoretical range of variation established on the basis of literature data)

Wastewater treatment costs of small works are highly influenced by the treatment scheme depending on discharge consent. Carbon removal and reduction of suspended solids concentration can be successfully achieved by low-cost natural treatment processes such as infiltration-percolation, stabilisation ponds (lagooning) or reed beds. In the case of land constraints and high land costs, rotating biological contactors (RBC), trickling filters and oxidation ditches become cost competitive. High levels of nitrogen and phosphorus removal can be achieved by the combination of several treatment processes. Finally, high-tech technologies, such as membrane bioreactors (MBR), can be used when there are stringent requirements such as, for example, unrestricted water reuse.

Stabilization ponds (natural or aerated lagooning) can be cost competitive only for small works and low land costs. The same applies to the implementation of other natural treatment processes, such as infiltration-percolation and reed-beds. It has become evident that under the conditions prevailing in Southern Europe and the Mediterranean, the capital costs of lagooning are similar and even higher than activated sludge for plant capacities over 2000-5000 p.e. due to high cost of land acquisition. Compared to reed beds, the cost competitiveness of activated sludge is observed for treatment plants of over 1000-2000 p.e.

As shown in Figure 12 , land requirements (the process footprint only) of lagooning is 6 to 10-fold higher compared to reed beds and infiltration-percolation, respectively, and over 60-fold higher compared to activated sludge. Consequently, the cost of land is often the major factor influencing capital costs of natural wastewater treatment processes.

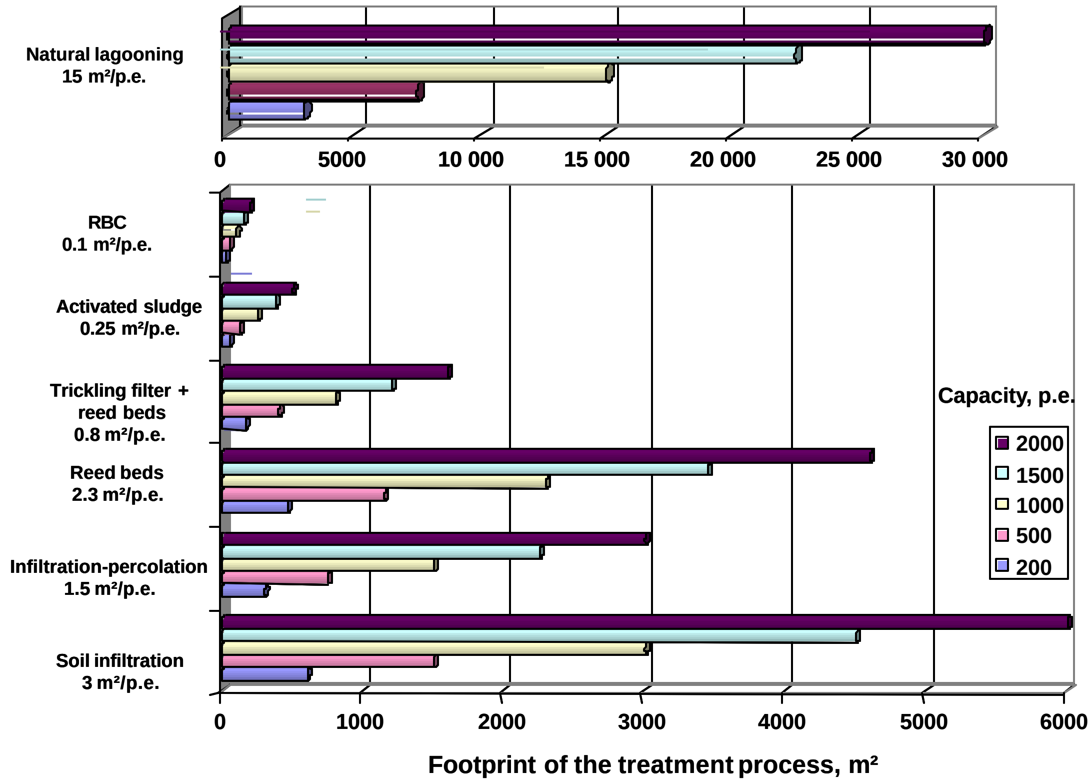


Figure 12	Land requirements of selected wastewater treatment processes depending on plant capacity (theoretical calculation)

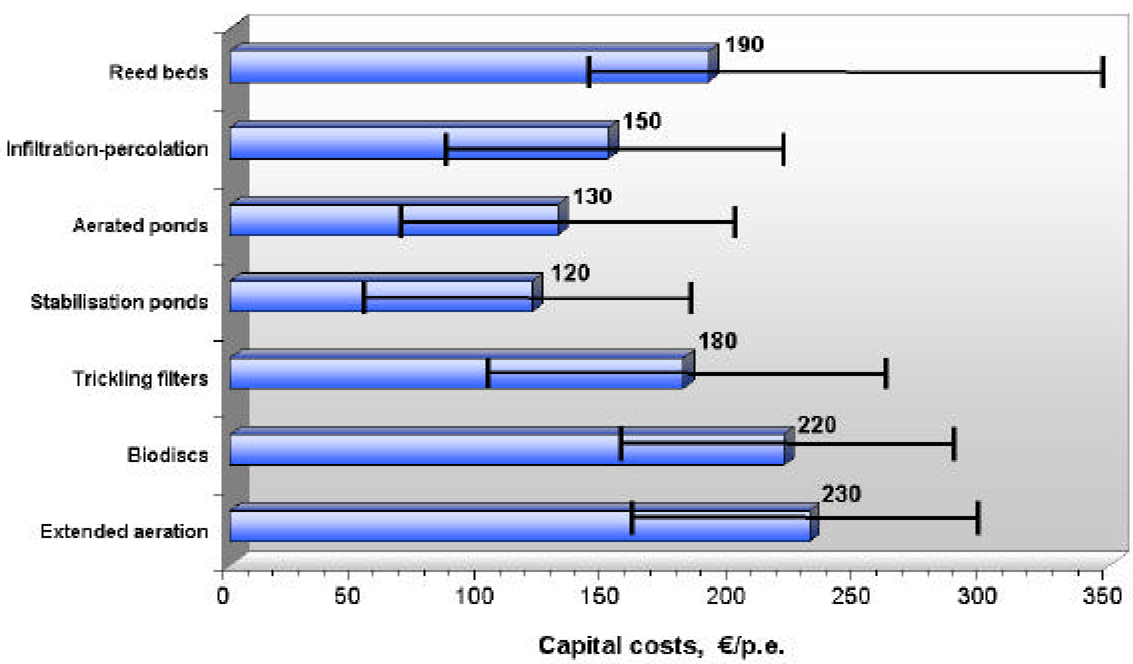


Figure 13	Average specific capital costs and range of variation of common treatment technology for plant capacity of 1000 p.e. (theoretical estimation on the basis of available data)

Figure 13 illustrates the typical specific capital costs of small-scale wastewater treatment technologies in Europe (average cost and range of variation) for plant capacity of 1000 p.e. The mean value and range of variation are estimated from available data (Alexandre *et al.*, 1998; European Commission, 2001; Geenens and Thoeye, 2000).

As mentioned earlier, with the exclusion of land costs, stabilization ponds may be the most cost competitive solution with an average cost of 120±70 €/p.e. Infiltration-percolation and trickling filters would be also an economic option, 150±75 €/p.e. and 180±80 €/p.e., respectively. For this plant capacity, extended aeration can be competitive solution, requiring 230±70 €/p.e. of investment only when land costs are considered.

4. OPERATING COSTS OF WASTEWATER TREATMENT

As mentioned previously, operating costs of wastewater treatment include all expenses that occur within the boundaries of the plant site, and in some cases wastewater collection costs (maintenance of sewer systems and external pumping stations).

The most important components of operating costs are energy consumption, repairs and maintenance and labour. With the implementation of more stringent effluent and sludge discharge rules, the contribution of other operating costs, such as sludge discharge and water quality monitoring is increasing. In addition to common administrative costs, new expenses for communication and marketing must be taken into account.

Likewise, capital costs and operating costs are highly influenced by plant size and decrease with the increase of plant capacity. Operating costs also increase with the increase in treatment level.

4.1. Effect of plant size on total operating costs

Figure 14 illustrates the wide variation in O&M costs in different countries, depending on plant size for secondary treatment with nitrogen removal and physical-chemical precipitation of phosphorus (Northern EU countries) or disinfection (Southern EU countries).

As shown in Figure 14, reported specific O&M costs vary from 3.5 to 24 €/p.e./year. Typical net operating costs are about 5 to 10 €/p.e./year for plant size of 20,000 to 500,000 p.e.

Higher costs are characteristic for the countries of North Europe that have high levels of nutrient removal (N and P). In the Mediterranean region, specific operating costs are higher for plants in tourist areas with tertiary treatment and reuse, such as the cost of treatment in Costa Brava, Spain (5 to 16 €/p.e./year).

In Greece, lower operating costs of about 3.5 €/p.e./year are reported for large wastewater treatment plants with treatment capacity of 120,000 p.e. and very large facilities of 2,000,000 p.e.(data not shown in Figure 14). Nevertheless, even in Greece the operating costs of conventional activated sludge with nitrification/denitrification in tourist areas are significantly higher and can reach 36 €/p.e./year for facilities operated at 13% of the maximum design capacity.

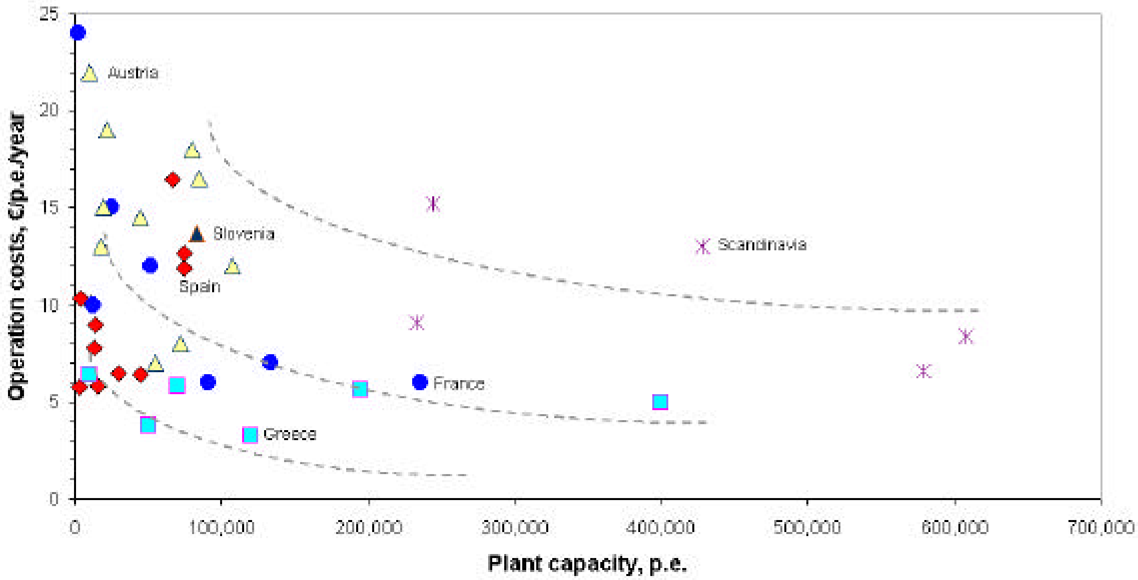


Figure 14 Distribution of annual operating costs for different wastewater treatment plants (predominantly activated sludge) depending on plant capacity (this survey and literature data)

4.2. Operating costs of small wastewater treatment works

It is extremely difficult to assess the operating costs of small treatment works, because as a rule the same staff operates several small wastewater treatment plants and a number of operational expenses are covered by other entities (municipality, large treatment plant, etc.).

For a given treatment technology and plant size, the difference in reported plant operating costs is ±50 to overt +500%. In general, total operating costs are very high for the very small works below 500 p.e. (over 150-200 €/p.e./year).

A significant difference exists between the operating costs of natural extensive treatment processes and those of conventional activated sludge (Figure 15). For example, operating costs of about 40 €/p.e./year are reported for activated sludge with a capacity of 2000 p.e. - almost double compared to natural stabilization ponds or infiltration percolation - which are in the range of 20 €/p.e./year for the same plant capacity. This increase which occurs with the decrease in plant size, is almost 3-fold for works of 200 p.e., almost 120 €/p.e./year for activated sludge compared to 40 €/p.e./year for natural systems.

Lower operating costs have been reported for small natural treatment processes in Southern Europe (Greece, France, Italy) that are in the range of 5 to 10 €/p.e./year (Alexandre *et al.*, 1998; Tsagarakis *et al.*, 2000). It should be stressed, however, that the reported costs cover labour and energy only and do not include pumping, monitoring, sludge discharge and other administrative and specific expenses.

The main component of the operating costs of small plants is manpower. Labour requirements depend on the type of treatment process and vary in large limits from 0.2 h/d to 12 h/d. Stabilization ponds have lower labour requirements in the range of 0.2 to 1 h/d (García *et al.*, 2000) with frequency of intervention from once a week to once a month.

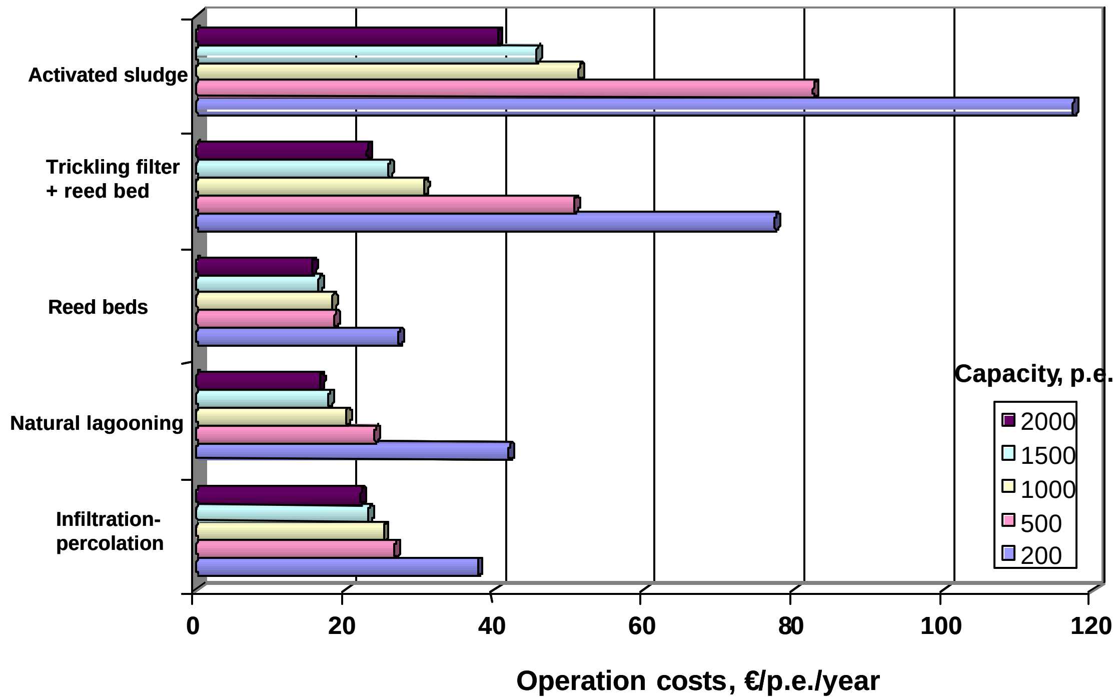


Figure 15 Inventory on operating costs of small wastewater treatment works: influence of plant capacity on average operating costs (theoretical estimation, range of variation ±75%)

Energy requirements for natural systems are limited to pumping costs and are about 6 kWh/p.e./year. Energy consumption of rotating biological contactors (RBC) and tricking filters is in the middle range of about 28 kWh/p.e./year. The higher energy demand is characteristic of activated sludge for both aeration and sludge treatment and disposal.

A recent survey of 24 pond systems in Catalonia, Spain (García *et al.*, 2000) showed that energy consumption per unit flow of aerated ponds is higher than design value and varies from 0.25 to 1.62 kWh/m^3. The average energy consumption of aerated ponds was estimated at 0.47 kWh/m^3, which is higher than conventional activated sludge of 0.26 kWh/m^3 probably due to the lack of dissolved oxygen control. Non-aerated stabilization ponds do not require aeration and their energy consumption varies from 0 to 0.19 kWh/m^3.

Sludge removal is a common operation activity, which, as a rule, is not included in the operating costs of small-scale natural treatment systems. Nevertheless, aerated ponds need to be wasted every 3 to 6 years and stabilization ponds every 10 to 15 years.

4.3. Distribution of Operating Costs

The operating costs of wastewater treatment plants assessed during this survey are divided into cost types and presented in the following figures. The predominant treatment technology is conventional activated sludge operated with nitrification and biological phosphorus removal. The plant capacity varies from 2200 to 300,000 p.e.

In general, the major component of operating costs in European and Mediterranean countries is labour, followed by energy consumption, repair and maintenance, chemicals, sludge disposal and others.

4.3.1 Relative distribution of the different elements of operating costs

As indicated in Figure 16, the main component of operating costs in Spain is labour, accounting for 32 to 62% of total operating costs. The highest value of 62% is reported for the smallest plant of 7400 p.e. with advanced tertiary treatment of coagulation/flocculation, filtration, UV disinfection and chlorination. For the same treatment train, the part of labour decreases with the increase in plant size (plant 1 to 4, 62 to 39%, respectively).

It should be noted that natural post-treatment by maturation ponds and reed beds (plant 6) has a similar distribution of operating costs as advanced tertiary treatment.

Energy consumption is the second largest component with values from 12 to 29% of total operating costs in the wastewater treatment plants assessed in Spain.

The other important elements of operating costs in Spain are repair and maintenance (7 to 17%), and sludge disposal (5 to 20%). Pumping costs could also be a significant component, but it is not systematically specified as an individual component of operating costs. Water quality monitoring is specified only for three of the assessed wastewater treatment plants in Spain, accounting for 1 to 9% of operating costs.

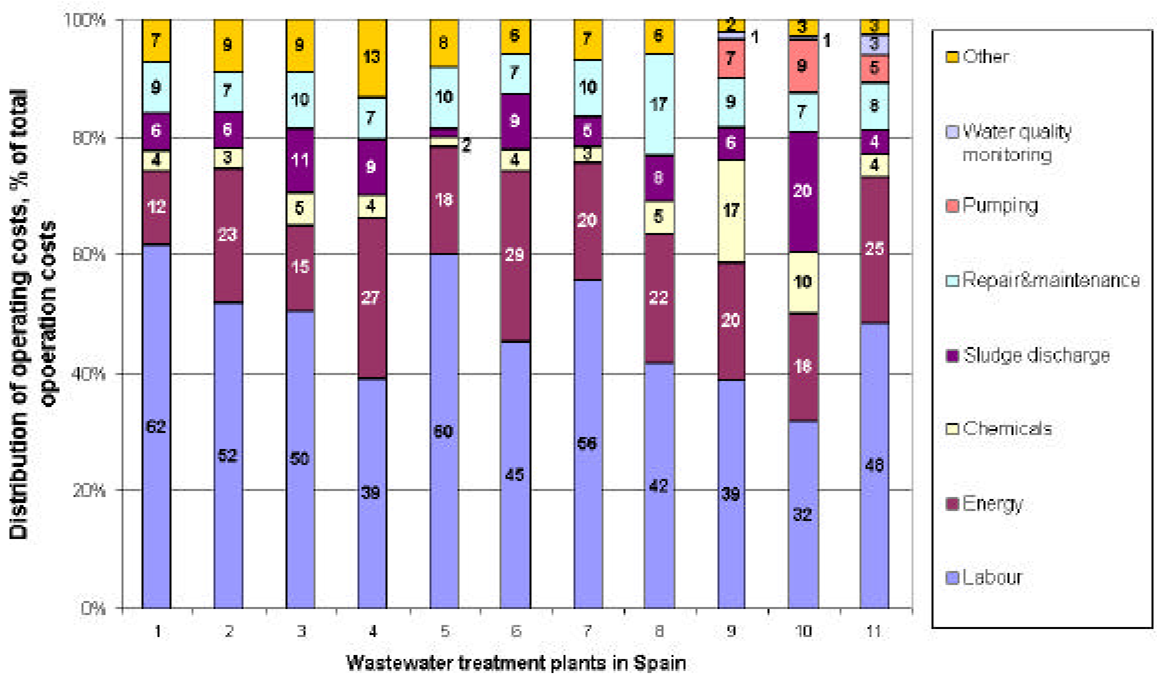


Figure 16 Distribution of operating costs of 11 wastewater treatment plants in Spain (this survey, 4000 to 75,000 p.e., activated sludge plus tertiary treatment with disinfection)

Similar cost distribution (Figure 17) is observed in wastewater treatment plants with nitrogen removal in Austria (3 plants 38,000 to 48,000 p.e.).

Compared to Spain and other countries, this survey demonstrated that the distribution of operating costs in France (Figure 18) is completely different with strong contribution of sludge disposal cost that becomes, in some cases, the major component of operating costs accounting for 45 to 17% of operating costs. The reported cost of only one wastewater treatment plant sludge discharge is very low, about 1%, with predominant high costs for chemicals needed for sludge dewatering and odour treatment (42%).

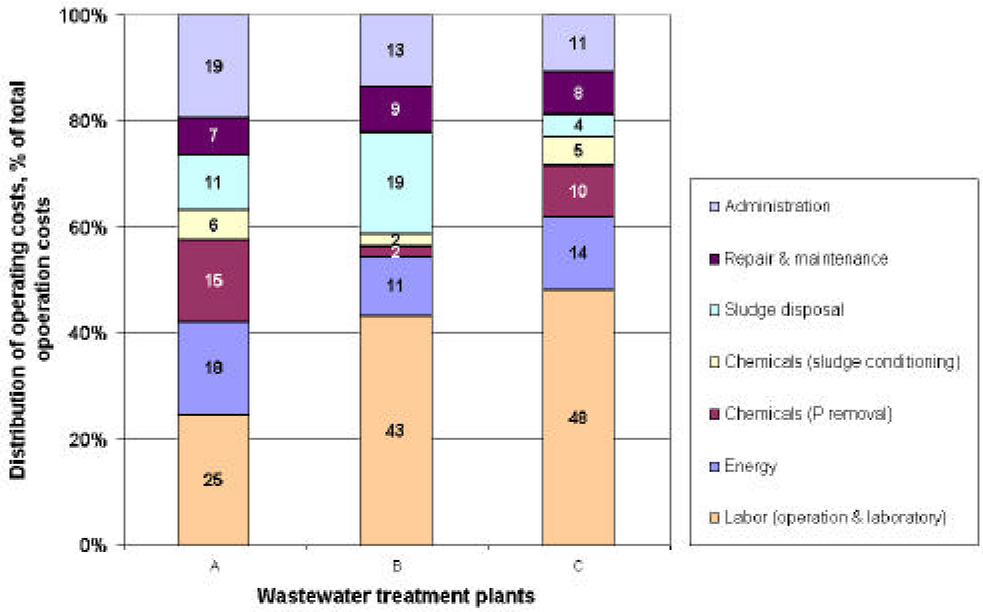


Figure 17 Distribution of operating costs of 3 activated sludge plants in Austria (38,000 to 48,000 p.e., adapted from Nowak, 2000)

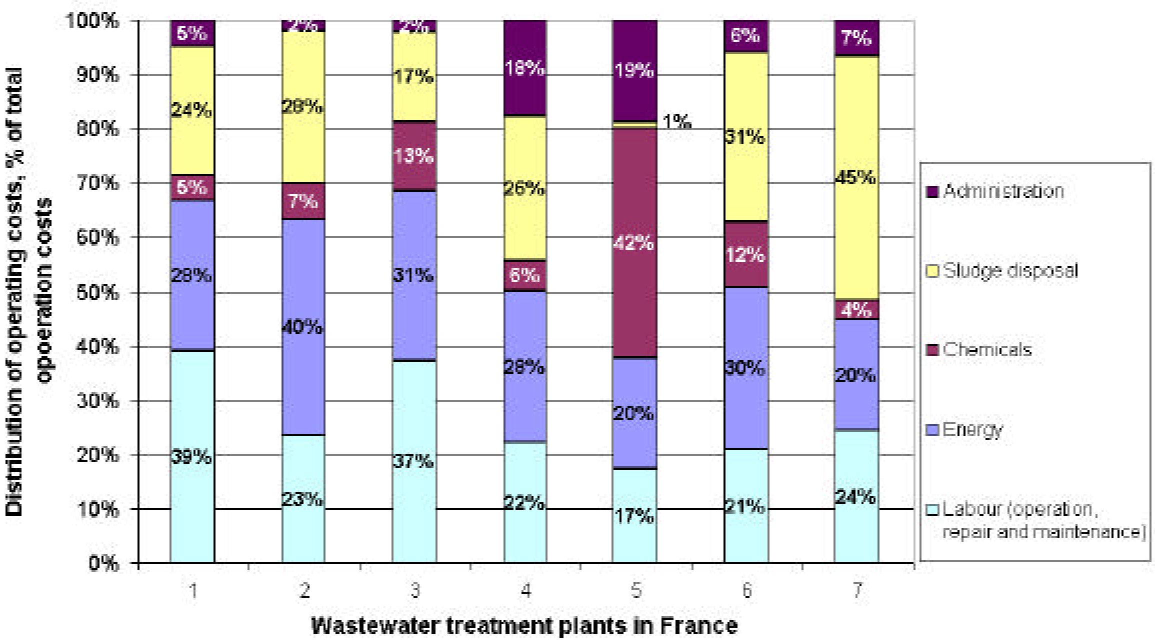


Figure 18 Distribution of operating costs of 7wastewater treatment plants in France (this survey, 2200 to 240,000 p.e., activated sludge systems)

In France, labour and energy remain the major components of operating costs accounting for 17 to 39% and 20 to 40% of operating costs, respectively. In this case, repair and maintenance is included in labour costs.

It is worth mentioning that administration costs vary in large limits from 2 to 19% of operating costs (Austria, France, Spain), probably because the included expenses are not the same.

Similar cost distribution as in France is observed in 2 large wastewater treatment plants with nitrogen removal (Figure 19) in Greece (200,000 p.e.) and Slovenia (85,000 p.e.).

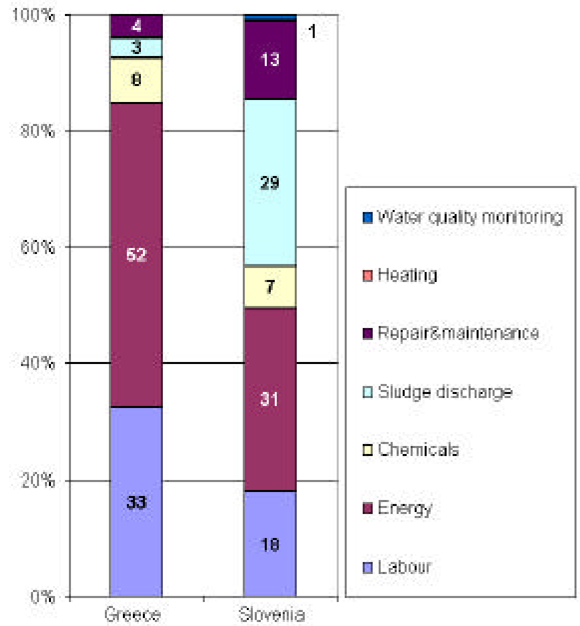


Figure 19 Distribution of operating costs of 2 wastewater treatment plants of activated sludge with nitrification in Greece (200,000 p.e.) and Slovenia (85,000 p.e.)

In these two cases, energy consumption is the major component of the operating costs, accounting for 52 and 31% of total operating costs in Greece and Slovenia, respectively.

According to the data reported for the Greek wastewater treatment plant, 85% of the operating costs is energy and labour. The reported energy consumption of two other large wastewater treatment plants in Greece, with treatment capacities of 400,000 and 2,000,000 p.e. is 17 and 32%, respectively. The cost of sludge disposal in Greece depends on local conditions and can be relatively low, for example 3% as shown in Figure 19, or significantly higher accounting for 15% of operating costs, which is the case for large wastewater treatment plants with treatment capacity of 2,000,000 p.e. (mainly transportation costs and garbage site fees).

Similar to France, Slovenian wastewater treatment plant expenses for sludge disposal are high and account for 29% of total operating costs. In this instance, administration costs are also higher in comparison to Greece (13% versus 4%, respectively).

4.3.2 Effect of the ratio of plant utilization on operating costs

By definition, total operating cost values vary depending on plant size. For this reason, it is suitable to use unit costs expressed in €/p.e./year or €/m^3 to compare different treatment plants, schemes and countries.

It should be stressed, however, that the degree of plant utilization greatly influences specific operating costs, particularly in tourist areas where the ratio between plant load in summer and winter can vary with a factor of up to 7 -10. As a rule, only 10 to 25% of the plant capacity is used during the winter season.

For example, in coastal areas in Spain with high tourist activity, the operating costs expressed in €/p.e./year vary between 5.8 and 16.5 €/p.e./year, but do not reflect the influence of plant size because the calculation is based on the design plant capacity.

The influence of plant size becomes clear by comparison of unit operating costs according to the annual throughput of the plant, *i.e.* the annual volume of treated wastewater (Figure 20). Small to medium size plants (5000 to 20,000 p.e.) have higher operating costs of up to 1.15 €/m^3, while large plants with capacities of 30,000 to 75,000 p.e. are characterized by similar operating costs of about 0.25 to 0.3 €/m^3.

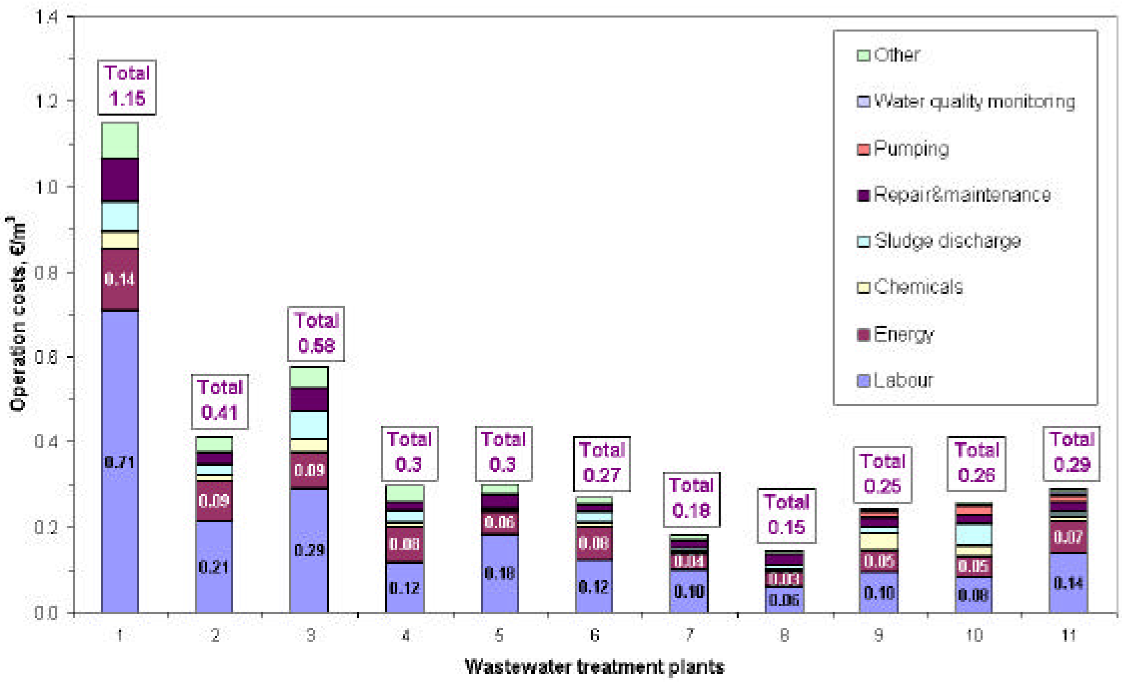


Figure 20 Distribution of operating costs in €/m3 of the assessed 11 wastewater treatment plants in Spain (4000 to 75,000 p.e., activated sludge plus tertiary treatment with disinfection)

Advanced tertiary treatment requires higher operating costs than conventional activated sludge. For example, 0.58€/m^3 versus 0.29€/m^3 for plant capacity of about 15,000 p.e. Surprisingly, such a big difference was not observed for large plants designed for about 75,000 p.e.: operating costs of plant 8 are even lower 0.15 €/m^3 compared to the unit costs of plants 9 and 10.

The implementation of natural polishing treatment by maturation ponds and reed beds (plant 6, 0.27 €/m^3) does not allow any significant increase in operating costs compared to conventional disinfection by chlorination, implemented in plant 5 (0.3 €/m^3) with similar design capacity.

4.3.3 Effect of plant size on distribution of operating costs

Figure 21 illustrates the influence of plant size on the distribution of operating costs on the example of the 7 Frenchwastewater treatment plants assessed (activated sludge with nitrification/denitrification).

As mentioned previously, small plants have significantly higher operating costs of up to 24.4 €/p.e./year; two times higher than medium size plants. About 70% of the operating costs are for labour and energy.

Total operating costs of large activated sludge plants (>75,000 p.e.) are 5.7 to 7.1 €/p.e./year with lower contribution of energy and labour of 40 to 50%, because of the high expenses incurred for sludge treatment (chemicals) and disposal.

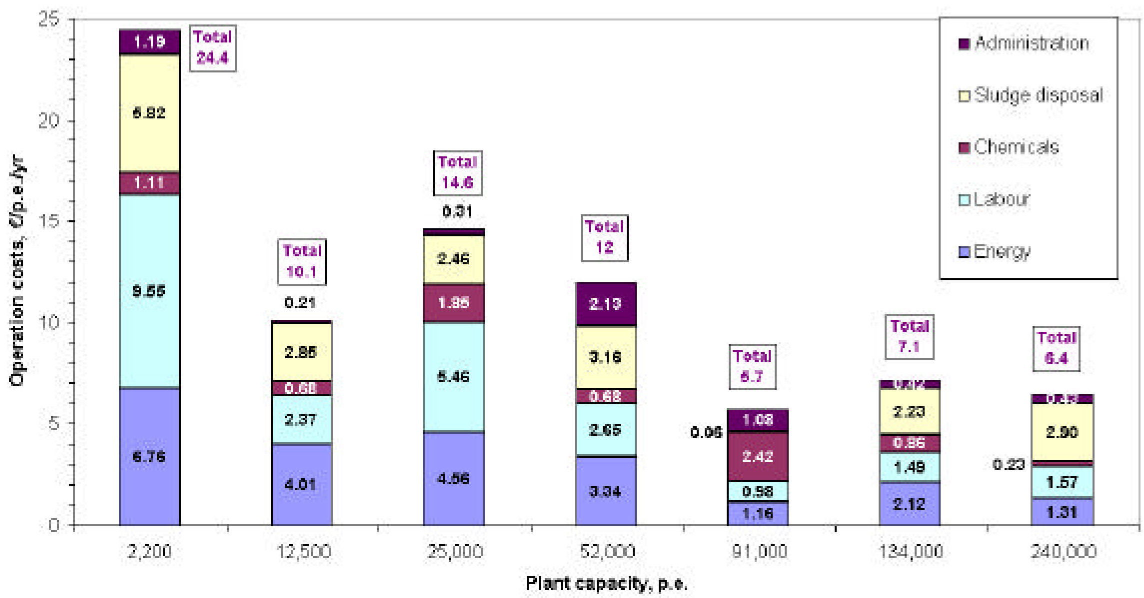


Figure 21 Influence of plant size on distribution of operating cost in France (this survey, conventional activated sludge with nitrogen removal)

When different countries are compared, the effect of plant size on distribution of operating costs is not so obvious (Figure 22). For a plant size of 43,000±5000 p.e., operating costs in Austria are 10.4±1.0 €/p.e./year compared to 13 €/p.e./year in Slovenia for a 2-fold larger plant.

Significantly lower operating costs of 5.2€/p.e./year are reported in Greece for a very large plant of 195,000 p.e., which is in the same order of operating costs of large plants in France. The same order of operating costs of 5 €/p.e./year is estimated in another large facility in Greece with capacity of 400,000 p.e., operated at only 13% of the design flow in a tourist area.

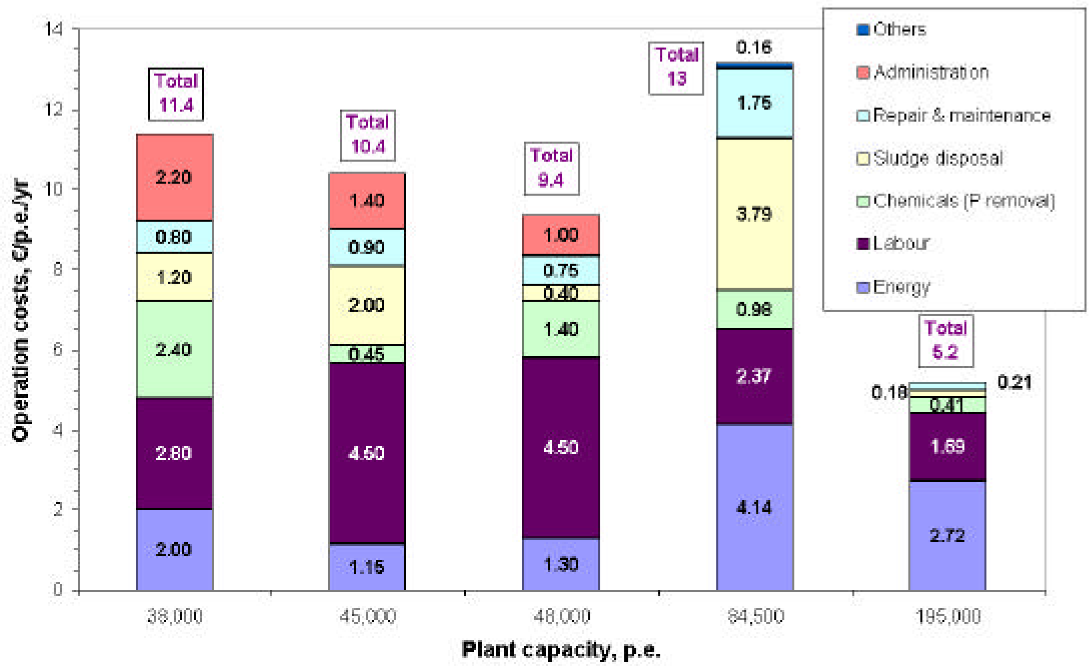


Figure 22 Influence of plant size on distribution of operating cost of activated sludge with nitrogen removal in different countries (this survey and literature data: Austria, plants 1 to 3, Slovenia and Greece)

4.4. Labour costs

The major component of operating costs of wastewater treatment in Europe is labour for operation and maintenance, and administration which accounts for 25 to 70% of the total operating costs (repair and maintenance included). Typical values are 40 to 50%. It is important to note, however, that labour costs are difficult to estimate because of the diverse administrative organization and social aspects in the different European and Mediterranean countries.

As a rule, labour costs include salaries and insurance for the operating personnel and managers. In Europe, working time is generally five days per week. Only very large plants with specific equipment require the continuous presence of personnel.

The main factors influencing labour costs are as follows:

- Plant size - the number of employed personnel decreases as plant size increases;
- Degree of automation - the number of employed personnel decreases as plant size increases;
- Type of treatment process - natural systems require less personnel, while advanced treatment needs more personnel with higher qualifications;
- Administrative organization - large public or private companies or municipalities operating several wastewater treatment plants have less personnel who are in

charge of several facilities;
- Management efficiency;
- Degree of training and education; and
- Unit cost of labour differs from country to country.

Analysis of the assessed wastewater treatment plants and literature data shows that the number of employees varies from 1 employee per 2000 p.e. to 1 per 16,000 p.e. (Figure 23) with an average values of 1 per 7000 ± 2000 p.e. (calculated for the mean load of the treatment plants). More personnel is required for small to medium size facilities of <10,000-15,000 p.e., *i.e.*, 1 per 2000 to 5000 p.e. It also appears that the number of employees is slightly higher in Southern countries (Greece, Spain).

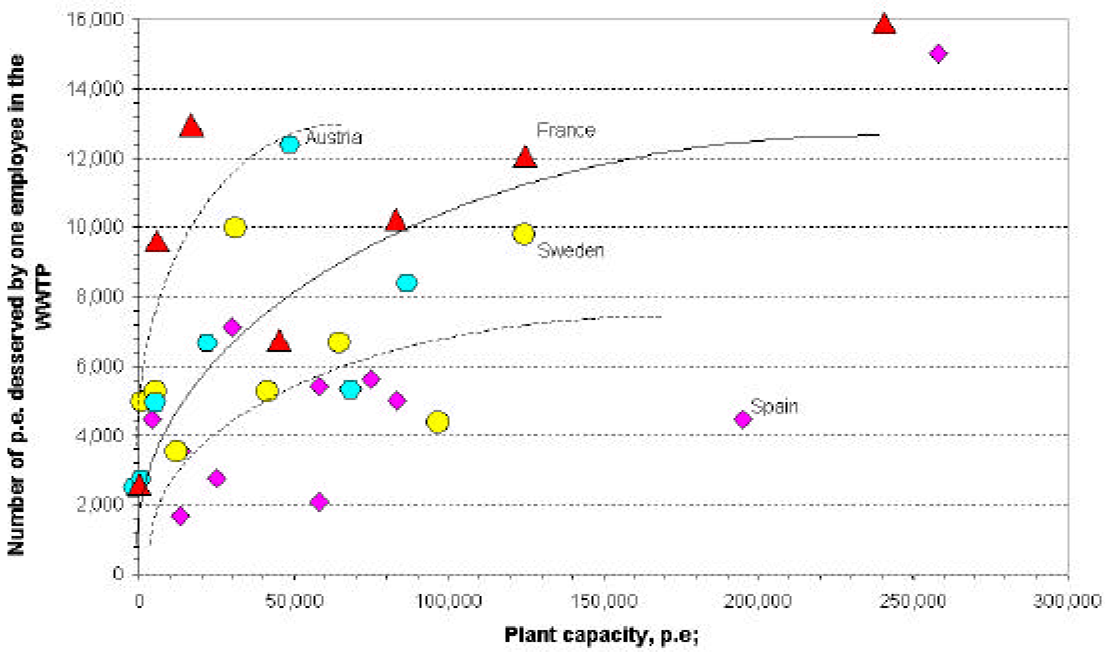


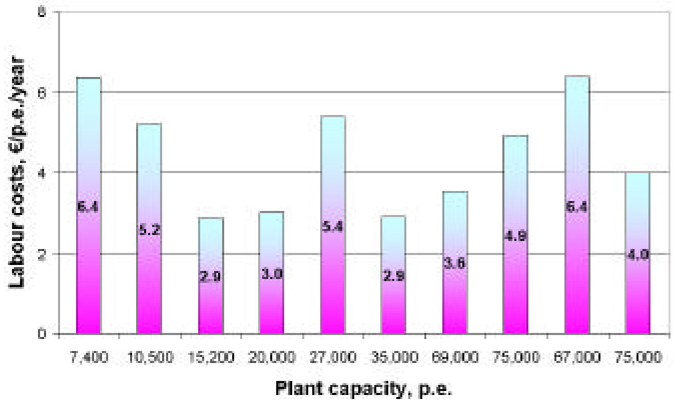
Figure 23 Total personnel employed in wastewater treatment plants in Europe (this survey and literature data)

Labour costs vary from 1 to 15 €/p.e./year depending on the plant size, load variations, treatment technology and automation (Figure 24). Typical reported values (plant capacity 50,000-100,000 p.e.) are 5-10 €/p.e./year in Northern Europe (Austria, Germany, Sweden) and 1.5-5 €/p.e./year in Southern Europe (France, Greece, Spain).

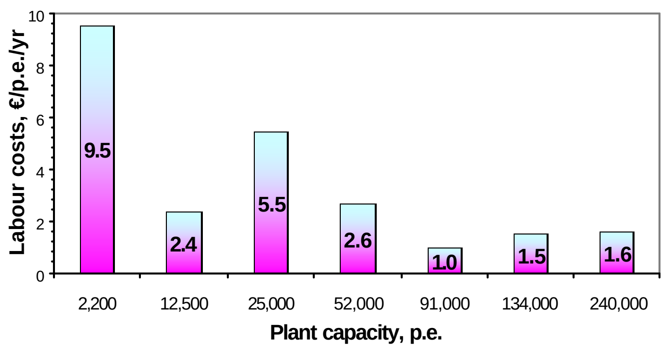
Labour costs are strongly influenced by plant size and can be halved when plant size increases from 50,000 to 100,000 p.e. and halved again for plant >250,000-500,000 p.e. For example, labour costs in the assessed wastewater treatment plants in France decrease from 2.7 to 1-1.5 €/p.e./year when the plant size increase from 50,000 to 100,000 p.e. Similarly, reported labour costs for very large nutrient removal plants in Scandinavia are in the range of 2.2 to 5.1 €/p.e./year (Balmér, 2000).

The higher costs in Northern Europe are associated with the stringent standards for nitrogen and phosphorus removal. Higher costs are typical for small works and plants with sophisticated sludge treatment and/or tertiary disinfection.

Unit costs of labour vary with qualification and are in the range of 10 to23 €/h in most European countries. The difference in salary is 2 to 3-fold between unskilled personnel and qualified engineers. Labour costs are still significantly lower in Central and Eastern European countries (<1 €/h), for example 0.35 €/h in Slovenia.



a) Spain



b) France

Figure 24 Examples of labour costs in France and Spain (this survey)

It is important to note that the difference in labour costs depends strongly on the cost of external services, which are very often not accounted for. External services include water quality monitoring, consulting, etc.

4.5. Energy costs

Energy consumption is not only a major component in wastewater operating costs, but is also the main factor used to compare cost efficiency of various treatment processes and schemes, specially for more advanced treatment including nutrient removal or disinfection.

During wastewater treatment, large amounts of energy are consumed, representing 11 to 52% of the total operating costs of assessed plants (see Figures 16 to 19). Typical values for conventional activated sludge systems are 20 to 30%.

For plant capacities over 10,000 p.e., specific energy costs vary from 1 to 4.7 €/p.e./yr with typical values of 2.5±0.5 €/p.e./yr. No significant influence of plant size is observed for the typical treatment scheme of activated sludge with nitrogen removal.

Aeration is the main energy consumer for secondary treatment of municipal wastewater and can account for 50 to 80% of energy costs. In some cases, pumping can greatly contribute to the overall energy consumption, as well as primary settling, sludge dewatering and disinfection.

Typical energy consumption of conventional activated sludge is 25±5 kWh/p.e. Extended aeration requires about 20% less energy with a specific energy consumption of about 0.5 kWh/m^3. Advanced treatment processes and disinfection would require higher energy consumption of up to 45 to 100 kWh/p.e. The highest value of 99 kWh/p.e. is reported for large wastewater treatment plants in Scandinavia using fluidised bed technology for denitrification (Balmér, 2000).

For large wastewater treatment plants, anaerobic digestion can greatly contribute to energy saving, providing up to 50% of the needed energy.#

4.6. Chemicals costs

Direct comparison of chemical costs of the assessed plants is difficult because of the difference in treatment levels for nitrogen and phosphorus removal, as well as for disinfection.

Chemical costs include the following expenses:

- Chemicals for phosphorus removal ($FeSO_4$, polymers, etc.);
- Chemicals for post-denitrification (methanol);
- Chemicals for sludge dewatering (coagulants, flocculants); and
- Chemicals for disinfection (hypochloride, chlorine gas, PAA, etc.).

Figure 25 illustrates chemical costs in wastewater treatment plants in Spain. Similar chemical costs are reported for plants with similar treatment schemes and the same order of capacity. For example, tertiary treatment by coagulation/flocculation and chlorination combined with sludge dewatering by centrifugation needs equivalent chemical costs of 0.34±0.03 €/p.e./year for plant capacity of 7400 to 20,000 p.e.

The chemical cost for a large plant of 75,000 p.e. with similar treatment scheme is, however, increased twice to 0.65 €/p.e./year.

Significantly higher chemical costs are required for chemical sludge dewatering up to 1.3 and 2.8 €/p.e./year for plant size of 67,000 and 75,000 p.e., respectively.

The effect of plant size is not obvious because these wastewater treatment plants are operated at variable loading rates during winter and summer due to high tourist activity. To better compare the contribution of chemical costs depending on plant size and treatment scheme, chemical operating costs are recalculated in €/m3/year (Figure 26).

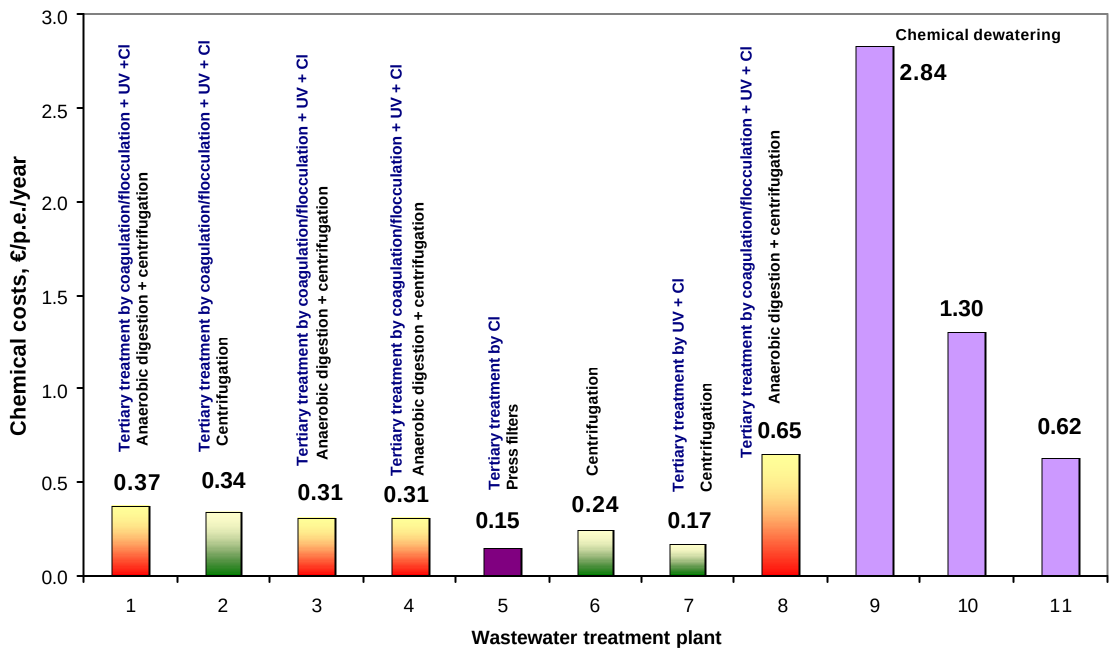


Figure 25 Chemical costs of wastewater treatment plants in Spain in €/p.e./year

In this case, for plant capacities of 7400 to 20,000 p.e. and similar treatment scheme, chemical costs vary from 0.012 to 0.041 €/m^3. As expected, the lower costs of 0.005 €/m^3 are needed for press filters and chlorination. For a similar plant capacity of 75,000 p.e., operating costs for chemical sludge dewatering are significantly higher compared to centrifugation and full tertiary treatment, 0.041 versus 0.008 €/m^3, respectively.

4.7. Sludge disposal costs

Despite the method of sludge valorisation, such as agriculture, industries and others, specific sludge disposal costs depend on the cost of transportation and storage.

Reported sludge disposal costs in different EU countries vary from 0.06 to 5.82 €/p.e./year with typical values of 1 to 3 €/p.e./year. The influence of scale is not significant.

The unit cost of sludge discharge depends on local conditions. For example in Spain, the cost of sludge disposal per ton dry matters (DM) is 15 €/t DM in the region of Madrid, while in Costa Brava high variations are reported from 8 to 60 €/t DM.

A recent survey of sludge treatment and disposal costs in France (Ferry and Wiart, 2000) on 71 wastewater treatment plants showed typical values for sludge recycling in agriculture of 15 to 25 €/t DM. Land filling, composting and incineration are associated with higher costs from 25 to 90 €/t DM.

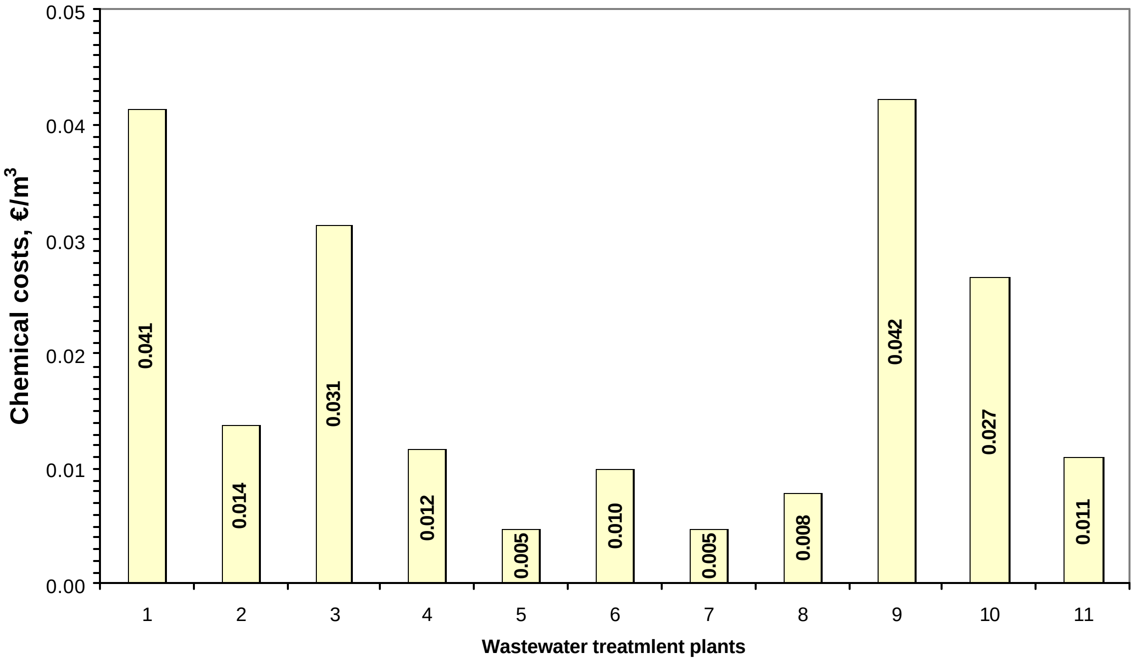


Figure 26 Chemical costs of wastewater treatment plants in Spain expressed in €/m^3

With the implementation of the new EU Directive of Urban Wastewater Treatment and the prohibition of landfill sludge discharge, significant increase in sludge disposal costs can been expected.

A recent assessment of economic impacts of the revision of the EU Directive 86/278/EEC carried out by Andersen consulting for the European Commission (Aubain, 2001) demonstrated that global costs of sludge disposal routes range from 110-160 €/t DM for land spreading of semi-solid sludge to 260-350 €/t DM for land filling, co-incineration and mono-incineration of sludge. Silviculture, land spreading of composted sludge and land reclamation costs are in the middle range of 210-240 €/t DM.

The implementation of the Sludge Directive by 2015 will be associated with an estimated cost of 400 million €/year for the Member States, which can increase to 1.2 billion €/year for the worst case scenario where land spreading is not possible.

5. CONCLUSIONS AND TYPICAL BREAKDOWN OF CAPITAL AND OPERATING COSTS OF WASTEWATER TREATMENT

As mentioned previously, the components of capital and operating costs depend on treatment scheme, level of treatment, constraints for effluent and sludge discharge and local conditions.

The comparison of capital costs, assessed in this survey and from other national or international studies and literature data is very difficult because plants have been build at different times, and very often step by step with one to three extensions. The degree of depreciation and depreciation period also differ. In addition, loans have been signed at different interest levels, 6, 8 or 10% for the time periods of 2000-2004 to 1980-1985, respectively.

The difference in currencies and currency values make trans-national comparisons problematic. In same cases, correction factors have been applied to take into account inflation rates. Nevertheless, direct comparison of various data from different countries and different periods of times can be considered as with low precision and used only to illustrate the main trends of variation.

When operating costs are examined and compared, the task is even more challenging, because some costs such as electricity and chemicals must be related to actual loads, while maintenance costs are mostly related to plant design capacity. The only operating cost item that easily can be related to treated flow is pumping, but very often no information is provided on the specific pumping costs. However, such correlation with the overall treated flow could be more representative for comparison of operating costs in the Mediterranean coastal region, where wastewater treatment plants are operated in much higher loading rates during the summer tourist season.

The costs of wastewater treatment that ideally should be compared are the life-cycle costs. Nevertheless, it is worth nothing that the life of wastewater treatment works varies in large limits and often includes several plant extensions.

The analysis of the survey data demonstrated that average annualised capital costs related to design capacity of large wastewater treatment works with nutrient removal vary from 16 to 60 €/p.e. with maximum values observed in Northern European countries with stringent discharge standards. Significantly lower expenses are needed for conventional activated sludge treatment as illustrated by the average values in Greece and Spain of 16 and 23 €/p.e., respectively. Calculated per unit treated volume, total average wastewater treatment cost in Northern European countries is about of 1 €/m^3, which is almost the double compared to the lower values of about 0.6 €/m^3 in Italy and the Netherlands. Average wastewater treatment costs of conventional activated sludge is almost 2-3-times lower in Southern EU countries such as Greece and Spain, *i.e.* 0.3-0.35 €/m^3. Wastewater treatment costs are higher +50 to +100% for medium size works (<50,000 p.e.) and significantly higher +200 to +500% for small-scale plants (<2000 p.e.). In addition to the influence of plant capacity, specific capital costs increase with +50 to +250% with the increase of the treatment level from conventional activated sludge treatment to full nutrient removal and disinfection.

The needed investment for full biological treatment and disinfection for the production of high-quality recycled water may by more than double compared to conventional activated sludge. For example, for plant capacity of 200,000 to 1,000,000 p.e., average annualised capital costs of full treatment and disinfection are 45±3 €/p.e./year compared to 24±5 €/p.e./year for conventional activated sludge (525±40 €/p.e versus 270±60 €/p.e).

Compared to large wastewater treatment plants, the effect of size for small works (2000 to <100 p.e.) is very high either for capital and operating costs. Capital costs, for example, decrease 10-fold from 2000 to 200 €/p.e. as population served increases from 100 to 2000 p.e. For small works of about 500 p.e., reed-beds and infiltration-percolation could be the most competitive treatment options. For larger works of about 2000 p.e., rotating biological contactors and activated sludge (package plants or oxidation ditches) become cost competitive solutions. As mentioned earlier, excluding land costs, stabilization ponds may be the most cost competitive solution with an average cost of 120±70 €/p.e. for average plant capacity of 1000 p.e. For such plant capacity, infiltration-percolation and trickling filters would be also an economic option, 150±75 €/p.e. and 180±80 €/p.e., respectively. Extended aeration could be a competitive solution in the case of high land costs and constraonts, requiring 230±70 €/p.e. of investment.

The analysis of the survey results shows that the contribution of operating costs vary from 41 to 75% of the total annual costs. According to these data, average operating costs in European countries are in the range of 56±12% (conventional activated sludge systems).

Specific O&M costs vary from 0.1 to 24 €/p.e./year. Typical net operating costs are about 5 to 10 €/p.e./year for plant size of 20,000 to 1,000,000 p.e. Higher costs are characteristic for the countries from North Europe with high level of nutrient removal (N and P). In the Mediterranean region, specific operating costs are higher for plants with tertiary treatment and reuse, *i.e.* 5 to 16 €/p.e./year.

Small plants need significantly higher operating costs of 10 to 100 €/p.e./year.

About 70% of operating costs are labour and energy. In general, the contribution of energy and labour is lower, 40 to 50%, for large activated sludge plants, mostly because the high expenses for sludge treatment (chemicals) and disposal.

The major component of operating costs of wastewater treatment in Europe is labour for operation & maintenance and administration, which accounts for 25 to 70% of total operating costs, repair and maintenance included. The typical value is 45±5%. Labour costs vary from 1 to 15€/p.e./year depending on plant size, load variations, treatment technology and automation. Typical reported values (plant capacity 50,000-100,000 p.e.) are 5-10 €/p.e./year in Northern Europe (Austria, Germany, Sweden) and 1.5-5 €/p.e./year in Southern Europe (France, Greece, Spain).

Energy consumption is the second large component with values from 12 to 29% of total operating costs. For plant capacity over 10,000 p.e., specific energy costs vary from 1 to 4.7 €/p.e./yr with typical value of 2.5±0.5 €/p.e./yr. No significant influence of plant size is observed for conventional activated sludge treatment with a typical energy consumption of 25±5 kWh/p.e. Extended aeration requires about 20% less energy. Advanced treatment processes and disinfection involve higher energy consumption of up to 45 to 100 kWh/p.e.

Direct comparison of chemical costs of the assessed plants is difficult because the difference in treatment levels for nitrogen and phosphorus removal, as well as for disinfection.

Sludge disposal costs in different EU countries vary from 0.06 to 5.82 €/p.e./year with typical values of 1 to 3 €/p.e./year. Depending of sludge disposal route, the unit costs per ton dry matter vary from 8 to over 90 €/t DM with lower values for landspreading and highest values for incineration. The influence of scale is not significant. With the implementation of the EU Sludge Directive 86/278/EEC, significant increase in sludge disposal costs is expected to 110-160 €/t DM for landspreading and up to 260-350 €/t DM for incineration.

It is important to stress that the reported costs are given only for illustration and they cannot be transferred to other projects because of the strong influence of local factors and the use of different cost estimation methodologies.

The next two tables (Table 3 and Table 4) provide the list of cost components that need to be taken into account during development of wastewater treatment projects and comparison of treatment options. The typical values and range of variations have been estimated on the basis of the survey results and literature data.

Table 3

Typical breakdown of capital costs

Type of cost	Component	Cost weight
Construction costs	Civil works	Technology-specific
	Equipment	Technology-specific
	Installation	25-55% of equipment costs
	Piping	30-60% of equipment costs
	Instrumentation and control	6-30% of equipment costs
Indirect costs	Engineering	15% of total construction costs
	Contingency	15% of total construction costs

Table 4

Typical breakdown of operating costs

Type of cost	Component	Cost weight
Current operating costs	Labour	Technology-specific, 25 to 70% of operating costs 1 to 15 €/p.e./year 1 employee per 2000 to 16,000 p.e.
	Power consumption Maintenance Chemicals	Technology-specific, 11 to 52% of operating costs 1 to 4.7 €/p.e./year 5 to 40 kWh/p.e./year (25±5 kWh/p.e./year for conventional activated sludge) high energy costs of advanced treatment, up to 45-100 kWh/p.e./year Anaerobic digestion can provide up to 50% energy saving 4% (2 to 6%) of total capital costs Technology-specific 0.1 to 3 €/p.e./year
	Sludge disposal	Location specific 0.06 to 6 €/p.e./year 8 to 90 €/t DM
	Water quality monitoring	Depending on water quality requirements Very often not specified 1 to 9% of operating costs
Administrative costs	Taxes and insurance	2% of total capital costs 2 to 19% of operating costs

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Web sites (Glossary):
http://glossary.eea.eu.int/EEAGlossary
http://www.wef.org/publicinfo/newsroom/wastewater_glossary.jhtml

GLOSSARY

Advanced wastewater treatment: The process which removes pollutants not adequately removed by secondary treatment, particularly nitrogen and phosphorus; accomplished by means of sand filters, micro-straining, or other methods. Similar to tertiary treatment.

Aeration: The process of exposing to circulating air.

Aerobic: Living or occurring in the presence of oxygen.

Alternative: The choice between two or more possibilities; one of the two or more possible choices.

Biodegradable: Capable of being decomposed (broken down) by natural biological processes.

Biological wastewater treatment: Processes which employ aerobic or anaerobic micro-organisms and result in decanted effluents and separated sludge containing microbial mass together with pollutants. Biological treatment processes are also used in combination and/or conjunction with mechanical and advanced unit operations. Similar to secondary treatment.

Biosolids: Solid materials resulting from wastewater treatment that meet government criteria for beneficial use, such as for fertilizer.

Capital cost: See also ‘Initial investment cost’. The capital cost of a depreciable property is usually the total of: the purchase price, not including the cost of land (which is not depreciable); the part of legal, accounting, engineering, installation, and other fees that relates to the purchase or construction of the depreciable property (not including the part that applies to land); the cost of any additions or improvements made to the property after acquisition, provided these costs have not been claimed as a current expense; and soft costs (such as interest, legal and accounting fees, and property taxes) related to the period of construction, renovation, or alteration of the building, if these expenses have not been deducted as current expenses.

Chlorination: Water disinfection by chlorine gas or hypochlorite.

Coastal area: The part of the land affected by its proximity to the sea, and that part of the sea affected by its proximity to the land as the extent to which man's land-based activities have a measurable influence on water chemistry and marine ecology.

Coliforms: Bacteria found in the intestinal tract of warm-blooded animals; used as indicators of faecal contamination in water.

Composting: The controlled biological decomposition of organic material in the presence of air to form a humus-like material. Controlled methods of composting include mechanical mixing and aerating, ventilating the materials by dropping them through a vertical series of aerated chambers, or placing the compost in piles out in the open air and mixing or turning it periodically.

Constructed wetlands: Wetlands that are designed and built similar to natural wetlands; some are used to treat wastewater. Constructed wetlands for wastewater treatment consist of one or more shallow depressions or cells built into the ground with level bottoms so that the flow of water can be controlled within the cells and from cell to cell. Roots and stems of the wetland plants form a dense mat where biological and physical processes occur to treat the wastewater. Constructed wetlands are being used to treat domestic, agricultural, industrial, and mining wastewaters.

Contaminant: An impurity, that causes air, soil, or water to be harmful to human health or the environment.

Cost: Cost is the value that must be given up to acquire a good or service.

Discharge: In the simplest form, discharge means outflow of water. The use of this term is not restricted as to course or location and it can be applied to describe the flow of water from a pipe or from a drainage basin. If the discharge occurs in a course or channel, it is correct to speak of the discharge of a canal or of a river. It is also correct to speak of the discharge of a canal or stream into a lake, stream or ocean. Discharge is a comprehensive outflow term. Other words related to it are runoff, stream flow and yield.

Discount rate: The rate of interest that balances an investor's time value of money.

Desalination: The removal of salts from saline water to provide freshwater. This method is becoming a more popular way of providing freshwater to populations.

Effluent: Waste material, such as water from sewage treatment or manufacturing plants, discharged into the environment.

Electricity: A general term used for all phenomena caused by electric charge whether static or in motion.

Energy efficiency: Refers to actions to save fuels by better building design, the modification of production processes, better selection of road vehicles and transport policies, the adoption of district heating schemes in conjunction with electrical power generation, and the use of domestic insulation and double glazing in homes.

Environment: The sum of all external conditions and influences affecting the development and life of organisms.

Filtration: The process of passing a liquid or gas through a porous article or mass (paper, membrane, sand, etc.), to separate matter in suspension.

Flocculation: The process of forming aggregated or compound masses of particles, such as a cloud or a precipitate.

Fresh water: Water containing an insignificant amount of salts, such as in inland rivers and lakes.

Groundwater recharge: The addition of water to an aquifer.

Incineration: Controlled process by which solid, liquid, or gaseous combustible wastes are burned and changed into gases; residue produced contains little or no combustible material.

Initial investment cost: Any cost of creation of a facility prior to its occupation.

Integrated management: Unified, combined and coordinated management of problems which correlates relevant organizations, groups, individuals and disciplines by bringing the parts together for a complete approach.

Lagoon: As a wastewater treatment method, an animal waste treatment method which uses a deep pond to treat manure and other runoff from a livestock operation may be aerobic or anaerobic (both use bacteria to break down wastes).

Land: The terrestrial bio-productive system that comprises soil vegetation, other biota, and the ecological and hydrological processes that operate within the system.

Landfill: A large outdoor area for waste disposal; landfills where waste is exposed to the atmosphere (open dumps) are now illegal; in "sanitary" landfills, waste is layered and covered with soil.

Life cycle: Consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to the final disposal.

Life cycle cost: The cost of a good or service over its entire life cycle. Represents the sum of all costs of creation and operation of a facility over a period of time.

Maintenance cost: Any cost of scheduled upkeep of building, equipment and other components of a wastewater treatment facility.

Monitoring: Testing that water systems must perform to detect and measure contaminants.

Municipal wastewater: Discharge of effluent from wastewater treatment plants which receive wastewater from households, commercial establishments, and industries. Combined sewer/separate storm overflows are included in this category.

Nutrient: Chemical elements which are involved in the construction of living tissue and which are needed by both plant and animal. The most important in terms of bulk are carbon, hydrogen and oxygen, with other essential ones including nitrogen, potassium, calcium, sulphur and phosphorus.

Nutrient removal: Elimination of nutrients from wastewater in order to prevent water eutrophication.

Operation or operating cost: Any cost of the daily function of a facility. This value represents the maximum expenditure for material, labour, outsourcing, overheads, and all other costs associated with any project.

Package plants: A small, semi-portable prefabricated wastewater treatment system that services an apartment complex, trailer park, camp, or self-contained business that is not connected to a city sewer system and is not on a site appropriate for a septic system.

Population equivalent: One population equivalent (p.e.) means the organic biodegradable load having a five-day biochemical oxygen demand (BOD5) of 60g of oxygen per day.

Price: The amount someone is prepared to pay for an activity or a good.

Primary wastewater treatment: The first stage of the wastewater-treatment process where mechanical methods, such as filters and scrapers, are used to remove pollutants. Solid material in sewage also settles out in this process.

Raw wastewater: Wastewater without any wastewater treatment.

Reclaimed wastewater: Treated wastewater that can be used for beneficial purposes, such as irrigating certain plants.

Recycled water: Water that is used more than once before passing back into the natural hydrologic system.

Regulation: A governmental order having the force of law.

Repair cost: Any cost of unscheduled upkeep of a building or equipment that does not require replacement of the entire system.

Replacement cost: Any cost of scheduled replacement of a building, equipment or any component of a facility that has reached the end of its design life.

Reverse osmosis: The process of removing salts from water using a membrane. With reverse osmosis, the product water passes through a fine membrane that the salts are unable to pass through, while the salt waste (brine) is removed and disposed of. This process differs from electrodialysis, where the salts are extracted from the feed water by using a membrane with an electrical current to separate the ions. The positive ions pass through one membrane, while the negative ions flow through another membrane, leaving the end product of freshwater.

Sanitation: The application of measures and techniques aimed at ensuring and improving general hygiene in the community, includingthe collection, evacuation and disposal of liquid and solid wastes, as well as measures for creating favourable environmental conditions for health and disease prevention.

Sensitive area: Areas of a country where special measures may be applied to protect the natural habitats that present a high level of vulnerability.

Secondary treatment: see also 'biological wastewater treatment'. Secondary wastewater treatment may be accomplished by biological or chemical-physical methods. Activated sludge and trickling filters are two of the most common means of secondary treatment. It is accomplished by bringing together waste, bacteria, and oxygen in trickling filters or in the activated sludge process. This treatment removes suspended and non-suspended solids and about 90 percent of the oxygen-demanding substances and suspended solids.

Sewage: Wastewater produced by residential and commercial establishments and discharged into sewers.

Sewage sludge: The accumulated settled solids separated from various types of water, either moist or mixed with a liquid component as a result of natural or artificial processes.

Sewage sludge directive: Council Directive 86/278/EEC on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture. The purpose of this Directive is to regulate the use of sewage sludge in agriculture in such a way as to prevent harmful effects on soil, vegetation, animals and man, thereby encouraging the correct use of such sewage sludge.

Sewage treatment plant: see 'wastewater treatment plant'.

Sludge: A semi fluid mass of sediment resulting from the treatment of water, sewage and/or other wastes.

Treatment: A substance with which to treat water or a method of treating water to clean it.

Treatment plant: Facility for cleaning and treating fresh water for drinking, or cleaning and treating wastewater before discharge into a water body.

Tertiary treatment: See also 'advanced wastewater treatment'. Selected biological, physical, and chemical separation processes to remove organic and inorganic substances that resist conventional treatment practices; the additional treatment of effluent beyond that of primary and secondary treatment methods to obtain a very high quality of effluent. Commonly, the tertiary wastewater treatment process consists of flocculation basins, clarifiers, filters, and chlorine basins or ozone or ultraviolet radiation processes.

Ultraviolet light: Similar to light produced by the sun; produced by special lamps. When organisms are exposed to this light, they are damaged or killed.

User charge: Charge paid for a specific environmental service provided to the payer. Example: treating wastewater or disposing of waste.

Wastewater: Water that has been used for domestic or industrial purposes.

Wastewater charge: Imposed fee, expense, or cost for the management of spent or used water that contains dissolved or suspended matter from a home, community farm, or industry.

Wastewater treatment: Physical, chemical, and biological processes used to remove pollutants from wastewater before discharging it into a water body.

Wastewater treatment plant: Plant where organic matter, bacteria, viruses and solids are removed through physical-chemical and biological processes, from residential, commercial and industrial wastewaters before they are discharged in rivers, lakes and seas.

Water pricing: Applying a monetary rate or value at which water can be bought or sold.

Water quality: The condition of water with respect to the amount of impurities in it. This term is used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water reuse: Treated wastewater can be indirectly reused when it is discharged into a watercourse, diluted and used again downstream. Direct reuse means the direct supply of treated effluent from the treatment plant to the user. It also can apply to the recharge of an aquifer.

Water use : Water that is used for a specific purpose, such as for domestic use, irrigation, or industrial processing. Water use pertains to human interaction with and influence on the hydrologic cycle and includes elements, such as water withdrawal from surface- and ground-water sources, water delivery to homes and businesses, consumptive use of water, water released from wastewater-treatment plants, water returned to the environment, and in-stream uses, such as using water to produce hydroelectric power.

APPENDIX 1 SURVEY QUESTIONNAIRE (ENGLISH AND FRENCH)

MED POL/WHO

Survey Questionnaire
Financial Aspects of Wastewater Treatment in the Mediterranean Region

Could you please consider and reply to the questions below to assist the Mediterranean Action Plan through MED POL to elaborate a synthetic document on the financial aspects of wastewater treatment to different quality levels and provide comparative analysis for the operation of treatment plants in the framework of a better water reuse strategy.
Do not hesitate to provide relevant attachments.

1. Project Identification

Name and Location of the wastewater treatment plant____________________

____
Year of construction/upgrading____________________
Plant operator:____________________ Plant owner:____________________
Activities outsourced : ____________________
Contact person name ____________________
Address____________________

____
Phone:____________________ Fax:____________________
E-mail:____________________

2. Characteristics of the Wastewater Treatment Plant

Please indicate both design and real values

Plant capacity (people equivalent)____________________
☐<2000p.e ☐2000-5000p.e ☐5000-10,000p.e ☐10,000-50,000p.e ☐50,000-100,000p.e ☐>100,000p.e

Plant daily flow rate (m^3/d)____________________
Peak dry whether flow rate (m^3/h)____________________
Peak wet whether flow rate (m^3/h)____________________
Organic loads: kgBOD/d:____________________ kgCOD/d:____________________
Percentage of industrial influents:____________________ %
Type of sewers: ☐Separated ☐Combined

Wastewater treatment processes: ☐Storm buffer tank ☐Screening ☐Primary settling ☐Activated sludge ☐Trickling filter ☐Biodiscs ☐Oxidation ponds ☐Lagoons ☐Chlorination ☐UV disinfection ☐Others:____________________

Sludge treatment processes: ☐Thickening ☐Chemical deshydratation ☐Anaerobic digestion ☐Others____________________

3. Level of Treatment, Discharge or Reuse

Please indicate the values of the treatment consent, and if available, the additional treatment limits in the case of reuse

Treatment level: ____________ mgSS/L:____________ mgBOD/L:____________ mgCOD/L:
____________ Fecal Coliforms #/100mL: Others:____________

Effluent discharge: ☐River ☐Sea ☐Other:____________________
Charges to pay for effluent discharge: ☐No ☐Yes ☐Specify:____________________
Financial penalty for non conformity: ☐No ☐Yes ☐Specify:____________________
Collection rates of charges (if available):____________________
Collection rates of penalties (if available):____________________
Total revenue collected from charges (if available):____________________
Total revenues collected from penalties (if available):____________________

Please send you reply to Dr. George Kamizoulis, E-mail: whomed@hol.gr Fax: +30.210.7253196 / 7
and to the reporter Dr. Valentina Lazarova, E-mail: valentina.lazarova@suez-env.com Fax: +33.1.30 53 62 11

Water reuse: ☐No ☐Yes

Type of reuse:____

Annual volume of reclaimed water: ____

Number of end-users of recycled water:______________________________________

Sludge valorisation: ☐No ☐Yes ☐Specify:___________________________

Charges to pay for sludge disposal: ☐No ☐Yes ☐Specify:_______________________

4. Capital and Operation Costs

Please specify year or average of several years or historic data (5 years, for example). Please provide a breakdown of the costs if available. Costs can also be referred in your national currency. In this case, please be sure to indicate the currency

Overall capital costs in ☐€ ☐Other currency (specify)_____________________________

Overall operation costs in ☐€ ☐Other currency (specify)___________________________

Number of employees:____

Average unit cost of manpower: ______________________________________€/h

Unit energy cost: ____€/kWh

Specific energy consumption____kWh/m^3

Overall annual cost of manpower: _______________________________________€

Overall administrative costs including training:

Overall annual energy cost: ____€

Overall annual cost of chemicals_______________________________________€

Type of chemicals:____

Overall cost of pumping: ____€

Pumping equipment:____

Cost of heating:____€

Cost of ventilation, air-conditioning and odor treatment______________________€

Overall cost of sludge discharge:____

Annual quantity of sludge production:______________________________tonnes

Mode of sludge disposal/valorisation:_____________________________________

Cost of repair and maintenance:_______________________________________€

List of the electromechanical equipment:___________________________________

Water quality monitoring costs:_______________________________________€

Type of analysis and frequency:____

Other specific expenses related to plant operation:_______________________________

4. Life Cycle Annualized Costs

Overall unit cost of treatment (operation and amortisation of capital costs):___________**$€/m^3$**

Interest or discount rate: ____

Comments:____

On behalf of the MED POL Programme, we would like to sincerely ***thank you*** *for your help in completing this document and sharing your experience. As soon as the survey will be completed we will provide you all the available results.*

Do not hesitate to transfer this survey to other colleagues with relevant experience in the field.

Please send you reply to Dr. George Kamizoulis, E-mail: whomed@hol.gr Fax: +30.210.7253196 / 7
and to the reporter Dr. Valentina Lazarova, E-mail: valentina.lazarova@suez-env.com Fax: +33.1.30 53 62 11

MED POL/WHO

Questionnaire d'enquête

Aspects financiers de l'épuration des eaux usées dans la région méditerranéenne

Veuillez étudier le questionnaire ci-dessous et y répondre afin d'aider le Plan d'action pour la Méditerranée, au titre du MED POL, à élaborer un document de synthèse sur les aspects financiers de l'épuration des eaux usées à différents niveaux de qualité et à fournir une étude comparative pour l'exploitation des stations d'épuration dans le cadre d'une meilleure stratégie de réutilisation de l'eau. N'hésitez pas à fournir toute documentation relative.

1. Identification du projet

Dénomination et emplacement de la station d'épuration______________________________

Année de construction/rénovation______________________________

Exploitant de la station:________________ Propriétaire de la station:________________

Activités hors site : ______________________________

Nom de la personne à contacter______________________________

Adresse______________________________

Téléphone:________________ Fax:________________

E-mail:______________________________

2. Caractéristiques de la station d'épuration

Veuillez indiquer les valeurs prévues à la conception et les valeurs réelles

Capacité de la station (équivalent-habitant)______________________________

☐<2000e.h ☐2000-5000e.h ☐5000-10,000e.h ☐10,000-50,000e.h ☐50,000-100,000e.h ☐>100,000e.h

Débit journalier de la station (m^3/j)______________________________

Débit de pointe par temps sec (m^3/h)______________________________

Débit de pointe par temps de pluie (m^3/h)______________________________

Charges organiques: kgDBO_5/j:________________ kgDCO/j:________________

Pourcentage d'affluents industriels:________________%

Type du réseaux d'égouts: ☐Séparatif ☐Unitaire

Procédés de traitement des eaux usées: ☐Réservoir tampon d'orage ☐Dégrillage ☐Décantation primaire ☐Boues activées ☐Lits bactériens ☐Disques biologiques ☐Chenaux d'oxydation ☐Lagunage ☐Chloration ☐Désinfection aux UV ☐Autres:________________

Procédés de traitement des boues: ☐Épaississement ☐Déshydratation chimique ☐Digestion anaérobie ☐Autres______________________________

3. Niveau de traitement, rejet ou réutilisation

Veuillez indiquez les valeurs du permit de traitement, et si disponible, les limites supplémentaires de traitement en cas de réutilisation

Niveau de traitement: ________mgSS/L;________mgDBO/L;________mgDCO/L;________Coliformes fécaux #/100mL; Autres:________________

Rejet de l'effluent: ☐Cours d'eau ☐Mer ☐Autre:______________________________

Redevance à acquitter pour le rejet d'effluent: ☐Non ☐Oui ☐Préciser:________________

Amende à acquitter pour non conformité: ☐Non ☐Oui ☐Préciser:________________

Taux de recouvrement des redevances (si disponibles):______________________________

Taux de recouvrement des amendes (si disponibles):______________________________

Recette totale provenant des redevances (si disponible):______________________________

Recette totale provenant des amendes (si disponible):______________________________

Veuillez adresser le questionnaire rempli à M. George Kamizoulis, E-mail: whomed@hol.gr Fax: +30.210.7253196 / 7 ainsi qu' au rapporteur M^me Valentina Lazarova, E-mail: valentina.lazarova@suez-env.com Fax: +33.1.30 53 62 11

Réutilisation des eaux: ☐**Non** ☐**Oui**

Type de réutilisation:__________

Volume annuel d'eau réutilisée: __________

Nombre d'utilisateurs finaux de l'eau recyclée:__________

Valorisation des boues: ☐Non ☐Oui ☐Préciser:__________

Redevances à acquitter pour le rejet des boues: ☐Non ☐Oui ☐Préciser:__________

4. Dépenses d'investissement et coûts d'exploitation

Veuillez spécifier l'année ou la moyenne sur plusieurs années ou les données chronologiques (pour 5 années, par exemple). Veuillez fournir la ventilation des dépenses et des coûts (si disponible). Les montants peuvent être indiqués dans votre monnaie nationale, en spécifiant bien cette monnaie.

Dépenses globales d'investissement en ☐€ ☐Autre monnaie (préciser)__________

Coûts globaux d'exploitation en ☐€ ☐Autre monnaie (préciser)__________

Nombre d'employés:__________

Coût unitaire moyen de la main d'oeuvre: __________€/h

Coût unitaire de l'énergie: __________€/kWh

Consommation d'énergie spécifique__________kWh/m^3

Coût annuel global de la main d'oeuvre: __________€

Coûts administratifs globaux (formation y comprise):

Coût annuel global de l'énergie: __________€

Coût annuel global des produits chimiques__________€

Type des produits chimiques:__________

Coût annuel global du pompage: __________€

Matériel de pompage:__________

Coût de chauffage:__________€

Coût de la ventilation, de la climatisation et de la désodorisation__________€

Coût global du rejet des boues:__________

Quantité annuelle de boues produites:__________tonnes

Mode d'élimination/valorisation des boues:__________

Coût de l'entretien et de la maintenance:__________€

Liste du matériel électromécanique:__________

____

Coûts de la surveillance de la qualité des eaux:__________€

Type d'analyses et fréquence:__________

____

Autres dépenses spécifiques concernant l'exploitation de la station:__________

____

5. Coûts annualisés sur le cycle de vie

Coût unitaire global de l'épuration (coûts d'exploitation et d'amortissement du capital investi):

__________**€/m^3**

Taux d'intérêt ou d'escompte:__________

Observations:__________

____

Au nom du programme MED POL, nous tenons à ***vous remercier*** *sincèrement pour votre concours dans le cadre de ce questionnaire et la communication de vos données d'expérience. Dès que l'enquête sera achevée, nous vous adresserons tous les résultats disponibles. N'hésitez pas à transmettre cette enquête à d'autres collègues ayant une expérience pertinente dans ce domaine.*