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Development of Tools and Guidelines for the Promotion of the Sustainable Urban Wastewater Treatment and Reuse in the Agricultural Production in the Mediterranean Countries

(MEDAWARE)

Task 3: Analysis of Best Practices and Success Stories

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"*water should not be judged by its history, but by its quality*" - D. Lucas van Vuuren (Twenty-five years of wastewater reclamation in Windhoek, Namibia. J. Haarhoff & B. Van der Merwe).

Introduction

In this document many examples of the potential benefits of wastewater reuse in different countries will be present. Naturally, they are most obvious for the arid areas but the general increasing pressures on water resources all over the world should also make wastewater reuse attractive in other areas.

Te use of reclaimed water is usually evaluated in terms of the following reuse categories, also summarized in Figure 1:

Agricultural reuse: Historically, agricultural irrigation has constituted more than 50% of all reuse activities (*Asano*, 1998). Within the agricultural reuse alternative, irrigation with reclaimed water may be utilized for food crops (spray or surface irrigation), fodder, fibre and seed crops and pasture for milking animals.

Landscape irrigation: Urban irrigation of landscaped areas using reclaimed water represents the fastest growing reuse option. Because residential and commercial landscape watering comprise more than 40 % of the total water consumption in arid or semi-arid regions, substitution of reclaimed water for potable water in a dual distribution system can generate significant long-term benefits to a community´s water supply sources. Based on the potential for public exposure to reuse activities, reclaimed water irrigation of landscaped areas can be divided into the following sub-categories: golf course, cemetery, freeway median and greenbelt irrigation and parks, playgrounds and schoolyard irrigation.

Impoundments: man-made ponds lakes or reservoirs constructed to store or hold reclaimed water are referred to as impoundments. Depending upon public access limitations or use restrictions, impoundments may be grouped under the following sub-headings: restricted recreational impoundments (recreation limited to fishing, boating and other non-body contact water recreation activities), non-restricted recreational impoundments (no limitation imposed on body contact water sport activities) and landscape impoundment (no public contact allowed).

Groundwater recharge: The use of reclaimed water for groundwater recharge and the control of saltwater intrusion may be accomplished through either injection wells and surface spreading basins. Recharge which represents an indirect potable water reuse option is employed to reduce, stop or reverse declines in groundwater levels due to aquifer overdrafting; provide a means to store treated effluent for future beneficial purposes and protect underground freshwater in coastal aquifers against salt water intrusion. Examples of large groundwater recharge projects in USA include Water Factory 21, operated by the Orange Country Water District, San Jose Creek-Whittier Narrows Reclamation Plant, operated by Los Angeles County Sanitation District and the Fred Hervey Water Reclamation Project in El Paso, Texas.

Industrial reuse: Reclaimed wastewater has been utilized by industry for cooling water, process water and boiled feed water. To date, reclaimed municipal wastewater used as cooling water constitutes 99% of the total volume of industrial reuse water (*Asano*, 1998). Industries with potential process water reuse requirements include primary metal production , petroleum and coal products, tanning, lumber, textiles, chemicals, pulp and paper, food caning and soft drinks. Although the use of reclaimed water for boiler feed water is technically feasible, it has proven to be operationally difficult to achieve because of severe problems with scaling.

Livestock, wildlife and fisheries: Within this category, reclaimed water may be used for livestock and wildlife watering and fisheries habitat (warm water and cold water fisheries).

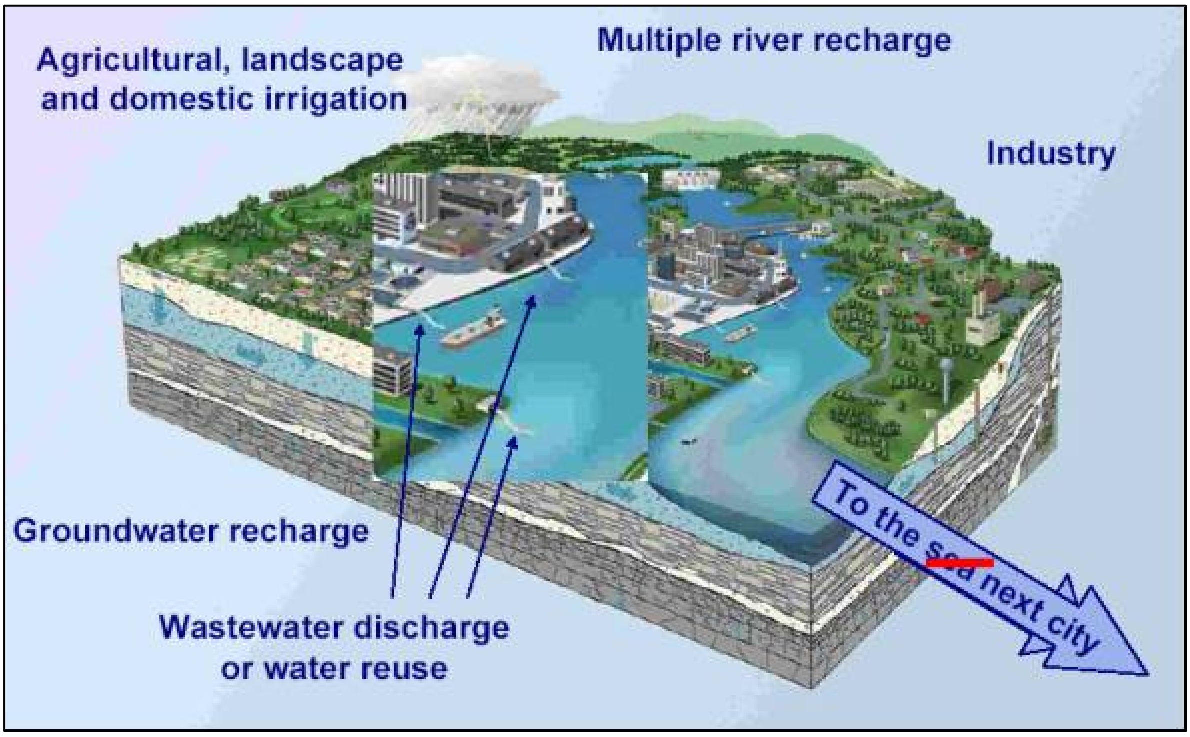

Figure 1. Wastewater reuses (Source: USEPA).

In many countries urban wastewater is used to irrigate agricultural land. The use of wastewater for irrigation is a way of disposing urban sewage water with several advantages. Wastewater contains a lot of nutrients, which make the crop yields increase without using fertilizer. Furthermore, sewage water is an alternative water source in arid and semi-arid areas where water is scarce. Besides these advantages, wastewater can contain heavy metals, organic compounds and a wide spectrum of enteric pathogens which have a negative impact on the environment and human health.

In 1989 WHO set guidelines for the maximum number of bacteria and helminth eggs in wastewater used for irrigation to protect farmers and consumers of crops. Treatment methods were developed to reduce the hazardous elements in wastewater before its use on agricultural fields. However, in many developing countries wastewater is still used without any treatment, as treatment plants are expensive and farmers are willing to use this nutrient rich water without treatment. Knowledge about costs and benefits of treatment in developing countries is limited, as is knowledge about the actual environmental and health risks of irrigation with untreated urban wastewater (*Feenstra et al.*, 2000).

Wastewater reuse can be a matter of choice in general water management strategy. Worldwide, wastewater reclamation and reuse is estimated to represent a potential extra water resource amounting to approximately 15% of existing water consumption. On a local basis this proportion can be significant higher (e.g., 30% of agriculture irrigation water and 19% of total water supply in Israel in the future). In view of the increasing pressure on all water resources, both in industrialized and in developing countries, supplementing water resources with reclaimed wastewater can not longer be neglected (*Asano*, 1998).

The Mediterranean region is characterised by the low level and irregularity of water resources, both through time (summer drought, interannual droughts) and through space (dry in the South). The region includes 60% of the world population with renewable national natural resources of less than 1,000 m^3 water/inhabitant/year. The strong growth in urbanisation, tourism, irrigation and population can only increase tensions in many countries and regions where consumption has already reached the amount of available resources.

On the other hand, the volume of wastewater is also increasing in the Mediterranean region. Large areas may be supplied with recycled water which may also be used for different other purposes depending on the demand, the water characteristics, its suitability, etc. Consequently, there is a major potential use of recycled water in the region. It is, however, essential that the development of water reuse in agriculture and other sectors be based on scientific evidences of its effects on environment and public health. Although several studies have been conducted on wastewater quality and for different purposes, at this time, there are no regulations of water reuse at a Mediterranean level. With the development of tourism and Mediterranean food market, there is a need for sharing a common rationale for developing water reuse criteria on both sides of the Mediterranean (*Kamizoulis et al.*, 2003).

According to the Blue Plan (*Margat* and *Vallée*, 2002), renewable water resources are very unequally shared across the Mediterranean basin with around 72% located in the North (Spain, France and Monaco, Italy, Malta, Bosnia-Herzegovina, Croatia, Slovenia, R.F. of Yugoslavia, Albania, and Greece), 23% in the East (Turkey, Cyprus, Syria, Lebanon, Israel, Palestinian Territories of Gaza and the West Bank, and Jordan), and 5% in the South (Egypt, Libya, Tunisia, Algeria, and Morocco). Countries of the Southern Mediterranean and Middle East region are facing increasingly more serious water shortage problems. Some of them have few naturally available fresh water resources and rely mainly on groundwater. Surface waters are already in most cases utilized to their maximum capacity. Groundwater aquifers are often over-drafted and sea and brackish water intrusion in coastal areas has reached threshold limits in some locations. Non-renewable deep or fossil aquifers are being tapped to varying degrees. Exploitation of non-renewable resources of Saharan aquifers is intensive in Libya, Egypt, Tunisia and Algeria. Desalination of brackish and seawater is already under implementation or planned in some countries despite its high cost. National exploitation ratios over 50%, or even nearing 100% in several Mediterranean countries (Egypt, Gaza, Israel, Libya, Malta, Tunisia) show that actual water consumption already exceeds the renewable conventional water resources. As a consequence, several problems appear all around the basin such as water and soil salinization, desertification, increasing water pollution, and unsustainable land and water use.

The Mediterranean basin is nowadays depending for its economic and social development on the agriculture (largest water use share reaching 61% on average, 42% to 84% of total demands) and tourism and, secondarily, on industry and other economic activities. Irrigated agriculture in competition with other sectors will face increasing problems of water quantity and quality considering increasingly limited conventional water resources and growing future requirements and a decrease in the volume of fresh water available for agriculture. Around the cities of the region, competition with other sectors often makes water the main factor that limits agricultural development. Policy makers have then been compelled to develop additional water resources as well as to preserve the existing ones. Reclaiming and recycling water is, among various measures, designed to encourage integrated and efficient management and use of water resources and is therefore becoming an important component of the national resources policy. The agricultural sector is influenced in the northern part by the common agricultural policy and in the Southern and Eastern parts by the agreements of agricultural exchange, and the future free trade area. Expansion of the irrigated area will continue in the southern and eastern countries with increasing demand for food and from the development of agricultural production for export markets. On the other hand, the irrigated sector will have to face major challenges with the future scenario of agricultural trade liberalization; a part of the water resources may be reallocated to high added-value export products instead of basic production or to industrial activities, tourism, and domestic water supply. Providing water quantities and qualities in compliance with the needs is one of the challenges facing the region (*Kamizoulis et al*., 2003).

Water recycling and reuse is meant to help close the water cycle and therefore enable sustainable reuse of available water resources (Figure 2). When integrated to water resources management, water reuse may be considered as an integral part of the environmental pollution control and water management strategy. It may present benefits to public health, the environment, and economic development. Recycled water may provide significant additional renewable, reliable amounts of water and contribute to the conservation of fresh water resources.

Figure 2. Benefits of water reuse.

It may be considered as a valuable source of water and nutrients in agriculture schemes and therefore contributes to reducing chemical fertilizers' utilization and to increasing agricultural productivity. Reuse of recycled water, if properly managed, may alleviate pollution of water resources and sensitive receiving bodies. It may also contribute to desertification control and desert recycling. Saline water intrusion may be controlled in coastal aquifers through groundwater recharge operations. Other social and economic benefits may result from such schemes such as employment and products for export markets. It is, however, essential that the development of reuse prevents negative effects on environment and public health since wastewater content in mineral and organic trace substances and pathogens represents a risk for human health. Adequate treatment has therefore to be provided for the intended reuse (*Kamizoulis et al*., 2003).

The main reuse projects in the Mediterranean region are related to agricultural and landscape irrigation, and groundwater recharge. The management of wastewater in the Mediterranean varies from country to country, as do the criteria and their enforcement. Some countries have no wastewater treatment facilities and direct reuse of raw wastewater is occurring with serious health hazards and environmental problems. Others have a well-established national reuse policy. Moreover, wastewater treatment and reuse criteria differ from one country to another and even within a given country such as in Italy and Spain. Some of the main discrepancies in the criteria are, in part, due to differences in approaches to public health and environmental protection. For example, some countries have taken the approach of minimising any risk and have elaborated regulations close to the California's Title 22 effluent reuse criteria, whereas the approach of other countries is essentially a reasonable anticipation of adverse effects resulting in the adoption of a set of water quality criteria based on the WHO (1989) guidelines. This has led to substantial differences in the criteria adopted by Mediterranean countries.

On the other hand, the increasing use of mineral fertilisers over the last decades has contributed to the appearance of numerous cases of water eutrophication, a new form of water pollution. The starting point of eutrophication is the increase of nutrient concentration (nitrogen and phosphorus) in a water mass, which is subsequently followed by an uncontrolled growth of primary producers and episodes of oxygen depletion due to microbial decomposition of algal organic matter. The excess nutrient loads reaching surface waters are usually associated to discharges from anthropogenic activities, which normally involve direct water usage instead of reuse of reclaimed effluents. Agriculture activities and livestock breeding are two of the main nutrient sources responsible for water eutrophication, as well as human – urban and industrial – wastewater discharges. Wastewater reclamation and reuse can be a suitable strategy for preserving the quality of natural waters, by suppressing effluent discharges and the associated nutrient contributions to receiving waters. Reuse of reclaimed water for agricultural and landscape irrigation as well as for environmental enhancement offers an adequate strategy for preserving natural water systems from eutrophication (*Sala* and *Mujeriego*, 2001).

Reclaimed water contains considerable amounts of nitrogen and phosphorus which can promote eutrophication of receiving waters; at the same time, agricultural and landscape irrigation requires systematic supplies of water and nutrients to be productive. A similar benefit can be obtained by using nutrients to develop trophic webs able to sustain wetland ecosystems, which have a high ecological value, but are in evident regression in many parts of the world. Thus, reclaimed water use either for irrigation or for environmental enhancement can be much more than an alternative water discharge and should be considered an additional component of the overall environmental protection system, together with the wastewater treatment itself, that can be used for improving natural water quality. This new approach should help politicians, planners, and developers to understand how water reclamation and reuse can provide a final and essential step in an integrated environmental protection strategy.

One of the newest applications for reclaimed water is environmental use for the restoration of those aquatic ecosystems affected by desiccation or pollution. In this case, the approach of the reuse activity is the opposite of that for agricultural or landscape irrigation. Whereas in the latter case the efforts are aimed at preserving public health (the effluents are disinfected, with or without a previous filtration step) and usually no specific treatment for nutrient removal is applied, in the case of environmental reuse it is necessary to provide a process to remove these elements, because otherwise the final result would be the eutrophication of the receiving waters.

Apart from the pond systems, generally well understood and easy to operate, another interesting option for the removal of nutrients in secondary effluents are the constructed wetland systems. Their high productivity makes them especially interesting for this purpose, since they are able to remove a large portion of nutrients from the water. This water can then be safely deposited in sensitive areas with a lower risk of eutrophication. The constructed wetland systems have a double benefit: on one hand, they are very efficient at reclaiming the water, especially with nitrified effluents, whereas on the other hand they provide areas with a high ecological interest because of their role of refuge for wildfowl and other wild animals.

If, with the use of reclaimed water for irrigation, the fate of the nutrients is to become part of the crops' biomass, in the constructed wetland systems, part of the nutrients are used to create a trophic web and to enhance the development of different forms of life, starting with the dissolved inorganic compounds. The algae growing in these compounds will provide dissolved oxygen to the ecosystem and they will also be the source of food for other organisms like protozoa, insects or crustaceans who, in turn, will be the source of food for higher, predator organisms, including birds. Another portion of the nutrients is taken in by the macrophyte plants, which also provide shelter for these larger animals, especially for the waterfowl. So, these nutrients that otherwise could be pollutants if the water were discharged to the nearest water mass, turn into a complex, highly productive ecosystem which also cleanses the water.

With reservations called for by the unequal validity of the available data, from the examination of contemporary changes in total water demand (Figure 3) there emerges a noticeable difference between:
- the northern countries (Europe), with slow and a diminishing rate of growth, even decreasing in Italy;
- most of the southern and Middle Eastern countries with strong, sometimes accelerating growth (Egypt, Syria and Turkey) or with signs of slowing (Morocco and Tunisia).

On the other hand, stability or decreases are manifest in countries where the demand is limited by the offer: reduced or no residual availability in exploitable interior resources - particularly insular situations—and/or strategic uncertainties about shared exterior resources (Israel, Jordan, the Gaza Strip and Cyprus); or again the need to adapt demands to costlier unconventional offers (e.g. Malta, Cyprus).

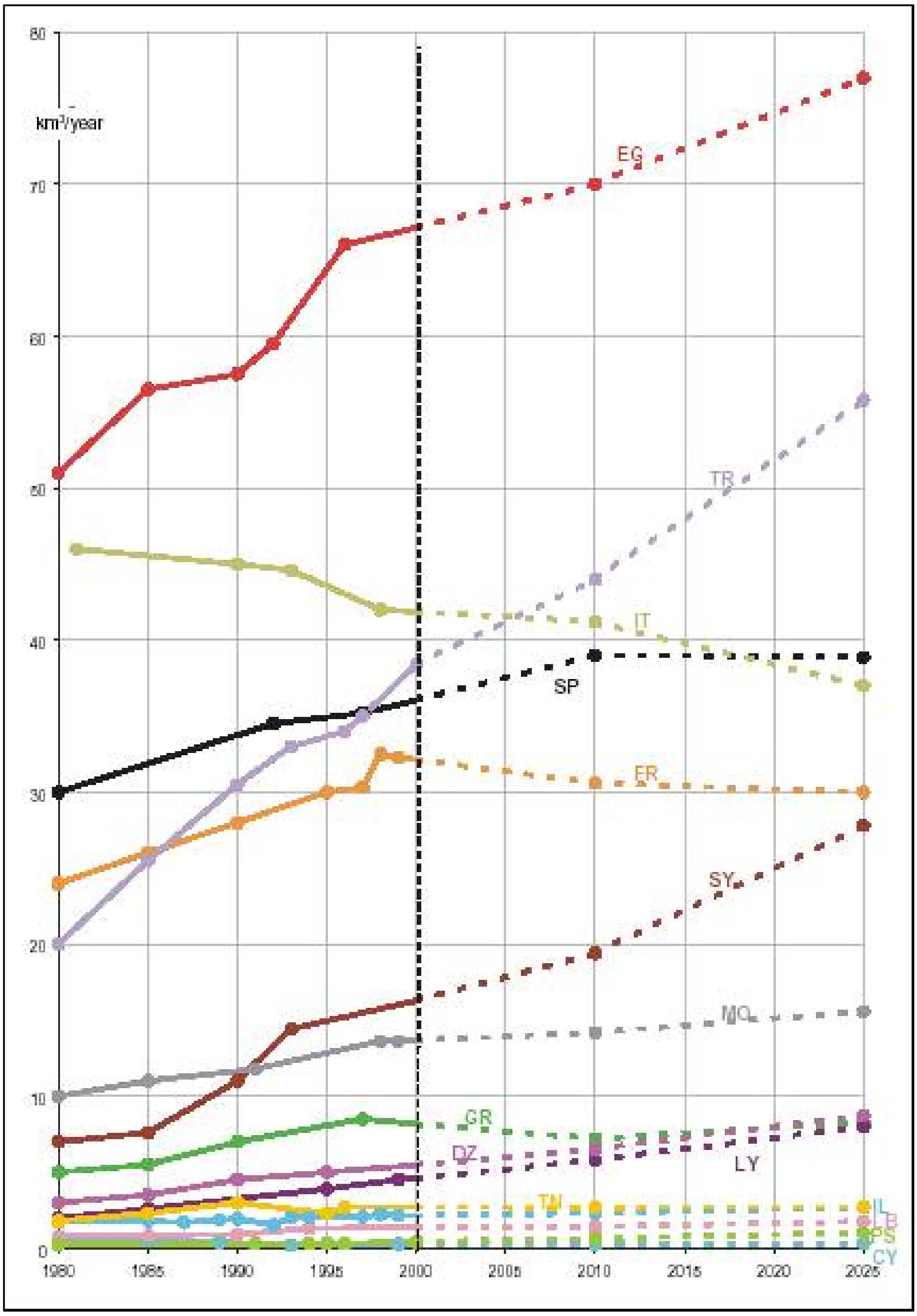

Figure 3. Approximate changes from 1980-2000 of total water use and 2010-2025 trend projections in different Mediterranean countries, (Source: *Margat*, 2001).

Changes in irrigation water demands (Figure 4) are unequally identifiable depending on the country, as a function of the available data affected by consistency flaws in a few countries such as Egypt, Italy and Turkey where this demand is the strongest. The trends which emerge are in Europe either slightly and regularly increasing (Spain, Greece) or decreasing (France, Italy); stabilisation or regular decrease also affects countries in shortage already mentioned (Israel, Cyprus) where resource allocations go as a priority to communities and where irrigation efficiency progress (linked to the expansion of the sprinkling and microirrigation) has been more noticeable, i.e. a drop in the water quantities allocated per hectare.

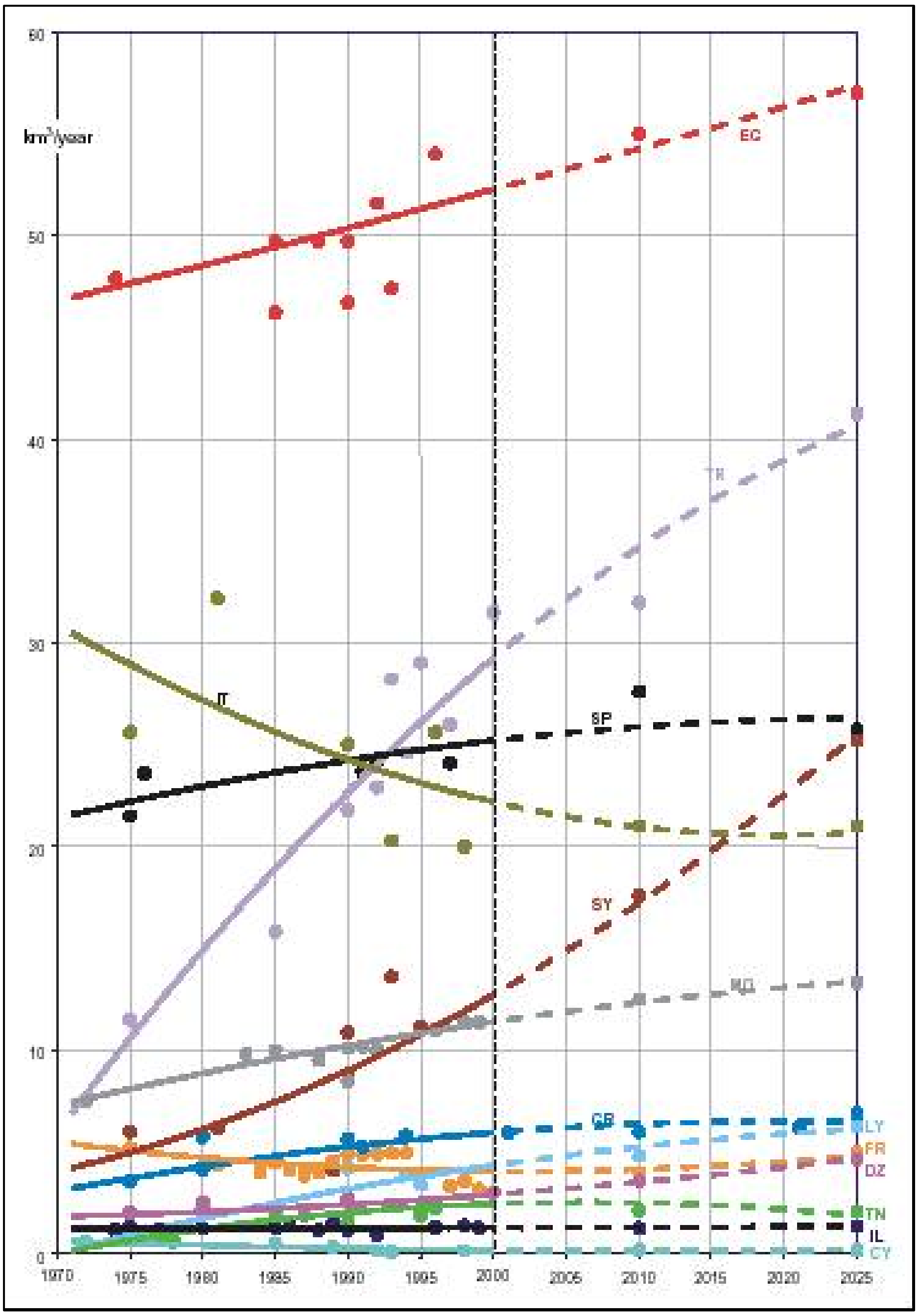

Figure 4. 1975-2000 changes in irrigation water demands in the main Mediterranean countries according to available statistics and 2010-2025 trend projections, (Source: *Margat*, 2002).

On the other hand more or less strong growth is typical of the southern and Middle Eastern countries (e.g. Egypt, Libya, Morocco, Tunisia, Syria and Turkey) where the extension of irrigation has been motivated by the need to deal with the increase in food demand (even without succeeding in self-sufficiency), but also by the development of more profitable non-food crops for exportation (cotton in Turkey, Morocco and Tunisia) and thus contributing to balance food imports ("virtual water"); with the exception of Algeria where irrigation appears to be stagnating, if not declining.

The 2010 and 2025 projections (Figure XX) show various trends in the North and the South and East:

- significant growth, sometimes stressing the contemporary trend (Syria, Turkey) or breaking with it, as in Algeria where a resumption of growth is scheduled or sought;
- slowed or decelerating growth (Egypt, Spain, Greece, Libya, Morocco);
- maintained stability (France, Israel, Cyprus);
- drop in growth (Italy, Spain after 2010, Tunisia).

However in the middle, and especially long-term, projections of "irrigation water demand" in the southern and Middle Eastern countries rather express the water allocations to the farming sector set out in development plans. These allocations generally tend to diminish in proportion to the total projected water demands in these countries.

Benefits of water reuse can be summarized as follow (*EUREAU*, 2001):

· Water reuse can further public policy that emphasises the sustainable development of water resources and nature conservation.
· Water reuse introduces an additional tier of management and control.
· Recycled water is a reliable alternative source of water and technologies are now available to produce water with characteristics consistent with any intended use.
· Treated wastewater can be reused to maintain or supplement natural river flows, lakes and wetlands, helping to sustain the aquatic life that depends on them.
· Recycled water can ease the pressure on water resources needed for potable supply by helping to satisfy other urban needs such as street cleaning, irrigating parks, sports fields and open spaces, car washing, etc.
· Recycled water can help crop production and sustain agricultural communities.
· Recycled water can be cost-effective means of supplying nutrients for agricultural irrigation and of possibly avoiding the need for nitrogen removal at waste water works in sensitive areas.
· Recharging aquifers with reclaimed water can augment groundwater stocks, control water table levels and maintain hydraulic pressures, preventing salt intrusions in coastal areas
· Recycled water can contribute to the environmental quality of urban areas and to development of tourism, maintaining the amenity value of areas to which the public has access, like street and motorway verges, parks and golf courses.
· Water reuse can contribute to the restoration of damaged environment and watercourses and can help curb dust erosion.
· The use of treated wastewater can represent a more drought-proof alternative water source which can help maintain industrial production through cooling or heating uses and thus avoid economic losses in case of water supply restrictions.

· In particular circumstances and with proper precautions to guarantee public health, recycled water can contribute as a source for the production of potable water. This can represent a practical solution to supplying sufficient amounts of good quality drinking water to many people in the world, preventing disease and death.

All these benefits contribute to the ultimate objective of sustainable development.

Recommendations of the Water Framework Directive

(partially extracted from the article "The new water framework Directive: prospects for sustainable water policy for the coming decades" by Asger Meulengracht)

European experience with recycled water can help to solve problems already being encountered in other countries.

There are many countries in the world and many different approaches have been developed for water recycling regulations and guidelines to provide effective measures to protect against risk to public health and the environment. Clearly economics is a key factor in the choice of philosophy. The developed countries have tended to adopt an approach which leads to conservative high technology/ high cost/low risk guidelines or regulations of which California's water recycling regulations are the best known examples. Some countries have endeavoured to follow this regulatory approach to guidelines, but have not always achieved low risk in practice because of insufficient money, experience or regulatory controls. Limits of affordability have led some developing countries to follow the low technology/low cost/controlled risk path of the attributable risk approach that is embodied in the World Health Organisation Guidelines. The WHO approach aims to provide guidance that can be adapted to national conditions and constraints, and allows the introduction of threshold criteria devised from balancing risk and affordability.

In the absence of international guidelines, there are inconsistencies between countries in the guidelines that have between adopted. Even when the approaches are broadly similar, there is wide variation in the details. There is also inconsistency within individual nations as evidenced by the variations in the guidelines adopted by the different state jurisdictions in federations such as the USA and Australia. The absence of a unified scientific position increases community concerns about risk and can lead to unnecessarily conservative responses to proposed water recycling projects. For example, excessive concern about infection from parasites can lead to prohibitively expensive treatment requirements, or costly operating limitations that preclude the use of normal agricultural methods. Development of a common international framework will improve public confidence in water recycling, improve risk management and lower costs (*Anderson et al.*, 2001).

The legal and administrative principles and obligations of the new sustainable European Community water policy constitute the framework within which the specific water policies of Member States will be developed. In September 2000 the European Parliament and the Council agreed on a new Water Policy for the Community by jointly adopting the Water Framework Directive. Long-term integrated planning finally became a cornerstone of Community water policy with wide ranging implications for spatial planning and water use.

The Water Framework Directive (2000/60/EC of 23 October 2000) combines protection of ecological status with long-term water use and sustainable development. It is a new instrument for spatial planning and integration of policies, a legal framework of common approach, principles, environmental and sustainability objectives. The obligations that this Directive involves are the protection of high ecological status and good surface water and groundwater status. The objectives are focused on respecting protected nature and drinking water areas, banning direct discharges to groundwater and pricing of water use.

The Water Framework Directive sets common objectives for water policies and establishes a coherent, legal and administrative framework, which may facilitate implementation of these objectives through co-ordinated measures within an overall planning process. The policy moves from protection of particular waters (fish waters, raw water for drinking water,…) to protection and use based on an overall appreciation of the hydrology and ecology of the entire natural cycle of each river basin.

The Directive does require that existing water of a high ecological status must not deteriorate. However, for most waters the main purpose is a combination of sustainable use of water and protection of the aquatic environment.

The essential requirements of the Water Framework Directive are as follows: the Directive establishes a common approach, objectives, basic measures and common definitions of ecological status of aquatic ecosystems. Focus is on water as it flows naturally through rivers towards the sea, taking into account natural interaction of surface water and groundwater in quantity and quality and covering the whole of a river basin district including estuaries, lagoons and other transitional waters and coastal waters. It requires a combined approach to discharges with control at source combined with environmental quality standards for the receiving waters. 6-years Management plans are required with co-ordinated programmes of measures to ensure good status of water by 2015, when main objectives of the Directive have to be achieved.

Programmes of measures must take into account all sources of pressures and impacts on the aquatic ecosystems, including impacts from agriculture, energy production, transport and spatial planning.

The proposal introduces charging requirement for recovering the cost for water services provided for water uses and, on a long term basis, prepares for the recovery of environmental and resource costs. The Directive contains a strong component of public participation with the requirement that all river basin management plans and updates must undergo a public consultation process involving the public in general, as well as all interested parties.

Article 1 of the Directive establish the purpose to achieve in the forthcoming years in order to protect inland surface waters, transitional waters, coastal waters and groundwater:

(a) prevents further deterioration and protects and enhances the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems;
(b) promotes sustainable water use based on a long-term protection of available water resources;
(c) aims at enhanced protection and improvement of the aquatic environment, *inter alia*, through specific measures for the progressive reduction of discharges, emissions and losses of priority substances and the cessation or phasing-out of discharges, emissions and losses of the priority hazardous substances;
(d) ensures the progressive reduction of pollution of groundwater and prevents its further pollution, and
(e) contributes to mitigating the effects of floods and droughts

and thereby contributes to:

- the provision of the sufficient supply of good quality surface water and groundwater as needed for sustainable, balanced and equitable water use,
- a significant reduction in pollution of groundwater
- the protection of territorial and marine waters, achieving the objectives of relevant international agreements, including those which aim to prevent and eliminate pollution of the marine environment, by Community action under Article 16 (3) to cease or phase out discharges, emissions and losses of priority hazardous substances, with the ultimate aim of achieving concentrations in the marine environment near background values for naturally occurring substances and close to zero for man-made synthetic substances.

The Water Framework Directive will achieve its objectives through the following structures:

- Creating an overall framework in the Community national, regional and local authorities and the social partners may develop integrated and coherent water management.
- The Water Framework is the conceptual and procedural framework within which all existing water legislation must be co-ordinated and complied with.
- Requiring transparency through publication and dissemination of information and through public consultation. This participatory process will also add an important element of control and quality insurance.
- Establishing a sound basis for collecting and analysis a large amount of information on the aquatic environment and the pressures upon it.

The Directive makes a special mention referring cost of water and charges for water use. Securing adequate supplies of a resource for which demand is continuously increasing is one of the drivers behind what is arguably one of the Directive´s most important innovations: the introduction of an economic analysis of water use within river basins and an obligation to charge for recovery of costs for water services. Water must be priced and users must take adequate contributions to the costs of using water, divided at least into industrial, agricultural and household users.

The Commission originally proposed that the price charged to households, farmers and industry for water services by 2010 should reflect the true costs, such an abstraction and distribution of fresh water and the collection and treatment of wastewater. It was also proposed to prepare for charging for environmental and resource costs, once methodologies were established, in order to discourage practices, with cause uncharged damage to the environment and/or depletion of water resources for future generations.

But the final Directive, more ambiguously says: “taking account of the principle of recovery of the costs of water services, including environmental and resource costs”, “provide incentives for using water resources efficiently” and “ensure an adequate contribution of the different water uses, disaggregated into at least industry, households and agriculture for the recovery of costs”. Current charges for water use are not generally in line with these provisions. In particular the agriculture sector is generally receiving referential treatment by not paying the real costs of water, neither the amounts consumed nor the large infrastructures that have build to manage water for agricultural use.

In many countries, in particular for agriculture, the principle of full cost recovery will introduce considerable changes even in the moderate version adopted in the Directive. But it is unreasonable that certain groups of economic actors, the tourist industry and in particular farmers, whose activities have important negative impacts on the aquatic environment, do no pay the real price for water.

It is also necessary to start preparations for the time where community agricultural products have to meet the world market prices as required within the World Trade Organization and for the plans to make a free trade area in the larger Mediterranean area by 2010. This opening inevitable will mean that subsidies in the form of free or cheap water cannot continue. Incentive must be created for changing both, crops and practices, in particular irrigation practices e.g. rapidly moving away from gravity irrigation. Prices reflecting the real cost would be a strong incentive for such a policy.

However, on a more positive note, the more visionary part of modern agriculture has begun to realise its role as a caretaker of the environment and the natural resources. We see more and more a tendency of targeted efforts to adjust agricultural production methods to a balanced interaction with the environment in order to reduce and improve water consumption and interact better with the environment. A new concept has evolved in Community language: the “European multifunctional agriculture”, where cultural traditions (family ownership), social structure and regional development (keep the countryside and remote areas populated functioning) combined with environmental services (adjusting to the environmental conditions and maintaining landscape and nature values).

There are explicit requirements in Community legislation that agriculture must comply with environmental legislation. Co-operation between water companies and farmers are virtually paid to produce and protect drinking water resources through better agricultural practices. Moreover, it is also incompatible with the principle of the polluter pays of the Treaty. Unreasonable both in terms of protecting the environment for the future and in terms of the other groups, who will have to bear the cost via consumer prices, taxes or other means. It should be emphasised that the Water Framework Directive, does not attempt to harmonize prices for water across the Community. This would run counter to the principle of recovering real cost and paying real prices for water use and run counter also the principle of the polluter pays. Implementation of charging provisions is strictly a national issue.

The objective of ensuring “good water status” takes into account the natural climatic and ecological variations across the countries. If aquatic ecosystems have developed in adjustment to a Mediterranean climate and ecology, this will be reflected in the practical implementation of what good ecological status is, e.g. for a river, which naturally dries out part of the year. The definition also takes into account the very particular and often very difficult situation of islands with little surface water and groundwater and often also low rainfall and long dry seasons. Moreover, the Directive does not required completely undisturbed ecological status.

In the Framework Directive, “water status” is defined in such a way that its ecological component uses the natural ecological status on a specific location in a specific aquatic ecosystem as its point of reference. What constitute good ecological status will always be measured in comparison with the natural ecological status for a specific water bodies at a specific location. The ecology of aquatic ecosystems in areas with naturally low precipitation and large seasonal variation in water availability is naturally adapted to such a dry conditions and harsh variations.

Under the new Water Framework Directive, water cannot be abstracted, transferred or diverted in large quantities without a throughout examination of the possible environmental impacts. This is likely to reduce transfer of water and give incentives towards a mix of other instruments, including demand management, charging, recycling and re-use of water, development of less water consuming technologies and agricultural practices, land use policies, etc. However, the Directive does not in itself prohibit or prevent water transfer and water diversion but it does give incentives for more balanced solutions, reducing the incentive for building large, expensive and often environmentally problematic infrastructures. First of all by the requirements that good water status must be achieved also in the areas of from where water is transferred or diverted. Focus of the Directive is on the ecology and quality of the aquatic environment and as a new element also on water quantity is mainly treated s an ancillary parameter for ensuring this. In addition, the requirement for a detailed economic analysis of the cost of water use will also create new incentives for changes by exposing the real figures for investments, running costs, environmental impact and for the distribution of the costs between user groups for water use.

The requirements and timetable of the Water Framework Directive for the coming years are the following:

By 2004 three important tasks must be completed within each entire River Basin District:

1. Analysis of the natural characteristics of all surface waters and groundwaters within each river basin, including natural vulnerability.
2. Review of the impact of human activity on the status of surface waters and groundwaters. This include all pressures on the aquatic environment from point and diffuse sources as well as from agriculture, energy production, transportation infrastructure and activity, tourism, etc.
3. An economic analysis of water use within the River Basin District taking account of long-term forecast of supply and demands for water. The analysis must also make judgements about the most cost-effective combination of measures in respect of water uses.
4. In addition, final specification of reference and the final location and boundaries of all bodies of water must be ready.

By 2006:

1. Monitoring programmes must be made operational.
2. The public consultation process for drafting river basin management plants starts with the publishing of a work programme indicating timetable and procedure.

By 2007 an overview of significant water management issues must be published. All major problems through the river basin districts must be identified and described. This so-called "scooping" should always form part of an overall assessment of environmental and other impacts of major plans and programmes.

By 2008:

1. A draft river basin management plan must be made available to the public and to interested parties for public consultation. Minimum half a year must be given for its

discussion. Based on the analysis required by 2004 specific information on the natural characteristic of waters, the pressure, impacts and current status of all waters as well as an analysis of the economics of water use in the river basin district must be included in such drafts. Furthermore, a programme of the measures, which will be taken over the 6-years of implementation of the River Basin Management Plan must be included. Explicit specification of its intended and expected impact on improving and protecting water status must be made. The River Basin Management Plan must also include a programme for monitoring status and development within the river basin district.

2. Public access must be given to all information and data, which has been used for preparing the draft management plant.

By 2009 final River Basin Management Plans must be agreed, including a description of the status of all waters and all measures, which are planned in order to protect high status waters and ensure good status of all other waters by 2015.

The obligation to assess environmental impacts, to examine alternatives and to take measures to reduce the impact of any of the solutions chosen is in fact a strengthening of the Directive of Environmental Impact Assessment (EA), in particular because it is now obligatory to respond to the results of the analysis and to take compensatory measures if a project is carried out in spite of a negative impact analysis. The Water Framework Directive thus makes such EIA-assessments obligatory, where the EIA Directive distinguishes between obligatory and non-obligatory cases. The Directive also makes it obligatory to follow the results of the EIA-assessment in much stricter terms than the EIA-Directive, and the criteria for the assessment may be seen as more than EIA-Directive.

It is evident that the natural environment and in particular the natural water resources and their ecological status is subject to environmental pressures, which will, if uncorrected, in the long term undermine hydrological and ecological sustainability. The main driver of this development is in particular the irrigation –based parts of the agricultural sector.

Demand management and reduced water consumption, inter alia through the use of water charging and other economic incentives as well as the use of less water consuming technology, re-use of waste waters, changes in crop choices and development of efficient irrigation systems must be explored.

It is important to acknowledge that the vulnerable situation of some Mediterranean areas is a fundamental challenge to the conventional thinking or logic behind the traditional economical and social development where technological solutions and means are being employed to allow an in principle unsustainable development to continue. The Water Framework Directive should be seen as an incentive for finding solutions, which build on a genuinely better balanced between exploitation of available resources and protection and improvement of the natural resources and natural ecology.

In general, the adoption of standards for wastewater reclamation and reuse follows the problems encountered in each country. As a result, for example across Europe, the legal status of wastewater reuse is not uniform. Many European countries and most northern European countries (e.g. The United Kingdom, Belgium, The Netherlands) do not have any specific legislation on the matter. Regarding European Mediterranean countries, France has national recommendations, Italy a national law and Spain various regional regulations. Portugal and Greece are considering developing national guidelines.

We will study now some of the related cases:

France:

In line with its administrative tradition, France has enacted a comprehensive national code of practice under the form of recommendation from the Conseil Supérieur d´Hygiène Publique de France (CSHPF). The 1991 "Sanitary Recommendations on the Use, after Treatment, of Municipal Wastewaters for the Irrigation of Crops and Green Spaces" use the WHO guidelines as a basis, but complement them with strict rules of application. In general the approach is very cautious and the main restrictions given are:

- the protection of the ground and water resources
- the restriction of uses according to the quality of the treated effluents
- the piping networks for the treated wastewaters
- the chemical quality of the treated effluents
- the control of the sanitary rules applicable to wastewater treatment and irrigation facilities
- the training of operators and supervisors

The CSHPF calls for a strict observation of these restrictions to ensure the best possible protection of the public health of the populations concerned. The WHO guidelines are introduced in the second point, but all the points covered are accompanied by very precise list of requirements, such as the performance of hydrogeological studies, the characterization of the waters to be reuse, the respect of distances from inhabited areas, the delivery of administrative authorizations, strict monitoring, and the like. In fact, the authorizations for wastewater reuse are attributed on a case by case basis after review of a very detailed dossier. There are nor explicit strict standards for minerals or trace organics, but the experts providing their advise before delivery of the permits follow recommendations and usual practices and can in every case refuse the authorization.

January 3, 1992 France´s water law required each city to define the zones to be served by public municipal sewerage, storage, treatment and disposal of reuse of wastewater. This was the first time wastewater reuse appeared in a French regulation. Wastewater reuse was thus acknowledged not as a marginal water supply but as an alternative solution to water discharge. A June 3, 1994 decree provided the basis for water reuse rules in France. First, it clearly stated the treated effluents can be used for agricultural purposes, but only if water projects are operated without any risk for the environment and public health. Second, wastewater treatment requirements, irrigation modalities and monitoring programs must be defined after an order of the Ministries of Health, Environment and Agriculture (*Faby et al*, 1999).

France has irrigated crops with wastewater for years (close to a century), in particular around Paris (Figure 5). This practice is still going on in the Achères region, where some of the wastewater is used after screening and settling, but is likely to be discontinued soon. Interest in wastewater reuse rose again in the early 1990s for two main reasons: (a) the development of intensive irrigated farming (such as maize), in particular South-western France and the Paris region, and (b) the fall of water tables after several recent severe droughts which have paradoxically affected the regions traditionally considered to be the wettest (Western and North-western France).

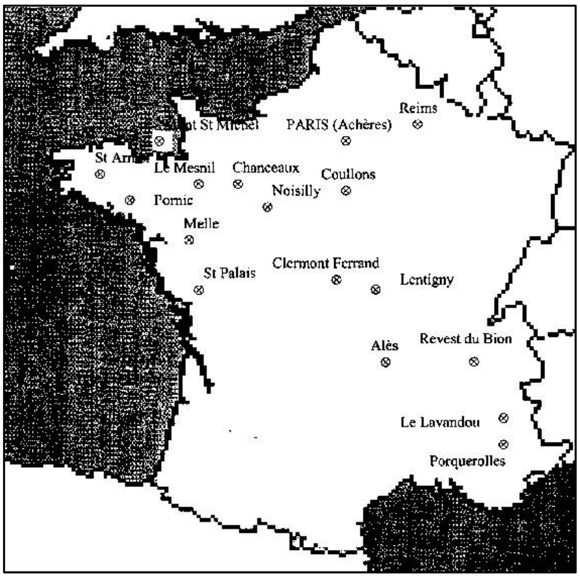

Figure 5. Agricultural reuse projects in operation in 1997, (Source: *Faby et al*, 1999).

Italy:

In Italy, a national water legislation exists (law 319 of May 10, 1976) complemented for wastewater reuse in agriculture by the “Criteria, Methodologies and General technical Standards” of February 4, 1977 (Ministero dei Lavori Pubblici, 1977). The standars aim at protecting the soil used for agriculture and the crops. It gives limits of certain minerals such as Na, Mg and Ca, by ways of ratios and tables of values. For the irrigation of crops that can be eaten raw (unrestricted irrigation), municipal wastewater effluents must go through secondary treatment and disinfection, in order for the level of total coliforms not to exceed 2 per 100 ml. In the case of crops that do not come in contact with the water (restricted irrigation) and in all the other cases, only primary treatment is required. However, “chemicals that may leave undesirable residues” in the crops must be absent.

The law n.152 issued on 11 May 1999 by Minister of Environment has totally revised the regulations concerning wastewater treatment and disposal and the law n. 319/76 (called the “Merli law”) has been repealed. At the moment reuse of municipal wastewater for irrigation is regulated by Annex 5 of a resolution of the National Interministry Committee for the Protection of Waters from Pollution (CITAI, 1977) (but nowadays the regulatory framework is been fully changed). Wastewater reuse is considered only in the form of discharge on soil for agricultural purposes and is allowed only if wastewater addition can increase crop production. Specific restrictions are imposed on wastewater quality. The presence of total coliforms in wastewater for irrigation is accepted at very low levels depending on the use of agricultural products. No limits are set for the concentration of toxic, poisonous or bioaccumable substances, but a specific evaluation is required of the annual volume of wastewater that can be applied depending on soil and crop type. It is required that environmental impact of the reuse system is assessed. In particular, the qualitative characteristics of wastewater and water bodies as well as the physical–chemical characteristics of soil must be monitored.

The current law require also that the areas irrigated with wastewater be marked with signs warning for health hazards, that access to the irrigated area be restricted and that the irrigated area be surrounded by a buffer strip of at least 80 m with no buildings or roads, regardless of the quality of the wastewater and the irrigation methods. It is evident that Italian legislation is outdated when it is considered that, in many countries throughout the world, treated wastewater is used even for the irrigation of public areas like parks. Moreover, it is difficult to understand why buffer zones exist for irrigation with wastewater but not, for example, for discharge into surface water bodies (*Barbagallo et al*., 2001).

In Italy, the regions benefit from a certain autonomy in the regulatory area, and the three regions where wastewater reuse is most practiced (Puglie, Emilia Romagna and Sicilia) have enacted comprehensive standards, without necessarily following the line set by the national legislation. Puglie takes a single value of 10 total coliforms per 100 ml; Emilia Romagna takes a value of 12 total coliforms per 100 ml for unrestricted irrigation and 250 per 100 ml for restricted irrigation; Sicilia takes a radically, and probably more realistic, stance. It forbids the irrigation of fodder crops and of food crops that come in direct contact with treated wastewater. For the other cases (restricted irrigation) the applicable standard is 3000 total coliforms per 100 ml and 1000 faecal coliforms per 100 ml, simultaneously. It also requires the absence of salmonella and less than 1 helminth egg per litre.

Microbial criteria for irrigation with recycled municipal wastewater in Italy are given in Table 1. Moreover, the law prescribes that in the presence of unconfined aquifers in direct contact with surface waters, adequate preventive measures must be used to avoid any deterioration of their quality. A new law relative to municipal wastewater is being prepared that gives better attention to the management of water resources and in particular to the reuse of treated wastewater. Industry will be encouraged to use treated wastewater. Municipal wastewater treatment companies have already planned to build a separate supply network for wastewater reuse by industries. In the metropolitan area of Turin, for example, the two main companies (Azienda Po Sangone (APS) and CIDIU) have already done so.

Table 1. Microbiological standards for irrigation with reclaimed municipal wastewater in Italy; comparison of regional guidelines with national and WHO standards (*Angelakis et al*., 2003).

Organisation or Region	TC (MPN/100 ml)[a]	FC (MPN/100 ml)	Faecal Streptococci (MPN/100 ml)	Nematode Eggs (no/l)
WHO	Not set	1,000[b]	not set	1
Italy	2[b], 20[c]	not set	not set	not set
Sicily	3,000[b]	1,000[b]	not set	1
Emilia Romagna	2[b], 20[c]	not set	not set	not set
Puglia	2[b], 10[c]	not set	not set	not set

[a] mean value of 7 consecutive sampling days.
[b] unrestricted irrigation.
[c] restricted irrigation.

Spain:

Spain, a country composed of autonomous regions, also has a national legislation and a number of regional regulations in the Autonomous Provinces. The national water law (Ley de Aguas, 29/1985) merely foresees that the government will "establish the basic conditions for the direct use of wastewaters" according to the treatment processes, water quality and foreseen uses.

A Royal Decree to extend this existing law was published in 2001 (Real Decreto Legislativo 1/2001). The Decree foresees a standard of 1 nematode egg per litre for all types of irrigation and 10 faecal coliforms per 100 ml for unrestricted irrigation. For restricted irrigation the faecal coliform standards becomes 200 per 100 ml and in the case of irrigations of cereals, industrial crops, fodder crops and pastures, it becomes 500 faecal coliforms per 100 ml. Limits on chlorine are also foreseen. Specific standards for heavy metals must be respected for the reuse of industrial wastewaters.

Also a few regional legislations and standards do exist (in Andalusia, Baleares, Catalonia and Canarias). In the Balearic Islands, wastewater reuse is regulated by a 1992 decree with legal value. The approach taken is strictly that of the WHO. Two other pieces of Balearic legislation favour the reuse of wastewater, One prescribes the irrigation of golf courses with water other than for domestic consumption or agricultural irrigation, and the other recognized agricultural irrigation with reused water as being of public utility (*Salgot* and *Pascual*, 1996).

Catalonia has guidelines with a de facto legal value containing limit values for boron, cadmium, molybdenum and selenium, all relevant for the health of irrigated crops (*Salgot et al.*, 1994). The microbiological standards are those of the WHO.

Andalusia also has recommendations dating from 1994, largely following the French approach with a case by case authorization. However, these guidelines specifically exclude the reuse of wastewater for potable water, street cleaning, municipal heating and cooling, and the cleaning of urban premises, as well as for the washing and transport of materials. Groundwater recharge is also restricted. Overall, the permitted types of reuse fall into seven categories. Table 2 summarizes the guidelines (*Castillo et al.*, 1994).

Table 2. Quality guidelines for the various applications of wastewater reuse in Andalusia.

Type of Standard	Application	Faecal Coliforms per 100 ml	Nematode Eggs per litre
1	Irrigation of sports fields and parks with public access	<200	<1
2	Vegetables to be consumed raw	<1,000	<1
3	Production of biomass intended for human consumption and refrigeration in open circuits	<1,000	None
4	Recreational lakes	<2,000	<1
5	Refrigeration in semi-closed circuits	<10,000	None
6	Industrial crops, cereals, dry fodder seeds, forest and conserved or cooked vegetables	None	<1
7	Irrigation of greens areas with no public access, production of biomass not intended for human consumption and recreational lakes with access prohibited	None	None

Source: Adapted from *Castillo et al.*, 1994

The reuse of treated wastewater is already a reality in several Spanish regions for four main applications: golf course irrigation, agricultural irrigation, groundwater recharge (in particular to stop saltwater intrusion in coastal aquifers) and river flow augmentation.

We will review now the status of regulation and guidelines concerning wastewater recycling and reuse in other Mediterranean countries, in order to compare then with the requirements of the Water Framework Directive:

Algeria:

The Algerian laws prohibit absolutely the reuse of the raw wastewater, treated wastewater for the irrigation of raw-eaten vegetable crops; but it is allowed in the production of fodder crops, pasture and trees. The Algerian laws oblige also the cities of more than 105 inhabitants to treat their effluents, prior to any disposal or reuse, through a wastewater treatment station, and in less populated areas through wastewater stabilization ponds or sedimentation basins. Consequently, in the last few years, the Algerian authorities have initiated an ambitious program that enables mainly: (a) the rehabilitation of 28 wastewater treatment stations, (b) the construction of new wastewater treatment stations for the cities of more than 105 inhabitants, and (c) for small populated areas, the construction of wastewater stabilization ponds and sedimentation basins.

Tunisia:

Wastewater reuse in agriculture is regulated by the 1975 Water Code (law No. 75-16 of 31 March 1975), by the 1989 Decree No. 89-1047 (28 July 1989), by the Tunisian standard for the use of treated wastewater in agriculture (NT 106- 003 of 18 May 1989), by the list of crops than can be irrigated with treated wastewater (Decision of the Minister of Agriculture of 21 June 1994) and by the list of requirements for agricultural wastewater reuse projects (Decision of 28 September 1995). They prohibit the irrigation of vegetables that might be consumed raw. Therefore, most of the recycled wastewater is used to irrigate vineyards, citrus and other trees (olives, peaches, pears, apples, pomegranates, etc.), fodder crops (alfalfa, sorghum, etc), industrial crops (cotton, tobacco, sugarbeet, etc), cereals, and golf courses (Tunis, Hammamet, Sousse, and Monastir). Some hotel gardens in Jerba and Zarzis are also irrigated with recycled wastewater.

The 1989 decree stipulates that the use of recycled wastewater must be authorized by the Minister of Agriculture, in agreement with the Minister of Environment and Land Use Planning, and the Minister of Public Health. It sets out the precautions required to protect the health of farmers and consumers, and the environment. Monitoring the physical-chemical and biological quality of recycled wastewater and of the irrigated crops is planned: analyses of a set of physical-chemical parameters once a month, of trace elements once every 6 months, and of helminth eggs every two weeks on 24h composite samples, etc. In areas where sprinklers are used, buffer areas must be created. Direct grazing is prohibited on fields irrigated with wastewater.

Specifications determining the terms and general conditions of recycled wastewater reuse, such as the precautions that must be taken in order to prevent any contamination (workers, residential areas, consumers, etc.), have been published. The Ministries of Interior, Environment and Land Planning, Agriculture, Economy and Public Health are in charge of the implementation and enforcement of this decree. It is interesting to note that in Tunisia, the farmers pay for the treated wastewater they use to irrigate their fields.

Cyprus:

The provisional criteria related to the use of treated wastewater effluent for irrigation purposes in Cyprus are presented in Table 3. They are stricter than the WHO guidelines and take the specific conditions of Cyprus into account. These criteria are followed by a code of practice to ensure the best possible application of the effluent for irrigation.

Table 3. Provisional quality criteria for irrigation with recycled wastewater in Cyprus, (Source: *Angelakis et al.*, 1999).

Irrigation of		BOD_5 (mg/L)	SS (mg/L)	Faecal coliforms (MPN/100ml)	Intestinal nematodes (No/L)	Treatment required
All crops[c]	A)	10[a]	10[a]	5[a] 15[b]	Nil	Secondary, tertiary, and disinfection
Amenity areas of unlimited public access -Vegetables eaten cooked	A)	10[a] 15[b]	10[a] 15[b]	50[a] 100[b]	Nil	Secondary, tertiary, and disinfection
Nil Crops for human consumption – Amenity areas of limited public access	A) B)	20[a] 30[b] -	30[a] 45[b] -	200[a] 1,000[b] 200[a] 1,000[b]	Nil Nil	Secondary, storage >1 week and disinfection or tertiary and disinfection. Stabilization maturation ponds total retention time >30 d or secondary and storage >30 d
Fodder crops	A) B)	20[a] 30[b] -	30[a] 45[b] -	1,000[a] 5,000[b] 1,000[a]	Nil Nil	Secondary and storage >1 week or tertiary and disinfection. Stabilization maturation ponds total retention time >30 d or secondary and storage >30 d or secondary and storage >30 d
Industrial crops	A) B)	50[a] 70[b] -	- - -	3,000[a] 10,000[b] 30,00[a] 100,00[b]	- - - -	Secondary and disinfection. Stabilization maturation ponds with total retention time >30 d or secondary and storage >30 d

a These values must not be exceeded in 80% of samples per month.
b Maximum value allowed.
c Irrigation of leaved vegetables, bulbs, and corns eaten uncooked is not allowed.
Note:
The irrigation of vegetables is not allowed.
The irrigation of ornamental plants for trade purposes is not allowed.
No substances accumulating in the edible parts of crops and proved to be toxic to humans or animals are allowed in the effluent.

Turkey:

Technical regulations and constraints for the use of wastewater effluents for agricultural purposes, with reference to Water Pollution Control Regulations are used in Turkey. In addition to the regulations there are other criteria included, regarding the classification of the waters to be used for irrigation, maximum allowable heavy metal and toxic elements concentrations as well as the mass limits for application of these pollutants in terms of unit agricultural areas.

Because of the absence of comprehensive international guidelines and of a scientific consensus, *Bahri* and *Brissaud* (2003) have proposed common guidelines on water reuse in all Mediterranean countries. These guidelines have been developed under a project funded by UNEP/WHO. These are based on the consideration that: (a) an agricultural Mediterranean market is developing with large amounts of agricultural products (vegetables, fruits, etc) imported and exported among Europe and other Mediterranean countries; (b) tourism is an essential part of the economic activity of the region; its development might be jeopardized in the long term by disease outbreaks linked to wastewater mismanagement; (c) there is a growing concern of consumers about the food quality and health hazards; (d) unfair competition among farmers should be avoided.

These guidelines have been prepared making a large use of the recent assessment of the WHO guidelines by *Blumenthal et al.* (2000) and of a model based QMRA data that have been obtained and compared to acceptable annual risk related to bathing and potable water drinking.

Mediterranean guidelines are minimum requirements which should constitute the basis of water reuse regulations in every country of the region. Wealthy countries might wish higher protection. Due to late development of wastewater treatment in several countries, all of them cannot be expected to comply with the guidelines within the same delay. However, every country could commit itself to reach the guidelines within a delay depending on its current equipment and financial capacities.

Only four categories of reclaimed water uses are considered, apart from groundwater recharge, in order to facilitate the implementation of the guidelines and take cost-effective water reuse into account (Table 4). A reclaimed water supply network must serve as many reuse applications as possible in the same area.
(a) Category I: urban and residential reuses, landscape and recreational impoundments.
(b) Category II: unrestricted irrigation, landscape impoundments (contact with water not allowed), and industrial reuses.
(c) Category III: restricted agricultural irrigation.
(d) Category IV: irrigation with recycled water application systems or methods (drip, subsurface, etc) providing a high degree of protection against contamination and using water more efficiently.

Water quality criteria are proposed for non potable water reuse categories I to IV. Groundwater recharge guidelines depend on whether the aquifer water is potable or not, the intended use of non potable recharged aquifer, the technique of recharge and the hydrogeological context. Wastewater treatments expected to meet the criteria were defined for each water category.

Uncertainties and approximations in the actual knowledge are far from allowing a definitive position regarding the guideline limits (*Bahri* and *Brissaud*, 2003).

Table 4. Recommended guidelines for water reuse in the Mediterranean region,
(Source: Adapted from *Bahri* and *Brissaud*, 2003).

	Quality criteria			
Water category	**Intestinal nematode[a] (No. eggs per liter)**	**FC or E. coli[b] (cfu/100 ml)**	**SS[c] (mg/L)**	**Wastewater treatment expected to meet the criteria**
Category I				
a) Residential reuse: private garden watering, toilet flushing, vehicle washing. b) Urban reuse: irrigation of areas with free admittance (greenbelts, parks, golf courses, sport fields), street cleaning, fire-fighting, fountains, and other recreational places. c) Landscape and recreational impoundments: ponds, water bodies and streams for recreational purposes, where incidental contact is allowed (except for bathing purposes).	0 - 0.1[h]	0 – 200[d]	0 - 10	Secondary treatment + filtration + disinfection
Category II				
a) Irrigation of vegetables (surface or sprinkler irrigated), green fodder and pasture for direct grazing, sprinkler-irrigated fruit trees b) Landscape impoundments: ponds, water bodies and ornamental streams, where public contact with water is not allowed. c) Industrial reuse (except for food industry).	0 - 0.1[h]	0 – 1000[d]	0 - 20 0 - 150[f]	Secondary treatment or equivalent[g] + filtration + disinfection or Secondary treatment or equivalent[g] + either storage or well-designed series of maturation ponds or infiltration percolation
Category III				
Irrigation of cereals and oleaginous seeds, fibre, & seed crops, dry fodder, green fodder without direct grazing, crops for canning industry, industrial crops, fruit trees (except sprinkler-irrigated), plant nurseries, ornamental nurseries, wooden areas, green areas with no access to the public.	0 - 0.1[h]	None required	0 - 350 0 - 150[f]	Secondary treatment or equivalent[g] + a few days storage or Oxidation pond systems
Category IV				
a) Irrigation of vegetables (except tuber, roots, etc.) with surface and subsurface trickle systems (except micro-sprinklers) using practices (such as plastic mulching, support, etc.) guaranteeing absence of contact between reclaimed water and edible part of vegetables. b) Irrigation of crops in category III with trickle irrigation systems (such as drip, bubbler, microsprinkler and subsurface). c) Irrigation with surface trickle irrigation systems of greenbelts and green areas with no access to the public. d) Irrigation of parks, golf courses, sport fields with sub-surface irrigation systems.	None required	None required	Pretreatment as required by the irrigation technology, but not less than primary sedimentation	

(a) Ascaris and Trichuris species and hookworms; the guideline limit is also intended to protect against risks from parasitic protozoa.
(b) FC or E. coli (CFU/100 ml): faecal coliforms or Escherichia coli (cfu: colony forming unit/100 ml).
(c) SS: Suspended solids.
(d) Values must be conformed at the 80% of the samples per month, minimum number of samples 5.
(e) In the case of fruit trees, irrigation should stop two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.
(f) Stabilization ponds.
(g) Such as advanced primary treatment (APT).
(h) As very few investigations, if any, have been carried out on how to reach < 0.1 nematode egg /l, this criterion is considered a medium term objective and is provisionally replaced by <1 nematode egg l.

Richa and *Durham* (2004) have recently elaborated a review about **Indirect European Incentives for Water Recycling** that we present in the following section.

Europe has focused on environmental improvement and indirect incentives through fiscal policy (effluent charges and water abstraction taxes). These policies aim to discourage the discharge of effluent, reduce over abstraction of groundwater and encourage sustainable innovative alternative solutions.

The use of taxes is becoming more widespread in EU, but they have often been implemented on a case by case basis, and generally do not appear to be part of a broader strategy of encouraging alternative water resources. Furthermore, taxes have been frequently focused on revenue generation and not explicitly on providing incentives to change behaviour.

A. Groundwater abstraction taxes:

The groundwater abstraction taxes are complementary to the abstraction licenses. They are still not commonly used in EU members states. It is also noteworthy that the rates of water abstraction taxes in the countries that have implemented such a tax are quite different.

Abstraction charges, other than administrative fees, have been used for several decades in France and Spain for the financing of river basin management. Abstraction taxes with a fiscal function have been in operation at regional level in Germany, and Denmark (1993) and the Netherlands (1995). The two recent tax schemes differ considerably in scope and effective tax rate.

The Danish tax is quite high, applies to households and some service businesses only. Green taxes have slashed groundwater abstraction rates with a 40% decline during the last 10 years as reported by the EPA. Groundwater supplies more than 99% of drinking water and water consumption has reduced year on year due to the price of water that has increased 150% since 1993. Both taxes exclude agriculture. These taxes do not rely on any valuation of the environmental pressures from water abstraction, but may be seen to have significant incentive effects.

The Dutch tax is relatively low and does not exempt industry. Groundwater is the source of 70 per cent of the total water supply in the Netherlands. Tax rates are:

• The standard rate 0.15 €/m^3 (applied to the water companies)
• For industry and agriculture 0.08 €/m^3
• For abstraction of groundwater that has been infiltrated 0.025 €/m^3

One of the goals of Dutch water policy is to contribute to the reduction of the use of groundwater relative to the use of surface water in water supply. Since groundwater is cheaper to extract than surface water, the tax serves to narrow the price differential. However, the price differential is on average 0.45 € so only in exceptional cases will the standard rate of the tax succeed in making groundwater abstraction less profitable. Exemptions:

- Irrigation < 40,000 m^3/year
- Pump < 10 m^3/hour
- Abstraction for skating rings

Total revenue (2002): 180 M€

B. Wastewater taxes:

Wastewater taxes are defined as compulsory payments independent of any service received. They apply to direct dischargers, i.e. those entities which discharge directly into surface water, and possibly to the residual discharge from sewage treatment plants after treatment. The waste water tax is a classical emission tax on a flow pollutant and was among the first economic instruments to be introduced in environmental policy.

A waste water tax scheme was introduced in France and in the Netherlands around 1970, while Germany followed suit with a scheme that took effect in 1981. Denmark recently introduced a waste water tax which took effect in 1997. In other Member States waste water taxes are applied at the regional level, such as in Flanders (Belgium) and in Italy and Spain.

Integrated Pollution Prevention Control (IPPC) legislation for manufacturing industry (including municipal landfill, incineration, biosolids and potentially municipal wastewater) has been implemented across Europe to ensure that the Best Available Techniques (BAT) are implemented as are result of defining total environmental impart and to provide sustainable environmental solutions. This is a daughter directive to the "umbrella" Water Framework Directive (WFD) and some countries provide tax incentives based on the adoption of IPPC BAT.

Wastewater taxes in the Denmark:

The other side of the tax incentive is increasing wastewater tax levels and the charges for pollutants such as 2.7 €/kg for nitrates, 14.7 €/kg of phosphate and 1.5 €/kg of organic material.

Wastewater taxes in the Netherlands:

Taxes have been identified as the primary driver for pollution reduction by 55% of industries affected. The tax applies to discharges of organic material, nitrogen, mercury, cadmium, copper, zinc, lead, nickel, chromium and arsenic. It now stands at:
• 29 Euro per pollution unit for state waters
• Ranging from 27-63 Euro per pollution unit for Water Boards (the state water tax is thus at the lower end of the spectrum)

The tax is imposed on all direct discharges to surface waters as well as on all indirect discharges. The tax covers the costs of sewage treatment. The tax also applies to direct dischargers, i.e. industries and municipal treatment plants which discharge directly to surface waters. Part of the taxes revenues is recycled to support municipal sewage treatment plants and in-house pollution abatement in industry.

The German wastewater tax:

The tax affects only direct dischargers, i.e. discharges from industries and municipal sewage outlets. Indirect dischargers are affected by the tax via the ordinary waste water user fee. It now stands at 36 Euro per damage unit for state waters (a damage unit represents either 50 kg of chemical oxygen demand (COD), 25 kg nitrogen, 3 kg phosphorus, 2 kg organic halogens, etc.) or 14.4 € per inhabitant equivalents (i.e). In 1998, the total revenue of wastewater taxes was about 370 M€ (60% coming from municipalities, 40% from industry). The tax is reduced when standards are adhered to, and further reduced if dischargers manage to keep their effluent at a quality level lower than the regulations standards. The revenue raised by the tax is spent by the authorities on improving municipal sewage treatment and set water quality programmes.

Table 5. EU countries groundwater abstraction/wastewater taxes and the use of their revenues.

Country	Type of taxes	Nature	Use of revenue
Belgium	Industrial wastewater charge.	Industry pay per m^3 of effluents discharged, at a rate that varies with the pollution content (Brussels, Wallonia, Flanders), Ground water abstraction fees have increased to reduce groundwater abstraction due to shortage.	Used in all three regions to finance the construction and the improvement of wastewater treatment plants.
Denmark		40% reduction in groundwater abstraction due to price increases.	
France	Pollution levy (municipality, industry).	On measured or estimated of substances discharged. River basin agency regulators have been funding up to 50% of the capital cost of environmental beneficial projects.	Revenue is redistributed to industries, regional authorities and farmers
Germany		75% tax charge reduction for best available technique (BAT) projects.	
Italy	Tax on polluted discharges into the environment (polluting firms).	On quantity of pollutants.	Partially finance to compensation of damages.
Netherlands	Higher tax on scarce ground water.	Groundwater tax to reduce abstraction. Tax subsidy if abstraction = recharge.	
Spain	Water pollution fee on discharges into rivers (municipality, industry).	No tax on reclaimed water.	
UK	Corporation tax.	UK Enhanced capital allowance tax being introduced as part of the Green Technology initiative to provide tax reductions on approved technological solutions.	

Source: Adapted from *Richa* and *Durham*, 2004

C. Reasons for environmental taxes and charges:

Most water prices are either subsidised or do not include the true cost of water such as the environmental, social and economic impact of the process. There are the direct costs of headworks, storage, treatment, distribution etc., but there are also the externalities such as the impacts on public health, water resource, CO_2, phosphates, nitrates, soil salinisation, environmental biodiversity, flood mitigation etc.

Theoretically, the main reason behind the implementation of taxes and charges for groundwater abstraction and wastewater effluent discharge is based on the existence of environmental externalities; unintended negative (or positive) impact on a party outside the transaction. These taxes and charges must be intended to absorb the externality cost. Levying a tax or a charge on the cause of the environmental damage gives an incentive to the taxpayer to reduce their liability to the tax/charge by reducing the cause of the environmental externalities. This gives the polluter an incentive to switch to other, less polluting alternatives, so water recycling alternative could be considered.

However this is not always the situation in Europe. The measurement of externalities in the EU countries is less than straightforward. It's true that taxes and charges are increasingly used by EU Member States as an economic instrument to implement the "polluter-pays" principle (polluters must pay for the consequences of their actions), but the approach for considering these taxes is usually not based on the cost of externalities, and the collected revenues from taxes are not always allocated in environmental improvement projects. This situation can reduce the incentives for polluters to find ways for alternative environmental friendly solutions.

Now that we have looked at the existing European incentives for implementing Water Recycling projects, it is important to give a brief overview of the existing funding arrangements all over the world, focusing on the Queensland Water Recycling Strategy (Australia). This will help in establishing the differences between the European and Australian situation.

World-wide, many governments provide financial incentives for sustainable development.

In China, a State Council requested all sewage plant to recover at least 10% of its treated effluent to overcome water shortages. Central government is supporting this strategy with 30% funding for 7 major cities. (China: 60% increase in flowrate of water recycled per annum for the last four years).

In USA, water recycling schemes receive heavy subsidies from Government for pilot projects and infrastructure expenditures. Tradable permits also exist to discourage discharge and indirectly encourage water recycling. In California the Water Factory 21 groundwater replenishment project is attracting State grants of 26% of the estimated US$352 million cost. (USA: 25% increase in flowrate of water recycled per annum for the last eleven years) In Israel the government funds 50% of the capital on reuse projects and recycles 60% of its wastewater.

In Australia there are a number of financial incentive schemes to promote water recycling. Even though most funding schemes aimed at encouraging water recycling apply to government bodies rather than to industries, industry seems to be indirectly encouraged through avoidance of emissions charges. (Australia: 40% increase in flowrate of water recycled per annum for the last nine years).

"To prevent water pollution and to economize on water resources" has been declared as a national policy by the Chinese government (*Pinjing et al.*, 2001). In 1986, the National EPA of China issued the Technical Policy of Water Pollution and Control (revised in 1996), that included recommendations concerning water reuse like:

• strengthening management of water resource and water use, pricing of the water resource exploitation;

• promoting the planned reuse of reclaimed municipal wastewater, especially in northern regions of China;

• considering the reuse of reclaimed municipal wastewater while the sewage system and treatment works are planed and designed;

• establishing stringent and systematic water quality standards for wastewater reuse.

Current situation on wastewater treatment and agricultural reuse in the Mediterranean region

(partially extracted from the article "Wastewater recycling and reuse in Mediterranean countries: recommended guidelines" by *G. Kamizoulis et al.*)

In Mediterranean countries there are many coastal and southern regions where there is a severe pressure on freshwater resources, due to low and seasonally uneven precipitation and high run-off. In some cases this is exacerbated by especially high demand from tourism and agriculture during the summer months. The main reasons are very high population density and low to medium precipitation (*Marecos et al.*, 1996).

The most off-stream water uses in Mediterranean countries are industrial cooling, agriculture for irrigation and domestic and industrial process water. On the other hand, there major losses from water delivered to agriculture for irrigation and domestic consumption. Notice should also be taken that Mediterranean countries have high agricultural use.

Albania

Treated water reuse is not practiced in Albania. A monitoring program for the quality of urban wastewater is implemented in Albania during the three last years. The construction of urban wastewater treatment plants in Vlora will create very soon the possibility for treated wastewater reuse.

Bosnia-Herzegovina

Before the war, in Bosnia and Herzegovina there was not any reuse of wastewater. There was an idea for reusing the wastewater of the city Posusje (the treated effluent of the wastewater treatment plant of about 5,000 population equivalent) for irrigation, but nothing happened. In the same line was the combined agricultural scheme for Krajina - Banja Luka, for a project on the reuse of wastewater following their treatment of bovine feedlots, following their treatment for the irrigation of cereal fields. Now, within the new country project (the general plan for water management, established for the water management, Sarajevo, 1998, p.218), it is foreseen that Bosnia and Herzegovina irrigate 10% of the agricultural land. For the irrigation process it was planned to use the natural watercourses and the artificial lakes (of the hydro-electric systems).

Croatia

Croatia is one of the countries with abundant water resources - 5,877 m^3/year per capita. Nonetheless, water management, and especially wastewater treatment is frequently ineffective. Water is, and could be, an even bigger problem during dry summers and high tourist seasons in "more arid karst" of Croatian Adriatic area that also happens to be the part of Croatia most oriented towards tourism. The biggest "drought" is on the islands whose water supply arrives from mainland through the pipes or with the water-carrier ships (except for the islands of Cres and Losinj). That is why it is important to introduce water reuse in this part of the country, moreover knowing that, at the present, wastewater is not being purified up to the needed standard, so the criteria for water reuse could be implemented with the future higher degrees of wastewater purification.

Water supply problems in Croatia manifest in the fact that the largest water consumption for both, the tourist resorts and the agricultural needs, coincide with the dry season. Until now a wastewater reuse in Croatia in any form of water supply has not been practiced so far. So far, water supply for local population and tourists in the coastal areas has been practised by transporting the water from the coast to the islands by submarine pipes and from locations reach in water (coastal rivers and spring) to the other coastal areas. But future development of these systems becomes expensive, both by investment and operation cost. Such practices do not include water supply for agricultural purposes. Consequently, in this area there is a need for new water supply sources either from desalinisation, which have already been practiced for water supply of population and tourists on the small islands near the coast or from the reuse of treated wastewater reuse mainly for agricultural purposes, which has not be practiced (*Margat,* 2002). Treated wastewater reuse has not been practiced due to the lack of effective sewerage systems and the absence of secondary treatment plants. Most of the towns in the coastal areas although small, are characterised with high fluctuation of population (tourists) and production of wastewater. The pretreated wastewater is discharged into the sea through long submarine outfalls. Prior to the wastewater discharge there is only preliminary treatment.

First wastewater treatment plant (WWTP) with water reuse in Croatia is case of constructed wetland in camp Glavotok – island Krk. That WWTP treats near 60 m^3/day of waste water. Quality of treated water is very high. Removal efficiency for faecal bacteria is 99,99%. Still treated water is disinfected by chlorine before being reused for flushing of sanitary devices. As camp has not got public water supply system and transport of drinking water is extremely high, it helped to the camp's owner to already return the investment to WWTP. Constructed wetlands with water recycling provide tremendous environmental benefits, including decreased wastewater discharges, pollution prevention and water conservation on that with water poor island. That pilot shows how water reuse could bring not only ecological, but economical benefits too (*Shalabi*, 2004).

The main possible future use of treated wastewater could be irrigation of tree crops, vineyards, olive trees, etc., as well as landscape irrigation. So far, there are no official plans or policy for wastewater reuse in Croatia.

Egypt

The Egyptian water strategy comprises the treatment and reuse of treated wastewater. Treatment of domestic wastewater is either primary or secondary. At present, wastewater is estimated at 4,930 Mm^3/yr, with 22 operational wastewater treatment plants, and about 150 plants under construction. The total capacity of the installed treatment plants amounts to about 1,752 billion m^3/yr (*FAO*, 2000).

Treated wastewater reuse in Egypt is an old practice. Sewage farming is deliberated as one of the most environmentally sound practices for disposing off sewage effluent. Since 1900, sewage water has been used to cultivate orchards in a sandy soil area at El- Gabal El-Asfar village, near Cairo. The area gradually increased to about 4,500 ha. According to the law, reuse of treated wastewater is not permitted for food and fibre crops. The Ministry of

Agriculture advocates the restricted reuse of treated wastewater for cultivation of non-food crops such as timber trees and green belts in the desert to fix sand dunes.

The major problem related to the current use of treated sewage water in Egypt is not enough infrastructure (treatment plants) to treat the amounts of wastewater produced and negative impacts of the above problems on both health and environment.

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 the high transportation cost, it is anticipated that most of the recycled water, about 55 to 60%, will be used for amenity purposes used as hotel gardens, parks, golf courses etc. A net of about 10 Mm^3 is conservatively estimated to be available for agricultural irrigation. The cost of recycled water is low, about 7.5 cents/m^3. This will reportedly allow irrigated agriculture to be expanded by 8-10% while conserving an equivalent amount of water for other sectors (*Papadopoulos*, 1995).

France

Few projects have in fact been carried out up to now in France, mainly because of problems relating to the cost of tertiary treatments. The projects implemented cover more than 3,000 ha of land, and quite a wide variety of applications: market gardening crops, orchard fruit, cereals, tree plantations and forests, grasslands, gardens and golf courses. The Clermont-Ferrand recycling scheme for irrigation of over 700 ha of maize is today considered to be one of the largest projects in Europe. The recent development of new treatment processes, such as membrane bioreactors (ultrafiltration, microfiltration), to obtain very high quality purified water, disinfected and with no suspended solids, could change the approach to the problem. and could open the door to recycling for domestic purposes (cleaning, toilet flushing, etc.). The reuse of industrial wastewater after purification to supply cooling water, wash water or even process water after sophisticated complementary treatment is widely developed in France (*Kamizoulis et al*., 2003).

Greece

In Greece, despite adequate precipitation, water imbalance is often experienced, due to temporal and regional variations of the precipitation, the increased water demand during the summer months and the difficulty of transporting water due to the mountainous terrain. In addition, in many south-eastern areas there is severe pressure for water demand, which is exacerbated by especially high demand of water for tourism and irrigation. Today, almost 65% of the Greek population is connected to over 350 centralised WWTP with a total capacity of over 1.45 Mm^3/d (*Tsagarakis et al*., 2001a). An analysis of data concerning the water balance of the areas of the treatment plants demonstrated that more than 83% of the treated effluents are produced in regions with a deficient water balance (*Tchobanoglous* and *Angelakis*, 1996). Therefore, wastewater reuse in these areas would satisfy an existing water demand. Few small projects on wastewater recycling and reuse are in practice, but no guidelines or criteria for wastewater recycling and reuse have been yet adopted beyond those for discharge (No E1b/221/65 Health Arrangement Action).

Israel

In Israel about 92% of the wastewater is collected by municipal sewers. Subsequently, 72% is used for irrigation (42%) or groundwater recharge (30%). The use of recycled wastewater must be approved by local, regional and national authorities. Effluent used for irrigation must meet water quality criteria set by the Ministry of Health. The trend is towards bringing all effluents to a quality suitable for unrestricted irrigation with wider crop rotation, which will require more storage and higher levels of treatment in the future. Cost-benefit analysis indicates that recycled wastewater is a very low cost source of water in Israel. As a result, treated wastewater within the overall water supply, particularly for irrigation, has risen to 24.4% of the allocations. The water crisis in Israel and the relatively low cost of treated wastewater, rather than pure environmental considerations, are the main driving forces behind the high percentage of reuse (*Angelakis et al.*, 2003).

Italy

A first survey of Italian treatment plants estimated the total treated effluent flow at 2,400 Mm^3/yr of usable water. This gives an estimation of the potential resource available for reuse. In view of the regulatory obligation to achieve a high level of treatment in Italy, the medium to large-sized plants (>100,000 inh. served), accounting for approximately 60% of urban wastewater flow can provide re-usable effluents with a favourable cost/benefit ratio. The use of untreated wastewater has been practiced in Italy at least since the beginning of this century, especially on the outskirts of small towns and near Milan. Among the oldest cases of irrigation with wastewater is the “Marcite” where water from the Vettabia river, which receives most of the industrial and urban untreated wastewater, is used. Nowadays, treated wastewater is used mainly for agricultural irrigation covering over 4,000 ha. However, the controlled reuse of municipal wastewater in agriculture is not yet developed in most Italian regions because of a stringent normative which ignores the findings of recent research work and experiences of uncontrolled reuse so common in Southern Italy. One of the largest projects was implemented in Emilia Romagna where over 450,000 m^3/yr of treated effluents are used for irrigation of more than 250 ha. The real costs for the distribution of recycled wastewater (power, labour, network maintenance) are covered by the users. New wastewater reuse systems have been recently completed in Sicily and Sardinia for agricultural irrigation (*Angelakis et al.*, 2003).

The difficulty in satisfying water demand with conventional resources (e.g. flowing and regulated surface water, groundwater) makes the use of unconventional water resources, such as wastewater, indispensable. Municipal wastewater is potentially the most useable, because of its reliability as supply (only slightly influenced by droughts), their allocation (in inland areas they are often available close to agricultural land), their composition (toxic compounds and salt concentrations are generally tolerable in various land and crop conditions) and the diffusion of treatment plants (imposed by the regulations on effluent disposal).

Agriculture is the largest water-consuming sector in Italy. In fact, it has been evaluated that water consumption is about 50 billions m^3/y, about 50% is used for irrigation purposes, 20% for industry, 20% for drinking purposes and 10% for other uses (*Barbagallo et al.*, 2001).

The planned exploitation of ever greater amounts of municipal wastewater could help to meet irrigation water demand particularly in Southern Italy, where in inland areas farmers have been practising uncontrolled wastewater reuse for a long time. In Northern and Central Italy, available water resources generally meet in full water demand from all sectors; however, the pollution of water bodies (both surface and groundwater) has raised problems about water quality. In these regions wastewater reuse could play an important role in controlling the pollution of water bodies, particularly in the Po Basin.

Wastewater reuse could easily become a common practice in Southern Italy; however, current legislation is extremely strict and does not take into account the achievements of research activity carried out all over the world and particularly in Mediterranean areas in the field of wastewater reuse.

Lebanon

In 1991, the total volume of wastewater generated in the country was 165 million m^3, of which 130 million m^3 from domestic uses and 35 million m^3 from industry. It was therefore evident that this huge potential for wastewater treatment and reuse has been lost. At present, only 4 m^3 of waste water are treated, of which 2 m^3 are used for irrigation, and the rest is disposed in the marine environment, or infiltrated by deep seepage to groundwater. Present estimates indicate that 35% to 50% of the untreated urban sewage water are infiltrated to the aquifers due to the lack of adequate discharge networks in some urban and rural areas, and pumped again for irrigation and domestic uses. Further, recent studies show that 89,6% of the industrial and domestic solid waste are untreated and put in natural places as rubbish, and 10,4% are dumped in the rivers (*Kamizoulis et al*., 2003).

Due to this situation, corrective measures are now carried out by the Government, aiming at implementing in different locations sewage treatments plants, with the aim to provide second-class water, suitable for irrigation and industrial use.

Libya

In Libya, At Hadba El Khadra (5 km from Tripoli on sandy soil), reuse of wastewater started in 1971. Wastewater is treated in a conventional treatment plant followed by sand filtration and chlorination (12 mg/L). The recycled wastewater is then pumped and stored in tanks with a 3-day storage capacity. Reuse was first conducted over 1,000 ha to irrigate forage crops and windbreaks. An additional area covering 1,970 ha: 1,160 ha forage, 290 ha vegetables like potatoes, onions, lettuce, etc. and 230 ha for windbreaks and sand dune stabilization) was also irrigated with recycled wastewater. 110,000 m^3/d were applied using sprinkler irrigation (pivots). Reuse is also taking place in Al Marj (north-east of Bengazi: 50,000 inhabitants) after biological treatment, sand filtration, chlorination and storage (*Angelakis et al*., 1999).

Malta

Malta, since agriculture is the main source of income, wastewater reuse for irrigation has been contemplated as early as 1884 in order to preserve freshwater for domestic use. Since 1983, the effluent of the Sant Antnin sewage treatment plant has been used for irrigation. The current 12,800 m^3/d of effluent are expected to be increased to 25,600 m^3/d after expansion of the plant. The plant uses an activated sludge process followed by rapid sand filters (9 $m^3/m^2 \cdot h$). The effluent is then disinfected with gaseous chlorine (20 mg/L and contact time 30 min) and pumped into irrigation reservoirs with a free chlorine residual of 2 mg/L. Due to low water consumption per inhabitant, the raw sewage in Malta is strong (BOD_5=530 mg/L and SS=445 mg/L) and has a high salinity (sodium and chloride) due to high levels of these ions in the domestic water supply. The effluent is used to irrigate 600 ha of crops by furrow and spray irrigation. The effluent quality is suitable for unrestricted irrigation and is used In to produce potatoes, tomatoes, broad and runner beans, green pepper, cabbages, cauliflower, lettuce, strawberries, clover, etc. Despite the high salinity, there are no problems with crops. This is probably associated with high permeability of the calcareous soil. Soil monitoring has shown a salt accumulation in the top soil during the irrigation season followed by leaching to the groundwater with the winter rains.

Morocco

Most Moroccan towns are equipped with sewerage networks, frequently collecting also industrial effluent. The volumes of wastewater collected were estimated at 380 Mm^3/yr in 1988 and are expected to reach 700 Mm^3 in 2020. For Casablanca alone, the annual production of wastewater was estimated at 250 Mm^3 in 1991, with forecasts of around 350 Mm^3 in 2010. However, out of the 60 largest towns only 7 have a MWTP, but 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 7,235 ha of crops after insufficient or even no treatment. A high proportion of the remaining water is discharged to the sea (Conseil Superieur de l' Eau, 1988 and 1994).

Due to the increase of the urban population by 500,000 inh./yr a rapid increase in drinking water consumption in towns is expected. This will require the transfer of freshwater resources from one catchment area to another and the replacement of freshwater by wastewater for irrigation. The volume of wastewater available for reuse will increase with the improvement of sewerage networks. Under these conditions the share of wastewater in the overall water resource could be several percentage points higher within a few decades, especially if the wastewater of coastal towns is also recycled. Even though wastewater only represents a small share of water resources on a national scale, it can help solve local problems. This is particularly true for towns located in arid areas that are isolated from the major supply systems. This is also proven by the high rate of spontaneous wastewater reuse in inland towns (*Kamizoulis*, 2003).

The reused water is mainly raw wastewater sometimes mixed with fresh water. The irrigated crops are mainly fodder crops (4 harvests of corn per year around Marrakech), fruit trees, cereals and produce (growing and selling vegetables to be eaten raw is prohibited). Morocco does not have yet any specific wastewater reuse regulations. Reference is usually made to the WHO recommendations. While reducing its environmental impact on the conventional receiving waters, the lack of wastewater treatment before reuse in inland cities results in adverse health impacts. Improvement in wastewater reuse methods and in the quality of reused water for irrigation is recognized as essential. In karstic areas, the infiltration of wastewater affects groundwater resources to varying degrees. Lastly, the inadequate sanitation, collection and treatment of wastewater, mostly in small towns, are often a risk to the eutrophication of dams. The discharge of raw wastewater to the sea without proper outfalls may affect the development of tourism by degrading the sanitary quality of beaches and generating unpleasant odours and aesthetics.

Palestine

Palestine has some guidelines apply to the reuse of treated wastewater from housing, municipalities, industry and commercial enterprises in the Gaza-Strip, Palestine. They are including the requirements for: a) the collection, additional treatment and storage of treated wastewater; b) the irrigation in agriculture as well as areas of public landscape; c) the enrichment and the quality improvement of the ground water; d) the monitoring of the treated wastewater quality and the specification of sampling analysis methods; e) the monitoring to assess the long-term impact on water, soil and public health. The discharge of treated wastewater into surface water and the sea is not regulated by these guidelines. The guidelines provide vital information for collection, additional treatment and storage of treated effluent in such a manner that the use of ground water can be replaced, the aquifer can be enriched and the inflow of saline water into coastal aquifer can be reduced.

The overall objective of the guidelines is to preserve the environment by sustainable management of the water resources. The main objective is to reuse all treated wastewater to improve the water balance and the ground water quality as well as protecting soil and the public health. The treated wastewater should be used for irrigation and groundwater recharge. For every project in the area of reuse of treated wastewater the participation of all relevant stakeholders should be achieved (*Zubiller, et.al*, 2002).

These guidelines serve the translation into action of the "Palestinian Environment Law" by the Ministry of Environmental Affairs, dated 6th of July 1999, that became effective on 28 December 1999, particularly the Section 3 Water Environment, Article s 28 – 30.

Some of the technical principles that include these guidelines, are the following: a) all wastewater shall be collected, treated and used according to these guidelines to minimise the deficit in the water balance; b) the reuse of wastewater that is not in compliance with the standards is forbidden; c)treated wastewater has to be transported in closed pipes; d) to reach the standards for reuse the dilution of wastewater with freshwater is forbidden; e) direct injection into the aquifer is forbidden; f) the reuse of wastewater for irrigation is only allowed if it follows the regulations and standards according to the relevant type of cultivation and irrigation technique; g) the use of sprinklers is not allowed for irrigation; h) all kinds of vegetables are not allowed to be irrigated by treated wastewater; i) irrigation with treated wastewater has to be stopped two weeks before harvest; j) fruits on the ground from trees that have been irrigated with treated wastewater are forbidden to eat, to process or to sell.

Slovenia

In Slovenia it has been recently started the development of the technology of treatment of various types of wastewater by constructed wetlands. One of the priorities of the constructed wetlands technology is water recycling and reuse. Unfortunately, so far the constructed wetlands are only used for small communities and consequently for rather limited amounts of water to be recycled. It is expected, that in the very near future, that technology, including water recycling and reuse, will be used widely and mainly in touristic areas.

Syria

The total volume of industrial and municipal wastewater effluent is estimated at 400, 700 and 1600 million m^3/yr for 1990, 2000, 2025 years, respectively. The discharge of these wastes in a non-treated form into watercourses and rivers led to the degradation of surface water quality to the point where it became unsuitable for direct use for drinking purposes. The most important results of this noticeable pollution of rivers and other water bodies were the disappearance of living organisms because of the lack of oxygen, the appearance of undesirable plants and weeds that clog water canals in certain regions, hateful odours resulting from decomposition of organic materials and the abundance of insects and rodents. The health conditions of the population living in the areas of intensive use of untreated wastewater also degraded. Diseases such as typhoid and hepatitis spread at a much greater rate in these regions (*Angelakis, 2003*). The total area irrigated with wastewater is estimated at around 40,000 ha, with 20,000 in Aleppo.

Several WWTP have been already implemented, such as Damascus (Adra), Aleppo, Homs, Salamyeh, Ras El Ein, and Haramil Awamid. The treated wastewater potentially available for reuse is estimated in 400 million m^3/yr by which an agricultural area more than 40,000 ha could be irrigated. Several other WWTP are under planning or construction such as Tartus, Sweida Idleb, Al Raqqua, Al Nabik and Dar'a. Thus, the treated wastewater is expected to increase substantially in the near future. To face this alarming situation and at the same time secure treated water for use in agriculture, the Syrian government launched a programme for constructing several treatments plants two of which are already operational in Damascus and Aleppo. The Damascus plant currently treats 300 m^3/d. using activated sludge method. The total area irrigated by treated and untreated water is 18,000 ha located in the outskirts of the city. With the exception of a large share of wastewater produced in Damascus and Aleppo, the collected raw sewage from the cities, villages and other residential areas is used without any treatment, either for direct irrigation of agricultural crops or disposed to the sea or water bodies that are used for unrestricted irrigation. The use of wastewater is restricted to fodder, industrial crops and fruit trees on smaller areas, but it is uncommon that it is used for other crops as well. The situation is expected to improve when the treatment plants under construction in all large cities of the country will be operational. In towns and areas where traditional sewerage systems have been inefficient, people are reluctant to pay.

Tunisia

Irrigation with recycled wastewater is well established in Tunisia. Wastewater from la Cherguia treatment plant, in Tunis, has been used since 1965 to irrigate the 1,200 ha of La Soukra (8 km North East of Tunis) and save citrus fruit orchards as aquifers had become overdrawn and suffered from saline intrusion. The effluents from the treatment plant were used, mainly during spring and summer, either exclusively or as a complement to groundwater. Water from la Cherguia's secondary sewage treatment plant is pumped and discharged into a 5,800 m^3 pond before storage in a 3,800 m^3 reservoir. The water is then delivered by gravity to farming plots through an underground pipe system. A Regional Department for Agricultural Development (CRDA) supervises the operation and maintenance of the water distribution system and controls the application of the Water Code. After this experience, a wastewater reuse policy was launched at the beginning of the eighties. The 6,366 ha involved in 1996 will be expanded to 8,700 ha in 1998 and ultimately to 20,000 ha.

Turkey

The use of reused water for irrigation in Turkey is mainly due to the scarcity of water resources and inefficient water resource management, both of which are exacerbated by growing population, economic conditions and increasing urbanization.

Although, domestic wastewater should not be used directly without proper treatment, it contains nutrients, which are essential for plant growth and can be used after treatment as a water resource in a more convenient way. Especially in arid summer times in which irrigation activities should be increased for agricultural production, it can be said that wastewater is reused for irrigation in some cases. As a result the concentration of nitrogen, phosphorus, salinity, biodegradable organic materials, trace elements may depict subsequent increases in the agricultural production areas if wastewater not treated properly. Boron is another parameter which should be given special emphasize since, high boron loaded characteristic of the water source, since accumulation of boron in such a heavy soil due to irrigation will lead to sharp decrease in agricultural productivity.

Success stories on agricultural reuse of urban wastewater in Mediterranean countries

Selected cases in Cyprus

In the following section some case studies regarding direct, official agricultural reuse of municipal wastewater have been reported. Detailed information about the selected WTP is given below.

Site visits for "CASE" 1 and "CASE 2" have been performed by ARI's sub-contractor, Epsilon Consulting Ltd. The selected wastewater treatment plants were visited in January 2004. During the site visits, information was collected from the operators of the Treatment Plants as well as some picture of the Treatment Plant and the reuse sites. All the information about the technical, operational, economical and social situation of the Wastewater Treatment Plant (WWTP) were then gathered together and given in the following sections of this report.

CASE 1: Larnaca Wastewater Treatment Plant

Location:

Meneou Area behind the International Airport of Cyprus.

Year of the project development:

The treatment plant has been in operation since 1995. The treated effluent has been used for irrigation purposes since 2000.

***Water origin*:**

The treatment plant of Larnaca Municipality provides domestic wastewater treatment for 46,340 PE. At the moment the WWTP serves only 36,000 PE.

***Volume (or flow) of water affected*:**

The design capacity of the treatment plant is 8,500 m^3/d. It increases in summer months to 5,500 m^3/d and decreases in winter months to 4,500 m^3/d. The effluent is being used for the irrigation of different crops in nearby areas.

***Water treatment before reuse (technologies/process applied)*:**

The treatment facility consists of: Bar racks, grit chamber, aeration tanks, secondary settlement tanks, sand filter and chlorination tank. The Flow Diagram of the Larnaca WTP is presented in Figure 6. On the other hand, Figures 7-10 show different parts of Larnaca WWTP.

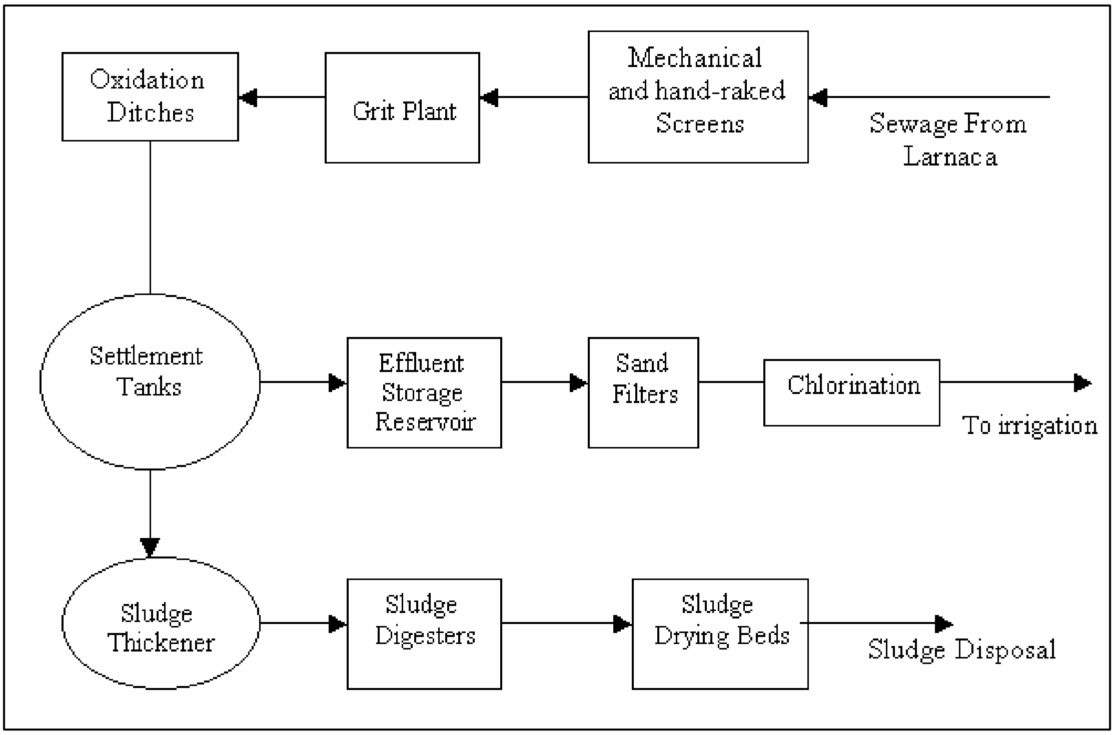

Figure 6. Larnaca WWTP Flow Diagram.

Figure 7. Sand Filter.

Figure 8. Irrigation Pumping Station.

Figure 9. Filter Press.

Figure 10. Sludge Drying Beds.

***Reclaimed water quality*:**

An analysis reveals the following parameters for the effluent of Larnaca WTP:

Table 6. Larnaca effluent quality.

Effluent Quality		Removal efficiency
Parameter	**Value (mg/l)**	
BOD_5	2.6	99.37
COD	56	93.10
SS	1.7	99.46
pH	7.5	-
Total N	8.5	90.22
NH_3-N	2.4	96.76
NO_3-N	6.9	-
N	17.8	-
Conductivity	3.4 (mS/cm)	-
Cl	555	2.97
B	0.8	-
P	0.6	92.04
Cd	<0.01	-
Cu	0.01	-
Ni	0.06	-
Pb	1.87	-
Zn	0.35	-
Cr III	<0.01	-
Total E.Coli/100ml	5	-
Intestinal E.Coli/100ml	0	-
Residual Cl	0.2	-

***Water reuse applications*:**

Since the plant has been in operation, the effluent is being used for irrigation of agricultural land at Dromolaxia Village where corn and alfalfa are cultivated. The treated water is also used by the hotels, International Airport and Larnaca Municipality for the irrigation of gardens, parks and fields during the summer season. For that purpose, the effluent is being discharged through pumping stations.

***Total area affected by irrigation*:**

An average agricultural area of 150 hectares is being regularly irrigated. In addition the recycled water is being used by the hotels connected to the Sewerage Network and also by the Municipality for the irrigation of gardens, parks and fields.

***Types of products cultivated in irrigated areas*:**

A variety of animal plants i.e. corn, alfalfa, as well as garden parks and fields are regularly irrigated with the treated wastewater.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The total cost of the project is 30 million CYP (50 million €), out of this, 5.5 million CYP (9.3 million €) is the cost of the tertiary treatment plant with the reuse network and pumping station. The cost for the production of tertiary treated water is around 0,3 CYP (0.5 €) per cubic meter.

***Problems founded in the start-up, development or final application of the project*:**

According to the information gathered from the plant staff, the major operational problem of the plant is the oils inserted in the system from the restaurants. Another problem is that the actual BOD concentration, is much higher than the envisaged in the plant's design (5,000 mg/l instead of 300 mg/l).

The extension of the current plant and the network is being planned in the nearest future due to the fact that the treatment plant capacity is not sufficient enough under current National and EU legislations.

Table 7. Larnaca WWTP Evolution.

Year	Population Equivalent (PE)	%	Capacity of the Treatment Plant (m^3/day)
2003	36,000	50%	8,500
2006	40,000	60%	10,000
2012	67,000	100%	17,000

Remarkable results:

For almost three years, the treated effluent is being used for irrigation purposes. It has recently been reported that animals crops are growing noticeably fast since the effluent application.

***Information Sources*:**

All information was provided from the treatment plant representatives.

<u>CASE 2</u>: <u>Ayia Napa - Paralimni WTP</u>

Location:

Cavo Greco area (between Ayia Napa and Paralimni)

Year of the project development:

The plant has been constructed in 2000 and has been operated since August 2002.

***Water origin*:**

The treatment plant provides municipal wastewater treatment within the boundaries of the municipalities of Ayia Napa and Paralmni for 75,000 PE.

***Volume (or flow) of water affected*:**

The design capacity of the treatment plant is 12,000 m^3/d. The plant operates close to its full capacity at 9,600 m^3/d in the summer and decreases in winter months to 4,000 m^3/d. Since the start-up of its operation, 100% of treated wastewater is being used as irrigation water in summer.

***Water treatment before reuse (technologies/process applied)*:**

The system consists of Primary Treatment (coarse and fine screen), Secondary Treatment (activated sludge) follows finally by the Tertiary Treatment (Sand Filter and Chlorination). There is also a sludge treatment unit, that consists of sludge thickening tank and belt filter press.

The mechanical pretreatment and the secondary treatment takes place in a common system for the two municipalities, while there are two storage tanks and two tertiary treatment plants one for each municipality.

Some photos and the Flow Diagram of the Paralimni and Ayia Napa WWTP are presented in Figures 11 to 15.

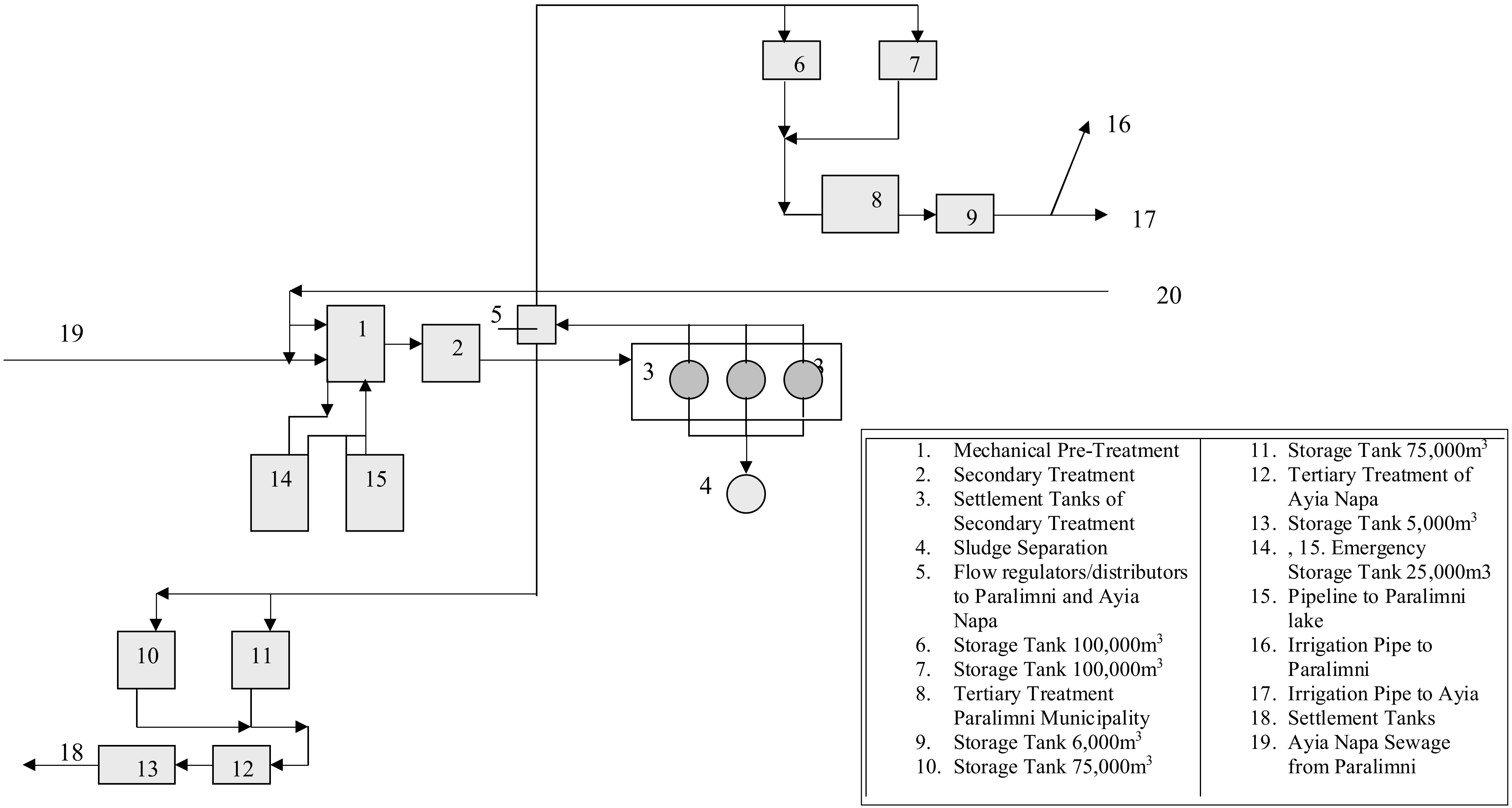

Figure 11. Paralimni and Ayia Napa WWTP Flow Diagram.

Figure 12. Pretreatment.

Figure 13. Settlement Tank.

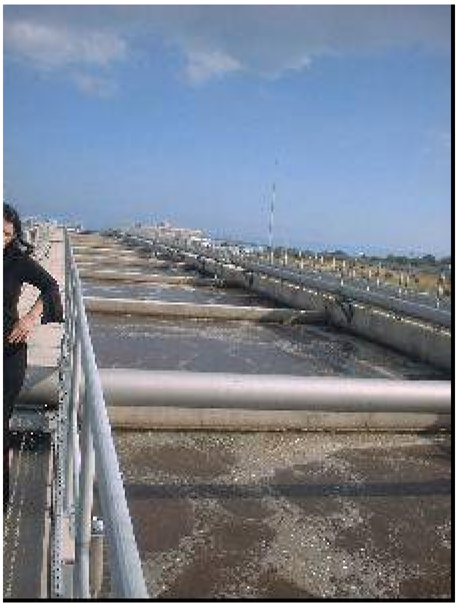

Figure 14. Aeration Tank.

Figure 15. Storage Tank (Secondary treated water).

***Reclaimed water quality*:**

Table 8 and 9 show the result of the analysis of the effluents to Paralimni and Ayia Napa treatment plants.

Table 8. Paralimni effluent quality.

Effluent Quality (Summer)		Removal efficiency	Effluent Quality (Winter)		Removal efficiency
Parameter	**Value (mg/l)**		**Parameter**	**Value (mg/l)**	
COD	52.5	92.50	**COD**	48.9	86.23
BOD	1.48	99.62	**BOD**	1.14	99.43
SS	2.65	98.93	**SS**	1.95	98.89
Total N	15.1	75.45	**Total N**	23.8	40.50
NH_4^+	0.95	97.29	**NH_4^+**	0.31	99.03
NO_2^-	52.3	-	**NO_2^-**	84.1	-
NO_3^-	52.3	-	**NO_3^-**	84.1	-
Total P	6.65	34.16	**Total P**	6.12	29.66
PH	6.8	-	**pH**	6.7	-
T	28.9	-	**T**	16	-
Alkalinity	1.67	72.17	**Alkalinity**	1.7	73.85
Conductivity	1.8	10.00	**Conductivity**	2.2	15.38
Free Cl	0.81	-	**Free Cl**	2.94	-
Total Cl	1.72	-	**Total Cl**	3.94	-
Total E.Coli	0	-	**Total E.Coli**	0	-
Intestinal E.Coli	7	-	**Intestinal E.Coli**	5	-
Intestine Worms	0	-	**Intestine Worms**	0	-

Table 9. Ayia Napa effluent quality.

Effluent Quality (Summer)		Removal efficiency	Effluent Quality (Winter)		Removal efficiency
Parameter	**Value (mg/l)**		**Parameter**	**Value (mg/l)**	
COD	55	92.14	**COD**	50.6	85.75
BOD	1.6	99.59	**BOD**	1.4	99.30
SS	3.1	98.74	**SS**	2.18	98.75
Total N	15.1	75.45	**Total N**	23.8	40.50
NH_4^+	0.84	97.60	**NH_4^+**	0.40	98.75
NO_2^-	0.09	-	**NO_2^-**	0.02	-
NO_3^-	58	-	**NO_3^-**	97.1	-
Total P	6.81	32.57	**Total P**	7.57	12.99
PH	6.71	-	**PH**	6.62	-
T	29	-	**T**	16	-
Alkalinity	1.65	72.50	**Alkalinity**	1.74	73.23
Conductivity	1.81	9.50	**Conductivity**	2.23	14.23
Free Cl	1.11	-	**Free Cl**	3.9	-
Total Cl	2.13	-	**Total Cl**	5.12	-
Total E.Coli	0	-	**Total E.Coli**	0	-
Intestinal E.Coli	7	-	**Intestinal E.Coli**	5	-
Intestine Worms	0	-	**Intestine Worms**	0	-

***Water reuse applications*:**

Since the plant has been in operation, the effluent is being used for irrigation of agricultural land in Paralimni where potatoes are mostly cultivated. The treated water is also used by the hotels and the Municipalities for the irrigation of gardens and parks during the summer season. For that purpose, effluent discharge is being pumped to the location where it is used for irrigation.

***Total area affected by irrigation*:**

An average agricultural area of 100 hectares is being regularly irrigated. In addition, the recycled water is being used by the hotels connected to the Sewerage Network and also by the Municipalities for the irrigation of gardens, parks and fields.

***Types of products cultivated in irrigated areas*:**

Effluent is used for the irrigation of potatoes, parks, gardens and fields.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The total cost of the plant is 8,5 million CYP (14.4 million €), out of this 3,5 million CYP (5.9 million €), is the cost of the tertiary treatment plant with the reuse network and pumping station. The cost for the production of tertiary treated water is around 0,3 CYP (0.5 €) per cubic meter (20 cents for secondary treatment and 10 cents for tertiary treatment). The Sewerage Board of Paralimni and Ayia Napa sell this water at the price of 15 cents CYP/m^3 for the hotels and 6 centsCYP/m^3 for agriculture (0.25 and 0.10 €/m^3 respectively).

***Problems founded in the start-up, development or final application of the project*:**

According to the information gathered from the plant staff, the major operational problem of the plant is the high temperature of the water in the summer (30-35^{o}C instead of 20-25^{o}C). Another problem is that the actual BOD concentration is much higher than the envisaged in the plant's design (5,000 mg/l instead of 300 mg/l).

The extension of the current plant and the network is being planned in the near future due to the fact that the treatment plant capacity is not sufficient enough under current National and EU legislations (Table 10).

Table 10. Ayipa Napa-Paralimni Plant Evolution.

Year	Population Equivalent (PE)	%	Capacity of the Treatment Plant (m^3/day)
2003	50,000 (A) 25,000 (B)	70% (A) 65% (B)	12,000
2006	70,000 (A) 27,000 (B)	100 (A) 80% (B)	15,500
2012	70,000 (A) 31,000 (B)	100% (A) 100% (B)	20,000

Remarkable results:

The effluent has been used for irrigation purposes since its first operation time. The demand of the treated water is, until the currently moment) less than the production.

***Information Sources*:**

All information was provided from the treatment plant representatives.

<u>CASE 3</u>: <u>Vathia Gonia WWTP</u>

Location:

Vathia Gonia, Nicosia, Cyprus. The Cyprus economy is heavily dependent on tourism. Tourist zones cover 105 km, i.e. 37% of the coastline, Predictions estimate that tourist arrivals will exceed 3 millions for the year of 2004; the peak flow of tourists usually comes in the period from January to June. This indicates that Vathia Gonia (Nicosia) is considered as an area with seasonal tourists' pollutant discharge loads.

Year of the project development:

The construction of the plant commenced in February 1996 and was completed in February 1998. The operation of the plant started gradually with domestic and industrial wastewaters.

***Water origin*:**

Domestic and industrial (dairy, metal, etc) wastewaters originating from the Districts of Larnaca and Nicosia.

***Volume (or flow) of water affected*:**

The capacity of the treatment plant is 2,200 m^3/d (0.8 Mm^3/yr). The effluent is stored in a 284,000 m^3 storage and balancing reservoir prior to distribution.

***Water treatment before reuse (technologies/process applied)*:**

Due to the variable composition of the incoming wastewater, various pre-treatment processes are employed for more effective results. Pre-treatment stage consists of: screening, grit removal, dissolved air flotation, chemical precipitation of metals, storage for gradual feed into the system, storage and transfer to the aerobic digesters via macerating pumps.

Secondary stage consists of: two parallel balancing tanks, anoxic tank, two parallel aeration tanks and two secondary settlement tanks. It is followed by tertiary treatment, where effluent from the final settling tanks is pumped into four continuously back-washed tertiary sand filters. Effluent is chlorinated in a contact tank prior to discharge to the storage reservoir of 284,000 m^3 capacity. The Figure 16 shows the flow diagram of the plant.

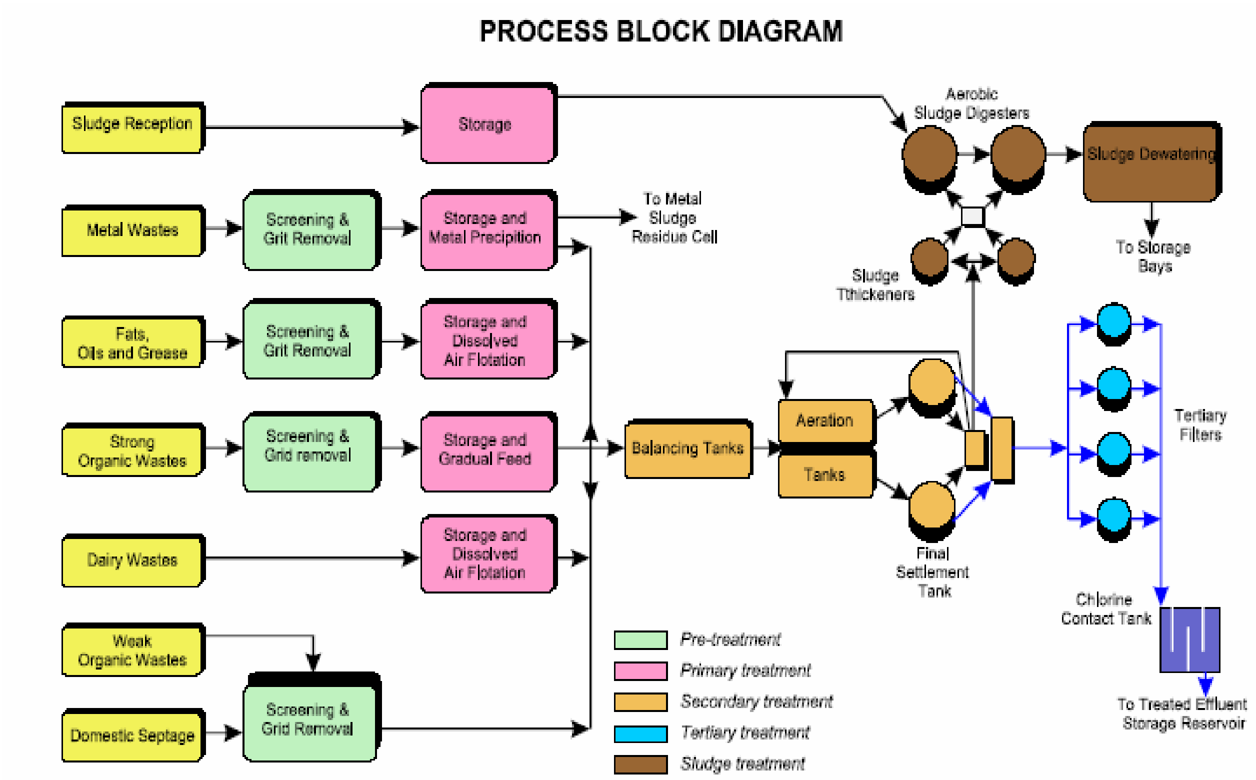

Figure 16. Vathia Gonia Wastewater treatment plant system,
(Source: Ministry of Agriculture, Natural Resources and Environment, Cyprus 2000).

***Reclaimed water quality*:**

Table 11. Reclaimed water quality of Vathia Gonia City.

Parameter	Units	Domestic Sampler	Balance tank Outlet	Anoxic Tank	Aeration Tanks	Secondary Effluent	Tertiary Effluent
pH		7.6	7.0	7.6	7.7	7.8	7.6
EC	micro S/cm	2,421	2,613	2,397	2,217	2,173	2,222
BOD_5	mg/L	960	896	-	-	8	10
COD	mg/L	3,006	2,631	-	-	80	72
SS	mg/L	1,532	1,658	2,964	2,910	31	9
NH_3	mg/L	147	103	-	9	0	2
NO_3	mg/L	10	9	-	3	12	3
SO_4	mg/L	-	99	-	186	-	193
PO_4	mg/L	122	57	-	33	47	32
Cl	mg/L	95	675	-	731	582	517
O & V	%SS	20	50	59	46	-	
Total Solids	mg/L	-	4,931	5,884	4,811	-	-

***Water reuse applications*:**

Treated water is used for irrigation.

***Total area affected by irrigation*:**

The irrigation network covers approximately 50 ha of land near Potamia and Geri villages.

***Types of products cultivated in irrigated areas*:**

Fodder crops.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Design and Construction: 14.2 million €. Five years operation and maintenance: 2.4 million €.

***Problems founded in the start-up, development or final application of the project*:**

Problems were mainly due to variable composition of the incoming wastewater. Particular attention was given to odor control such that air from the tanks is vented through biological filters for removal of odorous compounds.

Remarkable results:

The latest technology has been applied at the plant. Since the commencement of its operation, both its targets, namely the protection of environment and saving of water resources, have been fulfilled. Odour control is one of the main features of the plant due to the peculiarity of the wastes that are treated, which being septic, can cause serious odour nuisance. Particular attention was given to cover all tanks that may emanate odours and to ensure that all air from the tanks is vented through biological filters for the removal of odorous compounds.

***Information sources*:**

Marie-Pons, 1999. Available from:
http://www.ensic.inplnancy.fr/COSTWWTP/Work_Group/Wg5/Hamburg2000/Hajipakkos.pdf, [Accessed Nov. 26 2003].

Ministry of agriculture, natural resources and environment water development department, 2002. The central wastewater treatment at Vathia Gonia, Republic of Cyprus. Available from: http://www.pio.gov.cy/wdd/eng/publications/vgonia_eng.pdf, [Accessed Dec. 20, 2003].

The central wastewater treatment plant in Vathia Gonia, Cyprus.
http://www.hydro.ntua.gr/labs/sanitary/agricultural_reuse.htm.

http://www.caramondani.com.cy/completed.htm

<u>CASE 4</u>: <u>Limassol WWTP</u>

Location:

Limassol.

Year of the project development:

1995.

***Water origin*:**

Domestic and industrial wastewater.

***Volume (or flow) of water affected*:**

The mean flow rate at the ultimate stage will be 48,205 m^3/d. Currently, the average sewage flow is about 10,000 m^3/d (3.65 Mm^3/yr).

***Water treatment before reuse (technologies/process applied)*:**

Secondary and tertiary treatments are employed. Secondary treatment includes grit, oil, grease and large solids removal in its primary processes, followed by conventional activated sludge treatment. The sludge is anaerobically digested and dewatered on belt presses.

***Reclaimed water quality*:**

For secondary effluent:
BOD_5: 20 mg/l
TSS: 20 mg/l

The quality of the tertiary effluent, is of very high standards and well within the requirements of the European Union requirements as specified by the applicable guidelines, regulations and standards.

***Water reuse applications*:**

Reclaimed wastewater is used for many purposes including groundwater recharge, restricted irrigation such as public amenity areas, golf courses, etc., but excluding vegetable irrigation. The tertiary treated effluent is delivered to the Water Development Department of the Ministry of Agriculture, which has the responsibility of the distribution and sale to various users.

***Total area affected by irrigation*:**

Not data available.

***Types of products cultivated in irrigated areas*:**

Not data available.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The Sewerage and Drainage System of Limassol Amathus (SBLA), the largest in Cyprus, is being developed in phases. The population which is currently being served is about 70,000 people and at the ultimate stage 200,000 people will be served. Phase A of the project that started in 1995, consists of a sewage network of about 180 km, six large pumping stations, a tunnel of about 800m long, a sea outfall for emergency situations, a secondary treatment plant, a tertiary treatment plant. The total cost of Phase A of the project, including the tertiary treatment plant, is about 90 million US$. Phase B of the project is currently under construction in phases. On completion of the whole project, the ultimate cost for the sewerage treatment and water reuse scheme is projected to exceed 180 million US$.

***Problems founded in the start-up, development or final application of the project*:**

Not problems reported.

Remarkable results:

The cost of production of the tertiary effluent is much lower than the desalinated water. It is estimated that the marginal cost of the tertiary treatment effluent is currently about 0.09 US$/ml (not including the secondary treatment costs that should be employed in any case). Water resources are used more efficiently and cost effectively with the help of wastewater reuse scheme. Freshwater can be saved for domestic use.

***Information sources*:**

Papaiacovou I., 2001. Case study- wastewater reuse in Limassol as an alternative water source. Desalination 138, 55-59.

Selected cases in France

CASE 1: Mont Saint Michel Proyect

Location:

Mont Saint Michel.

Year of the project development:

1994.

***Water origin*:**

Domestic wastewater.

***Volume (or flow) of water affected*:**

Not data available.

***Water treatment before reuse (technologies/process applied)*:**

Activated sludge, 3 stabilization lagoons.

***Reclaimed water quality*:**

An analysis reveals the following parameters for the effluents:

Faecal Coliforms: 20/100 ml
Helminth Eggs: 0/100 ml

***Water reuse applications*:**

Irrigation.

***Total area affected by irrigation*:**

An average agricultural area of 265 hectares.

***Types of products cultivated in irrigated areas*:**

Meadows and maize.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Not data available.

***Problems founded in the start-up, development or final application of the project*:**

Not data reported.

Remarkable results:

Not data reported.

***Information Sources*:**

Faby J.A., Brissaud F. and Bontoux J., 1999, Wastewater Reuse in France: Water quality standards and wastewater treatment technologies, Water Sci. Technol., Vol. 40, No 4-5, pp 37-42.

Brissaud F., 2002, Wastewater Reclamation and Reuse in France, e-books in Hydrored web-site as personnel communication, http://tierra.rediris.es/hidrored/ebooks/ripda/bvirtual/articulo06.PDF

CASE 2: Clermont Ferrand Proyect

Location:

Clermont Ferrand.

Year of the project development:

1996.

***Water origin*:**

Domestic wastewater.

***Volume (or flow) of water affected*:**

25,000 m^3/day (9 Mm^3/yr).

***Water treatment before reuse (technologies/process applied)*:**

Activated sludge, lagoon.

***Reclaimed water quality*:**

An analysis reveals the following parameters for the effluents:

Faecal Coliforms: 90/100 ml
Enterococci: 24/100 ml

***Water reuse applications*:**

Irrigation.

***Total area affected by irrigation*:**

An average agricultural area of 600 hectares.

***Types of products cultivated in irrigated areas*:**

Maize.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Not data available.

***Problems founded in the start-up, development or final application of the project*:**

Not data reported.

Remarkable results:

Not data reported.

***Information Sources*:**

Faby J.A., Brissaud F. and Bontoux J., 1999, Wastewater Reuse in France: Water quality standards and wastewater treatment technologies, Water Sci. Technol., Vol. 40, No 4-5, pp 37-42.

Bontoux J., Courtois G., 1996, Wastewater Reuse for Irrigation in France, Water Sci. Technol., Vol. 33, No 10-11 pp 45-49.

Brissaud F., 2002, Wastewater Reclamation and Reuse in France, e-books in Hydrored web-site as personnel communication.
http://tierra.rediris.es/hidrored/ebooks/ripda/bvirtual/articulo06.PDF

CASE 3: Wastewater reuse in a French island

Location:

French island of Noirmoutier (Atlantic coast).

Year of the project development:

Since 1996.

***Water origin*:**

Treated domestic wastewater proceeding from two wastewater treatment plants (WWTP), La Salaisière (in the North) and La Casie (in the South), treat municipal sewage collected from the four communities of the island.

***Volume (or flow) of water affected*:**

Average sewage flow rates in La Salaisière and Casie WWTP´s are 8,000 m^3/d and 1,500 m^3/d, respectively. At present, from 150,000 to 300,000 m^3/year of wastewater stored at La Salaisière WWTP are utilised to irrigate 2.70 km^2 potato fields, while at La Casie about 30,000 to 50,000 m^3/year are used to irrigate an area of 0.35 km^2 potato fields.

***Water treatment before reuse (technologies/process applied)*:**

La Salaisière secondary effluents are stored in a series of 4 reservoirs, with an overall storage capacity of 220,000 m^3, making water available for irrigation and improving the microbiological quality of the stored water. Stored water that cannot be used for irrigation is disposed of to the sea. Between May and July, most of the stored water is used for irrigation and no water is discharged into the sea. Primary effluents of La Casie WWTP are stored in 90,000 m^3 stabilisation ponds.

***Reclaimed water quality*:**

Helminth Eggs: < 1 / 1,000 ml
Faecal Coliform: < 1,000 / 100 ml

***Water reuse applications*:**

Agricultural and landscape irrigation.

***Total area affected by irrigation*:**

2.70 km^2 in Salaisière and 0.35 km^2 in La Casie.

***Types of products cultivated in irrigated areas*:**

Potatoes.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The four communities of the island have constituted an association which is in charge of water supply and wastewater collection, treatment, reuse and disposal. This association purchases the treated water and sells it to the consumers. It also sells treated wastewater to the farmers. Prices listed in Table 12 vary with the quantity, quality and usage of water.

Table 12. Average water prices in Noirmoutier (including the cost of subscription and meters).

Potable water (€/m^3)				Reclaimed water (€/m^3)
Purchased	Sold			Sold
	Domestic, hotel,…	Landscape	Agriculture	Agricultural irrigation
0.60	4.57*	0.67	1.54	0.23-0.30

Note: *including the price for sewage treatment and disposal: 2.21 €/m^3

***Problems founded in the start-up, development or final application of the project*:**

Not data reported.

Remarkable results:

The study shows that, in Noirmoutier, wastewater reclamation and reuse for crop irrigation is the most cost-effective solution to the lack of water resources and the protection of sensitive environment. Treated wastewater is the resource most easily accepted by the farmers for its low price.

***Information Sources*:**

Xu, P., Valette, F., Brissaud, F., Fazio, A., Lazarova, V. Technical –economic modeling of integrated water management: wastewater reuse in a French island. Wat. Sci. & Technol. 43 (10), pp. 67-74, (2001).

Selected cases in Greece

CASE 1: Wastewater reuse in Chalkis, Greece

Location:

City of Chalkis.

Year of the project development:

The whole project of reclamation of wastewater started at 1998 and constructed the first UV.

***Water origin*:**

Mainly domestic wastewater.

***Volume (or flow) of water affected*:**

A total daily flow of 9,000 m^3/day.

***Water treatment before reuse (technologies/process applied)*:**

Wastewater treatment (Figures 17 and 18) consists of the following stages: pre-treatment of the municipal wastewater, pre-treatment of septage sewerage, primary clarifiers, aeration tanks, final clarifiers, advanced treatment, thickeners, digesters and dewatering unit for sludge treatment. The Advanced Treatment of the WWTP of Chalkis consists of, coagulation-filtration, ultraviolet disinfection using two types of UV systems (closed and open type) and chlorination. In 1998 the first UV bank was constructed, which produce 55 mWs/cm^2 dose. After test, it was decided to increase the total dose of the UV lamps at 120 mWs/cm^2.

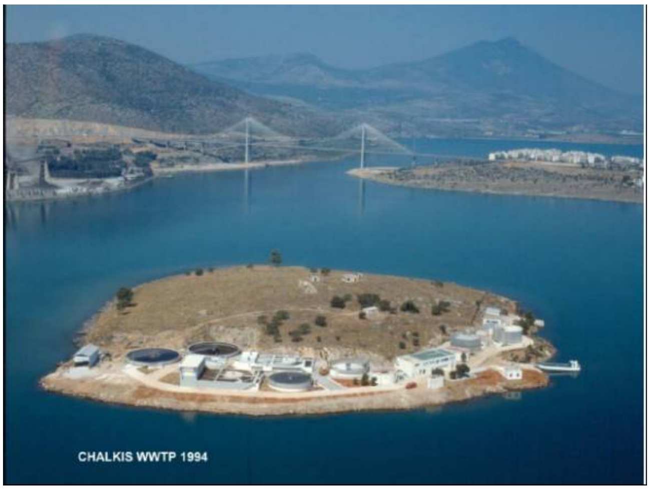

Figure 17. Advanced Wastewater Treatment for Reuse at the WWTP of Chalkis.

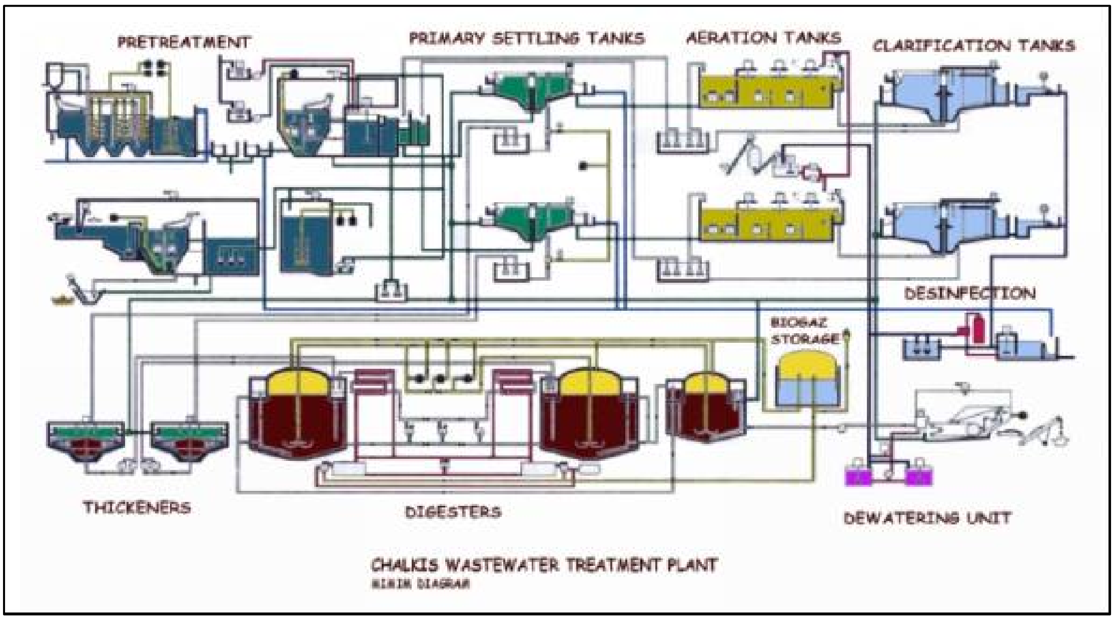

Figure 18. Flow diagram of the WWTP of Chalkis.

Reclaimed water quality:

Table 13. Effluent quality of the WWTP of Chalkis

Parameters	Units	Average value
Temperature	ºC	21.2
pH		7.14
Redox	mV	60
Suspended Solids (SS)	mg/l	12
COD	mg/l	54
BOD	mg/l	9
Ammonia $N\text{-}NH_4^+$	mg/l	6.6
Nitrate $N\text{-}NO_3^-$	mg/l	5.5
Nitrite $N\text{-}NO_2^-$	mg/l	0.3
Total Phosphorous	mg/l	4.0
UV Transmisión	%T	55.3

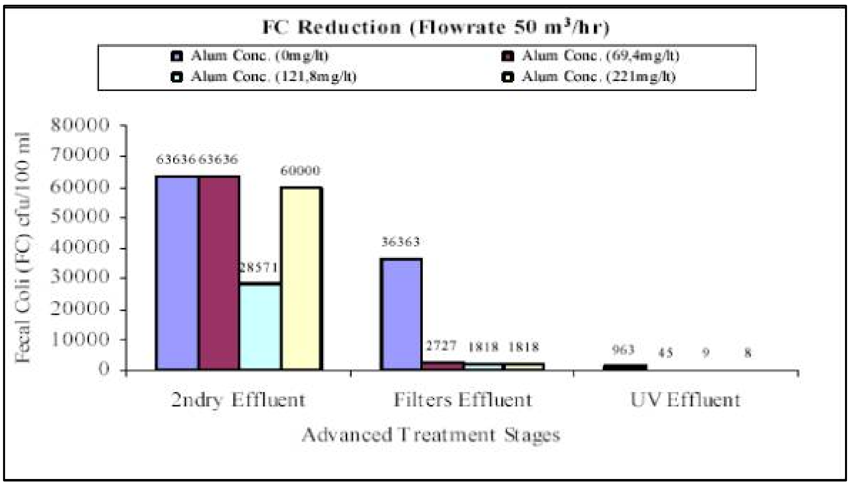

Figure 19. F. Coli distribution per stage.

***Water reuse applications*:**

Chalkis WWTP provides tertiary treated water primary for landscape irrigation and secondary (not in today use) for industrial use.

From a total daily flow of 9,000 m^3/day the 4,000 m^3/day can be used for landscape irrigation and industrial uses.

***Total area affected by irrigation* and *Types of products cultivated in irrigated areas*:**

Until today 2,500 trees have been planted at Passas island (3 ha) where the facilities of the WWTP are. There have also been planted 55 ha with 12,175 trees and bushes nearby the city of Chalkis, while the expectations are 280 ha with 100,000 trees and bushes (Figure 20).

Figure 20. Irrigation area in Chalkis.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Not data available.

***Problems founded in the start-up, development or final application of the project*:**

Not special problems reported.

Remarkable results:

The following good results have been reported:

- Achievement of Quality Criteria.
- Functional Flexibility of Advanced Treatment stages.
- Correlation between ratios of energy consumption and advanced treated wastewater volume.
- Adequate process performance of filters in the range of 50 to 200 m^3/hr and >70 mg/l Calum.

***Information Sources*:**

Kanaris, S., Koutsavlis, An., Mamais, D., Margaritis, N. Advanced wastewater treatment for reuse at the WWTP of Chalkis. International workshop Implementation and operation of municipal wastewater reuse plants. Thessaloniki, Greece, March-2004.

Selected cases in Israel

Israel is a semi-arid country with insufficient natural water resources. All the available water (290 m^3/capita/yr) is consumed causing severe water stress in drought years. Israel's water policy is based on the development of alternative water resources including brackish and seawater desalination, wastewater reuse, brackish water irrigation, stormwater storage and cloud seeding. The future aim is to increase effluent reuse by the year 2010 to minimum 500 MMCY from the 290 MMCY currently reused. Today, 95% of the 450 MCMY domestic sewage, is centrally collected in WWTPs. 60% of the treated effluents contain maximum 20 mg/l BOD and 30 mg/l TSS and are suitable by further filtration and disinfection for unrestricted irrigation. New (1999 Halperin – Committee guidelines and 2002 Inbar Committee standard proposal) regulations for unrestricted irrigation require, besides application of tertiary or more advanced treatments, also good O & M practice (*Chikurel* and *Aharoni*, 2004).

Within the considered cases, applications in Israel are the most notable ones in terms of capacity, effluent quality, application diversity, and suitability to Mediterranean region, and costs. Dan Region project in Israel seems to be the largest and most remarkable one with 120 million m^3/yr capacity, post-treatment water handling and reuse applications (e.g. groundwater recharge, reservoir storage, soil aquifer treatment, direct irrigation, etc). It also fulfils the above mentioned aims by further improving the effluent quality through the Soil Aquifer Treatment System to an almost drinking water quality and reclaiming and transporting the water for unrestricted irrigation to the South of the country. The second big project (Hakishon project) treats the wastewater from the Haifa and Afula area (20/30) and based on 60 days retention in a reservoir, screen filtration and chlorination, supplies almost 30 MMCY (570,000 PE) of unrestricted irrigation water quality effluents to the North of the country. Besides the reclaimed water supplied by these two big projects, another 7 WWTP effluents are filtered (deep bed) and chlorinated and supplied as unrestricted irrigation water (17 MMCY or 230,000 PE).

In addition, specific treatment schemes are adopted depending on the end-use goals in Israel. Reclaimed effluents, after tertiary treatment followed by soil aquifer treatment, are used for the irrigation of all crops without any restriction. Tertiary effluents (activated sludge and seasonal detention, or activated sludge with sand filtration) are used on a restricted basis for the irrigation of canned fruits, vegetables for cooking and for fruits with non-edible peels. Secondary effluents (activated sludge, trickling filters and oxidation ponds with seasonal detention), stored in surface reservoirs, are used, with restrictions, for the irrigation of industrial field crops (mainly cotton), fodder crops, forests and pastures (http://www.mni.gov.il/english/units/Water/PermittedIrrigatedCrops.shtml).

<u>CASE 1</u>: <u>Dan Region Proyect</u>

Location:

Dan Region, Tel Aviv, Southern Israel.

Year of the project development:

1991-1994.

***Water origin*:**

Wastewater of Tel Aviv Metropolitan Region, treated in Dan Region WWTP (Figure 21).

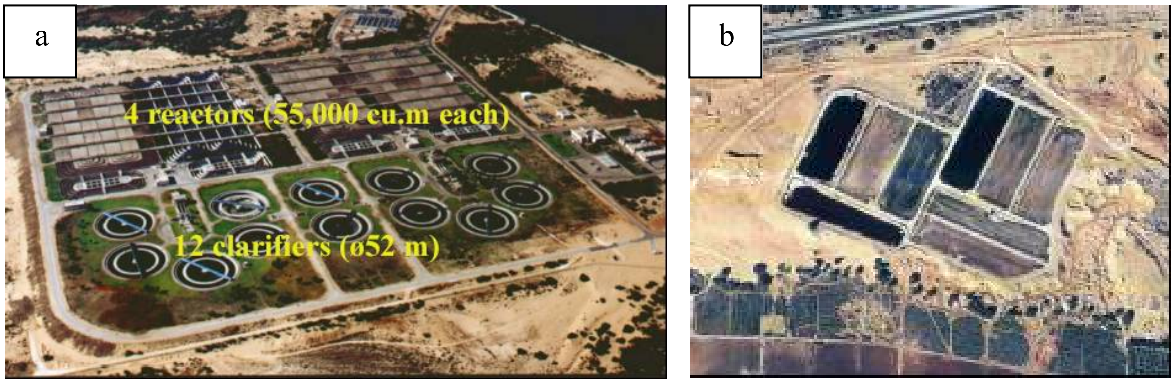

Figure 21. The Dan Region Wastewater Treatment Plant (a) and soil aquifer treatment (SAT basins) (b). (Source: *Chikurel* and *Aharoni*, 2004).

***Volume (or flow) of water affected*:**

120 Mm^3/yr.

***Water treatment before reuse (technologies/process applied)*:**

Effluents of biological treatment including nutrient removal are recharged into the groundwater aquifer by means of spreading sand basins for additional polishing and long-term storage. High quality reclaimed water is eventually pumped out and used for unrestricted irrigation. Treatment scheme is given in Figure 22.

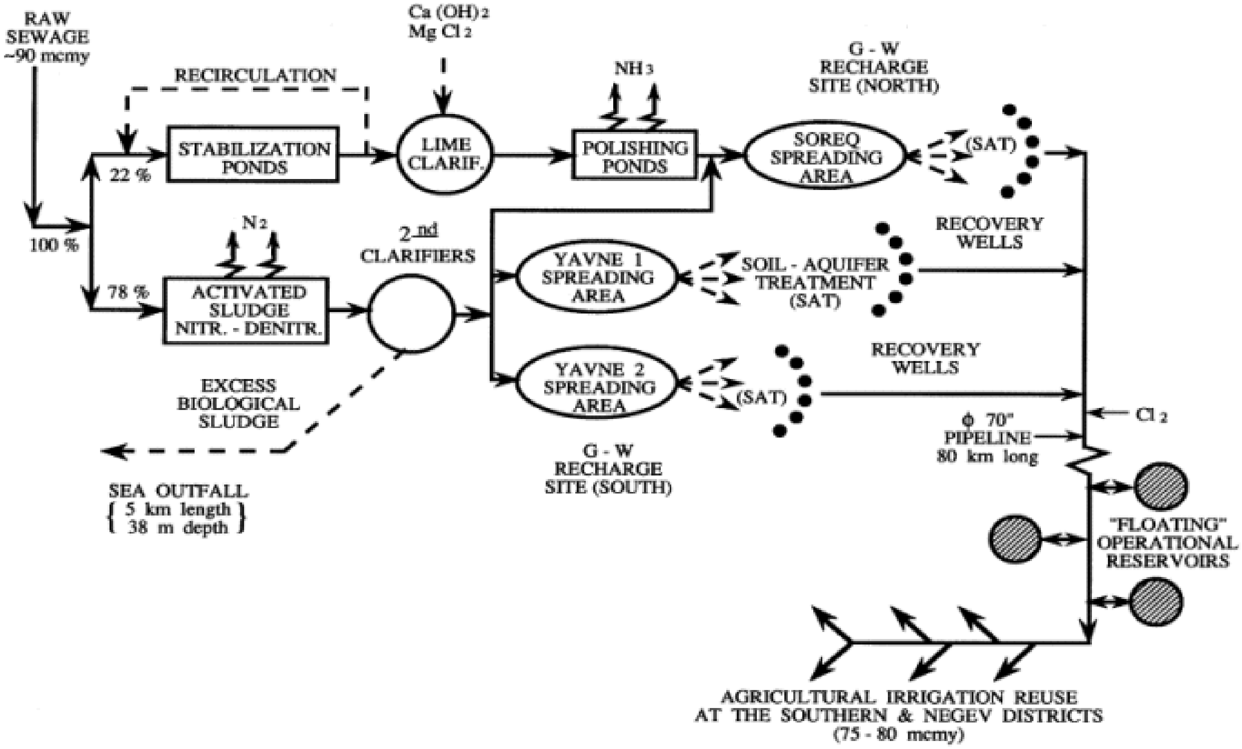

Figure 22. The Dan Region (Greater Tel-Aviv area) Wastewater Treatment and Reclamation Scheme, (Source: *Shelef*, 2004).

***Reclaimed water quality*:**

An analysis reveals the following parameters for the effluents:

FC : 1/100 ml
TC : 1/100 ml
BOD : < 0.5 mg/l
COD : 7 mg/L
TSS : 1 mg/l
TN : 0.4 mg/l
TP : 0.08 mg/l

***Water reuse applications*:**

In 1993, 87 Mm^3 of wastewater was treated, of which 75 Mm^3 was recharged and about 100 Mm^3 (together with groundwater) was supplied for agricultural irrigation in Negev.

***Total area affected by irrigation*:**

An average agricultural area of 16,000 hectares.

***Types of products cultivated in irrigated areas*:**

Field-crops (cotton, cereals, sunflower, etc.), fruit plantations and vegetables, flowers aimed for export.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

0,45 US$/m^3.

***Problems founded in the start-up, development or final application of the project*:**

Some of the physico-chemical processes, such as sorption and ion-exchange may become over-saturated with time, resulting in the breakthrough of certain substances. The open operational reservoirs require monitoring for algae growth and decline in water quality due to natural fowl (birds) as well as wind and dust-borne microorganisms. The possibility of physically covering the reservoirs with floating covers or geodesic domes is currently being studied.

Remarkable results:

Comparable (lower) reclamation costs are achieved with advanced treatment followed by reuse for irrigation, compared to advanced treatment followed by sea disposal. Scarce freshwater resources are preserved for uses other than agricultural irrigation. In addition, it is possible to upgrade the treatment plant effluent to a level suitable for unrestricted irrigation and even drinking water quality by soil aquifer treatment system. intensive biological activity takes place in various zones and levels of the soil and aquifer. Nitrification of ammonia and organic nitrogen thus continues in the unsaturated aerated zones, while denitrification proceeds in the anoxic zones, where organic matter is retained.

***Information Sources*:**

Chikurel, H., Aharoni, A. Treatment and distribution of effluents for unrestricted irrigation: The Israeli experience related to O&M aspects. Workshop on Implementation and Operation of Municipal Wastewater reuse plants. Thessaloniki, Greece (2004).

Israel Ministry of Foreign Affairs web site, http://www.mfa.gov.il/mfa/go.asp?MFAH0as90-Cikurel, H., Aharoni, A., Tal, N., 2001. Water reuse in Israel, http: //www.med-reunet.com/docsseminar/haim_cikurel.pdf.

Shelef, G., Wastewater treatment, reclamation and reuse in Israel, http://www.biu.ac.il/SOC/besa/waterarticle3.html, updated on 01/11/2004.

Shelef, G., Yossi, A. The coming of era of intensive wastewater reuse in the Mediterranean Region, Water Sci. Technol., Vol. 33 (10-11), pp 115-125 (1996).

CASE 2: Greater Haifa WWTP

Location:

Haifa, Israel (Kishon Scheme).

Year of the project development:

1983.

Water origin:

Greater Haifa Municipal Wastewater.

Volume (or flow) of water affected:

35 Mm^3/yr of wastewater flows to the treatment plant. The treated effluent, with an annual flow of 22 Mm^3/yr, is pumped to a reclaimed water convergence conduit. It is then seasonally stored in dual seasonal storage reservoirs, operating in series.

Water treatment before reuse (technologies/process applied):

The Haifa Joint Association of Towns Treatment Plant is composed of primary settling, integrated technology of activated sludge and trickling filter, secondary clarifiers and anaerobic sludge digestion, followed by sludge thickening and dewatering.

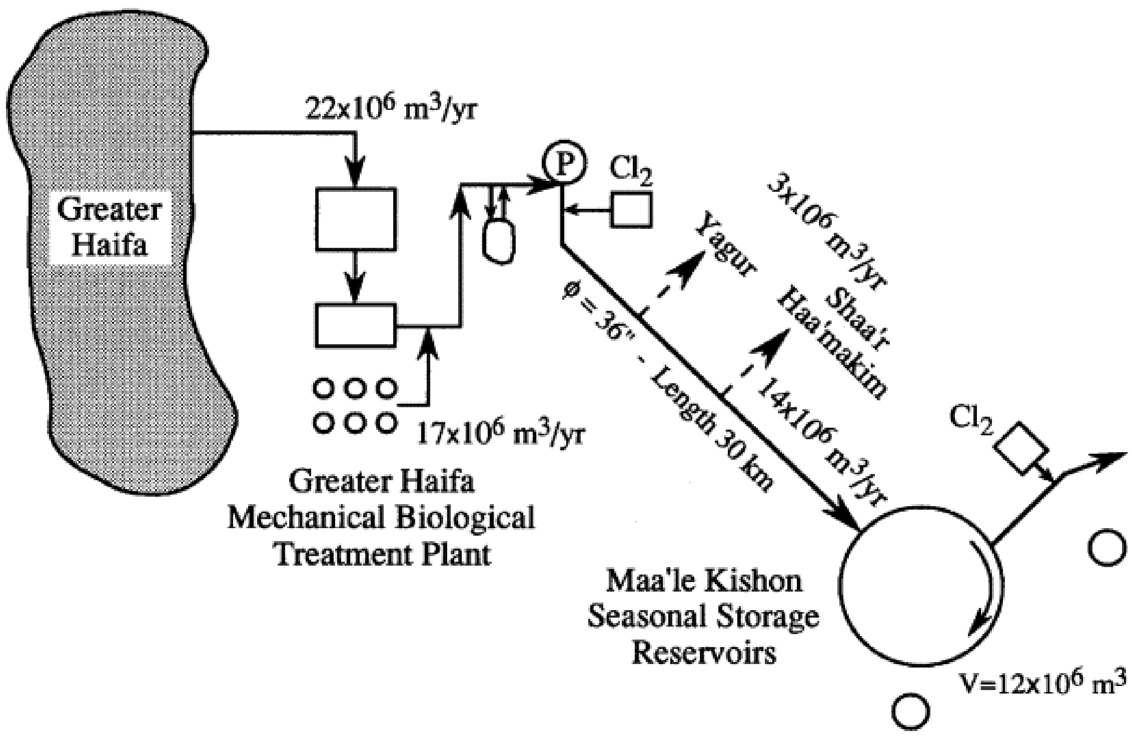

Figure 23. The Kishon Complex (Tishlovet Hakishon) wastewater reuse scheme of the Greater Haifa Region, (Source: *Shelef*, 2004).

Wastewater is conveyed to a 12 Mm^3 storage reservoir (12 m of operating depth). Two disinfection points add gaseous chlorine, one at the initial pumping stations near the treatment plant and the second at the outlet of the seasonal reservoirs. Treatment scheme is given in Figure 23.

***Reclaimed water quality*:**

FC: 910 /100 ml before filtration and chlorination (1 /100 ml at the end-user following filtration and chlorination).
TC: 3047 /100 ml before filtration and chlorination.
2 /100 ml at the end-user following filtration and chlorination).
BOD: 8.2 mg/l
TSS : 20.7 mg/l
NO_3: 14.7 mg/l
NO_2: 7.1 mg/l
NH_3: 15.2 mg/l
PO_4: 15.0 mg/l

***Water reuse applications*:**

Restricted irrigation. The reservoir is filled throughout the year with effluent at a relatively constant flow, while water is withdrawn only during the dry months.

***Total area affected by irrigation*:**

Data not available.

***Types of products cultivated in irrigated areas*:**

Cotton, silage and other non-edible crops.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Data not available.

***Problems founded in the start-up, development or final application of the project*:**

In the late summer, water quality may deteriorate due to decreased detention time. But the main problem is the salinity of the effluents that is around 400 mg/lm of chlorides and decreases to a great extent the variety of crops that can be irrigated by the reclaimed effluents.

Remarkable results:

Although less costly and less sophisticated compared to Dan Project, sufficient water quality is obtained for irrigation of cotton and other non-edible crops.

***Information Sources*:**

Shelef, G., Wastewater treatment, reclamation and reuse in Israel, http://www.biu.ac.il/SOC/besa/ waterarticle3.html, updated on 01/11/2004.

Shelef G., Yossi A., 1996. The coming of era of intensive wastewater reuse in the Mediterranean Region, Water Sci. Technol., Vol. 33, No 10-11, pp 115-125.

Israel Ministry of Foreign Affairs web site, http://www.mfa.gov.il/mfa/go.asp?MFAH0as90 - Cikurel, H., Aharoni, A., Tal, N. 2001. Water reuse in Israel, http: //www.med-reunet.com/docsseminar/haim_cikurel.pdf.

<u>CASE 3</u>: <u>Water reclamation and reuse in Arad</u>

Location:

City of Arad (Israel).

Year of the project development:

1997.

***Water origin*:**

Domestic wastewater.

***Volume (or flow) of water affected*:**

Two types of emitters and related spacings were used: emitters with a flow rate of 3.5 l/h were installed at 0.75 metres apart on the laterals and emitters with a discharge of 2.3 l/h were spaced 0.5 m on the drip laterals.

***Water treatment before reuse (technologies/process applied)*:**

The effluent obtained from the stabilization pond system of the City of Arad is transported to a large reservoir (a capacity of around 0.5 × 106 m^3) and subsequently is applied for irrigation.

***Reclaimed water quality*:**

The effluent quality hardly meets the Israeli secondary level reuse criteria (Table 14). The several high surges in potassium content are probably due to intermittent wastewater disposal from large adjacent laundries. The initial concentrations of the microorganisms in the wastewater were 10^6/100 ml for faecal coliforms, 10^3/100 ml for F+ coliphages, and 10^4/100 ml for CN13 coliphages, respectively.

Table 14. Ranges of major constituents content (mg/l) of the wastewater (after the filter) applied for irrigation in Arad Heights during 1997 season.

Constituent	Range
TSS	72-130
BOD_5	45-120
$N\text{-}NH_4$	34-58
Alkalinity as $CaCO_3$	330-495
Cl	204-260
PO_4	6.7-29.7
Na	180-270
K	26-90
EC, dS/m	1.50-1.80
SAR (-)	6.60-8.68
PAR (-)	0.41-1.41

Source: ISQW, 1981.

***Water reuse applications*:**

Vineyards irrigation.

***Total area affected by irrigation*:**

Not data available.

***Types of products cultivated in irrigated areas*:**

Vineyard orchards.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Data not available.

***Problems founded in the start-up, development or final application of the project*:**

Frequently, a high content of nitrogen was observed, which might have adverse effects on the wine quality.

Remarkable results:

When adopting disposal technologies that allow the effluent to remain in the soil media, with no exposure to workers or the on surface foliage parts of the plants, the health and environmental risks can be diminished. This benefit is reinforced by the fact that only relatively small and controlled amounts of effluent are discharged for irrigation, thus the flow towards the deeper soil layers is minimized. The field findings lead to the following main conclusions.

1. The soil is capable of removing Faecal Coliforms, F + and CN13 coliphages, and helminth eggs used as faecal pollution indicators, when drip irrigation system is applied.
2. The application of secondary treated domestic wastewater in this specific soil and under these irrigation systems, affects the survival of microorganisms, thus reducing the health and environmental risk.

3. Further research is needed on establishing the relationship among soil characteristics and removal of the microorganisms, and the mechanisms, which explain the helminth eggs elimination with this kind of irrigation systems.

***Information Sources*:**

Oron, G., Armon, R. , Mandelbaum, R., Manor, Y., Campos, C., Gillerman, L., Salgot, M., Gerba, C., Klein, I., Enriquez, C. Secondary wastewater disposal for crop irrigation with minimal risk. Wat. Sci. & Technol., 43 (10), pp. 139-146, (2001).

<u>CASE 4</u>: <u>The Jeezrael Valley project</u>

Location:

The Jeezrael Valley in Israel (Figure 24).

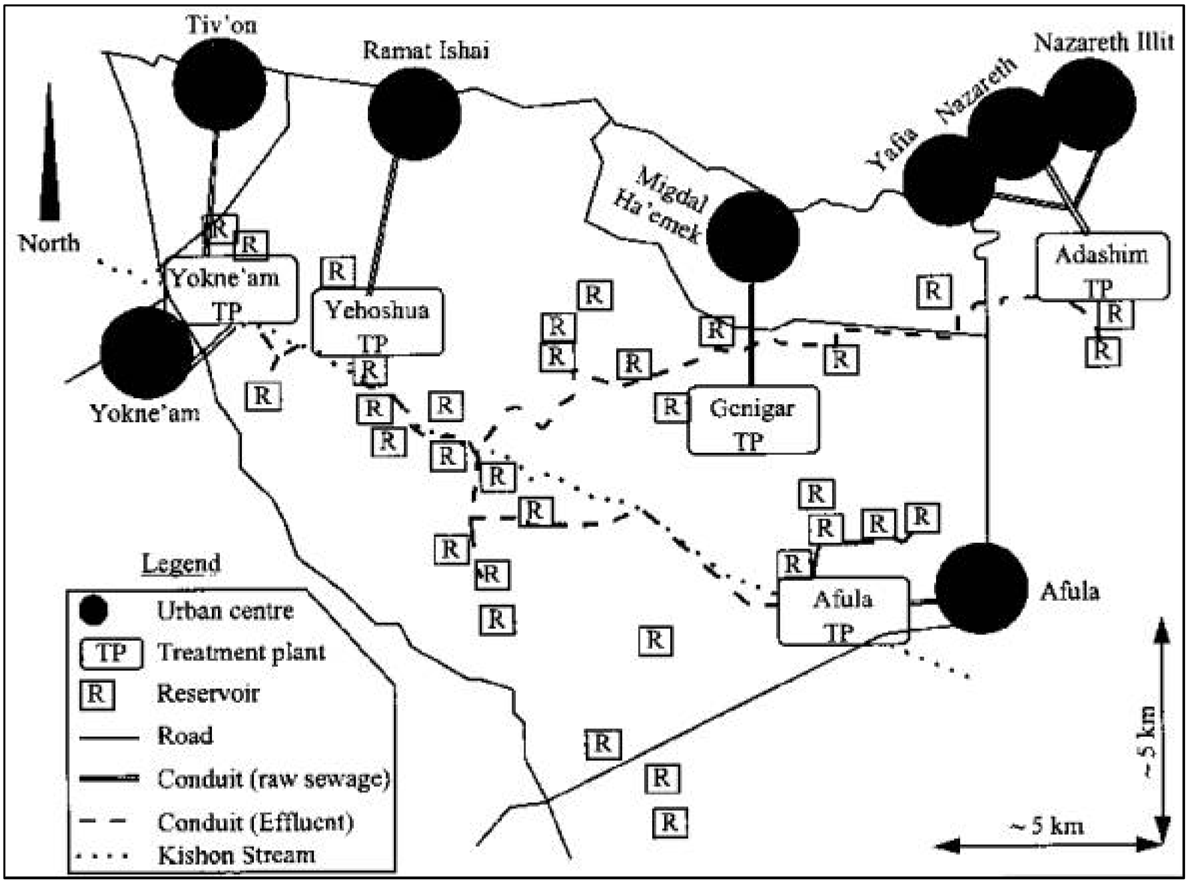

Figure 24. The Jeezrael Valley Project – Schematic map of the Master Plan.

Year of the project development:

The project began in1996.

***Water origin*:**

The Jeezrael Valley receives irrigation water from part of the wastewater effluent of the Haifa metropolitan area (about 45,000 PE) through the “Kishon Complex” wastewater treatment and reuse scheme, and wastewater effluent from towns and small settlements in and around the Valley (about 120,000 PE).

***Volume (or flow) of water affected*:**

The new Jeezrael Valley project supplied 6 Mm^3 of treated effluent during its first year of operation (1996) and its expected to supply about 13 Mm^3/year or more by 2010.

***Water treatment before reuse (technologies/process applied)*:**

The project combines semi-intensive wastewater treatment plants situated near the urban areas with wastewater reservoirs situated in the rural areas. The main components of the scheme are listed herewith:

- 5-6 semi-intensive sewage treatment plants for the treatment sewage from towns and settlements in and around the Valley. The treatment plants consist of anaerobic ponds followed by aerated lagoons.

- Conduits which inter-connect the treatment plants and connect the plants to a network of wastewater reservoirs situated in the rural cultivated areas. The conduits enable conveyance of effluent from any treatment plant to any reservoir.

- Wastewater reservoirs to be operated in SBR (Sequential Batch Reactor) mode, either in series or in parallel in order to obtain high quality effluent.

- Disposal-reuse of the treated effluent via agricultural irrigation within the Valley.

During the start-up three treatment plants were commissioned:

- Adashim treatment plant, which treats mainly the sewage of Nazareth and Nazareth Illit, consist of three anaerobic ponds in parallel of 10,000 m^3 each, followed by three aerated lagoons in parallel of 12,000 m^3 each. This plant does not have any pre-treatment unit.
- Genigar treatment plant treats the sewage of Migdal Ha´emek. The plant consist of screen bars as a pre-treatment step, followed by three parallel anaerobic ponds of 26,000 m^3 each, ending with two aerated lagoons in series of 26,000 and 30,000 m^3.
- Yehoshua treatment plant treats mainly the sewage of Ramat Ishai. Row sewage entering the treatment plant consists mainly of domestic sewage and a relatively small proportion on industrial and commercial sewage. The plant comprises of screen bars as a pre-treatment step, followed by two anaerobic ponds of 2,100 m^3 each (in parallel), ending with a single aereated lagoon of 8,000 m^3.

Sewage flow into Adashim and Genigar treatment plant averaged about 10,000 and 5,000 m^3/d respectively. Inflow to Yehoshua plant increased steadily throughout the first year of operation (from 450 m^3/d at the beginning of this period to about 1,000 m^3/d at its end).

***Reclaimed water quality*:**

Table 15 presents average values of the quality parameters defining the raw sewage entering the treatment plants.

Table 15. Flow capacity, organic loads and performance of the Jeezrael Valley sewage treatment, storage and reuse project.

Treatment step	Parameter average value	Units	Adashim WWTP	Genigar WWTP	Yehoshua WWTP
Raw sewage	Flow	m^3/d	9,850	5,520	1,000
	COD total	mg/l	1,175	960	910
	COD diss	mg/l	475	440	300
	BOD_5	mg/l	625	435	450
	Toxicity	% inhibition	46	37	32
Anaerobic ponds	Residence time	Days	3.1	9.6	2
	Organic load	g $BOD/m^3/d$	200	46	200
	COD removal	%	33	45	46
	COD removal	g $COD/m^3/d$	136	162	150
	pH		7.0	7.2	7.2
Aerated lagoons	Residence time	Days	3.7	10.3	8
	COD removal	%	37	65	53
	COD removal	g $COD/m^3/d$	82	72	47
Anaerobic ponds + Aerated lagoons	Outflow COD	mg/l	470	185	230
	Outflow BOD_5	mg/l	110	25	23
	COT removal	%	60	82	65
	BOD_5 removal	%	82	95	95
	Outflow toxicity	% inhibition	15	10	15
Wastewater reservoirs	Outflow BOD_5	mg/l	10	8	15
	Outflow F.Coli.	number/100 ml	1.3E3	1.4E3	1.7E3
	Outflow toxicity	% inhibition	4	7	5
	Outflow EC	mmhos/cm	1.58	1.97	1.91
	Outflow Boron	mg/l	0.42	0.39	0.33
System performance	BOD_5 removal	%	98	98	99
	Toxicity reduction	%	91	81	84

***Water reuse applications*:**

Irrigation of crops.

***Total area affected by irrigation*:**

Not data available.

***Types of products cultivated in irrigated areas*:**

Not data available.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Not data available.

***Problems founded in the start-up, development or final application of the project*:**

The massive population growth in the settlements connected to the plants made the inflow to the plants increases.

During the first year of operation Faecal Coliform removal was somewhat deficient. This was a result of temporary constrains not enabling operation of the reservoirs as real SBR reactors.

Remarkable results:

Water reuse in the Jeezrael Valley takes advantage of the proximity of the urban communities to the cultivated areas.

The scheme, which is based on an existing situation, succeeds to combine semi-intensive wastewater treatment plants with wastewater reservoirs. By integrating the reservoirs into the treatment system and operating then as SBR reactors it was possible to enhance the systems´s performance and reduce costs.

***Information Sources*:**

Friedler, E. The Jeezrael Valley project for wastewater reclamation and reuse, Israel. Wat. Sci. & Technol., 40 (4-5), pp. 347-354, (1999).

Selected cases in Italy

In Italy wastewater reuse is mainly geared toward agricultural irrigation, even if some projects concern industrial reuse and landscape irrigation. In the last years several wastewater reuse systems have been implemented not only in arid and semi-arid regions of Southern Italy, but also in Northern Italy (Emilia Romagna, Valle d'Aosta, Veneto), where available water resources generally meet water demand for different uses.

Since the 1970s water-planning studies have been carried out for various Italian regions including Sicilia, Calabria and Emilia Romagna. Some of these plans have raised objections because of the relevant works required, the elevated costs of construction and the optimistic forecasts of wastewater availability.

In Valle d'Aosta the municipal wastewater reuse system of St. Cristophe-Aosta-Quart (148,000 PE) will be in operation by the end of 2000. The treated wastewater (32,600 m^3/day) will mainly be used for landscape irrigation and fire-protection. In the Autonomous Province of Bolzano, even though water resources availability matches water demand, there is an increasing interest in wastewater reuse. Recently, two small reuse systems have been designed: Appiano (1,250 PE) and Verano (1,200 PE). In Veneto the wastewater reuse project (wastewater flow rate about 70 l/s) of Rosalina Mare (Province of Rovigo) has been designed for landscape and agricultural irrigation (30% and 70% of available flow, respectively). In Emilia Romagna, mainly in the coastal areas, there are many cases of the programmed utilisation of the municipal treated wastewater for irrigation and environmental protection purposes. The largest wastewater reuse system (Basso Rubicone treatment plant, 1250 m^3/day) covers an area of about 400 hectares for orchard irrigation.

In Toscana there are two important examples of wastewater reuse for industrial water supply. In Piombino the municipal treated wastewaters (10,000 m^3/day) are reused for the cooling in the steel industry. In Prato, in the textile industrial district, about 11,000 m^3/day of municipal treated wastewater are used for industrial processing. The regional governments of Abruzzo and Basilicata have recently included norms concerning wastewater reuse in their regional regulations regarding water resources management (Abruzzo) and reclamation water plan (Basilicata); however, no reuse systems have yet been designed. In the Sarno area (Campania), within a reclamation project of the river basin, six new plants will be constructed for treatment of municipal and industrial (agro-food) wastewater. The treated wastewater will be used for irrigation purposes (mainly tomatoes). In the Salento area (Puglia), where the lack of water resources is coupled with the organic pollution of groundwaters, about 16,000 m^3/day (about 100,000 PE) of treated wastewater (biological treatment plus final filtration) are about to be made available for irrigation.

In Sardegna, as a result of the lack of water resources exacerbated by the droughts of 1990 and 1995, a state of emergency was declared in 1995 and the Italian government drew up a programme for financial provision by the State and local government authorities with the aim of reducing, at least in part, the serious water shortage. Amongst others, wastewater reuse was considered one of the key-actions to face the water supply emergency. Within the framework of a local government programme and EU funded actions, a new wastewater reclamation scheme is actually implemented for using directly the effluent produced by the "Is Arenas" plant which serves the city of Cagliari and its suburbs. The treated wastewater volume is 35 Mm^3 per year, with a short-term forecast of 60 Mm^3. The reuse scheme includes both direct reuse for agricultural purposes and intermediate storage in reservoirs with further treatment before agricultural irrigation. In Villasimius (province of Cagliari) wastewaters of tertiary treatment plant will be soon available for irrigation of about 200 hectares.

In Sicilia, where the experiences of uncontrolled wastewater reuse are so common, for several years treated wastewater of Grammichele (about 1,500 m^3/day), a small rural town located in Eastern Sicily (district of Catania), have been used for the irrigation of citrus orchards. Several municipalities (such as Caltagirone, Mineo, S.Michele di Ganzaria, etc.) close to Grammichele have planned to reuse municipal wastewater in order to meet the increasing water demand for agricultural purposes. Recently the Sicilian Government has authorized and financed, with the support of the European Union, the wastewater reuse projects of Palermo (in a first stage about 28,000 m^3/day of treated wastewater will be soon available) and Gela (where the 2 WWTPs will be integrated with storage reservoirs for a total capacity of 5 million m^3). In both cases the treated wastewater will be used for agricultural irrigation of several thousand hectares.

CASE 1: <u>Water reuse at catchment scale in Catania</u>

Location:

Caltagirone and Grammichelle, Catanias, Italy.

Year of the project development:

2001.

***Water origin*:**

Urban wastewater from Caltagirone and Grammichelle WWTP.

***Volume (or flow) of water affected*:**

The treated effluent of Grammichelle is 1,500 m^3/d and the effluent of Caltagirone is 5,200 m^3/d.

***Water treatment before reuse (technologies/process applied)*:**

Grammichelle is equipped with a combined sewage network and an activated sludge treatment plant. The treatment plant includes the following steps: coarse screening, grit removal, aeration by activated sludge, secondary sedimentation and chlorine contact tank. The treated effluent is stored in a tank for daily regulation and then distributed to numerous farmer associations, located mainly in the Caltagirone Plains at the foot of the town, through a distribution pipeline network (over 10 km piping system).

The city of Caltagirone is equipped with a treatment plant where wastewater is subject to secondary treatment (activated sludge) and passed through sand filters. Effluent leaving the treatment plant is conveyed to a earth reservoir with a storage capacity of about 25,000 m^3 and a depth of 5.0 m.

***Reclaimed water quality*:**

Wastewater diverted from the Grammichelle and Caltagirone treatment plants had initially a BOD_5 of 130-200 mg/l and a COD of 200-280 mg/l. Analysis of samples collected from the reservoirs at the end of the storage period showed a decrease of such values of about 50%. At the end of the retention period and during release from the reservoirs, BOD_5 and COD values were lower than 10 mg/l and 30 mg/l respectively. In both cases, the control parameters establish to maintain water quality were the following:
DBO_5: < 25 mg/l
COD: < 125 mg/l
SS: <35 mg/l
E. Coli: <1000 CFU / 100 ml
Nematode eggs: <1 egg/l

***Water reuse applications*:**

Reclaimed water from the Grammichelle and Caltagirone sites is used for irrigation of orchards, irrigation of crops for caning industry and vegetables to be eaten cooked.

***Total area affected by irrigation*:**

Not data available.

***Types of products cultivated in irrigated areas*:**

Orange and olive trees.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Wastewater from the reuse system of Grammichele and Caltagirone has been used by the farmers free of charge. However, to recover network maintenance and pumping costs, the farmers are charged 0.05 €/m^3 during the irrigation season (April to October), and half that price in the winter time, versus the 0.1 €/m^3 charged by authorities fro freshwater supply. The higher price during the summer supports the additional costs for the water pumped from Pietranera well.

If water is stored in a 100,000 m^3 reservoir, it is possible to treat a volume of 2,500 m^3/d, with a detention time of about 40 days. Calculating that the costs for the construction for the reservoir is around 1,007,090 € and foreseen a life of 20 years (for amortisation purposes) with an interest rate of 5 %, the annual costs is 80,812 €. On the other hand, 15,494 € must be added to this amount for operation and maintenance costs, reaching a total annual costs of 96,306 € to treat 912,500 m^3, with a unit cost of 0.11 €/m^3. This additional cost (0.11 €/m^3) is the one to be compared to the price of freshwater (0.1 €/m^3). This comparison should also take into account the advantages stemming from treated wastewater reuse, as discharge into waterbodies is thus avoided.

The cost of 0.11 €/m^3 can vary on length of detention time which in turn depends on quality of influent water. A shorter detention time, when possible, further decreases the unit cost of water, thus making wastewater reuse even more advantageous.

***Problems founded in the start-up, development or final application of the project*:**

A bad behaviour of the Caltagirone treatment system at the beginning of the operation made necessary stop the process to solve problems related to a high phenol concentration in the effluent.

Remarkable results:

These cases show that storage in stabilization reservoirs offers the possibility to recover high volume, being this a desirable goal in coastal areas. The investigations carried out on wastewater storage as secondary treatment (Grammichelle site) or tertiary treatment (Caltagirone site), have shown the efficiency and the high reliability of this practice in the removal of microorganisms. At Caltagirone site, experiments have shown that storage in reservoir represented a valid solution to malfunctioning occurred in secondary conventional treatment (activated sludge system). Results from cost analysis allow to conclude that the overall economical and environmental cost of wastewater treatment and reuse is comparable, if not smaller, that the cost of using freshwater.

***Information Sources*:**

Barbagallo, S., Cirelli, G., Osma, F. Grammichele and Caltagirone case-studies (Italy). Work package 2, annex 6 of the project Enhancement of integrated water management strategies with water reuse at catchment scale. Programme Environment and Climate.

CASE 2: <u>Wastewater reuse in San Michele di Ganzaria, Sicily</u>

Location:

San Michelle di Ganzara, Sicily (Italy).

Year of the project development:

2001.

***Water origin*:**

It has been used the secondary effluent of San Michele di Ganzaria, a rural community of about 5,000 inhabitants, located 90 kilometres south-west from Catania at about 350 m above sea level. The area is characterised by a dry climate (around 500 mm/year precipitation) with severe summer droughts.

***Volume (or flow) of water affected*:**

1.75 l/s.

***Water treatment before reuse (technologies/process applied)*:**

In March 2001, within a wastewater reuse project for the irrigation of about 150 ha of olive orchards, the existing conventional WWTP (trickling filter) has been integrated with a horizontal subsurface flow (HSSF) constructed wetland (CW) unit. The whole project includes a tertiary system made of two parallel lines each with two serial H-SSF reed bed units followed by a stabilisation reservoir (Figure 25). The monitored reed bed unit is used for the tertiary treatment of about 1,100 P.E. with a nominal detention time of about 2 days. The WWTP effluent is conveyed to the CW by a 340 m PVC pipeline. The CW unit is 78 m long, 25 m wide and the filtering bed area is 1,950 m^2 (about 1.7 m^2/P.E.) corresponding to an hydraulic loading rate of 0.077 m/d.

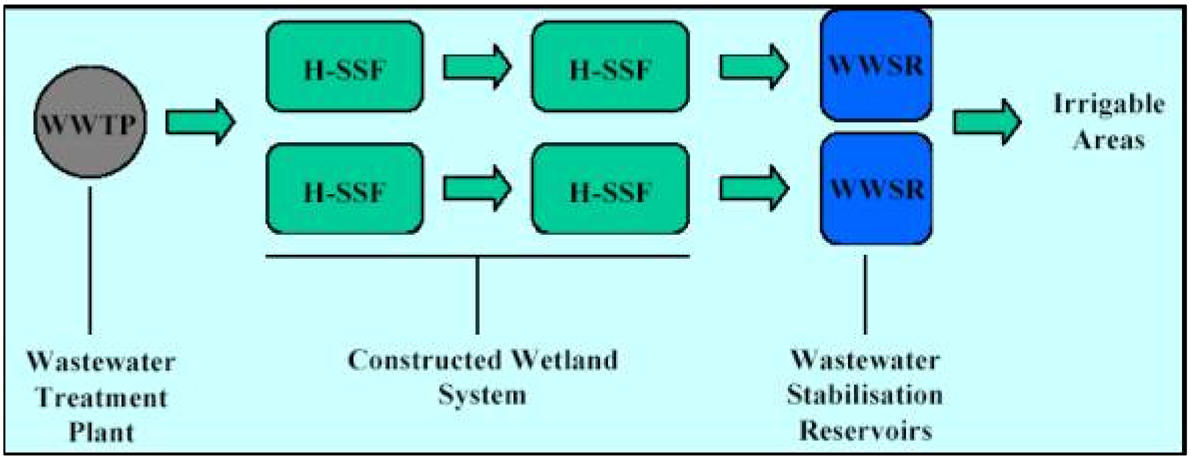

Figure 25. Lay-out of the treatment system of San Michele di Ganzaria, Eastern Sicily.

The filtering bed, made of 8-10 mm gravel with a porosity of 0.38, is 0.6 m deep and its bottom has a slope of about 1% while its surface is perfectly flat; the average water depth is 0.4 m. Both the excavated bed and the banks are lined with a 4 mm thick bentonitis sheet. Earth banks (with a slope of 3:1) were covered with jute nets to facilitate vegetation establishment and prevent soil erosion.

The influent is distributed at the bed-head through a perforated 200 mm pipe transversal to flow direction. Wastewater is intercepted downstream by a transversal perforated pipe and conveyed to an adjustable outlet controlling the water level in the filtering bed as recommended in USEPA.

***Reclaimed water quality*:**

The average concentrations of TSS (379,7 mg/l), BOD_5 (298,3 mg/l) and COD (516,8 mg/l) detected in rough wastewater can be classified as medium to strong. Other parameters had, in the same samples, the following concentration: Total Nitrogen 44,2 mg/l; Total Phosphorous

10,5 mg/l E. Coli 1.E+07 CFU/100 ml; Faecal Coliform 2.E+07 CFU/100 ml; Helminth Eggs 1.5/100 ml.

Mean removal efficiencies ranged from 65% to 88% (TSS), 53% to 84% (BOD5), 62% to 80% (COD), 14% to 52% (TN), 15% to 45% (TP), 95% to 99.8% (Faecal Coliforms).

***Water reuse applications*:**

Irrigation.

***Total area affected by irrigation*:**

150 ha.

***Types of products cultivated in irrigated areas*:**

Olive trees.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Not data available.

***Problems founded in the start-up, development or final application of the project*:**

In Sicily many wastewater treatment plants of small-medium communities are not in operation due to management problems and high O&M costs.

The bacteriological quality of CW effluent seems to be strongly affected by influent quality.

Remarkable results:

The reed bed unit determined a significant improvement of WWTP effluent quality in terms of TSS and BOD_5, with values always below the limits imposed by European Union and Italian regulation. The CW unit was very effective in removal of helminth eggs.

***Information Sources*:**

Barbagallo, S., Cirelli, G., Consoli, S., Toscano, A., Zimbone, S. Performances od a H-SSF constructed wetland as tertiary treatment for watewster reuse: the case study of “S. Michelle di Ganzara” (Sicily). www.med-reunet.com/05ginfo/05_case.asp

Selected cases in Jordan

CASE 1: Jordan University of Science and Technology (JUST) and Wadi Hassan Pilot Projects (WHPP) Wastewater Treatment Plants

Location:

Near Irbid City - North of Jordan.

Year of the project development:

The treatment plants have been in operation since 2003.

***Water origin*:**

The treatment plants abovementioned.

***Volume (or flow) of water affected*:**

From Wadi Hassan WWTP = 365,250m^3/y, 1000m^3/day.
From JUST = 219,150 m^3/y, 600m^3/day.

***Water treatment before reuse (technologies/process applied)*:**

Wadi Hassan WWTP = Extended Aeration.
(JUST) WWTP = Rotating biological contactors (RBC)

***Reclaimed water quality*:**

An analysis reveals the following parameters for the effluents:

Table 16. Effluents quality.

Parameter	Wadi Hassan WWTP	JUST WWTP
BOD	9 mg/l	5 mg/l
COD	64 mg/l	93 mg/l
TSS	23 mg/l	4 mg/l
NH_4	0.97 mg/l as N	< 0.09 mg/l as N
E-Coli	7,000 MPN/100 ml	-
Total Coliform	>=160,000 MPN/100 ml	< 2 MPN/100 ml
pH	-	6.6

***Water reuse applications*:**

Reclaimed water is used in irrigating fodder and fruit crops.

***Total area affected by irrigation*:**

An average agricultural area of 720 donum (9,500 hectares).

***Types of products cultivated in irrigated areas*:**

Fodder, cactus and fruit crops. At JUST main site, there are 5 sites included in the project. Field work went underway at all five sites, but only sites 1 & 5 were planted and the irrigation systems are established.

Site (1):- Known as Pilot Demonstration Site, contains 100 donums (1,300 ha, aprox.) includes cactus, fodder crops and pine trees.

Site (2):- Includes four hundred 400 donums (5,200 ha, aprox.), agriculture planning is underway and crop variety selection is determined.

Site (3):- Known as Memorial Site, includes 35 donums (450 ha, aprox.), site mapping and crop selection are underway.

Site (4):- Known as Orchard Site, includes 65 donums (850 ha, aprox.), site mapping and crop selection are underway.

Site (5):- Known as Wadi Hassan Site, contains 120 donums (1,600 ha, aprox.), planted with fruit trees, pistachio, almonds, olives and carobs.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Data not available.

***Problems founded in the start-up, development or final application of the project*:**

Not remarkable problems reported.

Remarkable results:

Using conventional spray irrigation with re-used water was not feasible as an aerosol effect will be created which would travel beyond the boundaries of the project location. The solution was utilizing a drip irrigation system using in colour-coded purple pipes .In addition, PA (Consultation Agency) and JUST engineers introduced a new spraying system. With that system larger drops of water are produces to ensure no aerosol effect and spray does not travel beyond the boundaries of the site. This is the first time such a US pioneering technology has been used in the Jordan.

The plant crops grown on the JUST site included vetch and barley, as well as tree crops such as pistachio, almond, carob, fruited and non-fruited pine, cactus and olives. Once the crop products from the test site were proved (checked by the PA) to be safe revenues were generated from this project. The first harvest of barley and vetch (some 1,700 kilograms) were sold as animal fodder and revenues proceeds from the sales went to the JUST Student Fund.

Active participation of the student was one of the good outputs of this project. The income return from this project is allocated for financial support for the poor students. In addition the project serves as a case study for public awareness and for training as well as research activities.

***Information Sources*:**

All information was provided from the treatment plant representatives.

<u>CASE 2</u>: <u>Wadi Mousa Pilot Project</u>

Location:

Near Petra City, South of Jordan.

Year of the project development:

The treatment plants have been in operation since 2003.

***Water origin*:**

The treatment plant of Wadi Mousa.

***Volume (or flow) of water affected*:**

316,306 m^3/y, 866m^3/day.

***Water treatment before reuse (technologies/process applied)*:**

Activated sludge

***Reclaimed water quality*:**

An analysis reveals the following parameters for the effluents:

BOD	9 mg/
COD	32 mg/l
TSS	20 mg/l
NH_4	4.2 mg/l as N.
Total Coliform	2,400 MPN/100 ml
E-Coli	23 MPN/100 ml

***Water reuse applications*:**

Reclaimed water is used in irrigation.

***Total area affected by irrigation*:**

An average agricultural area of 1,069 donum (14,000 hectares).

***Types of products cultivated in irrigated areas*:**

Fodder crops and fruit trees and ornamentals. The project includes 2 sites, a 69 donum (900 ha) demonstration site adjacent to Petra WWTP, and a 1000 donum site (13,000 ha) to be planted by local farmers. The demonstration site have been planted and its irrigation system is fully operational, soil samples have been collected, analysed and evaluated, work has been initiated on the (2^{nd}) site, lease agreements with local farmers are developed, but not finalized, currently 300 donums (about 14 Units) are under preparation for planting.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Data not available.

***Problems founded in the start-up, development or final application of the project*:**

One of the obstacles faced the project was the non uniform topography of the site which was overcame by the adoption f the appropriate irrigation design and cropping system.

Remarkable results:

This example may serve as a very good case study for wastewater reuse because it is highly organized and the farmers are actively involved in implementing the project. Moreover, the farmers, after hesitating at the beginning of the project and not accepting the idea of using wastewater for irrigation, began to compete with each other on conducting by themselves new projects. They start feel it can be managed safely and be a good source for their income and for employment.

Wadi Musa is near the historic city of Petra will be the first in the area to receive leases to irrigate with treated wastewater. These farmers are directly benefiting from the pilot demonstration farm that shows that reclaimed water can provide safe and reliable irrigation for some types of agriculture.

The experiment has been so successful that almost 60 hectares will now be distributed among local farmers for cultivation using reclaimed water re-use to encourage farmers to use reclaimed water for irrigation; the government is providing the know-how and latest technology through the project. This pilot project is managed by PA Consulting Group in co-operation with the Jordanian Ministry of Water and Irrigation, and funded by the US Agency for International Development (USAID).

The project exploits the Petra Regional Wastewater Treatment plant, using treated wastewater on a variety of agricultural crops with several different irrigation methods. PA has managed the design and planting in addition to the procurement and installation of a fully functioning drip irrigation system.

The farm grows field crops such as alfalfa, maize, sunflowers and Sudan grass, tree crops including pistachio, almond, olives, date palms, lemons, poplars, spruce and junipers, and many varieties of ornamental flowers including iris, geraniums, petunias and daisies. The yield of maize is approximately 25 percent higher than for maize grown with fresh water, and the yield for sunflowers is approximately 30 percent higher.

More than 2,000 trees and 400 shrubs and flowers have been planted to date. The poplar trees in particular have demonstrated impressive growth, doubling in size in the three months since planting.

The project created a demand for the cut flowers in several of Petra's tourist hotels. Hotel managers have said they will purchase all the flowers that can be produced at the site, demonstrating the economic benefits generated from the project and creating a market for the farmers even before they take control of the farm.

Funds from the sale of crops grown at the site will be used to establish a revolving fund for the farmers, including local Bedouin tribes, who will receive loans to help them establish and plant their lease holdings.

The land will be divided into plots of 1-2 hectares that farmers, after proper training, will begin cultivating. Training seminars for teaching farmers how to safely utilize re-used water in farming, as well as the best strategies for crop cultivation and the crops best suited for generating profits are hold.

***Information Sources*:**

All information was provided from the treatment plant representatives.

CASE 3: Aqaba Pilot Proyect

Location:

Aqaba City - South of Jordan.

Year of the project development:

The treatment plants have been in operation since 2003.

***Water origin*:**

Domestic wastewater from the treatment plant of Aqaba.

***Volume (or flow) of water affected*:**

109,575 m^3/y, for the project and 2,439,970 m^3/y, to irrigate 2,150 donum (28,000 hectares). (highly variable flow and strength as a result of seasonal fluctuations caused by touristic activities and temperatures changes).

***Water treatment before reuse (technologies/process applied)*:**

The existing WWTP consist of stabilization ponds. A new secondary mechanical and tertiary treatment plant is under execution now.

***Reclaimed water quality*:**

An analysis reveals the following parameters for the effluents:

BOD	111 mg/l
COD	345 mg/l
TSS	576 mg/l
NH_4	48.1 mg/l as N.
PO_4	11.04 mg/l
Total Coliform	160000 MPN/100 ml
E-Coli	17000 MPN/100 ml

***Water reuse applications*:**

It is used in forest irrigation.

***Total area affected by irrigation*:**

The project site = 100 donum (1,300 ha); the whole area to be irrigated = 2,150 donum (28,400 ha)

***Types of products cultivated in irrigated areas*:**

Fodders, date-palm and forestry trees. The project includes three sites, The Pilot Demonstration Site of 100 donum, The Airport Site and The Aqaba Industrial Estate Site. The Aqaba project is under subcontract to ECODIT, also includes the design of irrigation systems, irrigation networks and equipment.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The total cost of the three pilot projects is 3.4 million dollars funded by The United State Agency for International Development (USAID).

***Problems founded in the start-up, development or final application of the project*:**

Not remarkable problems founded.

Remarkable results:

The site is considered an active tourist site as being in Aqaba city (the only Sea port in the country) which at the coast of the Red Sea. In addition the soil in the site is mostly sandy soil.

***Information Sources*:**

www.hydro.ntua.gr/labs/sanitary/agricultural_reuse.htm#1.The%20Virginia%20Pipeline:%20Australia's%20largest%20water%20recycling%20project (Al-Shreideh, B.,(2000), Reuse of Treated Wastewater and Treated Sludge in Agriculture as a Non-Conventional Resource in Jordan, The Hashemite Kingdom of Jordan, Ministry of Water and Irrigation, Water Authority, Amman, Jordan)

www.morganti.com/International/curr.asp

www.mwi.gov.jo/Investment%20plan/B.Project's%20Under%20Implementation/B.2%20Private%20Sector's%20Projects/3-Samra%20Wastewater%20Treatment%20Plant%20(BOT).htm

A.I. Jamrah, Assessment of characteristics and biological treatment technologies of Jordanian wastewater, Bioprocess Engineering 21 (1999) 331±340, (1999).

CASE 4: Al-Samra WWTP

Location:

Al-Samra.

Year of the project development:

Al-Samra began operating in 1985.

***Water origin*:**

Domestic wastewater.

***Volume (or flow) of water affected*:**

150,000 m^3/day (54.8 Mm^3/yr).

***Water treatment before reuse (technologies/process applied)*:**

Three trains of ponds, each containing two anaerobic ponds, four facultative ponds and four maturation ponds.

***Reclaimed water quality*:**

In terms of overall performance in 1986, the Al Samra ponds were able to remove 80% and 91% of the incoming BOD on the basis of unfiltered and filtered final effluent samples, respectively. This result was obtained for only two trains of ponds in operation when the design organic and hydraulic loading were exceeded by 57% and 25%, respectively. At the same time, a reduction of 4.6 log was employed in Faecal Coliforms. It is clear that the final effluent did not meet the WHO (1989) guidelines but no Nematode Eggs were noticed in the final effluent:

pH	7.1
COD	320-382 mg/L
TSS	119-171 mg/L

***Water reuse applications*:**

Reclaimed wastewater is used in irrigation.

***Total area affected by irrigation*:**

Area irrigated by reclaimed wastewater is reported to be about 500 ha. The excess flows are diverted to the King Talal Reservoir before being used in the irrigation of agricultural land in the Jordan Valley.

***Types of products cultivated in irrigated areas*:**

At present 35% of the reuse area is planted with olive trees. Remaining 65% is forest area, fodder crops and non-restricted vegetables planted for experimental purposes.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The total cost of the project reached 320,000,000 US$.

***Problems founded in the start-up, development or final application of the project*:**

Due to high organic loading on the ponds, first eight ponds in each train can go anaerobic and only the final two behave as facultative aerobic ponds.

Remarkable results:

35% of the reuse area is planted with olive trees. Wastewater reuse in these areas is reported as very successful. The area is rented by private sector since 1996.

***Information Sources*:**

www.fao.org/docrep/T0551E/t0551e0b.htm#9.1%20advanced%20wastewater%20treatment:%20california,%20usa

www.hydro.ntua.gr/labs/sanitary/agricultural_reuse.htm#1.The%20Virginia%20Pipeline:%20Australia’s%20largest%20water%20recycling%20project

www.morganti.czom/International/curr.asp

www.mwi.gov.jo/Investment%20plan/B.Project's%20Under%20Implementation/B.2%20Private%20Sector's%20Projects/3Samra%20Wastewater%20Treatment%20Plant%20(BOT).htm

CASE 5: Ramtha WWTP

Location:

Ramtha.

Year of the project development:

1999.

***Water origin*:**

Domestic wastewater.

***Volume (or flow) of water affected*:**

0.7 Mm^3 in 1999.

***Water treatment before reuse (technologies/process applied)*:**

Waste stabilisation ponds are utilized. The plant will be expanded to treat 5,400 m^3/d. Modified treatment will also include pre-treatment, biological treatment and sand filters to remove algae and parasites.

***Reclaimed water quality*:**

Not data available.

***Water reuse applications*:**

It is used in irrigation.

***Total area affected by irrigation*:**

Area irrigated by reclaimed wastewater is reported to be about 50 ha.

***Types of products cultivated in irrigated areas*:**

Forest and fodder crops. 49 ha of reuse area has been planted with barley, Sudan grass, and alfalfa

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The plant will be expanded to achieve higher quality and water reuse. The cost of expansion will be 9.5 million €. The plant will be expanded to achieve higher quality and water reuse. The cost of expansion will be 9.5 million €.

***Problems founded in the start-up, development or final application of the project*:**

Not data reported.

Remarkable results:

Not data reported.

***Information Sources*:**

www.hydro.ntua.gr/labs/sanitary/agricultural_reuse.htm#7. The Jordanian Experience on Wastewater Reuse

www.vivendiwatersystems.com/uk/CP_311001/jordan.htm

A.I. Jamrah, Assessment of characteristics and biological treatment technologies of Jordanian wastewater, Bioprocess Engineering 21 (1999) 331±340 ,1999

Selected cases in Lebanon

Lebanon does not have any success stories, per se, since all wastewater treatment plants achieving secondary treatment are small-scale community-based plants that are discharging their effluent directly into the environment (river beds, natural drainage channels, etc…) and their use in irrigation at present is extremely limited.

Most operational secondary-treatment plants were initially designed with a specific objective of treating and reusing the wastewater stream for irrigation; however, none of these plants is actually doing so because of a number of reasons. In some cases the effluent quality does not comply with the standards set for treated wastewater reuse in agriculture. Another problem relates to the fact that these plants already generate relatively small quantities of effluent and this quantity is further subject to seasonal fluctuations that make its use unfeasible in certain periods of the year when it's needed most. Furthermore, the cost of transmitting the effluent to the areas to be irrigated has in many cases shown to be unfeasible.

Two interesting examples, where plants intend to use their effluent in irrigating ornamental trees, reeds, and bamboos are discussed in the following sections. These include the Hasbaya plant and the Yanta plant, both funded by USAID and implemented through Mercy Corps Lebannon (MCL) and Young Men´s Christian Association (YMCA), respectively. MCL and YMCA are two NGO's, among others, that execute small-scale wastewater treatment facilities throughout the country using external financing sources.

<u>CASE 1</u>: <u>The Hasbaya Plant</u>

The Hasbaya WWTP is one of the very few local examples that have the potential of becoming a success story; this plant was designed with the objective of having its effluent used in irrigation.

Location:

The plant is situated at the border of the town of Hasbaya and is located at an altitude of 750 m above sea level to the east of the Hasbani River, which is considered a major drinking water source supplying several villages in the area, including the village of Hasbaya. The town of Hasbaya is the main town in the Hasbaya Caza and one of the major towns in the Mohafaza of Nabatieh, South Lebanon (Figure 26). The area is mainly agricultural in nature and is intensively cultivated with olive trees. It can also be considered as a touristic area, especially during the summer season, when a large number of people visit the area and are served by many restaurants situated on both sides of the Hasbani River (Figure 27).

The major sources of pollution in the area include the municipal wastewater from Hasbaya town and the wastewater generated by the several olive oil presses located in the region. The wastewater from the different sources discharge directly into the Hasbani River or into natural drainage channels that lead to the Hasbani River. Before the implementation of the current wastewater plant in Hasbaya, the municipal wastewater used to be discharged into two open channels running from Hasbaya to the Hasbani River. The quantity of wastewater normally increases during the weekends and the summer season, when most immigrants and Hasbaya locals working in different cities across the country visit the village

Figure 26. Overview of the town of Hasbaya,
(EIA report for Hasbaya WWTP, MCL, 2002).

Figure 27. Restaurants located along the Hasbani River,
(EIA report for Hasbaya WWTP, MCL, 2002).

The restaurants located along the river are not connected to the sewer network and consequently all their wastewater is discharged directly, without treatment, into the river. This quantity increases during the summer. The olive oil presses represents one of the major environmental stresses in the area, especially during the olive harvesting seasons when the wastewater from these olive presses is discharged without any form of treatment into the river.

Year of the project development:

The plant, designed and constructed by MCL upon the request of the municipality of Hasbaya, covers a built up area of about 2000 m^2. Even though two municipal wastewater treatment plants were designed for this town, only one was completed and became operational by the year 2002 (Figure 28). The construction of the other plant was completed but has not been put into operation.

Figure 28. The Hasbaya Plant.

***Water origin*:**

The treatment plants abovementioned.

***Volume (or flow) of water affected*:**

The operating plant treats the raw wastewater discharged by the town of Hasbaya. It was designed to serve 14,000 persons (projected population for the year 2015). The estimated amount of wastewater that is treated by the plant at present is around 900 m^3/day.

***Water treatment before reuse (technologies/process applied)*:**

The treatment process adopted in the Hasbaya WWTP comprises anerobic/aerobic secondary treatment. Figure 29 illustrates the different steps of the process described in this section. The first stage includes the screening, which consists of two galvanized iron screens (coarse and medium) that are installed at several upstream manholes to remove bulky items before reaching the biological treatment level. The pore diameter of the screens installed range between 10 and 2 cm. The anaerobic process adopted is the up-flow anaerobic sludge blanket reactor (UASB).

This system was proven to be as efficient as conventional aerobic reactors in removing organic matter and total suspended solids with the advantage of not using mechanical equipment. The plant accommodates six UASB reactors; each reactor has been designed with an average volume of 70 m^3. The expected retention period within the reactors is estimated at 12 hours, while the BOD removal efficiency is expected to exceed 80 percent.

Aerobic filter beds are introduced to further treat the effluent from the anaerobic stage. Circular open brick tanks, with wall openings at the bottom and filled with a medium made of short pieces of hollow corrugated PVC tubes, are used for this purpose. A gravel-packed bed is used to filter the effluent from the aerobic filter beds before being passed to the holding tanks and the final effluent is discharged into a natural drainage channel which eventually reaches the Hasbani River.

The design of the plant includes a gas collection system. The anaerobic stage mainly produces a mixture of methane (CH_4) and carbon dioxide (CO_2) gas, which is transmitted through a one-inch diameter pipe to a metallic floating-cover gas-holding tank from where it is transmitted to a flare.

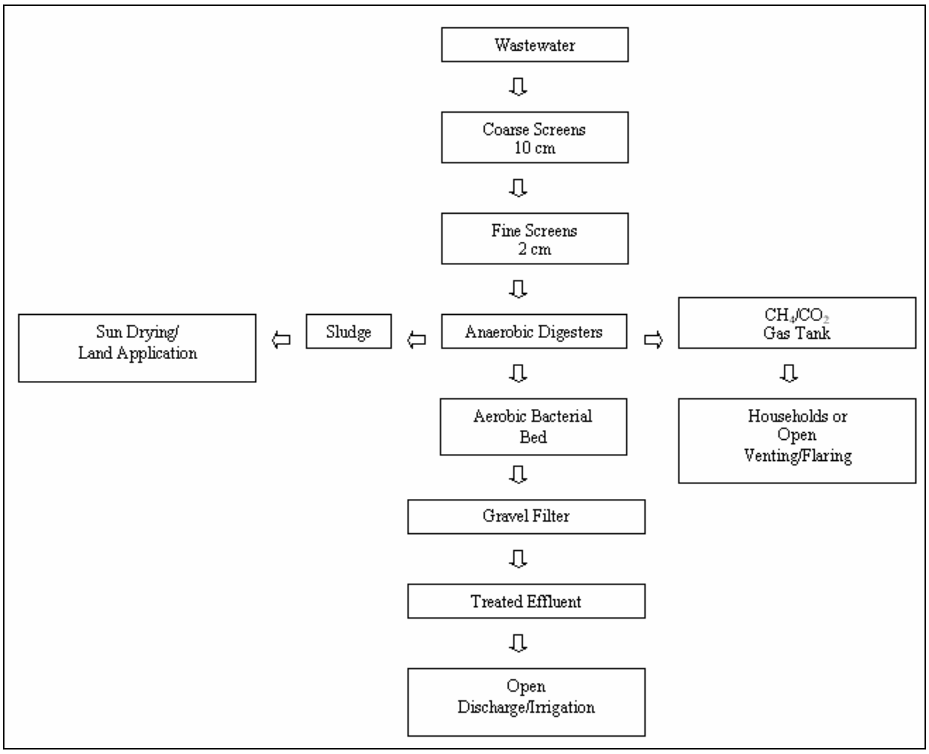

Figure 29. The Hasbaya Plant process diagram,

(EIA report for Hasbaya WWTP, MCL, 2002).

***Reclaimed water quality*:**

The physical and chemical characteristics of the raw sewage collected from Hasbaya's two open discharge channels are represented in Table 17.

Table 17. Raw sewage quality in Hasbaya*.

Parameter	Open Channel #11	Open Channel # 21
pH	7.34	7.21
Temperature	26.6 ºC	25.3 ºC
Ortho-phosphates	216 mg/L	140 mg/L
Nitrate-nitrogen	1.2 mg/L	1.1 mg/L
Ammonia-nitrogen	118 mg/L	50 mg/L
BOD_5	850 mg/L	60 mg/L
COD	1,058 mg/L	85 mg/L
TSS	800 mg/L	12 mg/L

Source: EIA report for Hasbaya WWTP, MCL, 2002

*Samples were collected from incoming channels to the plant.

Information on the quality of the influent and effluent of the Hasbaya WWTP is provided in Table 18.

Table 18. Removal efficiency of Hasbaya wastewater treatment plant.

Effluent quantity (m^3/d)	Influent quality	Effluent quality	Effluent disposal method	Removal efficiency
900	BOD_5: 245 mg/l COD: mg/l TSS: mg/l	BOD_5: 121.5 mg/l COD: 243 mg/l TSS: 36 mg/l	Natural drainage channel (ends in a river)	BOD_5: 50 % COD: 55 % TSS: 73 %

Source: EIA report for Hasbaya WWTP, MCL, 2002

The samples were collected and tested few months after starting the operation of the plant and the results of the tests do not comply with Lebanese standards for surface water discharge. However, the removal efficiency of this plant is expected to improve after some time even though no recent quality analysis is available to backup this assumption.

***Water reuse applications*:**

Currently the treated effluent in the Hasbaya WWTP is discharged mostly into the natural drainage channel located just below the plant. However, the municipality is using an unknown portion of the treated wastewater for irrigating trees grown around the perimeter of the plant in order to improve landscape conditions. Even though the plant was originally designed to use the treated effluent for irrigation, the current quality of the effluent does not comply with standards for use of effluent in irrigation.

With some upgrading, training of personnel working at the plant, and improvement in the monitoring and maintenance activities, the effluent quality of this plant could improve.

***Total area affected by irrigation*:**

Data unknown.

***Types of products cultivated in irrigated areas*:**

Olive trees mainly.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

As stated previously, the two WWTPs are located at the outskirts of the town of Hasbaya, and only one plant is currently operational. The actual total construction cost of the individual WWTPs was not available at the MCL; however, the actual total cost of construction for both plants was set at about 300,000 US$. The plant is located at the lowest part of the Hasbaya area adjacent to two existing open channels in order to reduce pumping needs. The municipality contributed an equivalent of 60,000 US$ in the form of land and labour/equipment used in excavation. The land is located within a privately owned agricultural area primarily used for olive cultivation. It is connected by a road and located in a sparsely populated area. The number and cost of the labour force was not available, and as such the unit cost of water produced for reuse could not be calculated.

***Problems founded in the start-up, development or final application of the project*:**

No data available.

Remarkable results:

The most remarkable result of this project is the mitigation of the environmental stresses in the area that were present before this project became operational. Even though the quality of the effluent is still not complying with standards, it is still a good step towards reducing the pollution resulting from the previous wastewater practices in the Hasbaya area. It also helped in reducing the environmental costs associated with the adverse impact on human health (especially of swimmers in the Hasbani River) and degradation of the current natural resources in the area.

As pointed out, the plant is located relatively far from residential areas of the village. No industrial, tourist or commercial establishments are currently operating in the vicinity of the plant. At the early stages of operation, some residents complained from the odours generated; this was due to a broken methane transmission pipe, which was later remedied. The only economic activity in the area of the treatment plant is agricultural in nature (olive cultivation). It is to be noted that several tourist establishments operate along the banks of the Hasbani River and can be adversely affected by the discharge of the low quality effluent into the river. In addition, due to the small size of the plant, no significant visual interruptions are associated with the facility.

The positive impacts include: (1) the abatement of pollution and public health hazards in the area, (2) improvement in the quality of the Hasbani River, (3) augmenting agricultural irrigation supplies, (4) reducing the use of chemical fertilizers and saving on the cost of fertilizers, and (5) generation of methane, which could be used as an energy source.

One major handicap results from the location of the plant at a level that is lower than the land available for irrigation. In this case pumping will have to be resorted to, which could prove costly and would limit the use of this water for irrigation purposes.

***Information Sources*:**

El Fadel, M.; Wastewater treatment plant assessment for Mercy Corps Lebanon; Environmental Impact Assessment for Hasbaya Wastewater treatment plant; Mercy Corps Lebanon, 2002.

CASE 2: The Yanta Plant

Two plants are located in Yanta village and both are constructed through YMCA. Their capacities are 240 m^3/day and 120 m^3/day, and their design population is 1,250 and 750 persons, respectively. However, the smaller plant is the one that is thriving more, since the second plant (Figure 30) is facing problems with the electrical supply (a drop in voltage is impeding the proper operation of the plant). The quality of the effluent from the smaller plant is quite acceptable and there are plans for using this effluent in irrigation.

Figure 30. The Yanta Plant facing power supply problems.

Location:

The Yanta WWTP is situated in Yanta village, which is located at an elevation of about 1,400 m above sea level. The village falls in the Caza of Rashaiya, Mohafaza of the Bekaa. The climate is relatively cold in the region, especially during winter season when invariably the village is covered by snow.

Year of the project development:

The Yanta Plant was completed and became operational at the beginning of the year 2002.

***Water origin*:**

The type of influent to the plant is domestic wastewater from near cities.

***Volume (or flow) of water affected*:**

The plant serves 750 people and its capacity is 120 m^3/day (Figure 31). However, at present it is using nearly half of its capacity and generating an average flow of about 60 m^3/day.

***Water treatment before reuse (technologies/process applied)*:**

The technology used is a combination of aerobic and anaerobic processes. Raw sewage flows by gravity through an inlet screen installed within an existing septic tank to a newly constructed buffer compartment, in which the influent submersible pumps are installed. Raw influent is then pumped to the Hans Reactor structure.

The Hans Reactor Structure as specified in the design sheet includes:
- Screen (washable)
- Air compressors (two- one duty/one standby)
- Airlift recycling system
- Sludge transfer system
- Aerator
- Bio filters
- Cover

Figure 31. The successful Yanta Plant.

The structure is made of steel, epoxy coated. Oxygen demand, for the stabilization, process is secured by the airlift aerator. The air being supplied by the compressor is dispersed by a maintenance-free special nozzle, in the form of a large number of micro bubbles which (while rising to the surface) saturate the sewage with oxygen and simultaneously drive the sewage to the surface. The evolved hydrostatic pressure forces the sewage back down to the bottom. A self cleaning feature is inherent in the behaviour of the unit, which protects the biological filter against any possible clogging and makes the unit virtually maintenance free.

Treated water flows to a final sedimentation compartment where suspended particles settle in the tank, from where the sludge is pumped back to the existing septic tank at periodic intervals by the airlift system.

Treated water rises through the surrounding compartment to the water outlet. When the septic tank becomes filled with sludge to about 50 % of its capacity, it is emptied in the standard manner. The advantage being that the septic tank is emptied less frequently then in a conventional plant.

Finally treated effluent is discharged. This effluent can be chlorinated and then directed to the treated effluent/irrigation tank at a quality that will eliminate the need for tertiary treatment. However, at present, the effluent is not being chlorinated. Refer to Figure 32 for a plan showing the components of the plant.

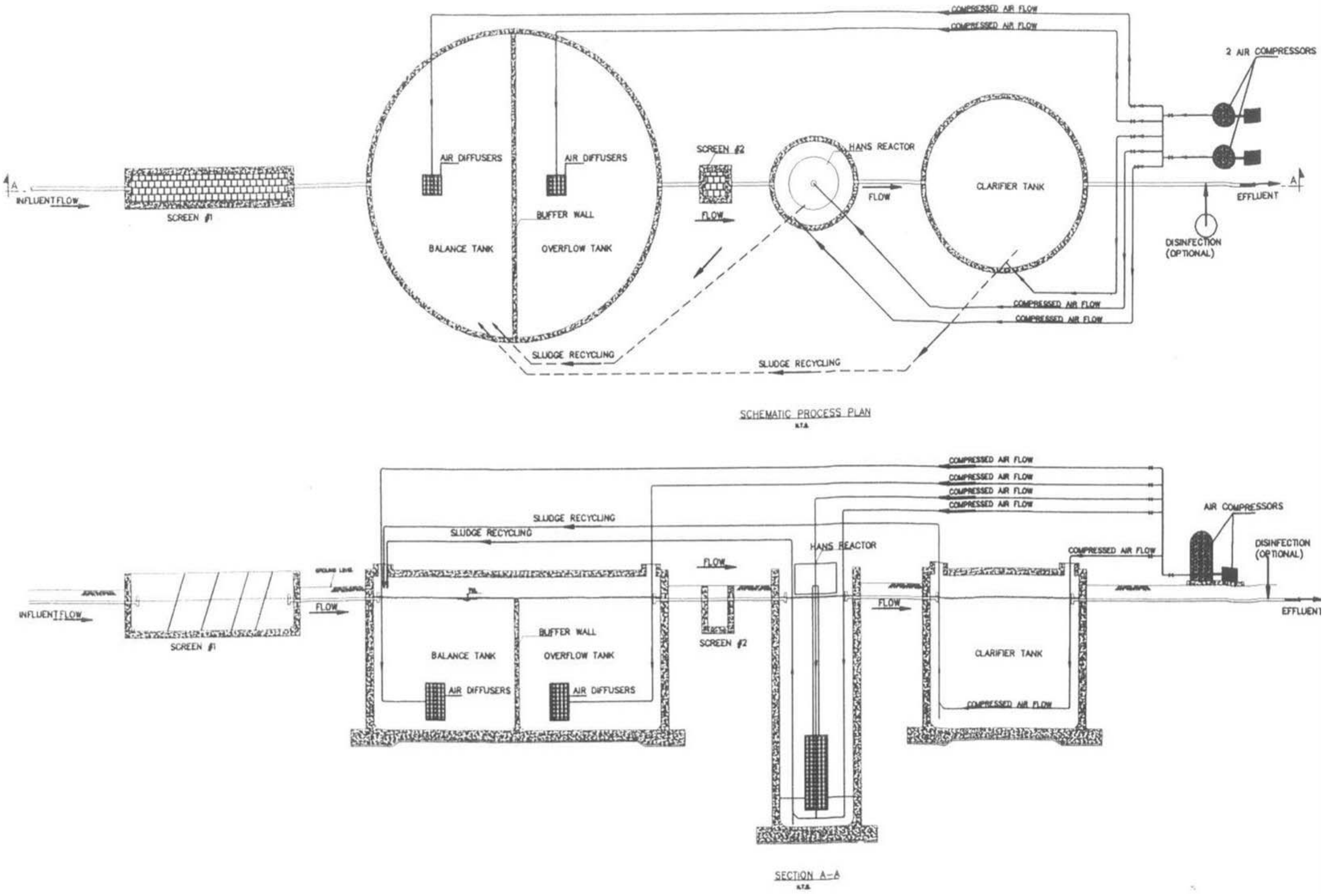

Figure 32. The technology used in Yanta Plant.

***Reclaimed water quality*:**

There are no recent quality test results for the influent and effluent of the plant. According to the manager of the Environmental Program at YMCA, the figures in the Yanta Plant are similar to those of another plant whose influent and effluent were sampled very recently. The BOD of the influent and the effluent was found to be > 750 mg/l and < 25 mg/l, respectively.

***Water reuse applications*:**

The effluent of Yanta is currently being discharged in a natural drainage channel. However, there are plans for using this effluent for irrigation of reeds and bamboos that are going to be planted in the 5000 m^2-land surrounding the plant (Figure 33). The land is owned by the Municipality. This project will help in enhancing the local livelihood of the people of Yanta through generating new work opportunities such as the manufacturing of baskets and chairs using the planted reeds and bamboo.

Figure 33. The future reeds and bamboo field surrounding the Yanta Plant.

***Total area affected by irrigation*:**

5000 m^2 land surrounding the plant.

***Types of products cultivated in irrigated areas*:**

Reeds, bamboos.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Although the deal was that YMCA will fund 70% of the project, and the remaining will be contributed by the Municipality from external funding, YMCA had to fund all of the project at the beginning as the Municipality was unable to contribute their share at the time of construction. In addition, they had to construct a wastewater collection network for the whole village at a cost of 307,000 US$. The total cost of the network and the 2 plants was 421,000 USD. The municipality contributed an equivalent of 114,000 US$ from the total cost after the completion of the project.

Table 19: Cost of the Yanta Plant.

Component	Cost of the two plants (USD)	Cost of the chosen plant (USD)[1]
Construction Material (Facility)	33,000	11,000
Equipment	67,000	22,333
Labour Force	14,000	4,667
Total cost	114,000	38,000

Source: Personal interview 2, 2003
[1] The cost of the plant considered as the success story was calculated as 1/3 of the total cost of the two plants of Yanta.

***Problems founded in the start-up, development or final application of the project*:**

Two major problems faced during the execution of the project included: (1) the local political conflicts, (2) the climate in the village; situated at an altitude of around 1,400 m, the low temperature and the snow cover slowed down the construction works.

Remarkable results:

The fact that the Yanta plants are situated very far from residences ensured a wide public acceptance. Moreover, the implementation of the project ended the hazardous discharge of raw sewage directly into the environment. It is expected that the effluent will be used in irrigation thus adding to the positive impacts of the project.

***Information Sources*:**

Personal Interview 1, with Engineer Nabil Abdulah, project manager at the Mercy Corps Lebanon, December 23, 2003.

Personal Interview 2, with Engineer Joseph Khalil Kassab, manager of the Environmental Program at YMCA, Lebanon, December 24, 2003.

Selected cases in Morocco

CASE 1: Ben Slimane Wastewater Treatment Plants

Location:

80 km South West of Rabat.

Year of the project development:

The treatment plants have been in operation since 1997.

***Water origin*:**

Urban water from 37,000 habitants.

***Volume (or flow) of water affected*:**

6,600 m^3/d.

***Water treatment before reuse (technologies/process applied)*:**

The wastewater suffers four stages of treatment: pretreatment and primary, secondary and tertiary treatment. The technology is based on a combination of the techniques of natural lagoons, improved by a light change: the installation of an air source at secondary level and the storage of a great amount of water, all in line with a poolish system in deep tanks.

***Reclaimed water quality*:**

An analysis reveals the following parameters for the effluents:

Table 20. Effluent quality.

Parameter	Influent	Effluent	Yield (%)
BOD (mg/L)	135	23	83
COD (mg/L)	365	63	83
TSS (mg/L)	148	14	91
TKN (mg N/L)	56.11	24.43	56
P-total (mh P/L)	6.71	4.02	40
Total Coliform	6 Ulog	22	100
Helminth egg per litre	9	0	100

***Water reuse applications*:**

Reclaimed water is used in irrigation of golf courses by sprikling.

***Total area affected by irrigation*:**

An average of 100 hectares.

***Types of products cultivated in irrigated areas*:**

Grass.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Investment: 96.44 MDH (~ 10 million US$)
Exploitation cost: 935, 784 DH/ year (~ 97,322 US$)
Cost of clean water produced: ~1.45 DH/m^3 (~0.1508 US$)
Selling price of one liter of purified water: 2 DH/m^3 (~ 0.208 US$)
Drinkable water price: 4 DH/m^3 (~ 0.416 US$)

***Problems founded in the start-up, development or final application of the project*:**

Not remarkable problems reported.

Remarkable results:

Water purified in conformity with WHO directives. Important fertilizing value (contribution to the land: 308 kg nitrogen per hectare.

***Information Sources*:**

All information was provided from the treatment plant representatives.

<u>CASE 2</u>: <u>Wastewater reuse under saline conditions</u>

Location:

The city of Quarzazate, located 600 km in the South-West of Rabat, Morocco. The treatment facilities are located in less than 1,000 m from the lake of the Dam Mansour Addahbi, where wastewater is usually disposed off.

Year of the project development:

1990-1993.

***Water origin*:**

Wastewater of domestic origin with not noticeable industrial contribution.

***Volume (or flow) of water affected*:**

From a flow of 50 l/s, only 5 l/s are diverted from main service to be treated in the waste stabilization pond (WSP) plant.

***Water treatment before reuse (technologies/process applied)*:**

The raw wastewater was pretreated for the removal of coarse material, grease and sand and then pumped into the anaerobic pond at the head of the water stabilization pond at the head of the WSP train.

***Reclaimed water quality*:**

The WSP treatment performances are satisfactory. On average, BOD is reduce by 80%, N-NH_4^+ by 37% and P-PO_4^{-3} by 32%. Four logarithmic units were recorded in Faecal Coiform (FC) reduction. FC counts do no exceed 1000/100 ml on a yearly mean and Helminth eggs were totally eliminated from the effluent. Table 21 shows the main physicochemical characteristics of agronomic interest for the two types of water: raw wastewater and treated wastewater.

Table 21. Physico -chemical characteristics of the wastewater.

Parameters	Raw Wastewater	Treated Wastewater
pH	7.59	8.50
EC (mmhos/cm)	3.06	2.94
P-PO_4^{-3} (mg/l)	23.00	15.73
N-NH_4^+ (mg/l)	40.30	25.2
N-NO_3^- (mg/l)	0.70	0.40
HCO_3^- (meq/l)	12.30	10.40
SO_4^{-2} (meq/l)	7.88	2.82
Cl^- (meq/l)	12.87	12.6
Ca^{+2} (meq/l)	7.25	5.9
Mg^{+2} (meq/l)	5.35	5.97
K^+ (meq/l)	0.45	0.63
Na^+ (meq/l)	14.10	14.0
SAR	5.62	5.75

***Water reuse applications*:**

Irrigation.

***Total area affected by irrigation*:**

The assays were carried out in an area of 33 m^2.

***Types of products cultivated in irrigated areas*:**

The crops tested on surface irrigation can be classified in two groups: a salt sensitive group which includes cucumber and turnips, and a salt tolerant group which includes alfalfa, corn, courgettes, beans and tomatoes.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Not data available.

***Problems founded in the start-up, development or final application of the project*:**

Not problems reported.

Remarkable results:

The experimentation showed that treated wastewater applications instead of groundwater, attenuated the detrimental effect of water salinity on the crop. Drip irrigation, "Bas Rhône" system, showed the highest irrigation performances and crop yields. The morphology and the way the crop was conducted were found to play an important role in determining its final bacteriological quality. Irrigated crops and soils did nor shown any helminth eggs contaminations.

***Information Sources*:**

El Hamouri, B., Handouf, A., Mekrane, M., Touzani, M., Khana, A., Khallayoune, K., Benchokroun T. Use of wastewater for crop production under arid and saline conditions: yield and hygienic quality of the crop and soil contaminations. Wat. Sci. Technol., 33 (10-11), pp. 327-334 (1996).

<u>CASE 3</u>: <u>Wastewater reuse by infiltration-percolation in Morocco</u>

Location:

Marrakech, Morocco.

Year of the project development:

1995.

***Water origin*:**

The treatment plant receives a raw domestic wastewater from a tourist complex.

***Volume (or flow) of water affected*:**

The plant has been designed to treat a flow of 300 to 1,000 PE.

***Water treatment before reuse (technologies/process applied)*:**

The treatment plant consisted of one anaerobic tank (capacity = 275 m^3, depth = 7 m, detention time = 5 days), five infiltration basins (area = 5x300 m^2) filled with 2 m of rapported sand (12% of clay-silt and 88% of sand).

The pretreated effluent, by anaerobic tank, was daily applied to sand filters alternatively until clogging.

***Reclaimed water quality*:**

Table 22 summarizes the mean characteristics of the influent entering the treatment plant.

Table 22. Characteristics of the plant influent.

	pH	TSS*	COD*	d-COD*	TP*	d-TP*	PO_4-P*	NH_4-N*	TKN*
Mean	6.57	500	650	225	8.5	5.8	3.8	18	41.4

* mg/l

The system has a high capacity to remove both, particulate and dissolved organic matter (TSS 91%, COD 93% and d-COD 89 to 93%).

Table 23 summarizes the physical-chemical and microbial characteristics of water irrigation.

Table 23. Characteristics of water used for irrigation.

	Raw wastewater	Settled wastewater	Filtered wastewater
pH	6.53	6.91	7.02
PO_4-P*	10.18	3.34	0.028
TP-P*	11.49	5.26	0.29
NH_4-N*	16.19	6.83	0.002
NO_2-N*	0.013	1.04	0.012
NO_3-N*	0.006	1.48	0.12
TKN*	30.21	11.06	2.12
Faecal Coliform**	21.9×10^5	36.25×10^2	41
Faecal Streptocoque**	17.6×10^3	6.6×10^1	13

* mg/l; ** UFC/ml

***Water reuse applications*:**

Irrigation.

***Total area affected by irrigation*:**

In order to test the fertilizer value of wastewater, ten experimental plots (area = 1 m^2) were tied with ray grass (Lolium perenne) and irrigated, every two days, by the raw wastewater, settled wastewater and completely treated wastewater.

***Types of products cultivated in irrigated areas*:**

Meadows.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Not data available.

***Problems founded in the start-up, development or final application of the project*:**

At spring the infiltration - percolation plant presented a low percent removal efficiency due probably to overloaded influent.

Remarkable results:

The test allows to see the promising possibility to promote the nutritional of farm animals food by using treated wastewater.

***Information Sources*:**

Ouazzani, N., Bousseljah, K., Abbas, Y. Reuse of wastewater treated by infiltration percolation. Wat. Sci. Technol., 33 (10-11), pp. 401-408, (1996).

CASE 4: Ville de Drargua Wastewater Treatment Plans

Location:

The Commune of Drarga is a commune which grows quickly in Souss-Massed (8,000 inhabitants).

Year of the project development:

The treatment plants have been in operation since 1999. Stages of the project:
1997: Study of feasibility
1997: Environmental impact study
1998: Convention of partnership sign
1998: Observation in the United States
1998: Design of the station
1999 - 2000: Construction
October 2000: Inauguration
May 2001: Beginning of the re-use

***Water origin*:**

Urban water from 5,700 habitants.

***Volume (or flow) of water affected*:**

600 m^3/d.

***Water treatment before reuse (technologies/process applied)*:**

The plant counts on a system of infiltration-percolation with recirculation of the effluents. Also an primary treatment (aerobic basins), a secondary treatment (sand filters) and a tertiary treatment are included in the process. Reads drying of sludges and a storage tank of purified water are other elements of the plant (see Figures 34 and 35).

***Reclaimed water quality*:**

An analysis reveals the following parameters for the effluents:

Table 24. Effluent quality.

Parameter	Influent	Yield (%)
BOD (mg/L)	625	98
COD (mg/L)	1,825	94
TSS (mg/L)	651	99
TKN (mg N/L)	317	96
P-total (mh P/L)	-	72
Total Coliform	$1.6x10^7$	99.9
Helminth egg per litre	-	100

***Water reuse applications*:**

The water is used for irrigation (surface, microjet and drop by drop irrigation).

***Total area affected by irrigation*:**

An average of 6 hectares belonging to a total of 12 farmers.

***Types of products cultivated in irrigated areas*:**

Alfalfa, Ray-grass Italien, tomatoes, Zucchini and corn.

The impact of the water reuse on crops grow is shown in Table 25. The savings in fertilizers thanks to the use of this water can be observed in Table 26.

Table 25. Biomass yield.

	First cut yield (T/ha)
Alfalfa	2.85
Ray-Grass	9.75

Table 26. Savings in fertilizer.

	Tomatoes	Zucchini	Alfalfa	Ray Grass	Italian	Corn
Water requirements (m^3/ha)	8,000	5,000	12,000	10,000	4,000	4,800
Nitrogen (kg/ha)	-	248	155	372	310	124
Phosphorus (kg/ha)	-	352	220	528	440	176
Potassium (kg/ha)	-	408	255	612	510	204

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The total cost of the project has been 2 million US$ as follows:

Design: 200,000 US$; Construction: 800,000 US$; Equipment: 500,000 US$; Transport: 200,000 US$; Others: 300,000 US$
The costs of operation reach 2,000 US$ per month.

The Drarga project was designed to maximize use exploitation of all treated wastewater products. The treated wastewaters are sold to farmers and reused in irrigation, the reeds of the wetland are cut and sold, the residual sludge is dried and then composted with the organic wastes of Drarga, and the biogas of anaerobic basins will be recovered and converted to energy.

***Problems founded in the start-up, development or final application of the project*:**

Not remarkable problems reported.

Remarkable results:

The costs of the treatment process are recovered following the recommendations of the Water Framework Directive, as follow: the methane of the anaerobic reactors is converted into energy. The purified wastewater is sold to the farmers for irrigation, the reeds are cut and sold, the sludge is dried and mixed with organic solid waste of Drarga in order to make compost.

Purified effluent is sold to the farmers through an association of users of water. This effluent has a high content of fertilizing elements (nitrogen, potassium, phosphorus) that makes it valuable. The result is the selling price of purified water 0.5 dirham/m^3 (0.056 US$/$m^3$) is competing with the alternative water sources.

With these actions, nowadays there are a completely lack of water problems in the village of Drarga and there is more water available for irrigation.

The agricultural production increased and the farmers save on the application of fertilizers. On the other hand, the values of the properties have increased in Drarga.

The station of treatment and re-use of wastewater of Drarga shows the use of non-conventional waters in a context of dryness.

***Information sources*:**

All information was provided from the treatment plant representatives and by:

Aomar, J., Abdelmajid, K. Wastewater reuse in Morocco. Ministry of Agriculture, Rural Development and Water and Forests, Rural Engineering Administration, Development and Irrigation Management Directorate, (2002).

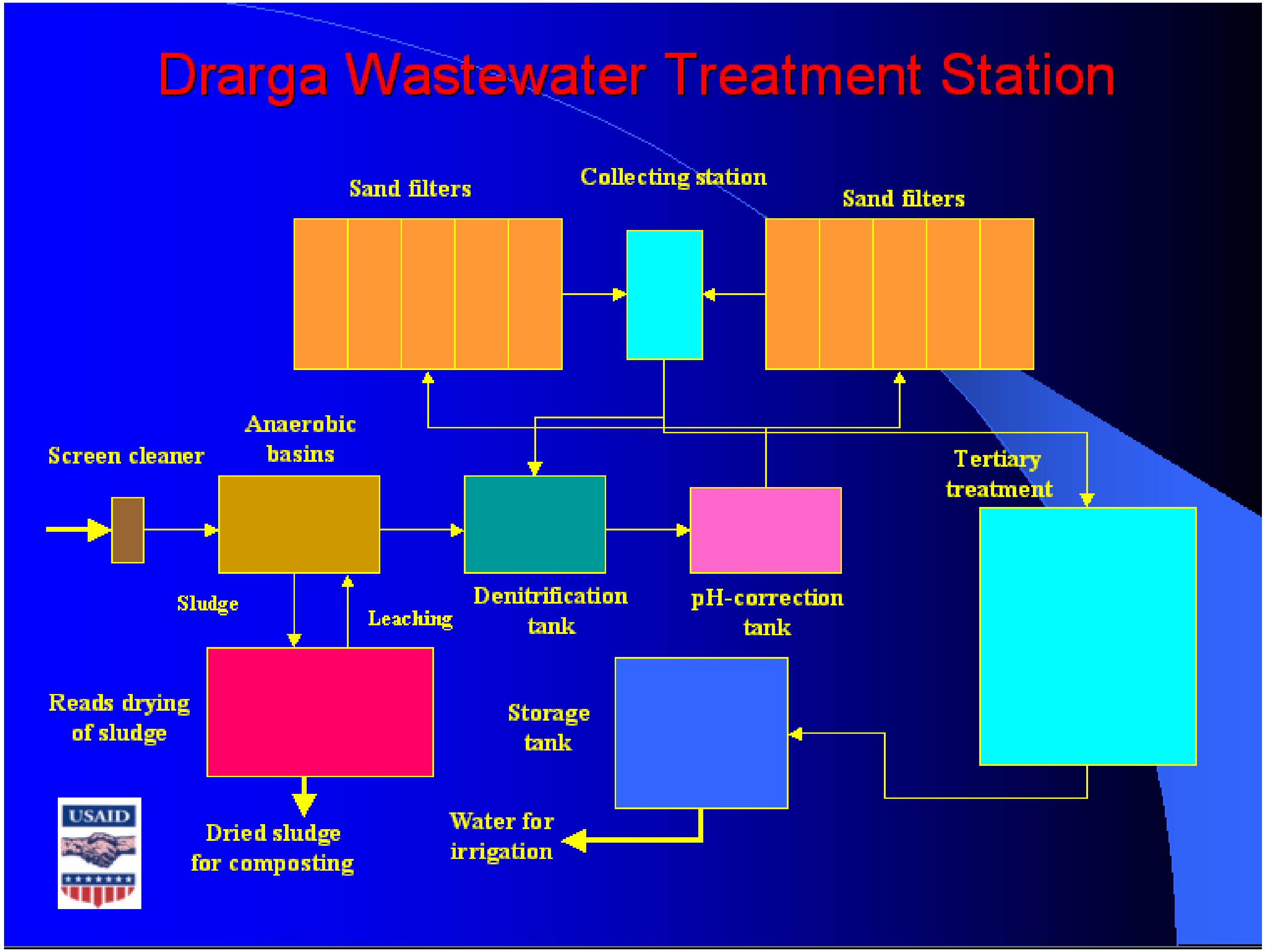

Figure 34: Drarga Treatment Plant.

Figure 35: Drarga Treatment Plant (Source: http://www.usaid.gov/ma/successstories/urbansanitation.htm).

Selected cases in Palestine

CASE 1: Wastewater reuse in Al-Beirah, Palestine

Location:

Al-Beirah city, West Bank, Palestine.

Year of the project development:

Al- Beirah wastewater treatment plant was developed in 2000.

***Water origin*:**

Municipal wastewater.

***Volume (or flow) of water affected*:**

The total volume of influent entering the plant is 3,200 m^3/day.

***Water treatment before reuse (technologies/process applied)*:**

- Preparation of wastewater influent is accomplished by grit removal and screening.
- After that it is diverted equally to two parallel aeration tanks, the effluent of aeration tank is diverted to two parallel final clarifies, then most of the sludge goes to the thickener for dewatering.
- The water passing to clarify goes to disinfection, by Ultraviolet (UV) radiation.

The final effluent is discharged through Wadi Al-Ein, by 5 km pipeline, to be reused for irrigation in Dir-Dabwan land where large uncultivated areas existed there.

***Reclaimed water quality*:**

Analysis reveals the following parameters for the effluent:

Table 27. Reclaimed water quality of Al-Beirah WWTP.

Parameter	Unit	Influent	Effluent
BOD	mg/L	500	10
COD	mg/L	1,000	90
SS	mg/L	10	10

***Water reuse applications*:**

The treated water is used in irrigation.

***Total area affected by irrigation*:**

About 2% of the treated wastewater is used for irrigation (60 m^3/day) for 0.54 ha open area and 600m^2 plastic houses.

***Types of products cultivated in irrigated areas*:**

Almonds, apricots, peach, plum, orange, lemon, grapefruit, pecan, fig, walnut, pomegranate, mango, cherries, red cherries, Guava, and avocado.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The construction cost of the wastewater treatment plant is about 7 million €. The total cost for treating one cubic meter is 0.32 €.

***Problems founded in the start-up, development or final application of the project*:**

Since the plant is new and no overload is observed or projected for the next few years, the most important problem is a political one (continuous Israeli closures) prevents spare parts supply, which leads to ineffective maintenances. The operation costs are high, therefore it has to be covered by the consumer served by the WWTP, which will lead to efficient use of water resources and considered it as an economically good.

Remarkable results:

The results of the three-year operation of the plant have indicated that use of treated wastewater for food crops (pilot scale) irrigation is safe and acceptable. No adverse impacts in terms of soil or groundwater quality degradation were observed. Conventional farming practices were shown to be adequate and the marketability of the produce did not appear to pose any problems, and no project-related health problems were detected through medical examinations

***Information Sources*:**

EQA. Data Base, 2003.

CASE 2: Planning wastewater reuse in the Gaza Strip

The quantity and quality of groundwater, the main water resource in the Gaza Strip, are being deteriorated. The aquifer is continuously over-pumped and the gap between water demand and water supply increases. The agriculture is the main consumer of groundwater. Wastewater reuse could be an option to cover part of the demand. The sewerage system serves only one third of the population in the Gaza Strip. The existing three wastewater treatment plants (Beit Lahia, Gaza and Rafah) are overloaded and impose serious environmental problems. The public acceptance to use treated wastewater is a crucial aspect to ensure the success of any reuse project. A sample of 79 farmers were questioned through a questionnaire especially designed to fulfil this purpose. The majority of farmers, 68 (86.1%), agreed completely to use the treated wastewater for irrigation of 2,856 donum (37,700 ha), 80.7% of the total targeted area. There is a master plan to construct three wastewater treatment plants which will replace the existed ones by year 2020.

Location:

Gaza Strip, Palestine.

Year of the project development:

2002-2020.

***Water origin*:**

Municipal wastewater.

***Volume (or flow) of water affected*:**

The existing wastewater treatment plants in different Governorates of Gaza Strip serve only Northern, Gaza and Rafah Governorates. However, not all houses in these Governorates are connected to the sewerage network. Despite that the existing three WWTPs are heavily overloaded as the actual flow far exceeds the design flow. To solve these crucial growing problems, Ministry of Planning and International Cooperation, in close cooperation with Palestinian Water Authority, has identified locations for new three regional plants that will replace the existing ones by year 2020. Their location will be far away from the residential areas near the eastern border of the Gaza Strip. The planned capacity and quality criteria of effluent for the new treatment plants will be about 116.8 Mm^3/year with a better effluent quality criteria (Class D) for irrigation than that of the already existed plants.

***Water treatment before reuse (technologies/process applied)*:**

Not data available.

***Reclaimed water quality*:**

The current effluent quality of the Gaza WWTP is:

Table 28. Reclaimed water quality of Gaza WWTP.

Parameter	Unit	Value
PH	-	7.7
TKN	mgN/L	57
$N\text{-}NH_3$	mg/L	18
$N\text{-}NO_3$	mg/L	27
Phosphate	mg/L	26
Chloride	mg/L	418
Faecal Coliform	CFU/100 ml	40×10^6

Source: Lyonnaise des Eaux-Khateeb & Alami, LEKA, 2002.

The quality of the effluent from Gaza and even Beit Lahia WWTPs would nearly meet class C standards whereas that of Rafah WWTP is of lower quality.

***Water reuse applications*:**

Currently, the reuse of treated wastewater is very restricted to a few illegal irrigation sites beside the treatment plants. New plants will serve all Gaza Governorates, will avoid environmental problems imposed by the existed treatment plants and will offer a better effluent quantity and quality (Class D) for irrigation of many crops including citrus, olives and almonds and even for edible vegetables.

***Total area affected by irrigation*:**

The irrigation of 2,856 donum (37,150 ha) is foreseen.

***Types of products cultivated in irrigated areas*:**

Citrus, olives, almonds, alfalfa and edible vegetables.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Not data available but most of the interviewed farmers 71 (89.9%) are welling to pay for treated wastewater.

***Problems founded in the start-up, development or final application of the project*:**

High salinity of Gaza water.

Remarkable results:

The reuse of wastewater effluent for irrigation will no doubt save potable water for human usage in addition to introducing solutions for some environment problems. To ensure the successful use of wastewater in agriculture, perception of farmers toward wastewater reuse has been investigated. This was explored through conducting a questionnaire among the farmers.

***Information Sources*:**

Tubail, K.M., A-Dadah, J.Y., Yassin, M.M. Present and prospect situation on wastewater and its possible reuse in the Gaza Strip (2003).
www.med-reunet.com/docs_upload/wastewater.pdf

Selected cases in Portugal

CASE 1: Wastewater reuse for irrigation in Portugal

Location:

Évora and Santo André, Portugal.

Year of the project development:

1995.

***Water origin*:**

The study includes experiments with three types of reclaimed water: primary effluent, secondary effluent and facultative pond effluent.

***Volume (or flow) of water affected*:**

Not data available.

***Water treatment before reuse (technologies/process applied)*:**

The secondary effluent proceeds from a high-rate trickling filter.

***Reclaimed water quality*:**

The average chemical characteristics of the three types of treated wastewater are presented on Table 29.

Table 29. Reclaimed water quality of Gaza WWTP.

Parameter	Effluent		
	Primary	Secondary	Facultative Pond
pH	7.4	7.5	8.2
TSS (mg/l)	53.0	29.8	36.2
BOD (mg/l)	178.8	85.8	61.2
COD (mg/l)	358.5	223.5	92.6
Org-N (mg/l N)	12.94	9.48	13.39
NH_4-N (mg/l N)	30.42	20.13	17.92
NO_3-N (mg/l N)	0.97	1.78	1.29
Tot-N (mg/l N)	40.77	31.43	30.20
Tot-P (mg/l N)	89.64	103.65	14.58
Conduct (µS/cm)	1,236	1,237.5	1,503
Na (mg/l)	118.6	129.7	142.5
K (mg/l)	22.3	24.7	36.8
B (mg/l)	0.68	0.76	1.53
Hardness (ºF)	9.84	9.75	31.9
FC / 100 ml	2.86×10^6	1.1×10^6	3.1×10^3
FS / 100 ml	5.0×10^5	1.0×10^5	6.8×10^2
Helminth eggs / l	56.2	22	Nil

***Water reuse applications*:**

Irrigation water was applied by localised (drip) irrigation in experiments with facultative pond effluent. Furrow irrigation was used with primary and secondary effluents.

***Total area affected by irrigation*:**

The assays were carried out in a total of 10 ha.

***Types of products cultivated in irrigated areas*:**

A forage crop (sorghum), a cereal (maize) and an oil-bearing crop (sunflower).

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Not data available.

***Problems founded in the start-up, development or final application of the project*:**

The removal efficiency of primary treatment was 97.6% for Faecal Coliform and 62% for Helminth eggs. However, primary effluent can be considered as highly contaminated. The microbial quality of the secondary effluent is only slightly better, as the mean removal of Faecal Coliform and Helminth eggs was 99% and 85% respectively regarding the raw wastewater. The effluent of the facultative pond was much better.

Remarkable results:

The irrigated crops did not show contamination of their consumable parts even when irrigated with the primary and secondary effluents, except the lower leaves of forage sorghum. This was due to the precautions taken when selecting the irrigation method and crops. It was found that no health risk occurred when using drip irrigation.

High yields were even obtained with the crops irrigated with the treated wastewater in comparison with the same crops irrigated with potable water and given commercial fertilizers. This indicates that important savings in commercial fertilizers are possible by using treated wastewater for irrigation.

***Information Sources*:**

Marecos do Monte, H., Angelakis, A., Asano, T. Necessity and basis for establishment of European guidelines for reclaimed wastewater in the Mediterranean region. Wat. Sci. & Technol., 33 (10-11), pp. 303-316 (1996).

Selected cases in Spain

<u>CASE 1</u>: <u>Wastewater reuse in Barcelona</u>

Location:

Barcelona, North-West of Spain.

Year of the project development:

Not data available.

***Water origin*:**

The effluent of Barcelona wastewater treatment plant.

***Volume (or flow) of water affected*:**

The reclaimed water will be used to create ecological flow, irrigate farm areas and humid deltaic areas and make an anti-salt intrusion barrier. The necessary flows to satisfy these demands are the following:

Ecological flow: 2 m^3/s
Irrigation farm areas: 0.75 m^3/s
Irrigation of humid deltaic areas: 0.4 m^3/s
Anti-salt intrusion barrier 1st phase: 2,000 m^3/day
Anti-salt intrusion barrier 2nd phase: 20,000 m^3/day

These demands, except the anti-salt intrusion barrier, are seasonal and are required only in the dry season. The annual demand is 50 km^3 with average rainfall. To supply these demands the treatment installations and pipes are designed to treat and transport a flow of 3.5 m^3/s.

***Water treatment before reuse (technologies/process applied)*:**

The wastewater passes through a biological treatment of activated sludge and the removal of nutrients and after passes a tertiary treatment, if the reclaimed water is used as environmental flow and irrigation. If the reclaimed water is used in the anti-salt intrusion barrier it receives a different kind of treatment (micro filtration and reverse osmosis).

The biological treatment has been designed combining anaerobic, anoxic and aerobic zones, in order to reduce nitrogen and phosphorus concentration until the limits required. The tertiary treatment is composed by: Regulation basin, Intermediate pumping, Fast mixing, Coagulation flocculation, Filtration, UV disinfections, Post disinfections, Oxygen saturation.

To operate the tertiary treatment with constant flow it is necessary to regulate the flow from the secondary treatment, this is the reason why a regulation basin is installed. Inside this basin there is a pumping station to feed the flocculation chambers, sending the flow necessary to supply the instantaneous demand.

The flocculation-coagulation chambers are divided in two lines, 4 chambers for each line. The remaining time is not less than 20 minutes. The reactives that are added in these chambers are polyelectrolyte and aluminium sulphate. The disinfection system is ultraviolet radiation in open channel. The plant has 4+1 channels with 263 lamps per channel. The UV transmittance is 60%.

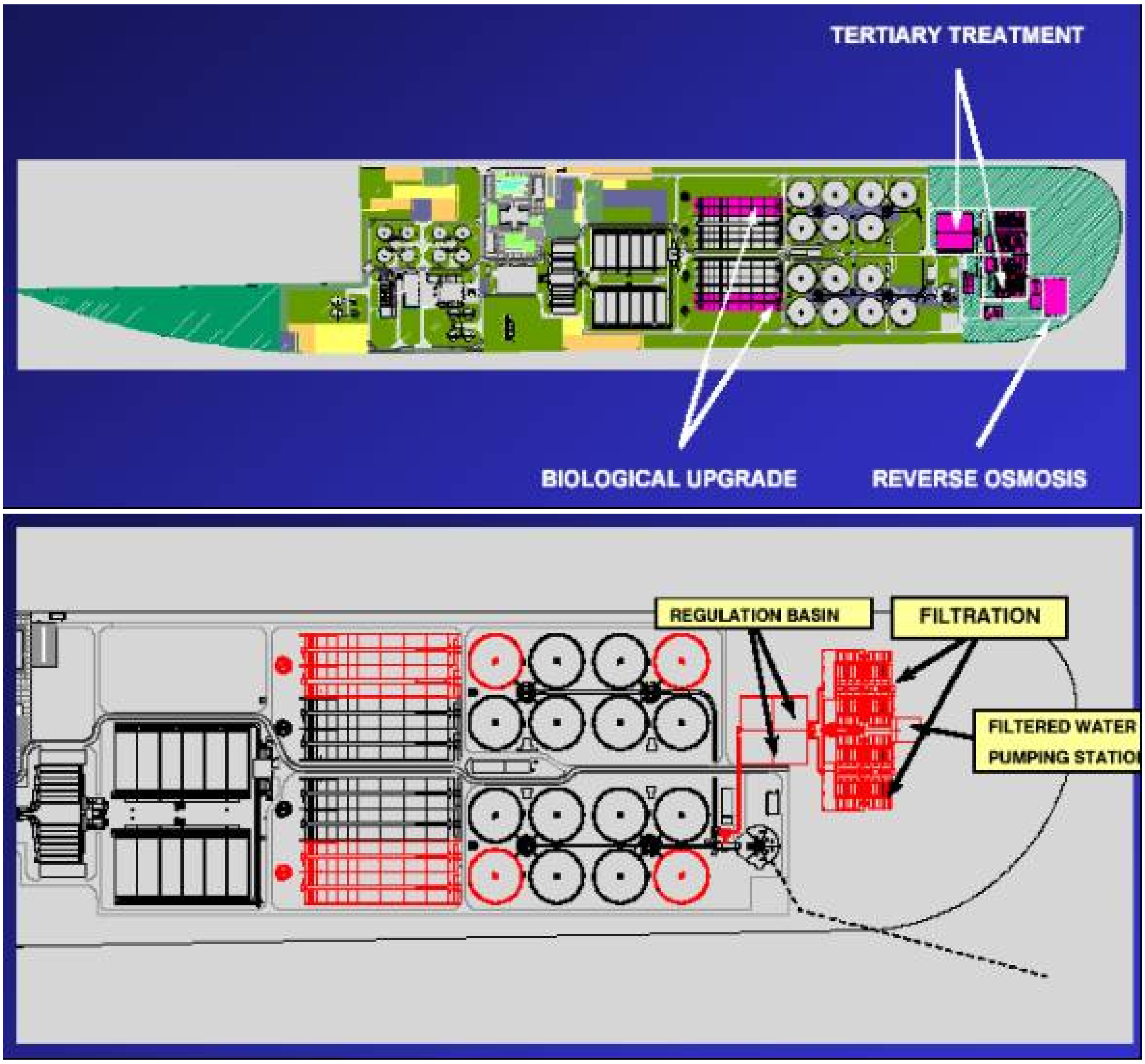

Figure 36. Barcelona WWTP- Treatment systems.

***Reclaimed water quality*:**

Although the reclaimed water quality for each use is different, the criteria taken has been producing two water qualities: one quality to ecological flow, irrigation farm and humid areas, and another different and stricter the anti-salt intrusion barrier. The water quality for ecological flow and irrigation is:

BOD: < 10 mg/l
MES: < 5 mg/l

Turbidity: < 5 NTU
Faecal coliforms: < 10 UFC/100 ml
Nematodic intestinal eggs: < 1 u/100 ml
Residual chlorine: > 0.6 mg/l
Dissolved O_2: > 7.5 mg/l

The water destined for the anti-salt intrusion barrier will go through an additional process (micro filtration and reverse osmosis) to get the following values:

MES: < 1 mg/l
Turbidity: < 0.1 NTU
Faecal coliforms: 0
Organic matter: < 10 mg/l

In Figure 37 the water qualities are indicated according to their uses.

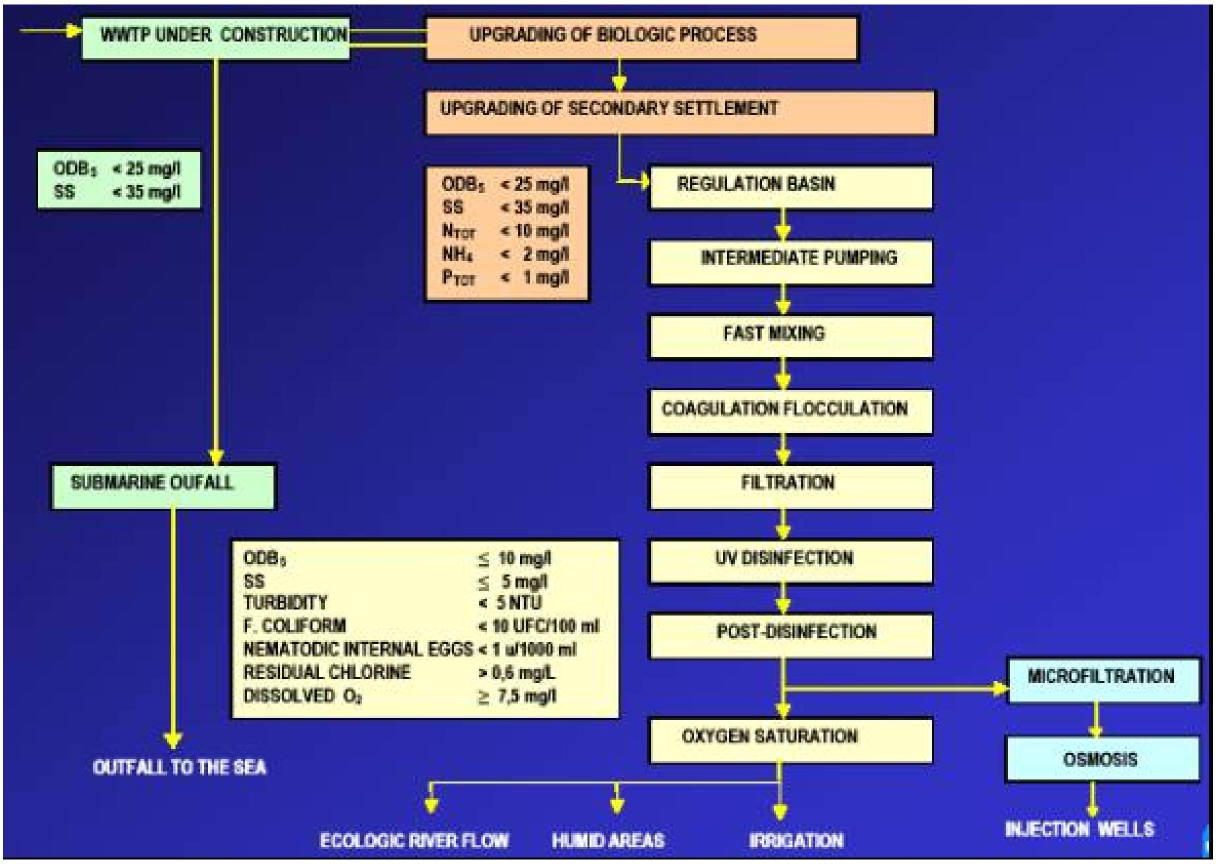

Figure 37. Flow diagram.

***Water reuse applications*:**

It is forecasted reuse 50 Hm^3/year of reclaimed water that will be used as ecological flow in Llobregat river, irrigation of farm areas and irrigation of humid deltaic areas.

To solve the salt-intrusion problem that the groundwater has, located below the Llobregat river, near the Mediterranean sea, reclaimed water will be used to avoid this intrusion making and hydraulic barrier.

All the water reuse application forecasted are drown in Figure 38.

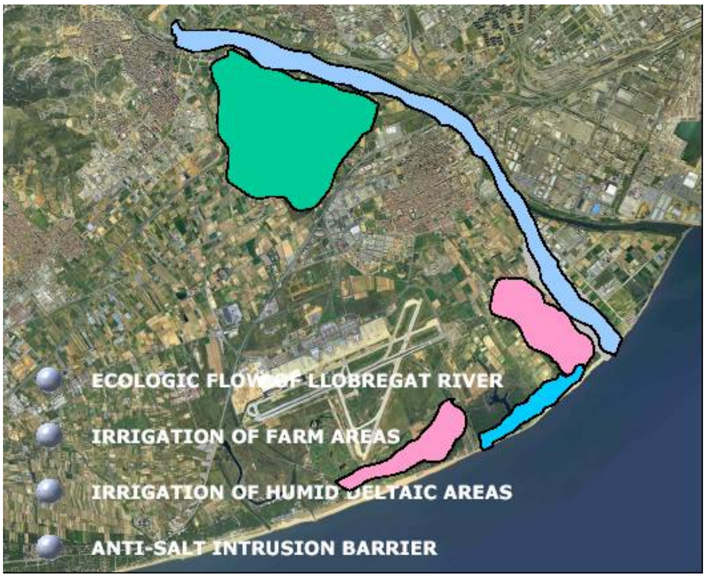

Figure 38. Reuse water demands in Barcelona metropolitan area.

***Total area affected by irrigation*:**

Not data available.

***Types of products cultivated in irrigated areas*:**

Not data available.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The investment distribution among the different works that shape the project of water reuse of Barcelona's wastewater plant are indicated in the Table 30.

Table 30. Investment costs (millions €).

	Construction	Soil preparation	Expropiation	Technical assistance	Planning	Total
Pumping stations and pipelines	44,38	3,66	0,37	2,22	0,57	51,2
Biological upgrade	11,07	.	-	0,55	0,24	11,86
Tertiary treatment	19,39	.	-	0,97	0,025	20,385
Anti-salt intrusion barrier	4,39	0,16	0,035	0,22	0,28	5,085
Total	79,23	3,82	0,405	3,96	1,115	88,53

The operational costs are estimated at approximately 2,083,500 € per year. The details of which are as follows:
Salaries: 245,000 €
Maintenance: 360,000 €
Electrical energy: 675,000 €
Process reactives: 578,500 €
General services: 225,000 €

Referring to project profits, at present in Catalonia there is a canon in the water supply invoice that includes the wastewater plants investment and maintenance. This canon is based on the principle "People who contaminate pay". The incomes at present are the following:

Table 31. Project profits.

User	Consumption (m^3/quaterly)	Tariff (€/m^3)	Annual volume (million m^3)	Annual incomes (million €)
Domestic	< 36	0.2619	22.22	5.82
Domestic	> 36	0.3928	14.82	5.82
Industrial		0.3571	9.26	3.31
Total			46.30	14.95

***Problems founded in the start-up, development or final application of the project*:**

Not problems reported.

Remarkable results:

The water reuse of wastewater plant in Barcelona will contribute with new resources to help to solve the hydraulic of scarcity problem that the Barcelona metropolitan area suffers.

***Information Sources*:**

Cazurra, T., Compte, J. Water reuse of Barcelona´s wastewater plant. Workshop on Implementation and Operation of Municipal Wastewater reuse plants. Thessaloniki, Greece (2004).

<u>CASE 2</u>: <u>Wastewater reuse in Almería</u>

Location:

Almería, South of Spain.

Year of the project development:

1997 (10 years period for the implementation of the project).

***Water origin*:**

The effluent of Almería wastewater treatment plant.

***Volume (or flow) of water affected*:**

32,000 m^3/day (11.7 Mm^3/yr).

***Water treatment before reuse (technologies/process applied)*:**

Activated sludge, high speed filtration, ozonation.

***Reclaimed water quality*:**

The reclaimed water quality in this case is the following:

COD: 20-120 mg/l
BOD_5: 35 mg/l
TSS: < 30 mg/l
TC: < 100 /100 ml
Phages: <100/100 ml
Helmith eggs: 0

***Water reuse applications*:**

Vegetable irrigation (Figure 39).

Figure 39. Crops irrigation.

***Total area affected by irrigation*:**

3,000 hectares.

***Types of products cultivated in irrigated areas*:**

Vegetables and fruit (tomatoes, citrus, etc.).

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The final cost of reclamation water is 0.65 €/m^3.

***Problems founded in the start-up, development or final application of the project*:**

The main problem is to gain support from farmers and the regulators.

Remarkable results:

The water price increase has been limited. With wastewater reuse, freshwater resources have been saved for domestic purposes, salt water intrusion in aquifers has been limited.

***Information Sources*:**

Thomas J. B., Durham B. Integrated water resource management: looking at the whole picture, Desalination, 156, pp.21-28, 2003.

Van Nieuwenhuijzen, A.F., Te Poele, S., Roorda, J.H. Standards for Reuse Options of Wastewater, Report on the 1st Small Group Meeting, 8 - 9 March, Delft – The Netherlands, 2001. .

COST 624, Optimal Management of Wastewater Systems, Reuse concepts and strategies, http://www.ensic.inpl-nancy.fr/COSTWWTP.

<u>CASE 3</u>: <u>Wastewater reuse in Girona</u>

Location:

Empuriabrava, The Aiguamolls de l'Empordà Natural Preserve (AENP), Northern Costa Brava, Girona. New Empuriabrava WWTP (1995) is located on the right bank of the Muga river, 3 km north of the AEN Reserve.

Year of the project development:

Wastewater treatment plant started its operation in May 1995. Wetland system started its operation in 1998 (Figure 40).

Figure 40. Wetland system in Empuriabrava.

***Water origin*:**

Domestic wastewater.

***Volume (or flow) of water affected*:**

Maximum capacity of the wastewater treatment plant is 10,000 m^3/day (3.65 Mm^3/yr), although nowadays the flow ranges between 1,000 and 6,500 m^3/d.

0.5 - 0.75 Mm^3/yr of denitrified reclaimed wastewater has been pumped to the Cortalet lagoon.

***Water treatment before reuse (technologies/process applied)*:**

The effluent of the Empuriabrava WWTP (Figure 41) is further treated in a constructed wetland system and the reclaimed water is entirely reused at the Cortalet lagoon, in the Aiguamolls de l'Empordà Natural Park. In summer, this lagoon is affected by a desiccation process due to the excessive consumption of water for agricultural irrigation upstream of the Park and the reclaimed water acts as an alternative supply of water to overcome summer desiccation.

Two parallel treatment lines are installed, each with an aeration tank, a clarifier, two lagoons for the storage and a final polishing lagoon. 7ha wetland system is used to reduce the nitrogen content in the secondary effluent from the Empuriabrava wastewater treatment plant. The characteristics of the wetlands are the following: 3 vegetated (reed, cattail) cells of 160 m x 50 m (8,000 m^2) and average depth of 0.5 m.

Figure 41. Empuriabrava WWTP.

***Reclaimed water quality*:**

Constructed wetland system that follows the wastewater treatment plant eliminates the nutrients and enhances the water quality of reclaimed wastewater for reuse (Table 32).

Table 32. Comparison of the average quality of the water produced by the Empuriabrava WWTP and the constructed wetland facility.

Parameter	Secondary effluent	Constructed wetland effluent
BOD (mg/l	4	8
SS (mg/l)	7	40
PH	7.6	9.1
EC (dS/m)	2.9	3.1
Ammonia (mgN/l)	5.8	1.0
Nitrite (mN/l)	0.2	0.1
Nitrate (mgN/l)	6.2	2.9
Inorganic Nitrogen (mgN/l)	12.2	4.0
Soluble Orthophosphate (mgP/l)	3.0	1.2

***Water reuse applications*:**

During 2000-2003 the amount of treated wastewater reused reached 70-80% (600,000 m^3/year of reclaimed water out of the 800,000 m^3/year of wastewater treated in the Empuriabrava WWTP). The aim of this action was to supply the Cortalet Lagoon with reclaimed water and prevent its summer desiccation due to the intense upstream water consumption for mainly agricultural irrigation purposes.

***Total area affected by irrigation*:**

Data not available.

***Types of products cultivated in irrigated areas*:**

Data not available.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

This project had a budget of 1.38 million € and received full support from the AENP. Finally, this project was approved by the European Union in April 1996, who has funded the 80% of the capital costs.

***Problems founded in the start-up, development or final application of the project*:**

Despite the excellent quality obtained in the secondary effluent of this plant in terms of BOD and TSS, the nutrients concentrations are too high to feed the Cortalet Lagoon. Therefore, the project was expanded to include a constructed wetland system in order to eliminate the nutrients and make the reclaimed wastewater suitable for reuse.

Remarkable results:

Since the system has started its operation, denitrified reclaimed wastewater helped to conserve the Cortalet lagoon. Apart from this, the constructed wetland has become one of the favourite spots in the natural preserve for birdwatching and other activities.

Apart from the benefits of the improvement in the quality of the water and of being an alternative supply, an added benefit from this project is the zero discharge into the Muga river, which has been released from the inputs of nutrient caused by the secondary effluent that was previously discharged into this river. Another benefit is the creation of new wetland areas which have quickly been colonised by many different waterfowl species, which has enhanced this particular area of the Park. For the moment, the project is a complete success and it is rapidly gaining a reputation in the area as a model for sustainable water reuse for environmental purposes.

Since 1998, the Empuriabrava WWTP has turned into a freshwater source for the AEN Reserve. Efforts made towards treatment (WWTP +CWS) and close monitoring minimize the issue of the origin of the water. Rational management of the system allows an improvement of the local aquatic flora and fauna. This project has multiple environmental benefits, far beyond the mere recycling of water.

***Information Sources*:**

Sala, L., Serra, M. Multiple benefits of the environmental reuse project at the Aiguamolls de L´Empordá nature reserve (Costa Brava, Girona, Spain). Workshop on Implementation and Operation of Municipal Wastewater reuse plants. Thessaloniki, Greece (2004).

Sala, L., Mujeriego, R. Cultural eutrophication control through water reuse. Wat. Sci. & Techn., 43(10), pp 109-116, (2001).

http://www.med-reunet.com/docs_upload/Water%20Reuse%20in%20the%20Costa%20Brava%20%20Case%20Studies.pdf

http://www.ddgi.es/ccb/jorn98/empeng.htm

CASE 4: Wastewater reuse in Santa Cruz de Tenerife

Location:

South Tenerife, Spain.

Year of the project development:

1995-1997.

***Water origin*:**

Municipal wastewater from Santa Cruz de Tenerife city (Figure 42).

Figure 42. Santa Cruz de Tenerife WWTP: a) general view; b) filtration station (Source: hispagua.cedex.es).

***Volume (or flow) of water affected*:**

The treatment plant is designed for a flow of 90,000 m^3/d. 50,000 m^3 of reclaimed wastewater, are stored in deep reservoir as part of the reuse system of reclaimed water of South Tenerife. In pipe, there is a permanent flow of 500 m^3/h.

***Water treatment before reuse (technologies/process applied)*:**

In Tenerife a complex infrastructure for the reuse of the effluent of a conventional activated sludge plant exists (Figures 43 and 44). The reclaimed wastewater undergoes a complete treatment in order to achieve quality standards for crop irrigation. Reclamation includes filtration, desalination and chlorination of the effluent.

The Santa Cruz Wastewater Treatment Plant treats the domestic wastewater from the metropolitan area of the city (350,000 inhabitants). The wastewater treatment includes a pretreatment, a primary treatment and an activated sludge system. The effluent from the treatment plant is transported by gravity to a pumping station, from where it is pumped to a gravity transportation reservoir. From there, a completely filled gravity pipe (Figure 4a) transports the Reclaimed Wastewater to the south of the island for agricultural reuse.

Water is reused fairly far from the city of Santa Cruz. It is then necessary to transport water through a 61 km pipe and to store it in two deep reservoirs of 50,000 and 250,000 m^3, respectively.

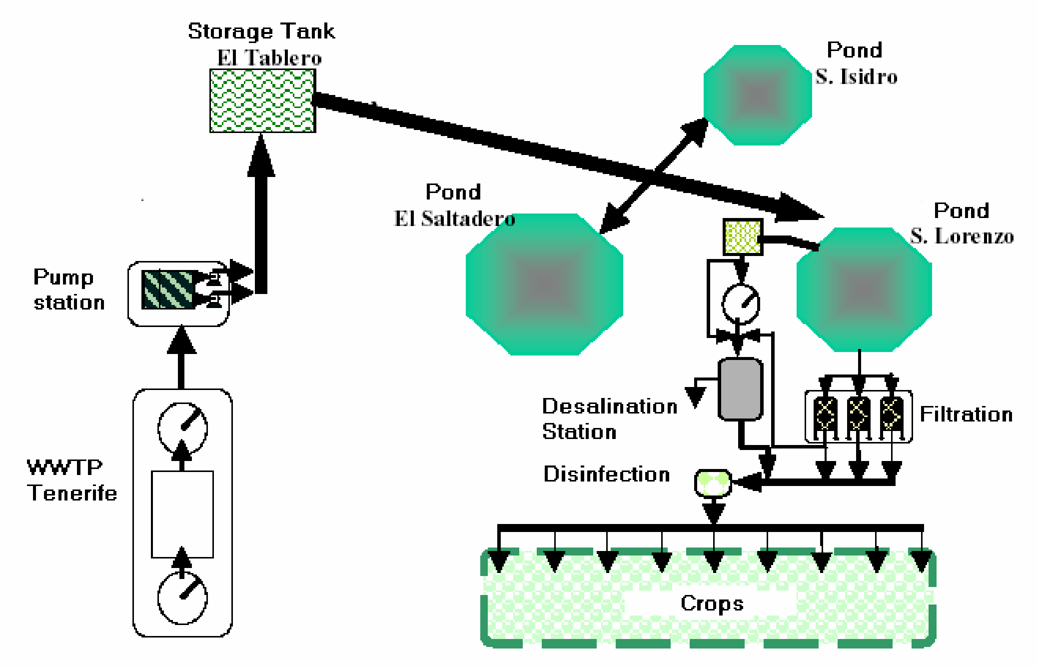

Figure 43. Scheme of the treated wastewater reuse system in Tenerife.

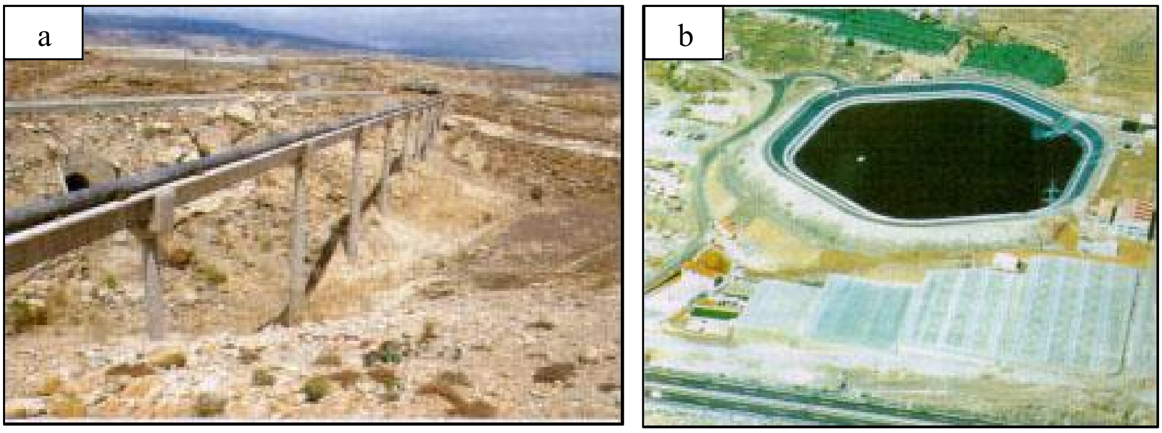

Figure 44. Reclamation system: a) water transport pipes; b) San Lorenzo pond (Source: hispagua.cedex.es).

An experimental study has been carried out to determine the ammonia removal in a deep reclaimed wastewater reservoir before agricultural reuse (Figure 45). The study has been conducted under batch mode operation, in three different periods (winter, spring-summer and winter-spring), with an average storage time of 85 days. Vertical profiles of temperature, dissolved oxygen and pH were determined together with NH_3-N, NO_2-N and NO_3-N concentrations at different points and different depths in the reservoir.

In order to improve wastewater quality, at 10 km from the inlet there is an injection of fresh water saturated in dissolved oxygen (DO), after which a fast nitrification process usually appears (less than two hours of space time).

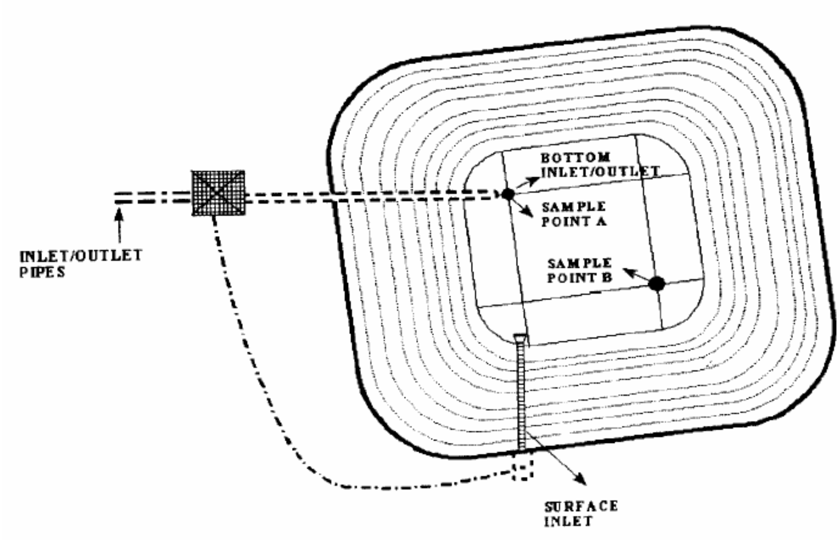

Figure 45. Layout of the deep wastewater reservoir showing sampling points.

***Reclaimed water quality*:**

The reclaimed water quality entering the reservoir depends on the season as is shown in Table 33.

Table 33. Average composition of the incoming water.

	Winter	Spring-Sumer	Winter-Spring
pH	7.74	7.98	7.91
EC (µS/cm)	1,288	1,659	1,585
SS (mg/l)	8	5	11
Total COD (mg/l)	48	59	52
N-NH_3 (mg/l)	26.3	42.3	23.5
N-NO_2 (mg/l)	0.04	0.02	0.03
N-NO_3 (mg/l)	0.06	0.46	0.31
PO_4^{3-} (mg/l)	27	41	30
SO_4^{2-} (mg/l)	-	119	91
S^{-2} (mg/l)	2.71	4.0	2.1
Faecal Col., log	4.1	4.2	4.1

The removal of nitrite is complete at the end of the pipe, whereas the nitrate does not disappear completely, leaving a concentration of about 0.4–0.5 mg/l, after the injection of fresh water.

Water reuse applications:

The reclaimed water is reused for crop irrigation in the South of the island, an area with plenty of agricultural activities.

***Total area affected by irrigation*:**

775 ha.

***Types of products cultivated in irrigated areas*:**

Mainly banana plantation but also potatoes and tomatoes.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The price of the final reclaimed water is 0,45 €/m^3. Economical influence of reclamation on the final price of irrigated agricultural products is reported to be high.

The inversion in infrastructures during the construction of the wastewater reclaimed system is the following:

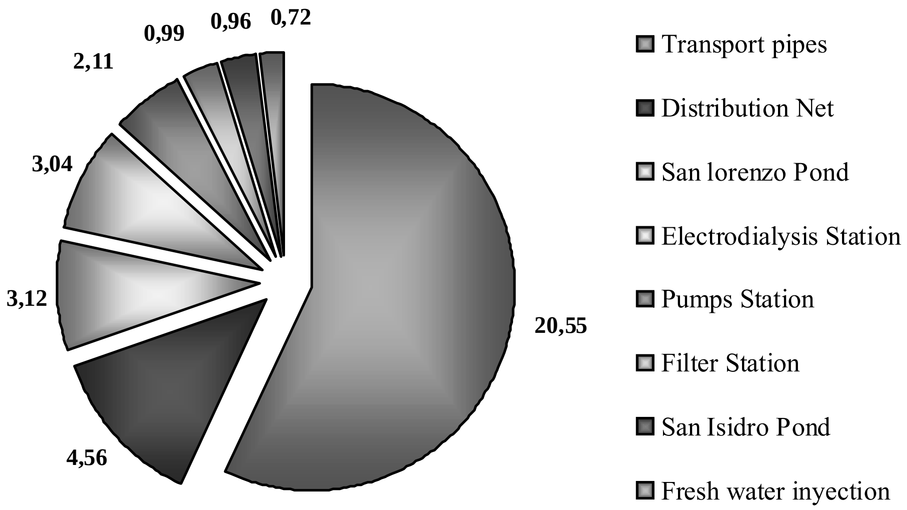

Figure 46. Inversion in infrastructures (millions €).

The costs associated with the management in the reuse of the reclaimed wastewater appear in Figure 47.

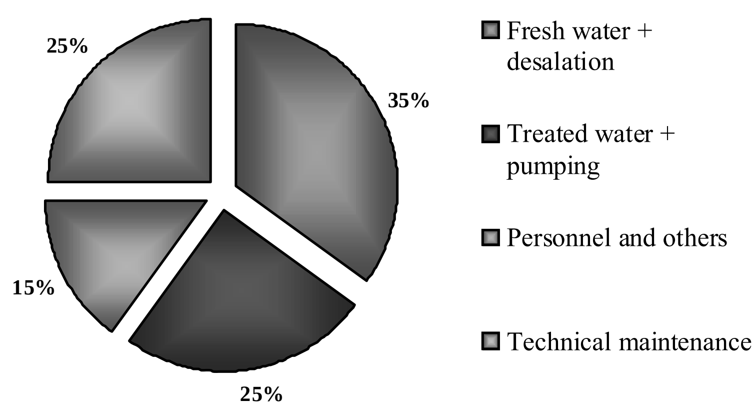

Figure 47. Maintenance costs (millions €).

***Problems founded in the start-up, development or final application of the project*:**

Thermal stratification, and therefore mixing throughout the water column, was the main factor that affected the overall ammonia removal in the reservoir.

When reclaimed wastewater has a high organic load and a space time above 25 hours, chemical and biochemical transformations in reclaimed wastewater may take place, especially in areas with high temperature like the Canary Islands. Under these conditions H_2S build-up is one of the most serious problems which can appear.

Remarkable results:

Maximum removal efficiency was obtained during the winter periods, in absence of stratification and with good mixing conditions throughout the water column. During these periods, nitrification took place in some extension, favouring the ammonia removal. Average NH_3-N concentrations in the reservoir were calculated and apparent first-order rate constants were determined for different stratification conditions. Although ammonia nitrogen could be used as nutrient in the agricultural reuse, its removal from reclaimed wastewater could be useful in order to diminish the chlorine needs for disinfection.

The injection of fresh water saturated in DO improves reclaimed wastewater quality during transportation (reduction in salinity and organic matter content). The DO injected with the fresh water provokes a nitrification-denitrification process. The appearance of oxidized nitrogen compounds inhibits the generation of sulphide, and the reduction in ammonia nitrogen content results in a less chlorine requirement for disinfection.

***Information Sources*:**

Delgado, S., Alvarez, M., Rodríguez-Gómez, L.E., Elmaleh, S., Aguiar, S. How partial nitrification could improve reclaimed wastewater transport in long pipes. Wat. Sci. & Techn., 43(10), pp 133-138, (2001).

Delgado, S., Elmaleh, S., Díaz, F., Rodríguez-Sevilla, J., Marrero, M.C. Ammonia removal in deep reclaimed wastewater reservoir before agricultural reuse. Wat. Sci. & Tech., 43 (10), pp 125-132, (2001).

Hernández, M.C., Delgado, S., Aguiar, E. Reutilización de aguas residuales para la agricultura en Canarias. International Conference: Spanish Hydrologic plan and sustainable water management. Zaragoza, Spain. June 2001.

CASE 5: Wastewater reuse in Costa Brava

Location:

Mas Nou golf course in Costa Brava, Spain.

Year of the project development:

1991-1993

***Water origin*:**

The water proceeds from the treatment system of Castell-Platja d´Aro, designed to treat the combined sewer flows of three nearby resort towns (Figure 48).

Figure 48. Castell-Platja d'Aro Wastewater Treatment Plant.

***Volume (or flow) of water affected*:**

The residential and tourist character of the area result in marked flow variations between winter (lower than 10,000 m^3/day) and summer (higher than 30,000 m^3/d).

***Water treatment before reuse (technologies/process applied)*:**

The treatment system of Castell-Platja d´Aro WTP is a conventional activated sludge process. Reclamation of secondary effluent has been limited to disinfection with sodium hypoclorite. Reclaimed affluent is stored in two landscape ponds connected in series.

***Reclaimed water quality*:**

Table 34 shows the effluent quality obtained during 1994.

Table 34. Effluent quality of Castell-Platja d´Aro WWTP.

Parameter	Annual average	Parameter	Annual average
pH	8.0	Sodium (mg/l)	190
Turbidity (NTU)	8	Potassium (mg/l)	15
Suspended Solids (mg/l)	10	$N-NH_3$ (mg/l)	25.5
BOD_5 (mg/l)	15	Nitrite (m/l)	0.2
COD (mg/l)	80	Nitrate (mg/l)	0.6
Elect. Conductivity (dS/m)	1,334	Ortophosphate (mg/l)	7.6
Chloride (mg/l)	200	Boron (mg/l)	0.6
Alkalinity (mg/l)	280		

***Water reuse applications*:**

Golf courses irrigation (Figure 49).

Figure 49. Golf Mas Nou irrigation.

***Total area affected by irrigation*:**

The reclaimed effluent flows into Pond 1, with has a capacity on 13,300 m^3 serves to irrigate 21 ha of turf; water from Pond 2 which has a capacity of 21,000 m^3, serves to irrigate 13 ha of turf. Daily flows of reclaimed effluent used by Mas Nou golf course vary with irrigation water demand, reaching its maximum value (slightly over 2,000 m^3/d) in July and August.

***Types of products cultivated in irrigated areas*:**

Grass.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Significant savings in fertilizers cost can be achieved by irrigation with reclamation water. Assuming that all the nitrogen applied with irrigation water had to be provided as a mineral fertilizer, the economic value of nitrogen contributions by reclaimed water represents a unit savings of 0.05-0.10 €/m^3 of reclaimed effluent.

***Problems founded in the start-up, development or final application of the project*:**

Water extraction from the two storage ponds takes place from the bottom layers. This design arrangement has resulted in oxygen depletion and odor generation in irrigation water, particularly during the warm period.

Mosquito larvae have been detected particularly during spring and summer. Regular cutting and removal of emerging vegetation on pond sides has proved an effective measure to prevent the spreading of mosquito populations.

Some fungal infections have been observed in the fall season, favoured by excessive nitrogen contributions with irrigation water during the summer. Fungicide applications have been used to prevent and eliminate those disinfections.

The relatively low iron contributions of reclaimed water, as compared to those of nitrogen and phosphorous, have resulted in occasional spots of ferric chlorosis. Those incidents have been recovered with localized applications of iron compounds.

Remarkable results:

Close and regular collaboration with the golf course greenkeeper in a more favourable attitude to reclaimed water quality requirements and a more effective and economical fertilization program. Greenkeeper perception has gradually evolved from a passive acceptance of using reclaimed water to a positive recognition of the benefits derived from using this alternative source of water.

***Information Sources*:**

Mujeriego, R., Sala, L., Carbó, M., Turet, J. Agronomic and public Health assessment of reclaimed water quality for landscape irrigation. Wat. Sci. & Techn. 33(10-11), pp 335-344 (1996).

CASE 6: Wastewater reuse in Vitoria

Location:

Vitoria, North of Spain.

Year of the project development:

1995-1997.

***Water origin*:**

Domestic wastewater from Vitoria-Gasteiz.

***Volume (or flow) of water affected*:**

A total of 45 Hm^3/year (27 Hm^3/year of wastewater and 18 Hm^3/year from brooks proceeding from the South).

***Water treatment before reuse (technologies/process applied)*:**

Secondary treatment (screening, sedimentation, nitrification-denitrification) and tertiary treatment (coagulation-flocculation, sand filters, chlorine disinfection).

***Reclaimed water quality*:**

Parameters corresponding the secondary treatment effluent, are the following:

Table 35. Water quality from Vitoria WWTP before tertiary treatment.

Parameters	min	max	average
E.Conductivity	397	1,881	814
pH	6.8	8.3	7.4
SST (mg/l)	0.2	13	2
DBO_5 (mg/l)	3	8	5
DQO (mg/l)	0	158	34
Turbidity (dS/m 25ºC)	0.1	9.1	1.3
$N\text{-}NH_4$ (mg/l)	0.2	39	23.9
$PO^{2-}{}_4$ (mg/l)	0.1	9.2	1.2
Free chloride	4	10	7.5
Fe (mg/L)	0.07	2.98	0.44
Al (mg/L)	0.1	0.68	0.37
Zn (mg/L)	0.07	3.54	0.36
Ni (mg/L)	0.02	0.27	0.09
Cr (mg/L)	0.001	0.674	0.051
Cu (mg/L)	0.002	0.15	0.015
Pb (mg/L)	0.011	0.025	0.0163

After tertiary treatment theses effluents are available for irrigation.

***Water reuse applications*:**

Unrestricted irrigation of orchards.

***Total area affected by irrigation*:**

An average of 6,500 ha.

***Types of products cultivated in irrigated areas*:**

Edible crops and forage.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The total cost is 0.057 €/m^3: products for treatment (coagulation, disinfection) 0.020 €/m^3; energy 0.002 €/m^3; personnel 0.006 €/m^3; maintenance 0.002 €/m^3; amortization initial inversion 0.027 €/m^3.

***Problems founded in the start-up, development or final application of the project*:**

Turbidity problems appeared during the process.

Remarkable results:

The economical balance of the project was positive with a profit of 1,203,000 €. The project has been a complete exit because of the excellent quality of the water reused on agriculture.

During the summer, the totality of the water treated is used in irrigation of crops but in autumn the excess is used in energy generation.

***Information Sources*:**

López, J., de Juana, I., del Río, F.J. La reutilización integral de las aguas residuales urbanas en Vitoria. International Conference: Spanish Hydrologic plan and sustainable water management. Zaragoza, Spain. June 2001.
www.unizar.es/fnca/congresos/congreso1/ docum/ponen/105.pdf

Selected cases in Tunisia

In Tunisia a gradual approach has been adopted to expand the reuse since mid 1960s. Nowadays, out of 61 treatment plants that treat 140 Mm^3/yr total are operating. 41 have a daily capacity less than 3,500 m^3 and 10 above 10,000 m^3, Choutrana being the largest with 120,000 m^3/d. Five treatment plants are located in the Tunis area, producing about 62 Mm^3/yr or 54% of the country's treated effluent.

Municipal wastewater is processed biologically up to a secondary treatment stage. The treatment processes vary from plant to plant depending on wastewater origin and on local conditions. Out of 61 treatment plants, 44 are based on activated sludge (medium or low rate), 3 on trickling filters, and 14 on facultative or aerated ponds.

Mean concentrations for effluents are: COD: 174 mg/L; BOD: 35 mg/L; TSS: 42.5 mg/L; Total Nitrogen: 42 mg/L; Total Phosphorous: 3.6 mg/L; Faecal Coliform removal ranged from 0-2 logs, 1-2 logs, 2-5 logs for activated sludge, aerated lagoons, and stabilization ponds, respectively.

The water reuse application is restricted irrigation, fodder (alfalfa, sorghum, berseem, etc.) (45.3%), fruit trees (citrus, grapes, olives, peaches, pears, apples, grenades, etc.) (28.5%), cereals (22.4%), and industrial crops (sugar beet) (3.8%).

The area currently equipped is about 6,500 ha, 80% of which are located around Tunis. Main perimeters are Cebala (3,200 ha), La Soukra (600 ha), Mornag (1,047 ha), Nabeul (350 ha), Hammamet, Sousse, Monastir, Sfax, and Kairouan. Other projects are being implemented extending the area to 9,000 ha. The area irrigated with treated wastewater is planned to expand up to 20,000 - 30,000 ha, 7-10% of the overall irrigated area, with 14,500 ha located around the Great Tunis. The main crops irrigated with treated wastewater are fruit trees (citrus, grapes, olives, peaches, pears, apples, grenades, etc.) (28.5%), fodder (alfalfa, sorghum, berseem, etc.) (45.3%), industrial crops (sugarbeet) (3.8%), cereals (22.4%). 57% of the equipped area is sprinkler irrigated and 43% is surface irrigated. Some farmers use localized irrigation systems. Cattle (milking cows, calves, sheep, and goats), not grazed on pastures irrigated with treated wastewater, is also feeded with forage crops cultivated on the irrigated areas.

Capital costs for facultative ponds are the lowest, followed by aerated ponds, extended aeration, conventional activated sludge and oxidation ditches. Annual operation and maintenance (O&M) costs include treatment facility personnel salaries, operating (power mainly), and maintenance costs (equipment repairs and replacements). The lower O&M reclamation costs were for facultative ponds, followed by extended aeration, conventional activated sludge, aerated ponds, and finally the oxidation ditch process. Energy fees represent 60% of O&M costs, salaries 30%, and maintenance 10%. The average wastewater treatment cost is around 0.34 US$/$m^3$, excluding wastewater collection costs. Investment costs represent 80% of the total cost. Total treatment costs at the reclamation plant remain the lowest for facultative ponds and extended aeration. With the creation of new schemes, water was often distributed free of charge to encourage farmers to use it, then at a fixed price per hectare before evolving towards a price per cubic meter of water used. The price of the reclaimed water varies from one scheme to another. The charges were meant to cover some of the O&M costs (operation, maintenance, salaries, and energy). In order to promote water reuse, it has been decided, in 1997, to fix the price at 0.01 US$/$m^3$. However, wastewater reuse did not increase as expected and a deficit was generated.

The high salt content of wastewater is generally due to sea- or ground-water seepage into the collection network, plant location (near a salt lake), and industrial activities. Salt content may seriously limit the range of crops to be irrigated and benefits obtained related to wastewater reuse. In addition, soil properties and composition is under stress. Treated wastewater appears to have a certain parasitic load due to treatment level achieved. Only stabilization pond effluents are free from parasites. Actual reuse is low due to technical, institutional, regulatory, social-cultural, economic and financial constraints. Absence of storage infrastructure, crop restrictions, lack of education of farmers and extension services poses difficulties.

Reuse of reclaimed wastewater helps to fulfil the water demand for irrigation in this region. In addition, sludge from the treatment plants is used to improve the soil fertility of low organic content Tunisian soils. Wastewater reuse was made an essential component of the Tunisian national water resources strategy. A national reuse policy has been elaborated and implemented and the institutional, regulatory, and organizational frameworks have been set up. Reuse is up to now mainly practiced for crop irrigation and irrigation of recreational facilities, such as golf courses. Many projects expanding the areas irrigated with reclaimed water are under implementation. Other reuse opportunities such as groundwater recharge and industrial reuse are screened.

CASE 1: Wastewater reuse in La Soukra

Location:

La Soukra irrigation area, 8 km North East of Tunis.

Year of the project development:

Irrigation with treated effluent has been practiced for more than 40 years.

***Water origin*:**

Effluent from La Cherguia Treatment Plant.

***Volume (or flow) of water affected*:**

60,000 m^3/day (21.9 Mm^3/yr).

***Water treatment before reuse (technologies/process applied)*:**

Activated sludge treatment.

***Reclaimed water quality*:**

pH: 7.6
TDS: 1.82 mg/l
COD: 51 mg/l
P (total): 4.1
TC/100 ml: $10^4 – 10^6$
FC/100ml: $10^4 – 10^6$
FS/100ml: $10^4 – 10^6$

***Water reuse applications*:**

Restricted irrigation.

***Total area affected by irrigation*:**

600 ha in 1989; additionally 200 ha in future.

***Types of products cultivated in irrigated areas*:**

Citrus trees and forage.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

0.34 US$/$m^3$.

***Problems founded in the start-up, development or final application of the project*:**

The chemical quality of the soil varied considerably, with an increase in electrical conductivity and a transformation of geochemical characteristics of the soil solution from bicarbonate-calcium to chloride-sulphate-sodium. Trace elements were concentrated in the surface layer of soil, particularly zinc, lead and copper, but did not increase to phytotoxic levels in the short term of the study period.

Remarkable results:

Higher annual and perennial crop yields were achieved with the usage of treated wastewater compared to groundwater irrigation. The results did not show notable effects on soils, crops, or groundwater. No clear cause-effect relationship was observed between the observed diseases and reuse practices. The reason for using the wastewater was to reduce the impact of salt water intrusion due to excessive pumping of groundwater. The reuse has enabled citrus fruit orchards to be saved. Effluents were thus used, mainly during spring and summer, either exclusively or as a complement to groundwater. Irrigation of vegetables was not allowed.

***Information Sources*:**

Bahri Akissa, Personal communication, 28.12.2004.

http://www.hydro.ntua.gr/labs/sanitary/agricultural_reuse.htm#6.
Major crop irrigation projects planned or under implementation in Tunisia.

http://lnweb18.worldbank.org/ESSD/essdext.nsf/26DocByUnid/77F0C524732B1A9985256B8B0070FD76/$FILE/BahriWaterWeek.pdf

http://www.fao.org/docrep/T0551E/t0551e0b.htm#9.4%20wastewater%20treatment%20and%20crop%20restriction:%20tunisia

CASE 2: Reuse of reclaimed water for golf courses in Tunisia

Location:

Three golf courses have been studied: Carthage in La Soukra, Yasmine in Hammamet, and Kantaoui in Sousse. The three golf courses are located in semi-arid areas with mild and rainy winters, and hot and dry summers. Average maximum temperatures (33°C) and evaporation (7.3 mm/d) are recorded in July and August, whereas rainfall occurs mainly from September to March. Average annual precipitations in La Soukra, Hammamet, and Sousse are respectively 470, 448, and 388 mm.

Year of the project development:

From May 1997 to May 1999.

***Water origin*:**

Urban wastewater.

***Volume (or flow) of water affected*:**

The maximum daily flow during the summer was 950 m^3 for Carthage golf course, 1,500 m^3 for Yasmine, and respectively 3,700 and 1,000 m^3 for Kantaoui 1 and 2. This flow could be equal to zero during the winter season. The daily consumption varied along the year between 7 and 67 m^3/ha/d; the annual average water consumption for the period 1993–1999 being around 12,000 m^3 per hectare, and ranging between 10,000 and 16,000 m^3 per hectare.

***Water treatment before reuse (technologies/process applied)*:**

The characteristics of the water supply systems in the three golf courses are drown in Table 36.

Table 36. Characteristics of water supply systems.

System step		Golf course		
		Carthage	**Yasmine**	**Kantaoui 1 and 2**
Wastewater Treatment Plant	Name	Cherguia	SE1	Sousse Nord
	Process	Activated sludge		
		Average-load	Low-load	Low-load
	Regulation Supply reservoirs	2	-	-
Supply system	Capacity	5,800 and 3,800 m^3	-	-
	Main pipe length	6,800 m	3,700 m	1,900 m /3,600 m
	Main volume	> 2,000 m^3	260 m^3	240 m^3 / 323 m^3
Storage ponds	Number of ponds	2	2	3+1
	Maximum depth	5 (B1) and 1.45 m (B2)	1.9 and 2.9 m	3.1, 2.9, 3.4 and 5 m
	Pond capacity	6,000 + 7,000 m^3	18,000 + 35,000 m^3	49,875 + 24,000 m^3
	Total pond capacity	13,000 m^3	53,000 m^3	73,875 m^3
Irrigation site	Irrigation area	18 ha	40 ha	90 + 20 ha
	Number of holes	18	27	36
	Irrigation system	Low range sprinklers		

***Reclaimed water quality*:**

The water quality for the irrigation of the three golf courses is drown in Table 37.

Table 37. Average irrigation water quality.

	Carthage	**Yasmine**	**Kamtaoui 1**	**Kantaoui 2**
pH	8.02	7.78	7.77	7.78
Electr. Conduct. (dS/m 25ºC)	3.81	3.39	3.24	3.25
SS (mg/L)	16.6	25.2	13.1	14.9
Total N (mg N/L)	11.4	17.0	48.6	32.1
Total P (mg P/L)	5.1	4.8	6.8	5.4
PO_4 (mg P/L)	2.8	3.3	5.4	4.5
K (mg/L)	42.7	23.8	37.0	37.4
CT (Log MPN/100 ml)	2.56	3.44	3.31	3.14
CF (Log MPN/100 ml)	1.96	2.77	2.62	2.59
CE (Log MPN/100 ml)	1.66	2.42	2.16	2.12
FS (Log MPN/100 ml)	2.02	2.54	2.33	2.49
Helminths Eggs(/L)	0	0	0	0

***Water reuse applications*:**

Golf courses irrigation.

***Total area affected by irrigation*:**

18 ha in Carthage, 40 ha in Yasmine and 110 ha in Kantaoui.

***Types of products cultivated in irrigated areas*:**

Grass.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Data not available.

***Problems founded in the start-up, development or final application of the project*:**

The water quality varies all along the water route, from the wastewater treatment plant up to the sprinkler. This variation depends on the wastewater quality, the length of the mains conveying water from the wastewater treatment plant up to the golf course, the number of regulation reservoirs and ponds, the residence time of water in the mains, the reservoirs, and the ponds, and the operation of the ponds as continuous flow or batchflow reactors.

Remarkable results:

The nutrient and bacteria contents decreased all along the three water supply systems. A larger variability of the bacteriological quality of the pond and irrigation water was noticed due to the operational regime. The mains had higher bacterial removal efficiencies (FC removal of 1.5–2.8 log. units) compared to the golf course ponds (FC removal of 0.4–1.3 log. units). Irrigation water was in compliance with the WHO guidelines for wastewater reuse on recreational areas from October to March. The best water quality was obtained for the three courses in January and February. The bacteriological quality deteriorated during the irrigation period as the ponds were operated as continuous flow reactors, i.e. from April to September.

The results obtained in this study indicate the inability of the water supply systems, as currently managed, to properly sanitize reclaimed wastewater to meet target quality criteria proposed by WHO (1989) for water intended for recreational use. This is largely due to increased hydraulic loads during the irrigation period shortening effective retention time in the ponds. A sequential operation of the ponds, with alternating closing and opening periods, would improve the water quality up to the required standards. For a safe reuse of reclaimed wastewater for golf course irrigation, changes in the design and operational characteristics of the ponds should be planned or additional treatment steps should be provided.

***Information Sources*:**

Bahri, A., Basset, C., Oueslati, F. and Brissaud, F. Reuse of reclaimed wastewater for golf course irrigation in Tunisia. Wat.Sci. & Technol., 43(10) pp 117–124, (2001).

CASE 3: Wastewater reuse in Cebela

Location:

Cebela, 8 km north of Tunis.

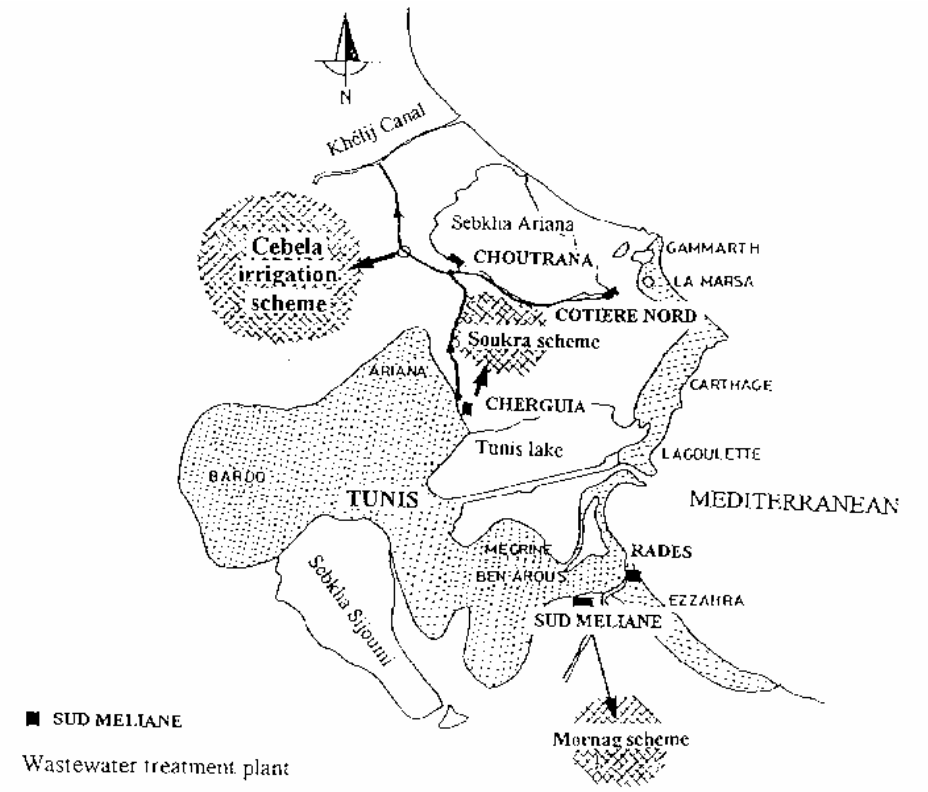

Figure 50. Schemes irrigated with great Tunis treated wastewater.

Year of the project development:

The project was launched at the beginning of the 80´s and carried out in 1992.

***Water origin*:**

The water proceed from three plants of the Great Tunis: Choutrana, Cherguia and Côtière Nord, which altogether treat 75% of the town sewage water.

***Volume (or flow) of water affected*:**

39 Mm^3/year.

***Water treatment before reuse (technologies/process applied)*:**

Treated effluents of three plants are mixed at the output of the Choutrana plant. Wastewater is pumped 4 km downstream from Choutrana and conveyed to a regulation reservoir, 4,000 m^3 capacity, located 120 m higher. The irrigation system planned for this case was the traditional furrow system.

***Reclaimed water quality*:**

Storing effluents would upgrade the water quality to meet the WHO guidelines for unrestricted irrigation.

***Water reuse applications*:**

Golf courses, green belts and hotel gardens irrigation have been assayed, moreover orchards.

***Total area affected by irrigation*:**

With 3,200 equipped hectares, Cebela is to date the biggest scheme irrigated with treated wastewater in Tunisia. But in 1992, just 430 ha were irrigated.

***Types of products cultivated in irrigated areas*:**

Winter farming essentially consists of cereals production (hard and soft wheat, barley, triticale and hay) and fodder crops (berseem, green barley, vetch-hay). In summer farmers grow cotton, grain, fodder corn and fodder sorghum.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

A water price of 3.10^{-3} US$/m^3 was planned to cover the operating costs.

***Problems founded in the start-up, development or final application of the project*:**

Not enough storage tanks are reported.

Some farmers expressed apprehension and others were slightly reluctant, given the crops restrictions imposed. The prohibition of market gardening is particularly difficult to bear for the farmers located near the zone irrigated with Medjerda water, who used to farm these crops before the project was implemented.

Planners of the early eighties did not consider assessing the reclaimed water market a basic step of project design, and this is the explanation that 15 years later reuse is so low compare with the initial forecast.

Remarkable results:

Production yields in the irrigated areas were satisfactory.

Before the wastewater reuse project was implemented, some farmers used residual waters of the schemes located upstream, Medjerda water blended with drainage water, to irrigate market garden crops.

***Information Sources*:**

Barhi, A., Brissaud, F. Wastewater reuse in Tunisia: assessing a national policy. Wat.Sci. & Tech., 33(10-11), pp.87-94 (1996).

Selected cases in Turkey

Most of the current wastewater reuse applications for agricultural irrigation are of small scale in Turkey. In most cases, treated wastewater is discharged to a creek or a stream. Farmers generally withdraw water from these water bodies to irrigate their fields. Therefore, wastewater is reused indirectly for agricultural purposes.

Facilities tailored towards wastewater reuse in agriculture are gaining importance in Turkey. However, such projects are currently in the design and construction stages. Two examples are at Viranşehir and Siverek.

Siverek:

In the extension of GAP (South Anatolian Project), the town of Siverek has been selected as a pilot site for feasibility and preliminary design for wastewater treatment and reuse for irrigation. The project aims to improve the health of a significant share of the local population by treating the wastewaters, and demonstrate the feasibility of reclaimed wastewater reuse for irrigation. Farmers in Siverek have been using raw municipal wastewater directly to irrigate 150 ha of field, resulting in a serious environmental and sanitary issue. In order to overcome these problems, an integrated project has been proposed that includes the renewal and construction of a sanitary sewer system, a wastewater treatment plant, and an irrigation network for wastewater reuse. It is intended to irrigate 350 ha of land, of which 250 ha are crops (cotton, wheat, eggplants, pepper, tomato, cabbage, carrot, spinach) and 100 ha is fallow land, with the reclaimed wastewater. Facilities and processes are designed to respect the Turkish discharge standards for physico-chemical parameters and WHO (Class A) recommendations for the bacteriological standards for wastewater reuse. Lagooning system is employed as the treatment option. The system includes four treatment ponds; one aerobic, two facultative aerobic, and one maturation pond. The project is comprised of three phases for the completion. Phase 1, phase 2, and phase 3 are designed for flows of 9,250 m^3/day in 2010, 14500 m^3/day in 2020, and 22500 m^3/day in 2030, respectively. The initial capital costs are estimated as 4.88, 0.34, and 4.74 million dollars for the wastewater treatment plant, irrigation system, and sewage system, respectively. The investment cost for the expansion of project is projected as 2.4 million dollars. Operating costs of the project is expected to be 205,000 US$/yr. The project is still in the approval stage for implementation.

Viranşehir:

A constructed wetland for domestic wastewater treatment and reuse has been designed and very recently constructed in the town of Viranşehir. In this system, wastewater will be settled in a primary settling tank within a detention time of 2 hr before being sent to the wetland with a design wastewater flow rate of 30 m^3/d. The system is composed of two parallel lines, each having a horizontal and a vertical flow bed connected in series. *Phragmites australis*, an extensively used species in wastewater treatment, will be exploited. The treated wastewater is planned to be consumed for irrigation depending on the effluent quality. It is anticipated to have low operational costs, low energy demand, and operational simplicity. Since the implementation is in the early experimental stages, it is not feasible to analyse the outcome of this project. Although far from setting examples for perfect reuse, there are wastewater treatment plants in Turkey, where some degree of reuse in agriculture is being/will be practiced. Some of them, under construction, are significant in size. Others, though in operation, are too small in size and treated wastewater quality is not well documented. For example, Kayseri treatment plant, which has a nutrient removing type activated sludge system and sludge digestion facility, was designed to produce an effluent fit for reuse in agriculture. Currently, the irrigation water distribution system is under construction. The plant produces 32.9 Mm^3/yr of secondary treated wastewater with less than 25 mg/l COD, 10 mg/l TN, 10 mg/l TSS and 1 mg/l TP in the effluents. Another nutrient removing type activated sludge plant, located in Izmir, produces around 182.5 Mm^3/yr of secondary treated wastewater with less than 20 mg/l BOD, 12 mg/l TN, 30 mg/l, TSS and 3 mg/l TP. The water distribution system that will transport the reclaimed wastewater from Izmir Wastewater Treatment Plant to irrigate the Gediz plane during summers is under construction. There are other small facilities distributed around the country. For example four plants, each serving populations between 2000 and 6000 are located around Konya region. These plants have oxidation ditches with very long solids residence times and equipped with rapid sand filters and chlorination units as tertiary processes. Numerous other small scale applications are scattered around the country where some degree of reuse is being practiced following the secondary treatment only.

Full scale applications of wastewater reuse is not widespread in Turkey. However, considering the number of wastewater treatment plants, volume of treated wastewater, and increasing water demand, the potential for the development of large scale wastewater reuse projects for irrigation and other reuse options seems to be significant.

In this part, it has been collected some technical, operational, economical and social information about Turkish urban WWTP that have been previously selected. In this respect, data has been collected from these treatment facilities in order to present the current situation of Turkey and actions to be achieved in Turkey in the content of the irrigation of the lands by reusing treated domestic wastewater.

The selected wastewater treatment plants were shared and visited between November-December 2003. During the site visits, grab samples were taken from influent and effluent of each treatment plant and preserved according to Standard Methods. In case that the samples could not reach the laboratories of the sub-contractors on the same day, they were sent to the laboratory by using the service of the private cargo firms.

In addition to the sampling, some critical questions related to the aim of the project were asked to the responsible person(s) (stuff working at the treatment plant) of the UWWTP. All the information about the technical, operational, economical and social situation of the UWWTP were then gathered together and given in the following sections of this report.

In the following section some case studies regarding direct, official agricultural reuse of municipal wastewater within the regions selected by Turkish Project Partners have been reported. It should be noted here that there are many other examples in Turkey, where “indirect” use as irrigation water is being practiced. These treatment plants discharge their treated effluent into creeks or rivers and then provide their irrigation water from these creeks or rivers.

CASE 1: Mugla, Bodrum-Golturkbuku Urban WWTP

Location:

Mugla, Bodrum-Golturkbuku.

Year of the project development:

The treatment plant has been in operation since 01.01.1996, and has been in charge of Golturkbuku since 2002. The treated effluent has been used for irrigation purposes since 2001.

***Water origin*:**

The treatment plant of Golturkbuku Municipality provides domestic wastewater treatment for 17,500 capita in summer and 4,500 capita in winter.

***Volume (or flow) of water affected*:**

The capacity of the treatment plant is 2,000 m^3/d. It increases in summer months to 2000 m^3/d and decreases in winter months to only 300 m^3/d.

The effluent has been applied to forest area since its first establishment, but is also being used for the irrigation of different crops in the same area.

***Water treatment before reuse (technologies/process applied)*:**

The treatment facility currently provides only organic carbon removal. The treatment units are as follows: coarse screen, fine screens, grit chamber and oil traps, aeration tank, final settling tank, chlorination tank, sludge thickening basin, sludge drying basin and belt filter press.

***Reclaimed water quality*:**

Table 38. Bodrum-Golturkbuku effluent.

Parameter	Unit	Specific Analyses Selected for the Project's Scope
pH	-	6.8
COD	mg/l	63
BOD_5	mg/l	-
TSS	mg/l	15
TKN	mg/l	3.9
NH_4-N	mg/l	-
TP	mg/l	8
Conductivity	µS	2,500
SAR	-	64.9
SO_4^{2-}	mg/l	125
Cl^-	mg/l	690
Faecal Coliform	CFU/ 100 ml	300
Boron	mg/l	0.50

***Water reuse applications*:**

Since the plant has been in operation, the effluent is being used for irrigation of forest area, agricultural land (vegetables and fruits) during summer season. For that purpose, effluent is being discharged to the respective area through a pump.

***Total area affected by irrigation*:**

Since its first establishment, an average forest area of 15 m^2 is being regularly irrigated.

***Types of products cultivated in irrigated areas*:**

A variety of plants and vegetables (maize, tomatoes, eggplant, mint, okra, squash, melon), forest land as well as the garden of the treatment plant are regularly irrigated with the treated wastewater.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Since 1996, 100,000,000,000 TL (80,736 US$) has been spent for wastewater reuse. For the establishment of the irrigation system, 3,000 m-long (Ø 110) pipeline has been constructed and two pumps have been bought.

***Problems founded in the start-up, development or final application of the project*:**

According to the information gathered from the plant staff and representatives, the construction of a new and higher capacity facility is being planned in the nearest future due to the fact that the treatment plant capacity is not sufficient enough under current circumstances. Consequently, the current plant will be closed as soon as the new facility is in operation. Almost 80% of the new planned treatment plant has already been completed.

Remarkable results:

For almost two years, the treated effluent is being used for irrigation purposes. It has recently been reported that forest trees are growing noticeably fast since the effluent application.

***Information Sources*:**

All information was provided from the treatment plant representatives.

CASE 2: Mugla, Bodrum-Bitez Urban WWTP

Location:

Mugla, Bodrum-Bitez

Year of the project development:

The plant has been constructed in 1998 by the Bank of Provinces and has been operated by Bitez Municipality since 1999.

***Water origin*:**

The treatment plant of Bitez Municipality provides municipal wastewater treatment within the boundaries of the municipality for 30,000 capita in summer and 5,100 capita in winter months.

***Volume (or flow) of water affected*:**

The capacity of the treatment facility is 3,500 m^3/d. The plant operates close to its full capacity at 3,400 m^3/d in summer, and only when needed in winter season because of low/insufficient wastewater input/supply. Since the start-up of its operation, 85% and 70% of treated wastewater is being used as irrigation water, respectively in summer and winter.

***Water treatment before reuse (technologies/process applied)*:**

The treatment plant currently features a biological treatment unit for organic carbon abatement. It consists of a coarse and fine screen, an aeration tank, a final settling basin, a chlorination basin, a sludge thickening tank and a belt filter press unit.

***Reclaimed water quality*:**

Table 39. Bodrum-Bitez effluent.

Parameter	Unit	Specific Analyses Selected for the Project's Scope
pH	-	7.7
COD	mg/l	170
BOD_5	mg/l	-
TSS	mg/l	50
TKN	mg/l	1.5
NH_4-N	mg/l	-
TP	mg/l	0,5
Conductivity	µS	13,000
SAR	-	168.9
SO_4^{2-}	mg/l	684
Cl^-	mg/l	3,740
Faecal Coliform	CFU/ 100 ml	9,600
Boron	mg/l	0.65

***Water reuse applications*:**

Since the start-up period of the plant, the effluent has been applied to agricultural land, forest and grassland in summer months. Effluent discharge is being pumped to the location where it is used for irrigation.

***Total area affected by irrigation*:**

Since the first installation of the plant, the effluent is regularly being applied for irrigation on 3 000 m^2 land in summer months.

***Types of products cultivated in irrigated areas*:**

Effluent is used for the irrigation of forest area and citrus fruits.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Until now 250,000,000,000 TL (201,840 US$) has been invested for an irrigation pipeline network since its construction in 1998.

***Problems founded in the start-up, development or final application of the project*:**

According to information provided by representatives of the facility, the effluent used for irrigation of grassy lawn and flowers by means of sprinklers resulted in dry and pale crop products. Therefore, it has been decided to switch to a more effective irrigation system, like the trickling type irrigation.

Remarkable results:

The effluent has been used for irrigation purposes since its first operation time. Parallel to the increase in population and thus in water demand, the capacity extension is planned in the nearest future. Fast growth of pine trees being irrigated with treated wastewater has also been reported.

***Information Sources*:**

All information was provided from the treatment plant representatives.

CASE 3: Mugla, Bodrum-Bitez Urban WWTP

Location:

Duzce- Merkez

Year of the project development:

The plant is in operation since 01.01.1993.

***Water origin*:**

The treatment plant of Duzce-Merkez municipality provides wastewater treatment for 100,000 capita.

***Volume (or flow) of water affected*:**

The capacity of the treatment plant is 480,000 m^3/day. The treatment plant currently operates at 50% of its total capacity. Hence, the daily treated wastewater corresponds to 240,000 m^3/day. The treated wastewater has been used for irrigation of grassy lawns since its first establishment and throughout the whole year. The irrigation system is operating once a week and every day in winter and summer seasons, respectively.

***Water treatment before reuse (technologies/process applied)*:**

The treatment plant currently provides biological organic carbon removal. The plant features the following units: fine bars and screens, three aerated sand filters, two primary settling tanks, one trickling filter, two secondary settling tanks, one sludge thickening basin, two belt filter presses.

***Reclaimed water quality*:**

Table 40. Duzce-Merkez effluent.

Parameter	Unit	Specific Analyses Selected for the Project's Scope
pH	-	7.35
COD	mg/l	107
BOD_5	mg/l	-
TSS	mg/l	10
TKN	mg/l	8.1
NH_4-N	mg/l	-
TP	mg/l	2.6
Conductivity	µS	700
SAR	-	16.7
SO_4^{2-}	mg/l	50
Cl^-	mg/l	98
Faecal Coliform	CFU/ 100 ml	27,000
Boron	mg/l	0.47

***Water reuse applications*:**

The treated wastewater has been used for irrigation of grassy lawns since its first establishment and throughout the year. The irrigation system has been operated once a week and every day in winter and summer seasons, respectively.

The effluent is also frequently used for cleaning the wastewater treatment units, and inside the treatment plant. It is discharged to Kucuk Melen Creek where water is withdrawn for irrigation purposes by the nearby agricultural land.

***Total area affected by irrigation*:**

Effluent from the treatment plant is frequently being used by local farmers for irrigation purpose that is discharged to Kucuk Melen Creek.

***Types of products cultivated in irrigated areas*:**

Water from the Kucuk Melen Creek (receiving/accepting the plant discharge) is being used for the irrigation, sowing and farming of vegetables, corn, tobacco and sugar beet throughout the year.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Pipelines have been installed for reuse activities such as grassy lawn sprinkling, irrigation and wash-water supply during the construction of the treatment plant. Unfortunately, no satisfactory data is available on the individual costs of these pipelines and the reuse network, because the current staff was not dealing with the plant from the beginning on. The total construction cost of the treatment facility was 42,000,000,000 TL (33,909 US$).

***Problems founded in the start-up, development or final application of the project*:**

According to the information gathered from the plant representative, no problem has been recorded till now.

Remarkable results:

Enlargement/extension of the treatment plant is being planned now. According to the program of the Bank of Provinces (Iller Bank), the construction of a second-stage grit chamber, a preliminary settling tank, a trickling filter, a secondary settling tank and a sludge thickening unit is planned for the year of 2013. Thus, the capacity of the plant will be extended to 136,680 population equivalent.

***Information Sources*:**

All information was provided from the treatment plant representatives.

CASE 4: Izmir-Karaburun Urban WWTP

Location:

Izmir-Karaburun.

Year of the project development:

Is not documented.

***Water origin*:**

The treatment plant of Taris settlement provides municipal wastewater treatment for 1,500 capita in summer and 150 capita in winter season.

***Volume (or flow) of water affected*:**

The total capacity of the treatment plant is 300 m^3/d. The plant operates at a capacity of 240 m^3/d in summer, and only when needed or appropriate in winter season because of low/insufficient wastewater input/supply. Since its first instalment, the plant's irrigation units operate throughout the summer months and in winter season whenever the facility is being operated.

***Water treatment before reuse (technologies/process applied)*:**

The treatment plant currently features a biological treatment unit for organic carbon abatement. The treatment facility consists of a grit chamber + a bar screen, an equalization tank, an aeration tank, a final settling basin, a chlorination basin and a sludge thickening tank.

***Reclaimed water quality*:**

Table41. Izmir-Karaburun effluent.

Parameter	Unit	Specific Analyses Selected for the Project's Scope
pH	-	7.65
COD	mg/l	107
BOD_5	mg/l	-
TSS	mg/l	60
TKN	mg/l	31.1
NH_4-N	mg/l	-
TP	mg/l	7.2
Conductivity	µS	1,650
SAR	-	24,9
SO_4^{2-}	mg/l	65
Cl^-	mg/l	260
Faecal Coliform	CFU/ 100 ml	17,000
Boron	mg/l	0.25

***Water reuse applications*:**

Since the first installation of the plant, the effluent wastewater is being used for irrigation purposes on agricultural land in summer months. The irrigation water is applied on agricultural land by means of pumps.

***Total area affected by irrigation*:**

Since its first installation, the effluent of the plant is being used for irrigation of 5,000 m^2 land only during summer.

***Types of products cultivated in irrigated areas*:**

The land where the treated effluent is being applied is used for production of olives and corn.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

A 250 m pipeline network has been constructed for agricultural reuse of the treated wastewater. Due to the fact that the current staff was not present during the construction year/period of the treatment plant, no information/data is provided/available about the pipeline network (and others) construction costs.

***Problems founded in the start-up, development or final application of the project*:**

No technical/operational problems have been encountered since the start-up period of the facility according to the local staff.

Remarkable results:
The effluent has been used as irrigation water, since its operation. Corn is being grown in this area and irrigated with the effluent. The farmers have reported that corn productivity has even increased since then. The treatment plant belongs to a holiday village and hence the effluent is being used by the farmers only in winter months. Consequently, irrigation water is only provided during this period.

The facility currently treats municipal wastewater of Taris Holiday Village. In future, the treatment unit is planned to be connected to a nearby sewer system in this area.

***Information Sources*:**

All information was provided from the treatment plant representatives.

<u>CASE 5</u>: <u>Bursa-Inegol Urban + Industrial of Organized Industry Region Wastewater Treatment Plant</u>

Location:

Bursa-Inegol.

Year of the project development:

Is not documented.

***Water origin*:**

The treatment plant of Bursa-Inegol district provides municipal wastewater treatment for 150,000 capita together with the treatment of all industrial wastewater originating from the Bursa-Inegol Organized Industrial District.

***Volume (or flow) of water affected*:**

The full capacity of the treatment plant is 60,000 m^3/day, and currently it operates at approximately 100 % of its total capacity which corresponds to 30,000 m^3/d of domestic wastewater and 30,000 m^3/d of industrial wastewater originating from the Organized Industrial District (Bursa-Inegol). Prevailing industrial activities include food and glue production, textile manufacturing, iron-processing, chicken-farming, animal feed production and textile dyeing/finishing.

When the treatment plant operation first started, 960 m^3/day of treated wastewater has been reused for irrigation purpose throughout the whole year/four seasons. However, because of the operational/technical problems faced during irrigation, the treated effluent is currently being used for irrigation only during the summer season with low capacity pumps and trunks.

***Water treatment before reuse (technologies/process applied)*:**

The treatment facility currently features an advanced treatment technology for nitrogen and phosphorous removal. The treatment units are: Primary/coarse screens, grit chamber and oil traps, 8 extended aeration activated sludge basins, 4 biological nitrogen and phosphorous removal tanks (2 for each), 4 final settling tanks, 2 sludge thickening units, and 2 belt filter presses.

***Reclaimed water quality*:**

Table 42. Effluent composition.

Parameter	Unit	Specific Analyses Selected for the Project's Scope
pH	-	8.15
COD	mg/l	195
BOD_5	mg/l	-
TSS	mg/l	50
TKN	mg/l	12.7
NH_4-N	mg/l	-
TP	mg/l	0.7
Conductivity	µS	2,200
SAR	-	119.4
SO_4^{2-}	mg/l	160
Cl^-	mg/l	325
Faecal Coliform	CFU/ 100 ml	14,500
Boron	mg/l	0.22

***Water reuse applications*:**

The effluent has been used for irrigation of grassy lawns since its first establishment and throughout the year. Currently, the treated wastewater is only being used for low capacity irrigation in summer. The effluent is being discharged to the Kalburt (Yenice) Creek. The Kalburt Creek with a flow of 17,280,000 m^3/d (1,728 m^3/d in summer) joins with Koca Creek (51,840,000 m^3/d and finally joins to Bogazkoy river dam that will serve as SHW's (State Hydraulic Works) irrigation dam in future. However, as the construction of the dam has not been completed yet, the effluent is currently being used for irrigation of Yenisehir Plain and the stream banks of Kalbur Creek (summer capacity of Kalbur Creek reduces to 1,728,000 m^3/d).

***Total area affected by irrigation*:**

During the start-up period of the plant, 15 000 acres of land has been irrigated during winter and summer. Currently, irrigation is only provided in summer at very low capacities when the groundwater supply becomes quite scarce (land irrigation by means of trunks).

The treated effluent water is being discharged into Kalburt Creek and is used by local farmers for irrigation of Yenisehir Plain located near the creek. An average of 3000 ha land is irrigated at the stream banks of Kalburt Creek.

***Types of products cultivated in irrigated areas*:**

The effluent currently being discharged to Kalburt Creek is used for irrigation of agricultural land where grapes, olives, vegetables and fruits are being planted. Additionally, populous, meadows and pastures for grazing animals are grown in this area.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

During establishment of the treatment facility, separate pipeline and irrigation systems have been established for irrigation purposes. Since the initial construction period, 150,000,000,000 TL has been invested for the irrigation/reuse project only.

***Problems founded in the start-up, development or final application of the project*:**

During the initial operation of the treatment facility, irrigation was provided for grassy lawns in winter and summer by means of the sprinkling technique. According to information provided by the plant's operating staff, the irrigation facilities were clogged due to extremely high TSS of the treated effluent. The sprinkling facility was shut down thereafter and subjected to maintenance for several times. However, after several attempts of shut–down and maintenance, the problem could not be solved and became unaffordable. Consequently, it was decided to irrigate the grassy lawns by means of groundwater wells as the groundwater table of the region where the treatment plant is located is very high. Hence, irrigation water is currently being provided from a well system. Exceptions are dry summer periods, when the groundwater table decreases and irrigation is continued using pumps or trunks.

Remarkable results:

The groundwater table in the region is relatively high and sufficient to supply irrigation water by means of wells. Many wells have been drilled and the water demand was completely satisfied through them. However, the wells are not capable of serving the full water demand, and SHW has advised the local authorities not to bore any more wells.

***Information Sources*:**

All information was provided from the representatives of the treatment plant, staff from the Organized Industry Region, and SHW representatives of the area.

CASE 6: Istanbul-Pasakoy UWWTP

Location:

Istanbul-Pasakoy.

Year of the project development:

The plant is in operation since 16.12.2000.

***Water origin*:**

The wastewater treatment plant serves to conserve the Omerli Dam located in Omerli River Basin, which is one of the most important and essential water resources of the megacity, Istanbul. The plant currently provides domestic wastewater treatment for the following districts in the Omerli River Basin: Sarigazi, Samandira, Sultanbeyli, Alemdag, Yenidogan and Sultanciftligi Omerli River Basin: Sarigazi, Samandira, Sultanbeyli, Alemdag, Yenidogan and Sultanciftligi.

***Volume (or flow) of water affected*:**

The treatment plant serves 250,000 capita at a capacity of 80,000 m^3/d. It thereby provides irrigation by treated effluent with four 60 m^3/h capacity and one 12 m^3/d capacity pump in summer and winter seasons. In addition, approximately 112,000 m^3 of effluent discharge is being used for cleaning the treatment units and for periodic maintenance efforts.

***Water treatment before reuse (technologies/process applied)*:**

The facility currently provides advanced biological treatment for organic carbon, nitrogen and phosphorous removal. The plant features coarse screens, fine screens, grit chambers and separators, 3 biological Phosphorous removal tanks, 4 aeration tanks with anoxic and aerobic compartments, 4 final settling tanks, a dissolved air flotation unit for sludge separation, 1 sludge storage tank and 1 sludge dewatering unit.

***Reclaimed water quality*:**

Table 43. Instanbul - Pasakoy effluent composition.

Parameter	Unit	Specific Analyses Selected for the Project's Scope
pH	-.	6,6
COD	mg/l	60
BOD_5	mg/l	-
TSS	mg/l	15
TKN	mg/l	2.2
NH_4-N	mg/l	-
TP	mg/l	0.9
Conductivity	μS	825
SAR	-	17.9
SO_4^{2-}	mg/l	105
Cl^-	mg/l	95
Faecal Coliform	CFU/ 100 ml	3,500
Boron	mg/l	0.57

***Water reuse applications*:**

Since the first establishment of the plant, the discharged effluent is used for irrigation of recreational area (parks, trees, etc.), and the cleaning/maintenance of the treatment units throughout the year (four seasons). Irrigation water is provided by means of trunks and the sprinkling method. A separate effluent distribution system is still under construction.

***Total area affected by irrigation*:**

The discharged effluent is regularly used for irrigation of 60 acres of grassy lawn and fruit trees located around the plant.

***Types of products cultivated in irrigated areas*:**

The discharged effluent is regularly used for the irrigation of 60 grassy lawn and fruit trees located around the treatment plant.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Since its first establishment and construction in year 2000, 15,000,000,000,000 TL (12,110,000 US$) has been invested.

***Problems founded in the start-up, development or final application of the project*:**

According to information gathered form the plant staff, the aeration system works with a capacity of 40%. An increase in performance by additional investments is planned. No problems related to irrigation have been encountered till today.

Remarkable results:

It is planned to provide service extension up to a capacity of 5,000,000 m^3/d to serve a population of 1,065,000 capita. Additionally, the construction of a tunnel to deliver the discharged effluent via the River Creek to the Black Sea is planned. Thus, the loss of effluent will be prevented. The sludge cake obtained from the sludge thickening unit has been tested on grassy lawn and the productivity (crop yield) was improved remarkably, according to recent reports.

***Information Sources*:**

All information was provided from the treatment plant representatives.

CASE 7: Afyon-Merkez Urban WWTP

Location:

Afyon-Merkez

Year of the project development:

The plant has been constructed in 1995 by the Bank of Provinces (Iller Bankasi in Turkish).

***Water origin*:**

The treatment plant of Afyon Municipality provides municipal wastewater treatment within the boundaries of the municipality for 150,000 capita in summer and winter months.

***Volume (or flow) of water affected*:**

The capacity of the treatment facility is 24,500 m^3/d. The plant operates at 20,000 m^3/d.

***Water treatment before reuse (technologies/process applied)*:**

The treatment plant currently features a biological treatment unit for organic carbon abatement. It consists of a coarse and fine screen, grit chamber, primary settling tank, trickling filter, secondary settling tank, sludge digestion tank and sludge drying bed.

***Reclaimed water quality*:**

Table 44. Afyon-Merkez WWTP effluent composition.

Parameter	Unit	Specific Analyses Selected for the Project's Scope
pH	-	7.8
COD	mg/l	130
BOD_5	mg/l	-
TSS	mg/l	30
TKN	mg/l	22.2
NH_4-N	mg/l	-
TP	mg/l	3.4
Conductivity	µS	1,650
SAR	-	41.9
SO_4^{2-}	mg/l	145
Cl^-	mg/l	202
Faecal Coliform	CFU/ 100 ml	43,200
Boron	mg/l	0.40

***Water reuse applications*:**

Since the start-up period of the plant, the effluent has been applied to forest and grassland in summer and winter months. Effluent discharge is being pumped to the location where it is used for irrigation.

***Total area affected by irrigation*:**

Since the first installation the plant, the effluent is regularly being applied for irrigation on 1,000 m^2 land.

***Types of products cultivated in irrigated areas*:**

Effluent is used for the irrigation of forest area where acacia and oleaster trees are grown.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Information not available.

***Problems founded in the start-up, development or final application of the project*:**

According to information provided by representatives of the facility, before the operation of the plant started, the farmers used to take water from the open channels for irrigation purposes. The same situation was valid for the effluent. Today, the effluent of the plant is also being used for irrigation purposes. The dried sludge is distributed to the farmers as fertilizer. It has been observed that the trees in the garden got much thicker after use of the dried sludge cake.

Remarkable results:

The effluent has been used for irrigation purposes since its first operation time. Parallel to the increase in population and hence in water demand, a capacity extension is planned in the nearest future. In addition, the capacity of the plant is planned to be increased in accordance with the increase in the population.

***Information Sources*:**

All information was provided from the treatment plant representatives.

CASE 8: Manisa-Akhisar Urban WWTP

Location:

Manisa-Akhisar.

Year of the project development:

The plant has been constructed in 1984.

***Water origin*:**

The treatment plant of Manisa-Akhisar Municipality provides municipal wastewater treatment for 83,600 capita in summer and winter months.

***Volume (or flow) of water affected*:**

The capacity of the treatment facility is 9,500 m^3/d but the plant is operated over its capacity at 13,200 m^3/d. The annual amount of sludge from the plant is approximately 700 t.

***Water treatment before reuse (technologies/process applied)*:**

The treatment plant currently provides only organic carbon removal. The units of the plant are coarse screen, fine screen, grit chamber, primary settling tanks, trickling filter with high rate and final clarifiers.

***Reclaimed water quality*:**

Table 45. Manisa-Akhisar WWTP effluent composition.

Parameter	Unit	Specific Analyses Selected for the Project's Scope
pH	-	7,33
COD	mg/l	285
BOD_5	mg/l	-
TSS	mg/l	51
TKN	mg/l	94,1
NH_4-N	mg/l	-
TP	mg/l	43,73
Conductivity	µS	1902
SAR	-	34,7
SO_4^{2-}	mg/l	87,6
Cl^-	mg/l	472
Faecal Coliform	CFU/ 100 ml	>10^6/100 ml
Boron	mg/l	0,035

***Water reuse applications*:**

Since the start-up period of the plant, the effluent has been applied to agricultural area. Effluent discharge is being pumped to the location where it is used for irrigation.

***Total area affected by irrigation*:**

Since the first installation of the plant, the effluent is regularly being applied for irrigation on 5,000 m^2 land.

***Types of products cultivated in irrigated areas*:**

Effluent is used for the irrigation of land where tobacco and cotton are grown.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The construction cost of the treatment plant was 1.75 billion TL (1,413,000 US$).

***Problems founded in the start-up, development or final application of the project*:**

According to information provided by representatives of the facility, no complaints have been reported during the start-up period, development and application of the project.

Remarkable results:

Not data available.

***Information Sources*:**

All information was provided from the treatment plant representatives.

CASE 9: Manisa-Alasehir Urban WWTP

Location:

Manisa-Alasehir

Year of the project development:

The treatment plant has been in operation since 1984.

***Water origin*:**

The treatment plant of Manisa-Alasehir Municipality provides domestic wastewater treatment for 55 000 capita in summer and winter seasons. There is no seasonal population change.

***Volume (or flow) of water affected*:**

The capacity of the treatment facility is 13 392 m^3/d, but the plant is operated over its capacity at 15 500 m^3/d. During the summer months, 54 m^3/h of the treated wastewater is also used for watering of the parks and gardens in the property of the plant.

***Water treatment before reuse (technologies/process applied)*:**

The treatment facility currently provides only organic carbon removal. The treatment units are designed as follows: coarse screen, fine screen, grit chamber, primary settling tanks, trickling filter with low rate, final clarifiers, aerobic sludge stabilization, and sludge drying bed.

***Reclaimed water quality*:**

Table 46. Manisa-Alasehir WWTP effluent composition.

Parameter	Unit	Specific Analyses Selected for the Project's Scope
pH	-	7.40
COD	mg/l	101
BOD_5	mg/l	-
TSS	mg/l	61
TKN	mg/l	47.3
NH_4-N	mg/l	-
TP	mg/l	14.93
Conductivity	µS	1,299
SAR	-	34.7
SO_4^{2-}	mg/l	196
Cl^-	mg/l	69
Faecal Coliform	CFU/ 100 ml	$>10^6$/100 ml
Boron	mg/l	0.055

***Water reuse applications*:**

The effluent was discharged directly to the Alasehir Stream which is connected to Gediz River. The Alasehir Creek is actually almost dry except the rainy periods during the winter months. Therefore the treated wastewater can be considered to form the whole stream and to be directly used.

***Total area affected by irrigation*:**

The typical area irrigated with effluent is 500,000 m^2, and also an area of 240,000 m^2 used for watering of the parks and gardens.

***Types of products cultivated in irrigated areas*:**

The typical crops that are grown and irrigated with this water in the region are cotton and grape. Also, the treated wastewater is used for watering of the parks and gardens in the property of the treatment plant.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The municipality is planning to discharge the effluent water directly to the irrigation channel of the General Directorate of State Hydraulic Works (SHW; Abbreviation is DSI in Turkish), which is located 2 km away from the plant, for the purpose of direct agricultural irrigation. The initial cost of the pipeline construction to the DSI channel (including the cost of pumping station + pipe + installation of pipeline + total labour costs) is given as 150 billion TL (121,104,000 US$) in 1998 and the project will be operational in the near future. The biggest obstacle in carrying out the project is financial problems.

***Problems founded in the start-up, development or final application of the project*:**

They came across some problems caused by the sludge five years ago. They received a lot of complaints about the flies from the sludge drying beds with a total area of 10.000 m^2. Upon using “larvasit” as insecticide they solved the above mentioned problem. Another problem that they have now is the odor and colour problem during the November-December period since the plant also accepts the effluent from two small-scale olive oil manufactories. This black olive oil process vegetation water is the main reason of the odor/colour complaints during this two-month period.

Remarkable results:

Demand from the farmers for the effluent of the plant is high since the groundwater has high Boron concentrations and water from the dam is not sufficient. Here it should be noted that Boron is a general problem in Turkey because of the high Boron content of soils. The farmers used to use the Alasehir Creek water before 1994 when the plant was not in operation but they are now more satisfied with the treated wastewater.

Dried sludge from the sludge drying beds is used as fertilizer for the growth of cotton, tobacco, olive and poplar trees in the region

***Information Sources*:**

All information was provided from the treatment plant representatives.

CASE 10: Antalya-Kumkoy Urba WWTP

Location:

Antalya-Kumkoy.

Year of the project development:

The treatment plant has been in operation since 1993.

***Water origin*:**

The treatment plant provides municipal wastewater treatment for 120,000 capita in summer and 60,000 capita in winter season.

***Volume (or flow) of water affected*:**

The capacity of the treatment facility is 12,000 m^3/d, but the plant is operated over its capacity at a rate of 15,500 m^3/d. The plant operates at a capacity of 17,000 m^3/d in summer, and of 10,000 m^3/d in winter.

***Water treatment before reuse (technologies/process applied)*:**

The wastewater treatment plant uses an extended aeration unit. The units of the plant are coarse screen, fine screen, grit chamber, skimmer, denitrification tank and a final chlorination.

***Reclaimed water quality*:**

Table 47. Antalya-Kumboy WWTP effluent composition

Parameter	Unit	Specific Analyses Selected for the Project's Scope
pH	-	7.33
COD	mg/l	17
BOD_5	mg/l	-
TSS	mg/l	2
TKN	mg/l	28.5
NH_4-N	mg/l	-
TP	mg/l	21.33
Conductivity	µS	1,074
SAR	-	16.3
SO_4^{2-}	mg/l	112
Cl^-	mg/l	132
Faecal Coliform	CFU/ 100 ml	>10^6/100 ml
Boron	mg/l	0.042

***Water reuse applications*:**

The effluent was discharged directly to the Ilica Stream following the chlorination process. The stream water is used for agricultural irrigation downstream of the plant discharge point. In addition, since the plant has been in operation, the effluent is being used for irrigation of grassland.

***Total area affected by irrigation*:**

The typical area directly irrigated with effluent is 5,5 acres, and also a large area indirectly because of stream water.

***Types of products cultivated in irrigated areas*:**

Crops grown in the region and irrigated by the stream water are cotton, sesame, wheat, and citrus trees.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The initial capital cost of the plant was 10 billion TL (8,073,600 US$) in the year 1986. A second, additional stage investment cost 600 billion TL (484,416,000 US$) in 1998. Future investments may be made on increasing the current capacity of the plant and installing a diffuser system.

***Problems founded in the start-up, development or final application of the project*:**

They are currently no complaints on their wastewater discharge and reuse methods. Operational/technical problems have also not been reported in the past.

Remarkable results:

Not data available.

***Information Sources*:**

All information was provided from the treatment plant representatives.

CASE 11: Antalya-Titreyengol Urban WWTP

Location:

Antalya-Titreyengol.

Year of the project development:

The treatment plant has been in operation since 1986, the effluent has been used since 1993.

***Water origin*:**

The treatment plant provides municipal wastewater treatment for 30,000 capita in the summer and 7,500 capita in the winter season.

***Volume (or flow) of water affected*:**

The capacity of the treatment facility is 10,725 m^3/d. The wastewater flow ranges from 6,000 to 7,500 m^3/d in the summer and 2,500 to 3,000 m^3/d in the winter.

***Water treatment before reuse (technologies/process applied)*:**

The wastewater treatment plant features an extended aeration unit. The units of the plant are coarse screen, fine screen, grit chamber, skimmer and extended aeration tank.

***Reclaimed water quality*:**

Table 48. Antalya-Titreyengol WWTP effluent composition.

Parameter	Unit	Specific Analyses Selected for the Project's Scope
pH	-	7.45
COD	mg/l	49
BOD_5	mg/l	-
TSS	mg/l	15
TKN	mg/l	23.1
NH_4-N	mg/l	-
TP	mg/l	14.19
Conductivity	μS	745
SAR	-	17.0
SO_4^{2-}	mg/l	37
Cl^-	mg/l	195
Faecal Coliform	CFU/ 100 ml	>10^6/100 ml
Boron	mg/l	0.036

***Water reuse applications*:**

The effluent was formerly discharged to the Mediterranean Sea from the Ayiguru.

***Total area affected by irrigation*:**

The typical area irrigated with effluent is 3,7 acres directly.

***Types of products cultivated in irrigated areas*:**

Since 1993, the effluent is being used for the irrigation of grassland.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The capital cost of the plant was 10 billion TL (8,074,000 US$) in the year 1986. Future investment plan might be increasing the current capacity of the plant.

***Problems founded in the start-up, development or final application of the project*:**

They have had no complaints on their wastewater discharge and reuse methods.

Remarkable results:

Not reported.

***Information Sources*:**

All information was provided from the representatives of the treatment plant, staff from the Organized Industry Region, and SHW representatives of the area.

CASE 12: Samsun-Ondokuzmayis Urban WWTP

Location:

Samsun-Ondokuzmayis.

Year of the project development:

The wastewater plant became operational in 1997. The effluent from the plant has been used for irrigation in a constructed vegetable field and a nursery since 2000.

***Water origin*:**

The treatment plant of Ondokuzmayis Municipality provides domestic wastewater treatment for 12,000 capita in summer and 10,000 capita in winter.

***Volume (or flow) of water affected*:**

The capacity of the treatment plant is 1,000 m^3/d. The amount of treated wastewater is 200 m^3/day.

***Water treatment before reuse (technologies/process applied)*:**

The system is advanced biological treatment with nitrogen removal. The plant consists of primary units of bar racks, a grit chamber and a primary sedimentation tank. The biological unit includes nitrification, denitrification, and aeration tanks followed by final clarifiers and a chlorine contact tank.

***Reclaimed water quality*:**

Table 49. Samsun-Ondokuzmayis WWTP effluent composition.

Parameter	Unit	Specific Analyses Selected for the Project's Scope
pH	-	6.9
COD	mg/l	61
BOD_5	mg/l	-
TSS	mg/l	55
TKN	mg/l	24.2
NH_4-N	mg/l	-
TP	mg/l	14.28
Conductivity	µS	1,319
SAR	-	18.4
SO_4^{2-}	mg/l	52
Cl^-	mg/l	103.5
Faecal Coliform	CFU/ 100 ml	600/100 ml
Boron	mg/l	0.049

***Water reuse applications*:**

The effluent is being used for irrigation of forest area and agricultural land.

***Total area affected by irrigation*:**

The surface area of the vegetable field and nursery are 4,500 and 1,500 m^2, respectively.

***Types of products cultivated in irrigated areas*:**

The crops are vegetable and nursery. Irrigated crops in the vegetable field include water melon and corn. The stuff of the facility has observed 50% increase in water melon yield which is now 6 t/year. Growth of nursery products such as maple, palm, willow, fig, different types of pine and gallnut, rose, local tree type Kavlahan were carried out at the nursery. Currently 6,000 nursery products are grown yearly.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Total cost of the irrigation project could not be itemized one by one since it started with the manager's initiative by the personal municipality workers worked and the irrigation system was constructed as independent of the initial wastewater treatment plant project. The cost can roughly be estimated by considering the following expenses items:

100 D 200 m pipe.
2 irrigation sprinklers: 100 million/each.
Labour: Municipality workers.
The construction of handals: 1,200 bricks.
Nylon bags for stapling: 150 million TL/year (121,104,000 US$).
Construction cost of the greenhouse for nursery: 300 million TL (242,208,000 US$).

According to above items, the plant manager estimated total cost as 1 billion TL (807,000 US$) including labour.

***Problems founded in the start-up, development or final application of the project*:**

They have had no complaints on their wastewater discharge and reuse methods.

Remarkable results:

This irrigation idea came from the plant manager of the municipality and the municipality authorities welcomed this idea very much since it would decrease the discharge to the sea and would reduce the cost of the purchase of nursery products by supplying those for the municipality uses. The municipality provided the soil from its other excavated areas and the municipality workers prepared the field for the planting. The biggest problem encountered in implementing the irrigation project was the lack of financial sources. Other than that, at the beginning, people were very sceptical about eating the crops irrigated by the treated wastewater. However, local people are currently very receptive of the idea of eating these crops that are distributed to them for free. Farmers in the area make requests for getting the fertilizer prepared using the excess activated sludge from the plant.

***Information Sources*:**

All information was provided from the treatment plant representatives.

CASE 13: Gaziantep WWTP

Location:

Gaziantep

Year of the project development:

The wastewater plant became operational in 1999.

***Water origin*:**

Wastewater of Metropolitan Gaziantep.

***Volume (or flow) of water affected*:**

The capacity of the treatment plant is 200,000 m^3/day capacity (73 Mm^3/yr).

***Water treatment before reuse (technologies/process applied)*:**

Screens, grit removal, primary settling, aeration (activated sludge), secondary settling, sludge thickening, sludge digestion.

***Reclaimed water quality*:**

Table 50. Gaziantep WWTP effluent composition.

Parameter	Unit	Specific Analyses Selected for the Project's Scope
TSS	mg/l	<35
BOD_5	mg/l	<25
NH_3	mg/l	17
NO_2	mg/l	2.5
NO_3	mg/l	5.5

***Water reuse applications*:**

Reclaimed wastewater is used for irrigation of nearby fields especially in summer months.

***Total area affected by irrigation*:**

8,000 ha.

***Types of products cultivated in irrigated areas*:**

Edible-crops, vegetables, crops.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

56 million US dollars (capital costs)

***Problems founded in the start-up, development or final application of the project*:**

At initial period of the operation, detergents present in wastewater caused problems. Farmers reported adverse effects on their crops. However, no such complaints have been received since that time.

Remarkable results:

There are few cases where treated wastewater is planned to be reused through an irrigation system or network. One example for such an application is the Gaziantep Wastewater Treatment Plant. Currently, treated wastewater is discharged to a creek. Farmers are pumping out water especially in summer months. The extension project for the irrigation network in the area is still under construction together with the surface impoundment structure. In near future, it will be possible to detain reclaimed wastewater for irrigation. This will enable the enhancement of reclaimed wastewater quality, if necessary monitoring and controls are applied. Farmers are satisfied with the water supplied in summer months in this arid region.

***Information Sources*:**

Gaziantep Municipality. Gaziantep Wastewater Treatment Plant, booklet, 1989.
Gaziantep Wastewater Treatment Plant Management. Personal communications, 2004.

Other good examples on agricultural reuse of wastewater all over the world

A total of 20 wastewater reuse reclamation projects of different scales were examined in this sectionamong the ones for which relatively satisfactory amount of information was available through literature and Internet search.

Applications in United States of America and Australia are almost ultimate with respect to the technologies employed and the quality of the reclaimed wastewater almost reaching to drinking water standards in some cases. However, although noteworthy, these applications may not be suitable for the Mediterranean countries due to the economics of scale.

Selected cases in Australia

<u>CASE 1</u>: <u>Bolivar WWTP and Virginia pipeline scheme</u>

Location:

Adelaide, South Australia (Figure 51).

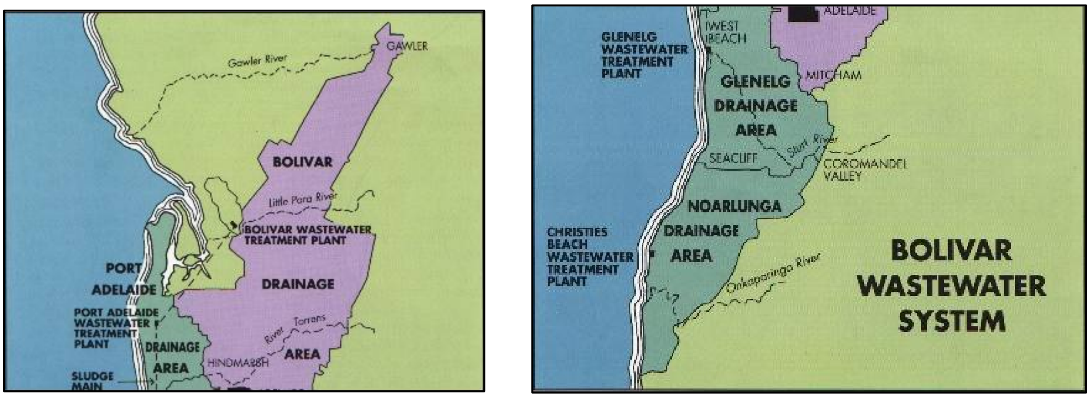

Figure 51. Bolivar wastewater treatment plant and reuse system location,
(Source: www.environmentdirectory.com.au/technologies/wateremissiontecharticle4.html).

Year of the project development:

1999-2002.

Water origin:

Wastewater arrives at the plant (Figure 52) through two gravity trunk sewers, one from Gawler-Elizabeth-Salisbury, the other from the southern area which includes a large part of Adelaide.

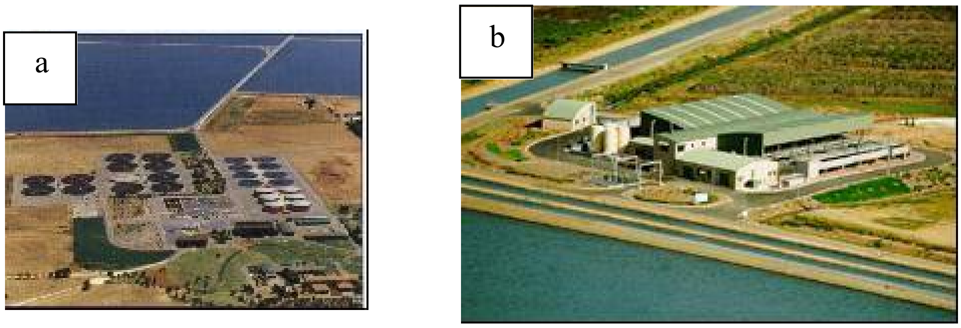

Figure 52. Bolivar wastewater treatment plant: a) Aerial view of tanks and lagoons; b) Tertiary treatment DAF/F.,(Source: www.environmentdirectory.com.au/technologies/wateremissiontecharticle4.html).

***Volume (or flow) of water affected*:**

Wastewater treated at Bolivar wastewater treatment plant. The plant was designed to serve 600,000 people, plus industrial wastes equivalent to 700,000 people. Now the flow is 0.15 Mm^3/day maximum (30 Mm^3/yr). The Bolivar Wastewater Treatment Plant discharges an average 40,000 megalitres of sewage effluent per year.

***Water treatment before reuse (technologies/process applied)*:**

The main elements of the project consist of a 120 megalitre per day dissolved air flotation filtration (DAF/F) treatment plant, a disinfection contact and balancing storage reservoir, a pump station and 150 kilometres of distribution pipework ranging from nominal diameters of 850 mm down to 100 mm.

The first step is to remove debris by passing the raw wastewater through screens. The screened wastewater passes into a series of grit removal and pre-aeration tanks. Air is pumped into these tanks, to keep organic material in suspension. The sludge is pumped to grit lagoons for drying and ultimate disposal to landfill. The wastewater then enters the four primary sedimentation tanks, each 69 m long and 23 m wide. Floating material is skimmed at this stage using water sprays.

Figure 53. Pre-aeration tanks.

In the secondary treatment, the settled wastewater passes via a recirculation and by-pass chamber to the biological filters. They are 55 m in diameter, 2 m deep, and filled with graded stones supported on a grid floor which allows air to pass upwards through the stones. These stones are covered with a slime of micro-organisms, known as zoogleal slime. With the upward flow of air supplying the necessary oxygen, these micro-organisms digest the organic matter in the wastewater. In these aerobic conditions carbohydrates are oxidised to carbon dioxide and water, and nitrogenous matter such as proteins to ammonia and nitrates.

The filter effluent is pumped to tanks, where the slime particles settle as humus sludge. This is pumped back to the pre-aeration zone while the humus effluent flows, via the recirculation chamber, to the stabilisation lagoons. The final stage of treatment takes place in stabilisation lagoons. There are two sets of three lagoons covering a total area of 347 hectares all about 1.2 m deep.

A research project at Bolivar, South Australia has investigated the viability of aquifer storage and recovery (ASR) of reclaimed water in a brackish aquifer (Figure 54). The field trial involved the injection of ~360 megalitres and recovery of ~240 megalitres of reclaimed water into a confined limestone aquifer over two ASR cycles.

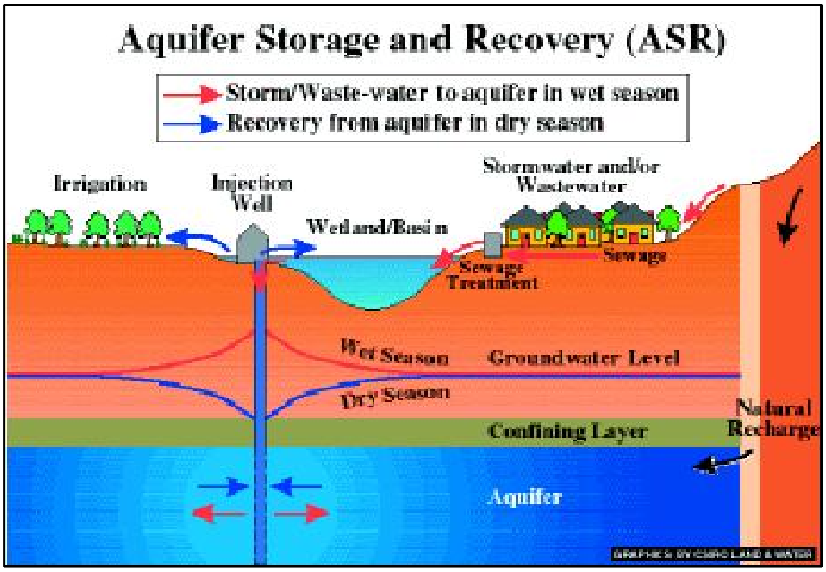

Figure 54. Aquifer Storage and Recovery system, (Source: www.pecc.org).

The ASR trial used water from the nearby Bolivar sewage treatment plant. The secondary treatment was achieved by trickling filters from October 1999 to January 2001, prior to being replaced by activated sludge digestors. The water was then stored in oxidation ponds and passed through a water reclamation plant involving DAF/F followed by disinfection (chlorination). The water was delivered to the ASR site via the Virginia Pipeline Scheme (VPS), which supplies reclaimed water to farmers across the Northern Adelaide Plains.

***Reclaimed water quality*:**

The quality of the effluent from the treatment plant of Bolivar is shown in the next Table:

Table 51. Bolivar WWTP effluent composition.

Parameter	Recovered water
E. Conductivity (µS/cm)	1,975
Temperature (º C)	18.3
pH	6.9
Dissolved Oxygen (mg/l)	6.0
TSS (mg/l)	-
Total Nitrogen (mg/l)	7.8
Total Phosphorous	2.3
TOC	20.1
E. coli (units/100 ml)	-

The effluent, after storing in the ASR system achieved the quality required for non-restricted irrigation:

Table 52. ASR effluent composition.

Parameter	Recovered water from ASR
E. Conductivity (µS/cm)	2,470
Temperature (º C)	22.7
pH	7.06
Dissolved Oxygen (mg/l)	0
TSS (mg/l)	1
Total Nitrogen (mg/l)	15.6
Total Phosphorous	0.24
TOC	10.6
E. coli (units/100 ml)	0

***Water reuse applications*:**

Recycled water is used extensively for irrigated agricultural activities, for watering the plant's lawns and gardens and for flushing and cleaning purposes around the plant. Recycled water not used on site flows into a 12 km long channel which meets the sea just north of St. Kilda. This recycled water is available for industrial, recreational, and agricultural use on the Northern Adelaide Plains.

***Total area affected by irrigation*:**

Despite some 12,000 hectares of good quality soil being available, the annual area of irrigated cultivation is limited by water to only 3,500 hectares (Figure 55).

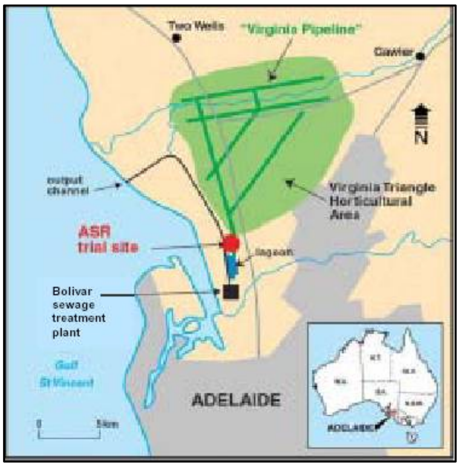

Figure 55. Adelaide horticultural area indicating location of the Bolivar ASR site, (Source: *Dillon et al*, 2003).

***Types of products cultivated in irrigated areas*:**

Vegetable irrigation.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Irrigation system: 23 million AU$; DAF/F construction: 30 million AU$; operating cost: 0.12 AU$/m^3.

The project has, currently, more than 240 clients that pay 0,09 AU$/m^3 in summer and 0.05 in winter. This prices will rise in a near future.

***Problems founded in the start-up, development or final application of the project*:**

Most irrigators also have access to groundwater supplies. In order to consume reclaimed wastewater in preference to groundwater, long term contracts based on "take or pay" principle were negotiated with irrigators. In this respect, wastewater reuse is expected to maximize and, therefore, aquifer demand will decrease.

Remarkable results:

The Bolivar Wastewater Treatment Plant has served Adelaide, providing a high degree of protection for both public health and the environment.

It has been demonstrated that the recovered water met the guidelines for unrestricted irrigation. The quality of the water improved during ASR, particularly with respect to pathogens, disinfection by-products, suspended particles, organic carbon and most metals. The anticipated clogging was found to be manageable using simple methods and the cost of the operation was found to compare favourably with conventional alternatives.

The Bolivar Reclaimed Water ASR Research Project has been the first reclaimed water ASR project in Australia, and is the first known successful trial with nutrient-rich irrigation water. It has also been demonstrated that no drinking water wells beyond the trial site or in the overlying aquifer will be adversely affected by ASR. In addition to establishing the viability of ASR with reclaimed water in this limestone aquifer containing brackish groundwater, the research undertaken at this site has provided valuable new information about water treatment processes in aquifers. These suggest conditions under which ASR with reclaimed water is likely to be viable.

Success at Bolivar suggests further applications as sustainable recovery of potable water from non-potable sources, which may be a robust low-cost solution to water supply problems in arid developing countries.

***Information Sources*:**

The Department of Water, Land, and Biodiversity Conservation,
http://www.dwlbc.sa.gov.au/publications/pdfs/fact_sheets/dwlbc/fs2_water_resuse.pdf

Bolivar wastewater treatment plant.
http://www.environmentdirectory.com.au/technologies/wateremissiontecharticle4.html

Dillon, P., Martin, R. et al. Aquifer storage and recovery with reclaimed water at Bolivar, South Australia. Australian Water Association South Australian Branch Regional Conference on 6 August 2003.

Kracman, B., Martin, R., and Sztajnbok, P., 2001. The Virginia Pipeline: Australia's largest water recycling project, Water Sci. Technol., Vol. 43, No 10, pp 35-42.

CASE 2: Picton WWTP

Location:

Picton, Australia.

Year of the project development:

The wastewater reuse component of the scheme began operation in December 2000.

***Water origin*:**

Domestic wastewater.

***Volume (or flow) of water affected*:**

Picton Wastewater Treatment Plant was commissioned in February 2000 to treat wastewater from an estimated population of 10,000. On average 1.2 ML/d (0.44 Mm^3/yr) of treated wastewater is available for irrigation.

The Picton Sewage Treatment Plant (STP) receives between 1.2 and 1.4 megalitres (Ml)per day of influent from 3 towns. Once treated the effluent is stored in 2 dams. One dam contains highly treated effluent (filtration and UV disinfection) which is suitable for irrigation, re-use on the STP or, on very rare occasions, discharge to the local waterway. The other dam contains effluent high in nutrients, which is only suitable for irrigation. The volume of treated wastewater used for irrigation annually is over 600 Ml/annum. Daily irrigation can vary up to 5 Ml per day depending on weather conditions but averages 6.7 Ml per hectare per year.

***Water treatment before reuse (technologies/process applied)*:**

Picton wastewater treatment plant treats sewage to tertiary effluent. The treatment scheme applied is the following:
Head of works ~ screening
Intermittently Decanting Aeration Lagoons (IDAL) x 2 ~ chemical dosing, solid settlement, aeration, nitrification/de-nitrification.
Equalisation Basin ~ balancing the effluent from the IDAL´s
Anthracite filtration and UV disinfection ~ high treatment storage.

The land that the Picton STP and re-use farm are built on was originally used to breed race horses so all the infrastructure, except the two dams had to be built from scratch. This includes pumps, pipes, pivot and solid-set irrigation. There is only one farm so the maintenance is reasonably simple and managed by the farming contractor.

***Reclaimed water quality*:**

Total Nitrogen: 0.37 mg/l
Total Phosporous: 0.015 mg/l

Ground water is monitored frequently and to date the data has not indicated or identified any significant detrimental impacts.

***Water reuse applications*:**

The crops currently irrigated are lucerne, ryegrass and clover pastures at 5mm per application and run on a moisture deficit program.

***Total area affected by irrigation*:**

There are a total of 175 hectares available in 2 stages. They are currently irrigating 90 hectares ion stage 1. There are a total of 175 hectares available in 2 stages. They are currently irrigating 90 hectares ion stage 1.

***Types of products cultivated in irrigated areas*:**

Lucerne, rye, oats, corn and clover.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

48 million AU$ (construction of the Picton STP, eight pumping stations and a reuse farm). As the STP is new, accurate operation and maintenance costs are difficult to calculate as they are not yet fully functional with only one of the two IDALs working, but farm operations and maintenance costs are approximately 140,000 AU$ per annum. Income from the sale of crops is off-set against true operational costs as the venture is set up for environmental reasons not commercial.

***Problems founded in the start-up, development or final application of the project*:**

Availability of reclaimed wastewater is less than the demand. To address this shortage, plans are now underway to expand the storage capacity of the scheme. As the scheme is designed to accommodate wet years, there is insufficient treated effluent available in very dry years to maintain full crop production.

When it is running out of wastewater it is used minimum irrigation to ensure the survival of 50 - 70% of crops. Management of soil health, irrigation scheduling, nutrient balance and environmental monitoring and reporting requires a high level of management commitment.

Remarkable results:

Using treated wastewater for irrigation has diverted significant loads of nutrients from the sensitive Hawkesbury-Nepean River system.

To date, 99.8% of treated effluent from the Picton STP has been irrigated onto crops, and 100% of bio-solids used as soil conditioner. Treatment plant operators have managed to provide local farmers with high grade feed for their stock and maintain a very competitive pricing structure regardless of weather conditions. The past 2 years they have been suffering drought conditions but have kept our feed prices for locals well below stockfeed from other farms. The local waterways have shown a remarkable improvement in water quality.

***Information Sources*:**

Sydney Water Corporation
http://www.sydneywater.com.au/html/tsr/eirc/wastewater/upperhawkes.html
http://www.sydneywater.com.au/everydropcounts/leaks/water_reuse&recycling_program.cfm
http://www.sydneywater.com.au/html/environment/tsr/csgrp021.html-
http://www.sydneywater.com.au/html/tsr/eirc/specialobjectives/sewagetreatment.html
Information was also provided from the treatment plant representatives.

CASE 3: Willunga ASR project

Location:

McLare Vale region (Figure 59), Willunga, Australia.

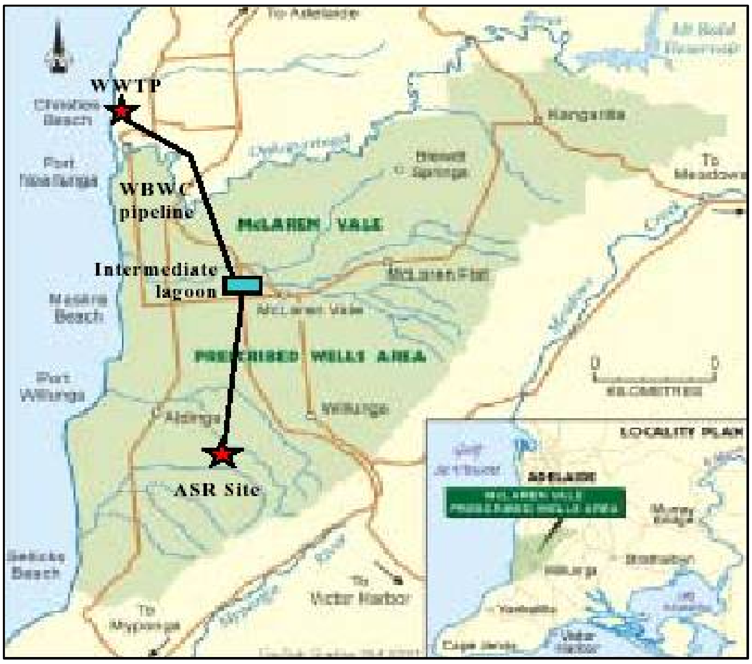

Figure 56. McLaren Vale region indicating the Willunga ASR trial site,
(Source: *Buisine* and *Oemcke*, 2004).

Year of the project development:

The Willunga ASR project is currently at the development stage for which pilot trials were completed in 2001.

***Water origin*:**

Domestic wastewater treated at Christies Wastewater treatment plant.

***Volume (or flow) of water affected*:**

9,500 megalitres/year.

***Water treatment before reuse (technologies/process applied)*:**

Secondary and/or Tertiary treatment (depending on the final use).

***Reclaimed water quality*:**

In Willunga, reclaimed water quality is suitable for restricted irrigation (Class B) after secondary treatment and disinfection at Christies Beach WWTP. However, Class A effluent is required by the EPA for ASR.

***Water reuse applications*:**

Irrigation of crops.

***Total area affected by irrigation*:**

1,550 ha.

***Types of products cultivated in irrigated areas*:**

Vineyards and olive trees

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Not data available.

***Problems founded in the start-up, development or final application of the project*:**

Biological and physical clogging were potentially serious issues.

Remarkable results:

These trials demonstrated the need for filtration to meet the system needs for Class A water provision via ASR in Willunga. It was demonstrated that the injected water quality had to be of a higher standard than Bolivar, due to quality differences and that conventional filtration is the most appropriate treatment technology. Furthermore, it was demonstrated the importance of an integrated water quality management strategy.

***Information Sources*:**

Buisine, F., Oemcke, D. Wastewater quality treatment and management for reuse in the Willunga ASR project. 4th International Symposium on Artificial Recharge of Groundwater (ISAR4), Adelaide, Australia (2002).

Selected cases in Kuwait

CASE 1: Wastewater treatment and human exposure control in Kuwait City

Location:

Kuwait City, Kuwait.

Year of the project development:

1976.

***Water origin*:**

Municipal wastewater, (Ardiyah, coastal villages and Jahra sewage treatment plants).

***Volume (or flow) of water affected*:**

150,000 m^3/day Ardiyah sewage treatment plant (secondary stage).
96,000 m^3/day coastal villages.
65,000 m^3/day Jahra sewage treatment plants.

***Water treatment before reuse (technologies/process applied)*:**

An activated sludge treatment plant was upgraded in the middle 1980s by the provision of tertiary treatment, consisting of chlorination, rapid gravity sand filtration and final chlorination

***Reclaimed water quality*:**

Typical composition of influent and effluent for the Jahra wastewater treatment facility are summarized in Table 53.

Table 53. Irrigation water quality of Ardiyah, coastal villages and Jahra sewage treatment plants.

Parameter	Effluent
Suspended solids	10 mg/L
BOD_5	10 mg/L
COD	40 mg/L
Cl_2 residual	about 1 mg/l after 12 hours at 20°C
Coliform bacteria	10,000 count/100 ml for forestry, fodder and crops not eaten raw, 100 count/100 ml for crops eaten raw

***Water reuse applications*:**

Irrigation.

***Total area affected by irrigation*:**

An 850 ha farm was established in 1975 by the United Agricultural Production Company (UAPC), under Government license, especially for the purpose of utilizing the treated wastewater.

The ultimate project design provides for the development of 2,700 ha of intensive agriculture and 9,000 ha of environmental forestry.

***Types of products cultivated in irrigated areas*:**

In 1975, only part of the area was under cultivation; with forage (alfalfa) for the dairy industry. However, aubergines, peppers, onions and other crops were grown on an experimental basis, using semi portable sprinklers and flood and furrow irrigation.

In 1985, the treated effluent supplied to the experimental farm and irrigation project was used to irrigate the following:

- Fodder plants - alfalfa, elephant grass, Sudan grass, field corn (maize), vetch, barley, etc.
- Field crops - field corn (maize), barley, wheat and oats.
- Fruit trees - date palms, olive, and early salt-tolerant vines (sprinklers were not used for fruit trees).

Vegetables - potatoes, dry onions, garlic, beet and turnip as well as vegetables which are to be cooked before consumption, such as egg plant, squash, pumpkin, cabbage, cauliflower, sweet corn, broad beans, Jews mallow.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Not available.

***Problems founded in the start-up, development or final application of the project*:**

The impact of treated effluent irrigated vegetables on the consumer has not been possible to assess because no segregation of vegetables produced in this way is effected in the market.

Remarkable results:

Agricultural workers dealing with sewage effluent are medically controlled as a pre-employment measure and given periodic (6 monthly) examinations and vaccinations. No outbreaks of infectious disease have occurred since this procedure began in 1976.

The yield of green alfalfa was 100 tons/ha per year and the total production from the agricultural irrigation project, using primarily treated sewage effluent, was 34,000 tons of vegetables and green fodder plants, including dehydrated alfalfa and barley straw. At this production level, a reasonable supply of some vegetables was made available to the local market, the total demand for green alfalfa for animals was satisfied and some of the needs for dehydrated fodder were met.

***Information Sources*:**

FAO. 1992. Wastewater treatment and use in agriculture, FAO irrigation and drainage paper, no. 47, Rome, Italy. Available in: http://www.fao.org/docrep/T0551E/t0551e0b.htm#9.1%20advanced%20wastewater%20treatment:%20california,%20usa, [Accessed Nov. 19, 2003].

Selected cases in Mexico

CASE 1: Wastewater reuse in Guanajuato

Location:

Guanajuato City, Mexico.

Year of the project development:

June, 2002.

***Water origin*:**

Municipal wastewater from Wastewater Treatment Plant in Guanajuato, Mexico.

***Volume (or flow) of water affected*:**

The expected sewage effluent from Guanajuato city is around 12,100 m^3/day.

***Water treatment before reuse (technologies/process applied)*:**

Activated sludge with chlorine treatment.

***Reclaimed water quality*:**

Table 54. Plant treatment design parameters.

Parameter	Unit	Influent	Effluent
TSS	mg/l	217	<60
BOD	mg/l	337	<60
Faecal coliforms	MPN /100 ml	6.2×10^6	<1000

Source: Aqua Orbi Ingenieros S.A. De C.V, 2001

***Water reuse applications*:**

Irrigation.

***Total area affected by irrigation*:**

140 ha.

***Types of products cultivated in irrigated areas*:**

The most common cultivated crop is alfalfa, and vegetables come next.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The operation cost of one cubic meter of treated water is 0.11 US$.

***Problems founded in the start-up, development or final application of the project*:**

The major potential impact of the water-treatment plant is the possible reduction in wastewater discharge in the river, if the treated water is sold to an industrial consumer outside the Guanajuato River sub-basin. However, this would lead to competition over the water. The position of the farmers is weak because only 30 to 40 ha have proper water entitlement. This impact is not affected yet, because of additional sources of urban wastewater entering into the river downstream of the treatment plant. Water users are more afraid about water-level reduction in the river than about nutrient reduction in the river effluent.

Remarkable results:

The existing concentration of nitrogen phosphorous in the effluent is enough to meet the nutrient requirements for alfalfa (the most common cultivated crop).

The expected water productivity in small-scale irrigation systems is only around 0.15 US$/$m^3$. A higher productivity could be reached, even up to 0.50 US$ /m^3, if more profitable crops like vegetables are cultivated.

The sludge would represent another important source of nutrients.

***Information Sources*:**

Paula Silva, 2002 Impact treatment plant wastewater irrigation Mexico, RUAF magazine no.8. Available from: http://www.ruaf.org/no8/33_mexico.html , [Accessed Nov. 26 2003].

Selected cases in Saudi Arabia

In the kingdom of Saudi Arabia the policy is to promote wastewater reclamation and reuse. The emphasis on the utilization of reclaimed wastewater is due to the lack of rainfall in this arid region.

CASE 1: Wastewater reuse in Dariyadh

Location:

Dariyah , Riyadh City, Saudi Arabia.

Year of the project development:

1982.

***Water origin*:**

Municipal wastewater, Riyadh Sewage Treatment plant (Manfouaha).

***Volume (or flow) of water affected*:**

Treatment plant treats and disinfects about 340,000 to 380,000 m^3/day of wastewater, while the treated wastewater pumped to Dariyah 80,000 m^3/day.

***Water treatment before reuse (technologies/process applied)*:**

Treatment plant provides full biological treatment and chlorination. Plans have been completed to provide advanced treatment by rapid-gravity sand flirtation. Plans have also been executed for the construction of another wastewater facility of 200,000 m^3/day.

***Reclaimed water quality*:**

Typical composition of influent and effluent for the Riyadh wastewater treatment facility are summarized in Table 55.

Table 55. Effluent quality of Riyadh Sewage treatment plant.

Parameter	Unit	Influent	Effluent
Total dissolved solids	mg/l	1300	1200
Suspended solids	mg/l	250	46
BOD_5	mg/l	250	45
COD	mg/l	450	100
Phosphates	mg/l	10	7
Chlorides	mg/l	180	160
Alkalinity	mg/l	240	200
Temperature	C^o	29	27
pH	-	7.3	7.4
Dissolved oxygen	mg/l	0	5
Total Coliform	Count/100ml	million	50-100/100ml

The tentative water quality criteria with restriction for irrigation:

BOD_5	10 mg/l
TSS	10 mg/l
Average Faecal Coliform standard	2.2 count /100 ml over 7days period.

***Water reuse applications*:**

Irrigation.

***Total area affected by irrigation*:**

1800 ha, (estimations).

***Types of products cultivated in irrigated areas*:**

Crops being irrigated with wastewater at Dariyah are: date palms, fruit trees, vegetables and fodder.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Not available.

***Problems founded in the start-up, development or final application of the project*:**

Not mentioned.

Remarkable results:

The evaluation of Riyadh treated wastewater and the well water used for irrigation at Dirab and Dariyah indicated that in general, the Physical and Chemical characteristics of Riyadh treated wastewater is as good as or better than the ground water, except for turbidity and suspended solids.

While the NH_3 and $PO4^-_3$ concentration found in the treated wastewater were well above those found in the groundwater. These constituents are essential plant nutrients and contribute to plant growth, and thus are beneficial when the water is to be used for agricultural irrigation.

***Information Sources*:**

Donald R.Rowe & Isam Mohammed Abdel-Magid, Wastewater reclamation and reuse, 1995.

Selected cases in USA

CASE 1: Wastewater reuse in Boca Roca, Southern of Florida

Location:

Boca Roca, Southern of Florida. The population of Florida was 13 million in 1990, and is estimated to be 17 in 2005 with around 40 million vacationers comes to the state each year. Hence it is considered a tourist zone.

Year of the project development:

1991

***Water origin*:**

Municipal wastewater.

***Volume (or flow) of water affected*:**

Total volume	45,000 m^3/day
Tertiary treatment	10,000 m^3/day
Secondary treatment	30,000 m^3/day

***Water treatment before reuse (technologies/process applied)*:**

The preliminary treatment consists of fine screening, grit removal and primary clarifiers, the secondary treatment is a biological treatment that employs the activated sludge process which is used in combination with secondary clarifiers.

The secondary treated effluent is disinfected by chlorination. About 20-30% of the secondary treated effluent is given advances or tertiary treatment (two automatic backwash filter).

***Reclaimed water quality*:**

Table 56. City of Boca Raton Water Reclamation Facility.

Parameter	Unit	Min	Max	Avg.
TSS	mg/l	0.5	0.9	0.5
CL_2 (resid)	mg/l	2.5	3.8	3.3
Turbidity	NTUs	0.39	0.73	0.55
Faecal Coliform	count/100(max)	0	1	-
CL_2 DOSE	mg/l	14	19	16
NO_2^-	mg/l	0.1	0.8	0.3
NO_3^-	mg/l	1	5.2	3
BOD_5	mg/l	4.5	7.5	3

pH not less than 6.0 standard units or greater than 8.5 standard unit. Over a thirty days period, 5 percent of Faecal Coliform values shall be below the detection limits, any tested sample shall not exceed 25 Faecal Coliform values per 100 ml.

***Water reuse applications*:**

Tertiary treatment is used for in-plant purposes as well as for landscape irrigation at Florida Atlantic University.

Secondary treated effluent that has not been given advanced or tertiary treatment is then pumped through 8 km long out fall terminating about 1.5 km off shore in the Atlantic Ocean at a depth of 27 meters.

***Total area affected by irrigation*:**

Data not available.

***Types of products cultivated in irrigated areas*:**

Landscape irrigation.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The final estimated cost of the project has been divided into three main categories:

The reclaimed water production and distribution facilities	10,000,000 US$
The reclaimed transmission main system	15,000,000 US$
The reclaimed water distribution mains	15,000,000 US$
Estimated total cost (in 1990 in US dollars)	40,000,000 US$

***Problems founded in the start-up, development or final application of the project*:**

Not available.

Remarkable results:

The urban wastewater reclamation and reuse project is beneficial in many ways, such as:

- Reduces the demand for valuable groundwater, which is suitable for drinking water purposes.
- Eliminates surface water discharge to the Atlantic Ocean.
- Saves approximately 7.7 to 8.7 million US$ investment in development of water . supply wells and expansion of the Boca Raton water treatment facility.
- Contributes to groundwater recharge.
- Allows for multiple use of reclaimed water.
- Provides aesthetic value by contribution to keep the landscape fresh and green.

***Information Sources*:**

Donald R.Rowe & Isam Mohammed Abdel-Magid. Wastewater reclamation and reuse (1995).

CASE 2: Wastewater reuse in Monterey, California

Location:

California, The Monterey Wastewater Reclamation Study for Agriculture (MWRSA) was designed to evaluate the safety and feasibility of irrigating food crops (many eaten raw) with reclaimed municipal wastewater (experimental study).

Year of the project development:

1980.

***Water origin*:**

Domestic wastewater.

***Volume (or flow) of water affected*:**

Secondary effluent from the 1500 m^3/d (0.5 Mm^3/yr) Castroville wastewater treatment plant of the Monterey Regional Water Pollution Control Agency was upgraded in a pilot tertiary reclamation plant before being used to irrigate the plots.

***Water treatment before reuse (technologies/process applied)*:**

Two parallel tertiary treatment processes were used, complete treatment in a 'Title 22' (T-22) process and a direct filtration process, termed the 'filtered effluent' (FE) process. The T-22 train included coagulation, clarification, filtration and disinfection, the full treatment process required for spray irrigation of food crops in the Wastewater Reclamation Criteria of California. Alum dosages of 50 to 200 mg/l and polymer dosage of 0.2 mg/l were applied in this process. In the FE process, low alum dosages between 0 and 15 mg/l and polymer dosages from 0 to 0.18 mg/l were applied with a combination of either static or mechanical rapid mixing and dual-media gravity filtration at 3.4 l/m^2s. The chlorine contact tank had a 90 minute theoretical retention time.

***Reclaimed water quality*:**

Effluents contained very low levels of heavy metals, an order of magnitude lower than the metal input from impurities in commercial fertilizers. Both T22 and FE processes were capable of producing reclaimed wastewater that meets the most stringent California Wastewater Reclamation Criteria (2.2 MPN coliforms/100 ml) most of the time. *Ascaris lumbricoides, Entamoeba histolytica* or other parasites were never detected in any of the irrigation waters. During the five years of field study, the quality of reclaimed effluents from T22 and FE processes have improved as a result of better treatment plant operations and reclaimed water storage procedures.

Table 57. Effluents to Monterey wastewater treatment.

Parameter	Secondary	Tertiary
Turbidity	not reported	1.8 NTU
Giardia	6.1/1,000 ml	0.06/l
Faecal coliform	596,000/100ml	0/100 ml
Salmonella	4/100 ml	0/100 ml
Cryptosporidium	0.38/1,000 ml	0/1,000 ml

***Water reuse applications*:**

Full scale farm practices using reclaimed municipal wastewater.

***Total area affected by irrigation*:**

Two 5 hectare experimental plots.

***Types of products cultivated in irrigated areas*:**

Artichokes were planted on one of the plots, while broccoli, cauliflower, lettuce and celery were grown on the other.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

The Monterey Wastewater Reclamation Study for Agriculture (MWRSA) was a 10-year, 7.2 million dollar field-scale project designed to evaluate the safety and feasibility of irrigating food crops (many eaten raw) with reclaimed municipal wastewater.

***Problems founded in the start-up, development or final application of the project*:**

Salinity of the reclaimed effluents was high (611-1,621 mg/l) but this situation did not produce significant soil permeability problems.

Remarkable results:

Results of this field-scale experimental study indicated that use of tertiary treated wastewater for food crop irrigation is safe and acceptable. No adverse impacts in terms of soil or groundwater quality degradation were observed. Conventional farming practices were shown to be adequate and the marketability of the produce did not appear to pose any problems. No project-related health problems were detected through medical examinations and the serum banking programme routinely conducted on the project personnel.

***Information Sources*:**

http://www.fao.org/docrep/T0551E/t0551e0b.htm#9.1 advanced wastewater treatment: California, USA

Sheikh,B., Cooper, R.C., Israel, K.E., Hygienic Evaluation of reclaimed Water Used to Irrigate Food Crops – A Case Study, http://www.watereuse.org/Pages/information.html.

CASE 3: Wastewater reuse in Tallahassee, Florida

Location:

Tallahassee, Florida.

Year of the project development:

1966.

***Water origin*:**

Domestic wastewater.

***Volume (or flow) of water affected*:**

3,800 m^3/hr (33.3 Mm^3/yr).

***Water treatment before reuse (technologies/process applied)*:**

Secondary treatment.

***Reclaimed water quality*:**

BOD: 20 mg/l
TSS: 20 mg/l
Faecal Coliform: 200/100 ml

***Water reuse applications*:**

Irrigation of crops.

***Total area affected by irrigation*:**

Until 1980 the system was limited to irrigation of 50 ha of land used for hay production, which since 1992 was expanded to a total area of 700 ha.

***Types of products cultivated in irrigated areas*:**

Corn, soybeans, coastal bermuda grass and rye. Corn and soybeans are sold. Both rye and bermuda grass are grazed by cattle, while some is harvested as hay.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Data not available.

***Problems founded in the start-up, development or final application of the project*:**

Not reported.

Remarkable results:

Treated wastewater has been used successfully for irrigation. Since 1966, extensive evaluation and operational flexibility have been key factors in the success.

***Information Sources*:**

http://www.hydro.ntua.gr/labs/sanitary/agricultural_reuse.htm#2.Agricultural%20Reuse%20in%20Tallahassee,%20Florida.

CASE 4: Wastewater reuse in San Francisco Bay area

Location:

Application of water reclamation and reuse in an urban/suburban environment by the Central Contra Costa Sanitary District (CCCSD), a wastewater collection and treatment public utility in the San Francisco Bay area.

Year of the project development:

The original idea of water reclamation in the CCCSD was conceived in the mid-1970s with the design and construction of a water reclamation facility which included tertiary filtration. After a hiatus lasting until the mid-1990s, the CCCSD began to plan for expansion of water reuse including modernization of the water reclamation facility and substantial extension of the reclaimed water distribution system. In 1998 the plant started to operate again.

***Water origin*:**

Domestic wastewater.

***Volume (or flow) of water affected*:**

Wastewater is treated in a full secondary treatment plant with the average dry weather wastewater flow of 1.7×105 m^3/d and the maximum flow during rainy seasons reaching 9.1×105 m^3/d.

***Water treatment before reuse (technologies/process applied)*:**

Wastewater passes through pretreatment, primary sedimentation, activated sludge and secondary sedimentation. Secondary effluent is disinfected by UV before the final discharge to the Suisun Bay, the upper part of the San Francisco Bay.

***Reclaimed water quality*:**

Not data available.

***Water reuse applications*:**

Mainly landscape irrigation. In addition, a large fraction of the reclaimed water is used internally in the main wastewater treatment plant.

***Total area affected by irrigation*:**

The actual annual water demand of the ten connected customers was, in 1998, 2.63·105 m^3/yr (213 acre-ft/yr) or 19% of the maximum potential. This ratio, achieved after only ten months of operation, is quite promising but it is obvious that the full demand will be reached only after a longer time. Two additional large customers, which were not initially identified, will be connected by mid-1999.

***Types of products cultivated in irrigated areas*:**

Landscape.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Distribution of internal process water consumes most energy. The second major energy use is for the treatment of reclaimed water while distribution of reclaimed water to external customers requires least energy.

***Problems founded in the start-up, development or final application of the project*:**

The goal of water reuse is often presented as a replacement of water withdrawn from other sources. In an urban environment, potable water provided by a utility is often the most common such source. In the case of the CCCSD reclaimed water customers, a majority of the potential customers (77% of the projected demand) obtained water from a local water utility which supplied them with two types of water: potable (at approximately 0.73 US$/$m^3$ or 900 US$/acre-ft) and untreated surface water (at half the price). Only 23% of water was supplied from other sources, mostly from individual wells and a small volume from an older reclamation facility. This situation required delicate negotiations between the CCCSD and the local water utility which was faced with a loss of revenue. Currently, among actually connected customers, only a smaller volume of potable (expensive) water has been replaced by the reclaimed water but future expansions will bring this sensitive issue for considerations.

Earlier attempts of water reuse were not successful because reclaimed water quality did not match the requirements of potential large customers.

As the reclaimed water is used by the external customers for landscape irrigation, its demand varied seasonally.

Remarkable results:

The project, which includes a water reclamation facility and a separate distribution system, is operated by a wastewater utility and reclaims approximately 4% of its dry-weather flow. Planning, and especially demand analysis, was critical for project development..

***Information Sources*:**

Hermanowicz, S.W., Sánchez Díaz, E., Coe, J. Prospects, problems and pitfalls of urban water reuse: a case study. Wat. Sci. & Tech., 43 (10), pp. 9-16, (2001).

CASE 5: Wastewater reuse in San Francisco, California

Location:

San Francisco, California (USA).

Year of the project development:

1992-1994.

***Water origin*:**

The City operates three wastewater treatment plants North Point (NPP), Southeast (SEP) and Oceanside Water (OWP). The first two plants treat all the flow from the Bayside of the City. NPP, which provides primary treatment only, is only used for treating wet weather flow in excess of SEP capacity. Secondary treatment in both plants is accomplished with pure-oxygen activated sludge systems.

***Volume (or flow) of water affected*:**

SEP provides secondary treatment for a design average daily flow of 323,000 m^3/d, with a maximum dry weather capacity of 537,500 m^3/d. Peak hydraulic capacity is 795,000 m^3/d. Analogous numbers for OSP are a design average daily flow of 79,500 m^3/d, a maximum dry weather capacity of 162,700 m^3/d, and a peak hydraulic capacity of 246,000 m^3/d.

***Water treatment before reuse (technologies/process applied)*:**

Three studies were conducted that investigated the following tertiary treatment systems:
S1: In-line filtration (ILF) followed by chlorination.
S2: Microfiltration (MF) followed by disinfection with ultraviolet light.

S3: In-line filtration followed by disinfection with ultraviolet light

***Reclaimed water quality*:**

Table 58 presents available feed water quality information.

Table 58. Feed water quality.

Parameter	S1	S2	S3
Turbidity (NTU)	2.1-9.8	4.4-9.7	3.9-10.0
TSS (mg/l)	17-47	18-44	15-33
Alkalinity (mg/l as $CaCO_3$)	170-215	175-210	175-200
pH	6.5-7.1	6.5-7.0	6.8-7.2
BOD_5 (mg/l)	8-15	8-26	13-21
TDS (mg/l)	1,210-1,570	1,150-2,930	285-590
Chloride ion (mg/l)	480-660	420-1,080	110-220
Total Coliform (x10 CFU/100 ml)	44-360	38-400	5.5-98

The three systems are capable of producing an effluent that meets the turbidity standard of less than 2 NTU.

Microfiltration produces an effluent virtually free of suspended solids and coliforms.

***Water reuse applications*:**

Landscape irrigation.

***Total area affected by irrigation*:**

Not data available.

***Types of products cultivated in irrigated areas*:**

Grass.

***Costs: total cost of the project; final cost of water reuse per cubic meter*:**

Table 59 presents the costs attributed to treatment only, for a 75,000 m^3/d average daily flow reclamation plant.The difference in costs between Microfiltration and in-line filtration is associated with construction costs, and O&M costs for the two options are comparable. Also, for this plant size (Q_{avg}=75,000 m^3/d), chlorine and UV disinfection are equally costly. For larger plants (Q_{avg}=75,000 m^3/d), UV disinfection is more economical than chlorine disinfection, as the economies of scale increase at a faster rate for UV than for chlorine-based disinfection facilities. For smaller plants, the higher construction costs of Microfiltration become less dominant, and microfiltration and in.line filtration can be implemented at equal costs.

Table 59. Feed water quality.

	In-line filtration	Microfiltration
Chlorine disinfection	185 €	n/a
UV Light disinfection	185 €	210 €

***Problems founded in the start-up, development or final application of the project*:**

Not problems reported.

Remarkable results:

In-line filtration followed by UV-disinfection is less costly for water reclamation than any other combination of treatment tested. On the other hand, microfiltration is a better barrier for viruses and coliforms than granular filtration.

***Information Sources*:**

Jolis, D., Hirano, R., Pitt, P., Müller, A., Mamais, D. Assessment of tertiary treatment technology for water reclamation in San Francisco, California. Wat. Sci. & Tech., 33 (10-11), pp. 181-192, (1996).

Problems associated with reclaimed water reuse projects

Successful development of a water reclamation and reuse project requires careful planning and depends on many factors, not all of which are under the control of project owner or manager. Identification of large customers of reclaimed water and a realistic assessment of their water demand is crucial for project development. Water quality requirements of all customers must be evaluated. If these requirements cannot be met, especially for large potential customers, project feasibility is questionable as shown the experience of the Central Contra Costa Sanitary District (CCCSD), a wastewater collection and treatment public utility in the San Francisco Bay area (*Hermanowicz et al*., 2001).

Large customers should be connected as early as possible to provide both the revenue and the support for project completion. By early connections of the largest customers, the CCCSD achieved a potential for almost 20% of the projected water demand. Both short-term and long-term demand for reclaimed water is highly variable. Project viability may be adversely affected by counting on the project water demand that did not materialize. Collaboration with other reclamation and reuse projects may be an important factor in achieving a “critical mass” in dealing with stakeholders. Linking the CCCSD project’s distribution system to a reuse project of another utility provided a great degree of flexibility and a possibility of additional revenue.

In the planning process, existing sources of water supply for the potential customers must be considered. If a substantial consumption of water is to be replaced by the reclaimed water, cooperation of water suppliers is needed to mitigate their revenue losses. In the case of the CCCSD project, 44% of reclaimed water demand by connected customers was previously supplied by a local water utility but if all potential customers are eventually connected this value would rise to 77%. During actual operation, it is difficult to disaggregate both costs and energy consumption but such an effort should be undertaken to provide clear estimations for different parts of the whole project. In this project, the largest fraction of energy was consumed for the distribution of plant process water. Energy consumption for external distribution was relatively small. It seems that the revenue collected from the external customers could cover at least the energy costs of major pumps.

Another problem associated to wastewater reclamation is that the real cost of the projects are usually considerably higher than the estimated previously. This is in large part a result of insufficient planning before design and construction of water reclamation projects. While technical, environmental and social factors are considered in project planning, monetary factors tend to control the ultimate decisions of whether and how to implement a wastewater reuse project. The objective of conducting economic analyses of wastewater reuse projects is to quantify impacts on society, whereas financial analysis are targeted on the local ability to raise money from project revenues, government grants, loans and bonds to pay for the project.

There are a variety of problems that can be encountered related to potential reclaimed water users, estimating the amount and timing of reclaimed water demands, institutional arrangements, and other factors that should be anticipated and resolved during planning. As evidence of this, one can look at the amount of time it takes for implementation of a project after an agency perceives it has finished with planning and is ready to begin the project design).

The main objective when treated wastewater is reused in agriculture, is to make sure that the good produce will be of the same quality as when it is produced directly with freshwater.

The technical difficulties are linked to the problems to be solved. However, they are solutions or possible solutions for most of them.

The oldest problem is the presence of pathogens in water. Technically, there are many solutions: chlorinate UV radiation, stabilisation ponds or membranes, whose cost is the main driving factor. Another problem is the chemical contaminants or heavy metals. This challenge can be dealt with by further treatment or by adding a 3rd treatment phase in the WWTP, e.g. membrane filtration.

Another problem is the method used to apply the treated wastewater. Indeed some techniques can increase and propagate pathogens over distance around fields. On the other hand, the cost in term of technology and manpower is also very different. The Table 60 summaries for the different methods, the risk and the cost associated.

Table 60. Risk versus Cost for different application methods.

Method	Risks	Costs
Sprinkler	Cover the vegetables even for trees. Generate aerosols.	Controllable water consumption. Low labour cost. Low technological cost.
Dripping	Minimal.	Low water consumption. Low labour cost. High technological cost.
Flooding	Large area covered.	Large water consumption. Low labour costs.

Source: *Junger*, 2000

The socio-economical aspect of the reuse of water in agriculture is probably the most important and most difficult to solve. Research is this area is undoubtedly required as well as communication towards the public.

Costs of the water vs traditional sources: The cost of water has to be acceptable for farmers. If the burden imposed makes the water more expensive to use the traditional water, the possibility of promoting the practice will be seriously jeopardised. Therefore further research is required to understand what are the quality of water required for different type of agriculture. Also new technique or cheaper technique (e.g. micro filtration) to produce clean water needs developing.

Social acceptance (farmers, retailers and consumers): With recent events, the food safety has to be seriously considered. This is the most sensitive area of this topic. Farmers are not going to reuse water, if their product cannot be sold. Consumers will not buy products where reuse water was used unless it is proven to be safe. The example of the UK for addressing the similar problem of the sludge reuse, should be mentioned. The British government has set-up a working group to investigate the possibility of reusing sludge in agriculture. The group included people from the environment ministry, farmer's associations, water companies and retailer associations. The group had to produce guidelines for sludge treatment required for the different areas in agriculture in which sludge could be used. The overall result was guidelines accepted by all. Obviously to maintain consumer confidence, monitoring mechanisms has to be installed to maintain sludge quality controls, but also to monitor any new problems not foreseen earlier.

In general, many problems can be encountered by reclamation projects, some of which are peculiar to water reclamation and others that are common to all projects. Some typical problems that can be founded, are the following (extracted from *Mills* and *Asano*, 1996):

Permit approvals:

Certain approvals from country, state or federal agencies should be obtained before commencing planning, because the conditions issued with the approvals can affect the overall feasibility of the project, the location of facilities or design criteria. Permits approvals from regulatory agencies should be sought early in the planning process. It should not be assumed that approvals will be automatic and routine. Even if regulatory agencies cannot provide approval until the completion or planning or even design, meeting with regulatory officials early during planning can alert project planners to potential problems and the approval procedures. Necessary information required by regulatory agencies can be gathered during planning to expedite approval at the appropriate time. Water reclamation projects particularly involve regulatory agencies responsible for water quality, wastewater discharges, public health and water rights.

Reclaimed water market:

Securing water users for a project is the single most critical factor to the success of a reclamation project and raises a number of unique issues. This has proven most troublesome on practically every project because a change in the conception could result in months of delay. Not only must a potential reclaimed water market be identified for planning purposes, there must be some assurance that particular users intend to purchase reclaimed water (or at least, to use this water) before embarking on design and construction of facilities to serve them. It is common to receive very favourable interest from potential users in using reclaimed water during early planning. The closer one approaches to securing a firm commitment from a potential user, the more that obstacles seem to become apparent. From the user viewpoint, issues on water quality, water price, cost of conversion to reclaimed water (retrofit costs), reliability of supply and liability are the major concern.

Retrofits costs are a major factor than are often neglected by agencies because they are often expected to be minor and to be borne by the reclaimed water user. From the reclaimed water supplier viewpoint, the cost for pipelines and facilitates for the individual service and the amount of reclaimed water demand are analysed more critically as the time approaches to establish a firm market. A systematic approach to assessing the potential reclaimed water market and securing users, while not foolproof, will provide the greatest assurance of success. Several useful references are available for advise on doing a reclaimed market assessment, identifying issues of concerns to users, and securing user contracts.

Reliable data:

It is essential that reliable data be obtained on the amount of wastewater flows that will available for reuse, the potential reclaimed water demands, and the monthly, daily and hourly variation in these flows and demands. Excessive estimates of available wastewater flow may also lead false expectations of the amount of reclaimed water that can be delivered. The variations in available flow and water demand are also very important. While on a monthly basis wastewater flows tend to be stable if there are not seasonal population changes, irrigation water demands are quite variable. Peak irrigation demands can occur is summer. It may be necessary to use a source of fresh water to augment the reclaimed water supply during the summer months.

Because of the high cost in urban areas of seasonal storage of reclaimed water, it is usually not possible to use all the winter wastewater flows. To use a higher percentage of winter flows, the summer peak demands may exceed water supply. While this concept of design captures more reclaimed water, it must be recognized that the supplemental fresh water added in the summer does not replace fresh water. The project justification must clearly distinguish between the amount of water demand connected to a system and the amount consisting of reclaimed water. Hourly variations are also important. Landscape irrigation tends to occur at night to avoid contact with people, while wastewater flows are at their lowest level. Without proper system design, supply and demand cannot be matched.

While textbook factors may be suitable for preliminary project planning, before design, should be based on measured data whenever possible. Hourly treatment plant flow data should be obtained. Three years of actual monthly water use records should also be used as a basis for estimating reclaimed water demand, adjusting the past water use to the account for uses that cannot be served with reclaimed water. Estimates of water use for users and even retail water agencies tend to be unreliable unless verified with actual records. Water use patterns over the typical course of a day, week and season should be obtained directly from users.

The tendency for engineers to be conservative in design criteria can be misleading for certain planning criteria. Estimating water demands on the high side is not appropriate for evaluating economic justification and financial feasibility of a project and leads to false expectations.

Institutional issues:

Water reclamation projects involve encounters between wastewater agencies and water agencies, between reclaimed water purveyors and potable water purveyors, between wholesale reclaimed water suppliers and retail reclaimed water distributors. Even while intending to be cooperative, each agency has it own interest to protect. Unfortunately, at times, for political reasons of previous negative encounters, cooperation is not always offered. It is a mistake to assume that because water reclamation seems to be in the public interest, that all of the necessary players in a project have the same motivation to ensure its success.

Service of reclaimed water without the jurisdiction of a freshwater purveyor can lead to these conflicts of service duplication, unless early in planning a cooperative agreement is sought with the willingness to share revenue in an equitable manner.

It can be concluded therefore that social issues play a significant role in water reuse initiatives and should be adequately addressed. With adequate political will accompanied by awareness programmes these cultural, religious and social objections can be overcome.

On the other hand, we are facing a situation where economic activities are declining, leading to political instability and environmental degradation in many developing countries. In many situations, water resources are limited and the water quality is deteriorating, particularly in the case of Africa and South Asia. Water pollution issues, however, are not the main concern because other issues are more pressing such as national or racial security, food availability and epidemic control.

In general, the problems in these developing countries can be summarised as follows (*Ujang* and *Buckley*, 2002):

• Lack of environmental awareness among the majority of policy makers and the general public create a situation where water and wastewater management sectors are perceived to be less important than to other sectors such as military empowerment, road improvement, electricity, mass education and health care facilities.

• Insufficient expertise, leading to gaps between ideal policies and implementation.

• Inappropriate policies on the conservation of water resources such as no legal requirement for prohibition of deforestation activities in water catchment areas.

• Insufficient funding for water supply and sanitation programmes because of competing public expenditures due to rapid urbanization and population growth rate.

• Insufficient water resources especially in arid and urban areas.

• Inappropriate management systems and institutional support for providing water supply and sanitation facilities.

Good reuse practices

When a wastewater reclamation and reuse system is operating, it is necessary to take into consideration a code of good practices in order to avoid any possible problem related to the use of this water. In the Table 61, some of these good practices are summarized.

Table 61. Suggested measures for good reuse practice, (Adapted from CEDEX, 2001).

GOOD PRACTICE	Observation
Reclaimed wastewater must only be reused for the uses for which permit was issued.	Other (non-mentioned uses are not allowed unless an extension of the permit is granted.
When reclaimed water quality does not meet the fixed standards, reuse must cease.	
Sprinkler irrigation should not take place in strong winds.	Define wind speed limit.
Quality monitoring and process controls should be supported.	
Parameters and conditions to be controlled in wastewater reuse facilities	
Control heavy metals (Cd, Mo, Se) and Boron contents.	Limits: 1mg/1<B<2mg/1 Cd <0,01mg/1 Mo<0,01 mg/1 Se<0,02 mg/1 To discuss the heavy metals to be included and the concentrations
Relative situation of groundwater and surface water.	Establish the distances.
Soil slope.	Define the figure (<15%).
Runoff.	Do not allow runoff from the reuse site.
Irrigation type.	Define for each use the types not allowed.
Characteristics of wastewater reclamation facility.	Define this in the permit.
Origin of wastewater.	Not from hospitals or similar.
Sludge quality.	When sludge contains heavy metals, check the reclaimed wastewater.
Grazing animals.	Define the animals that are allowed.
User.	Training/education plan.

(continued)

GOOD PRACTICE	Observation
Protection of Public Health and Environmental Quality	
Optimise performance of the filtration process to maximize the effectiveness of disinfection.	
Routine inspections of reclaimed water facilities, including facilities located on the property of end users.	Ensuring that reclaimed water is used in accordance with state and local requirements.
Recognition that distribution of reclaimed water for non-potable uses could potentially come into contact with the public, and that such contact could have consequences for public health.	
Compliance with all applicable requirements for water reclamation, and storage, transmission, distribution, and reuse, of reclaimed water.	
Provision of reclaimed water that is safe and acceptable for the intended uses when delivered to the end user.	
Reuse System Management	
Adoption of a “water supply” philosophy oriented toward reliable delivery of a high-quality reclaimed water product to the users.	
Recognition that reclaimed water is a valuable water resource.	
Promotion of these practices in cooperation with the Department of the Environment, the users, the public and other local and regional agencies.	
Development of response plans for unanticipated events, such as inclement weather, hurricanes, tornadoes, floods, drought, supply shortfalls, equipment failure, and power disruptions.	
Preparation and implementation of a preventative maintenance plan.	
Continuous improvement of all aspects of water reclamation and reuse.	
Public Awareness	
Provision of signposting to advise the public about the use of reclaimed water and to provide effective written notification to the end users of reclaimed water concerning the origin, nature, and proper use of reclaimed water.	
Education for the public, schools, and other agencies concerning the need for water conservation and reuse, reuse activities in the state and local area, and environmentally sound wastewater management reuse practices.	
Establishment of a specific colour for all equipment, facilities and distribution systems.	

Selection of wastewater reclamation facilities

As it has been said before, in recent years, the water demand has increased dramatically, at the same time the volume of safe water has decreased. Hence the demand to use the water effluent of wastewater treatment plan. In fact the practice is expanding quickly all over the world. Although mainly southern European countries are practising it, northern countries are also thinking if not already applying it too. Even though this practice is not new, and goes back some centuries, it has to be done safely. Public health and food safety requires setting safety standards to minimise potential problems, but also to gain public acceptance when practised (*Junger*, 2000).

A number of parameters should be considered when choosing the appropriate technology. These can be grouped as economic, institutional and political, climatic, environmental, land availability /properties, sociocultural, and other local ones. Once these factors have been taken into account the most cost-effective system should be selected, unless the population being served is willing to pay more (*Tsagarakis et al.*, 2001b).

To screen these processes, three major levels of analysis should be undertaken (Figure 57). Firstly, the required effluent quality should be considered. Then a number of aspects that could restrict the applicability of some processes should be examined. Finally, a cost effectiveness analysis should be undertaken so that the optimum economically viable solution can be identified. For developing countries, the criterion of required effluent quality is considered after the other two criteria.

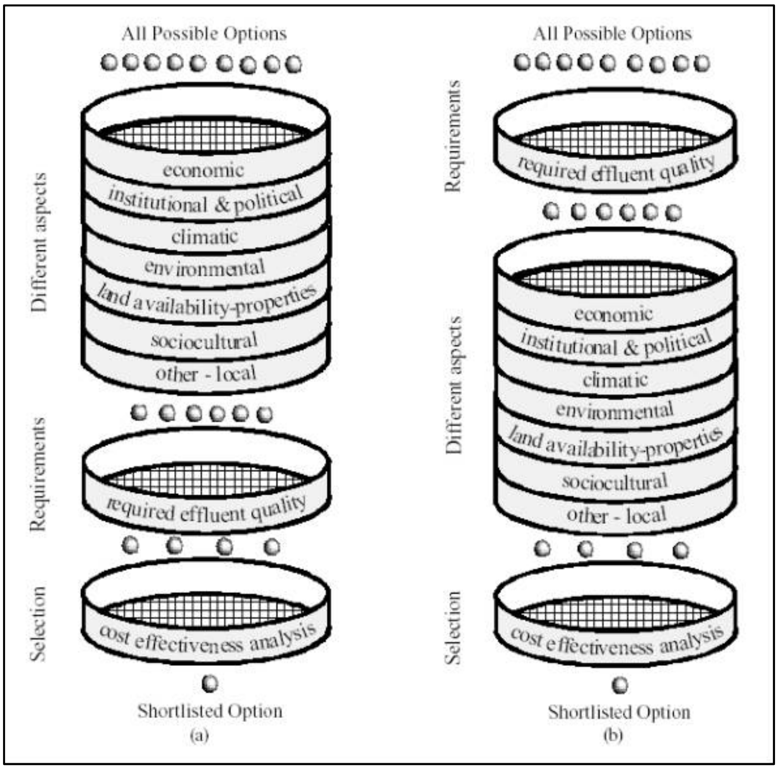

Figure 57. Considerations when “screening” alternative processes for (a) developing and (b) developed countries (Source: *Tsagarakis et al.*, 2001).

The tender procedure comes at the end of this screening process. Materials, deadlines and the responsibilities of the constructor are prescribed and can influence the plant's future. A major factor is the method of tendering and what stages of the project are included in the tender. Recent practice in Greece has been to invite tenders for both design and construction of municipal WWTP at the same time, with one company undertaking both. In the past design and construction were considered separately. Where design and construction are considered together, advantages can accrue: the overall duration of the project decreases, more effective monitoring is possible, it is easier to make adjustments to account for developments in technology and consequently improve the quality of the project. Some of the important factors to be considered are discussed in more detail below (*Tsagarakis et al.*, 2001b):

Economic. It is of prime importance to take into account the economic status of the country and the municipality in question. The more developed a country is, the greater is its concern for environmental issues. The ability of the inhabitants to pay operation and maintenance costs is not the same everywhere.

Institutional and political. It is very important for the state to be able to control the design, construction and operational efficiency of all wastewater treatment plants. There is no point in imposing any kind of effluent requirement or adopting the most advanced technology for wastewater treatment if there is no mechanism to ensure maximum efficiency. It is therefore important to predict whether a proposed technology can be supported by the institutions. Appropriate legislation needs not only to be developed, but also implemented. This will require adequate funding. Political interference has been reported regarding site selection and other aspects of municipal WWTP construction and operation. Those municipal WWTP that are supervised by specialised agencies generally operate well. Putting MWTP in the hands of non-technical and non-specialised agencies has led to problems and poor performance. Most of the time, the causes of poor performance are non-technical and the majority of them could have been avoided by better administration of the plants' construction and operation.

Climatic. Climatic conditions can influence the dimensions of the units and the efficiency of the processes. Temperature is the crucial parameter, but moisture, wind direction and strength, and other factors can be important for some processes. Therefore, it is important that the design engineer considers climate before applying a technology that has been proved reliable under conditions that are not the same as those pertaining locally. Historical data should be examined.

Environmental. The impact of noise, odours, insects, visual and landscape distortions should be assessed. Scenic areas should not be interfered with without appropriate consideration. Where wastewater has to travel long distances at low speeds, septic conditions can develop. Thus preliminary treatment units such as screens and grit chambers often release odours. Care should be taken to house these units in buildings to avoid environmental nuisance. Nowadays, odour control is particularly important.

Land availability and its properties. The availability of land is a major consideration when determining wastewater treatment strategies. If systems that demand large areas of land are being considered, it is vital to ensure that the required amount of land is available on the proposed site. Availability of land for future expansion of the plant should be considered as well. The properties of land are also very important and should be well defined beforehand.

Topography: For each proposed MWTP the local topographic characteristics of the area should be considered. While land in hilly and mountainous terrains is relatively cheap, extra costs might be incurred because of the volume of earthworks necessary and the cost of pumping raw wastewater.

Geology: Geohydrology has to be considered for individual cases when there are plans for water table recharge or irrigation with treated effluent. The water table should also be examined: if it is too high, provision needs to be made to drain the base of the installation. The load-bearing properties of the soil should be considered. When planning the construction of a waste stabilisation pond, potential difficulties of removing earth should be taken into account. In general terms, rocky areas do not favour natural systems.

Coastal installations: It should be assumed that corrosion will occur and non-corrosive materials should be used. In addition, possible effects of wind on the transportation of viruses from aeration tanks should be considered. Surface aeration is not recommended for installations close to bathing beaches.

Water resources: The required effluent quality is determined by the proposed disposal method for the effluent. For instance, if the effluent is intended for irrigation, stricter criteria apply for microbiological content, which will require additional treatment.

Sociocultural. There are many social and cultural aspects of both MWTP workers and the population being served by the installation that can have a direct influence on the efficient operation of the plant. For example the quality and efficiency of the personnel employed in the MWTP has to be considered by decision makers. Relevant factors relating to the local population include such things as the use of large quantities of olive oil in cooking, a significant proportion of which may find its way into the waste stream. Or the fact that deposits other than human waste will be put into toilets – paper and cigarettes for example. During community celebrations, such as a festival or marriage, many animals may be slaughtered to feed hundreds of people – the high levels of blood entering the sewers could cause biological shock to the waste treatment facility. In agricultural communities the population should be educated to understand that washing agricultural instruments contaminated with pesticides or herbicides could cause these harmful substances to enter the sewage system.

Cost-effectiveness analysis for the best choice of system. After considering all the aspects mentioned above, plus any other relevant factors that relate to local circumstances, the best option for a wastewater treatment system will be selected from a shortlist. To make the final selection a technique based on cost effectiveness should be undertaken. This technique should employ properly evaluated life cycle costs, taking into account the capital cost for planning and construction, the costs of operation and maintenance and the value of the land used.

Table 62. Processes and operations used in wastewater reclamation.

Process	Description	Application
Solid/liquid separation		
Sedimentation	Gravity sedimentation of particulate matter, chemical floc and precipitates from suspension by gravity settling.	Removal particles from wastewater that are larger than about 30 μm. Typically used as primary treatment and downstream of secondary biological processes.
Filtration	Particle removal by passing water through sand or other porous medium.	Removal of particles from wastewater that are larger than about 3 μm. Typically used downstream of sedimentation (conventional treatment), or following coagulation/flocculation.
Biological treatment		
Aerobic biological treatment	Biological metabolism of wastewater by microorganisms in an aeration basin or biofilm (trickling filter) process ..	Removal of dissolved and suspended organic matter from wastewater.
Oxidation pond	Ponds with 2 to 3 feet of water depth for mixing and sunlight penetration.	Reduction of suspended solids, BOD, pathogenic bacteria and ammonia from wastewater.
Biological nutrient removal	Combination of aerobic, anoxic and anaerobic processes to optimise conversion of organic and ammonia nitrogen to molecular nitrogen (N_2) and removal of phosphorous.	Reduction of nutrient content of reclaimed wastewater.
Advanced treatment		
Activated carbon	Process by which contaminants are physically absorbed onto the surface of activated carbon.	Removal of hydrophobic organic compounds.
Air stripping	Transfer of ammonia and other volatile constituents from water to air.	Removal of ammonia nitrogen and some volatile organics from wastewater.
Ion exchange	Exchange of ions between an exchange resin and water using a flow through reactor.	Effective for removal of cations such as calcium, magnesium, iron, ammonium and anions such a nitrate.
Chemical coagulation and precipitation	Use of aluminium or iron salts, polyelectrolytes, and/or ozoner to promote destabilization of colloidal particles from reclaimed wastewater and precipitation of phosphorous.	Formation of phosphorous precipitates and flocculation of particles for removal by sedimentation and filtration.
Lime treatment	Use of lime to precipitate cations and metals solution.	Used to reduce scale forming potential of water, precipitate phosphorous and modify pH.
Membrane filtration	Microfiltration, nanofiltration and ultrafiltration.	Removal of particles and microorganisms from water.
Reverse osmosis	Membrane system to separate ions from solution based on reversing osmotic pressure differentials.	Removal of dissolved salts and minerals from solution; also effective from pathogen removal.
Disinfection	The inactivation of pathogenic organisms using oxidizing chemicals, UV light, caustic chemicals, heat or physical separation processes (e.g. membranes).	Protection of public health by removal of pathogenic organisms.

Source: *Asano*, 1998

The selection of wastewater reclamation facilities is dependent upon specific treatment objectives and desired effluent quality. The destination for the effluent is a critical factor in the choice of technology for waste treatment. The simplest treatment system involves solid/liquid separation processes and disinfection whereas more complex treatment systems involve combinations of physical, chemical and biological processes employing multiple barrier treatment approaches for contaminant removal. An overview of the major technologies that are appropriate for wastewater reclamation and reuse systems is shown in Table 62.

The basis for treatment process selection is described below as a function of final effluent quality characteristics. Based on a review of the literature (*Asano*, 1998) treatments flow diagrams have been developed for various process configurations that will produce a specific effluent quality. Wastewater reclamation treatment flows diagrams have been selected based on their ability to produce reclaimed water of the quality required to meet the end-use criteria enumerated in Table 63. The treatment processes selected for analysis are summarized in Table 64.

Table 63. General treatment required for various water reuse alternatives.

Reuse alternative	Treatment required
Agricultural food crop	Secondary treatment, filtration and disinfection
Fodder, fibre and seed crops, orchards and vineyards	Primary treatment
Pasture for milking animals	Secondary treatment and disinfection
Golf course, cemetery, freeway median and greenbelt irrigation	Secondary treatment and disinfection
Parks, playgrounds and schoolyard irrigation	Secondary treatment, filtration and disinfection
Restricted recreational impoundments	Secondary treatment and disinfection
Non-restricted recreational impoundments	Secondary treatment, filtration and disinfection
Landscape impoundments	Secondary treatment and disinfection

Source: Adapted from *Asano* et al, 1998

Table 64. Summary of reclamation treatment processes.

Number	Flow Diagram
1	Primary treatment
2	Conventional activated sludge
3	Combined trickling filter and activated sludge
4	Extended aeration
5	Secondary treatment plus flocculation-coagulation and filtration
6	Secondary treatment plus direct filtration
7	Secondary treatment plus contact filtration
8	Secondary treatment plus contact filtration and phosphorous removal
9	Five stage process (EIMCO)
10	Secondary treatment plus contact filtration and carbon adsorption
11	Secondary treatment plus contact filtration and carbon adsorption plus reverse osmosis
12	Secondary treatment plus lime treatment and reverse osmosis

Source: Adapted from *Asano* et al, 1998

The flow diagrams have been developed based on an increasing level of treatment, with the lowest quality effluent produced from Treatment Flow Diagram number 1, primary treatment, and the highest quality effluent available from Treatment Flow Diagram number 12, secondary treatment plus lime treatment and Reverse osmosis.

Detailed flow diagrams for the treatment processes summarized in Table 64, are presented in Figures 59 through 69. Within each flow diagram, unit processes have been configured based on their inter-changeability in other flow diagrams. As an example, conventional activated sludge (Treatment Flow Diagram number 2) is compared to extended aeration (Treatment Flow Diagram number 4) and therefore, can be substituted, if desired, for extended aeration in the various filtration alternatives. In this manner, by creating a matrix of individual comparable components and developing a basic cost comparison of unit processes, both the cost and overall treatment flow diagrams and incremental increases in treatment can be evaluated.

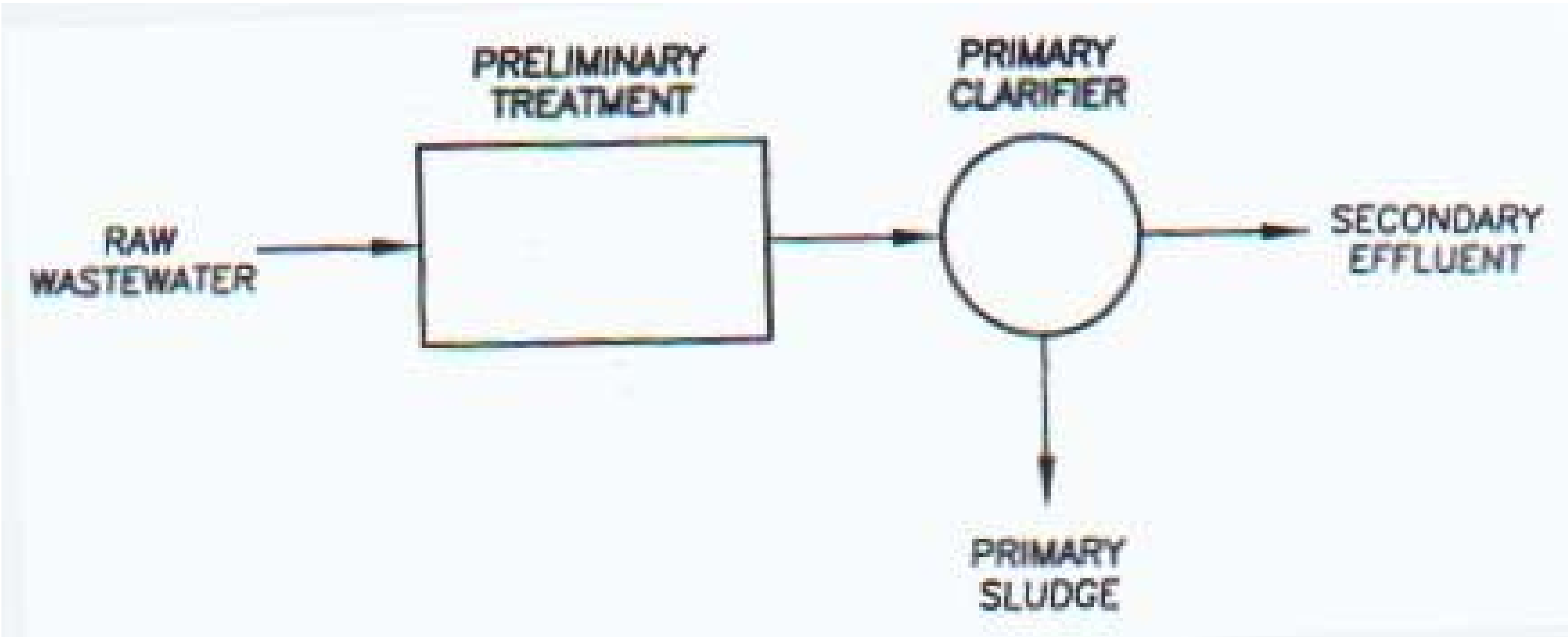

Figure 58. Treatment flow diagram number 1: primary treatment.

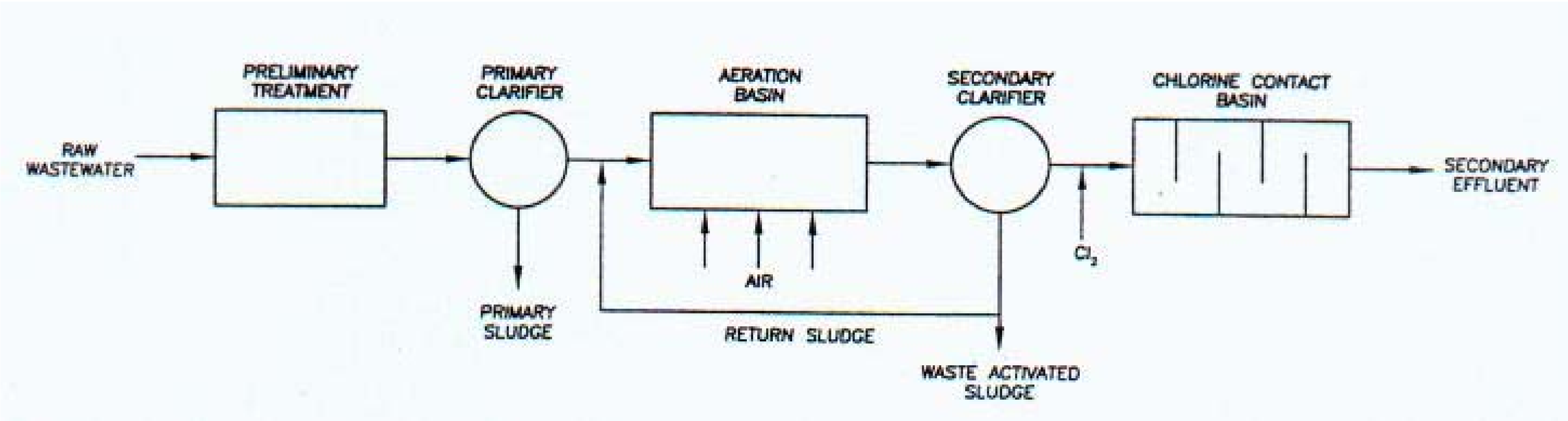

Figure 59. Treatment flow diagram number 2: conventional activated sludge.

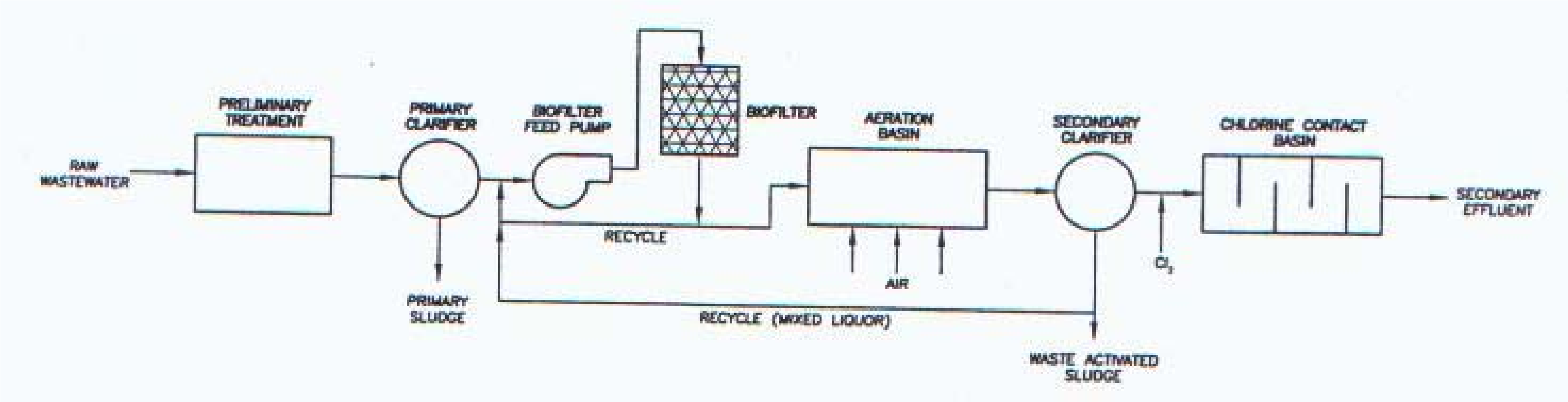

Figure 60. Treatment flow diagram number 3: combined biofilter-activated sludge process.

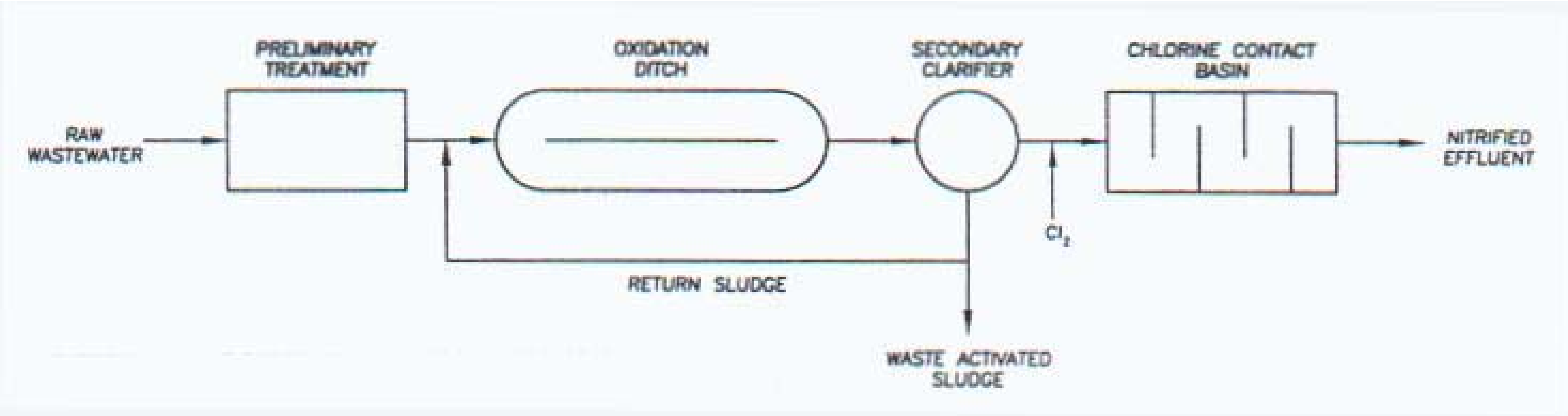

Figure 61. Treatment flow diagram number 4: extended aeration.

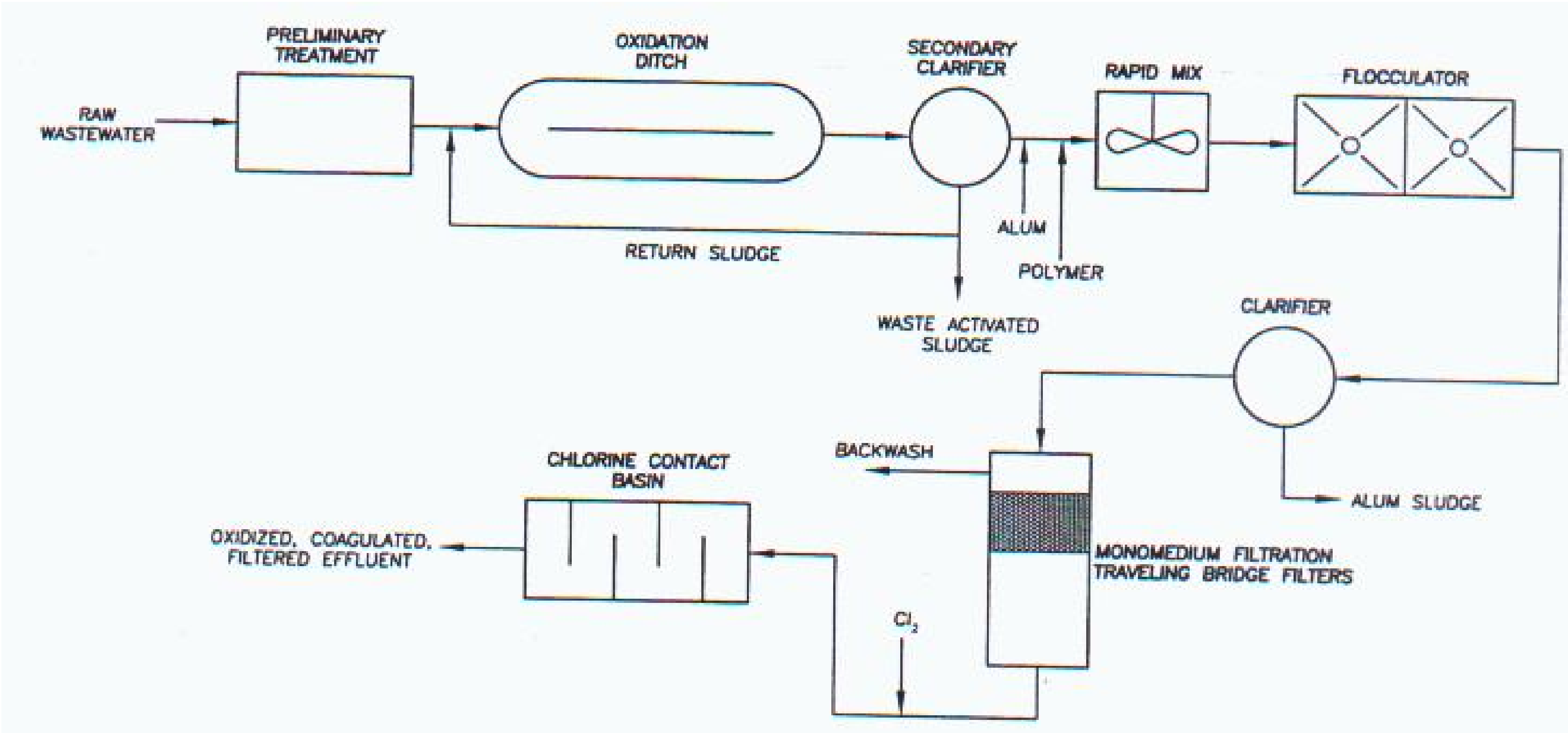

Figure 62. Treatment flow diagram number 5: secondary treatment plus flocculation-coagulation and filtration.

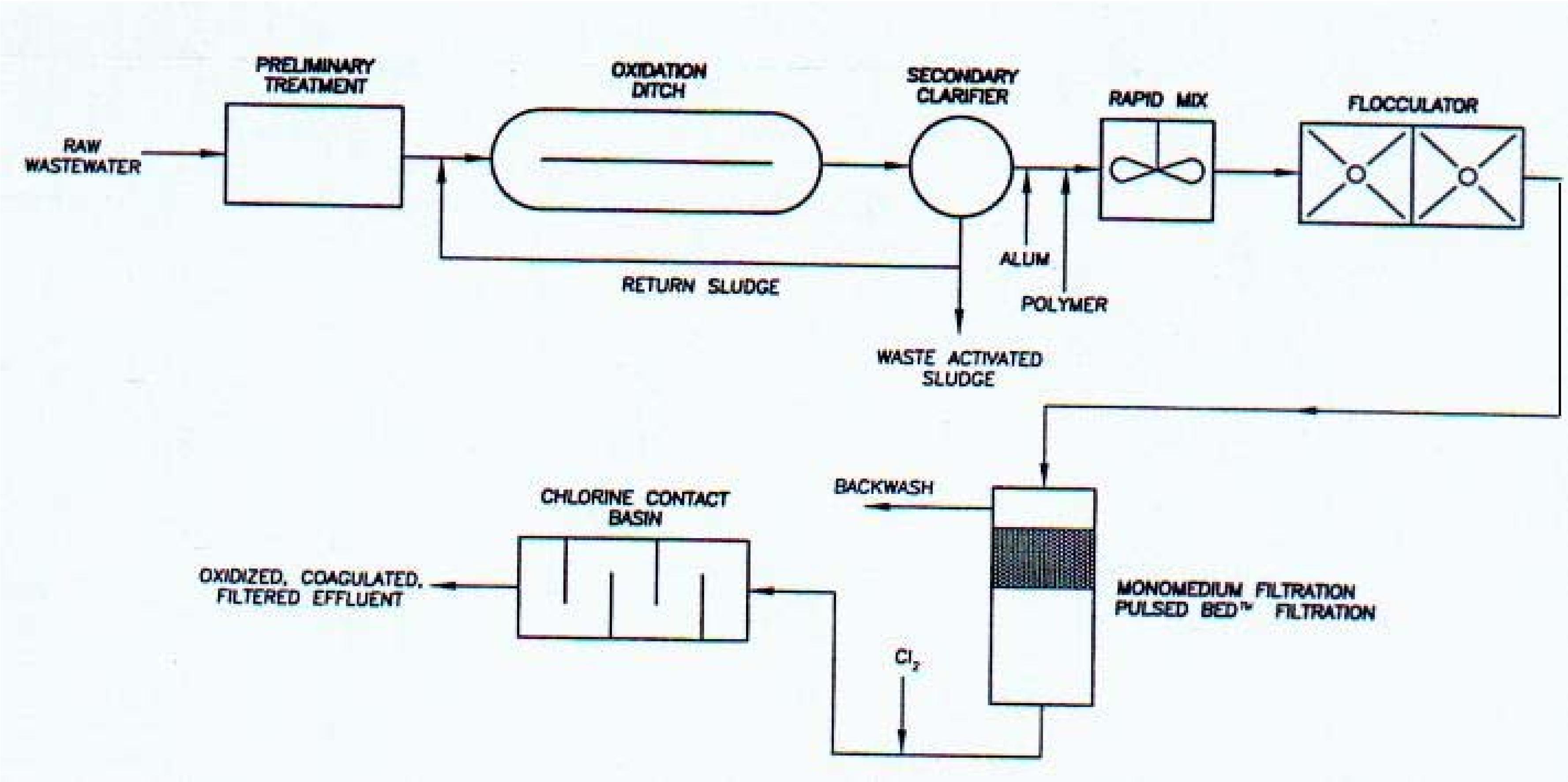

Figure 63. Treatment flow diagram number 6: secondary treatment plus direct filtration.

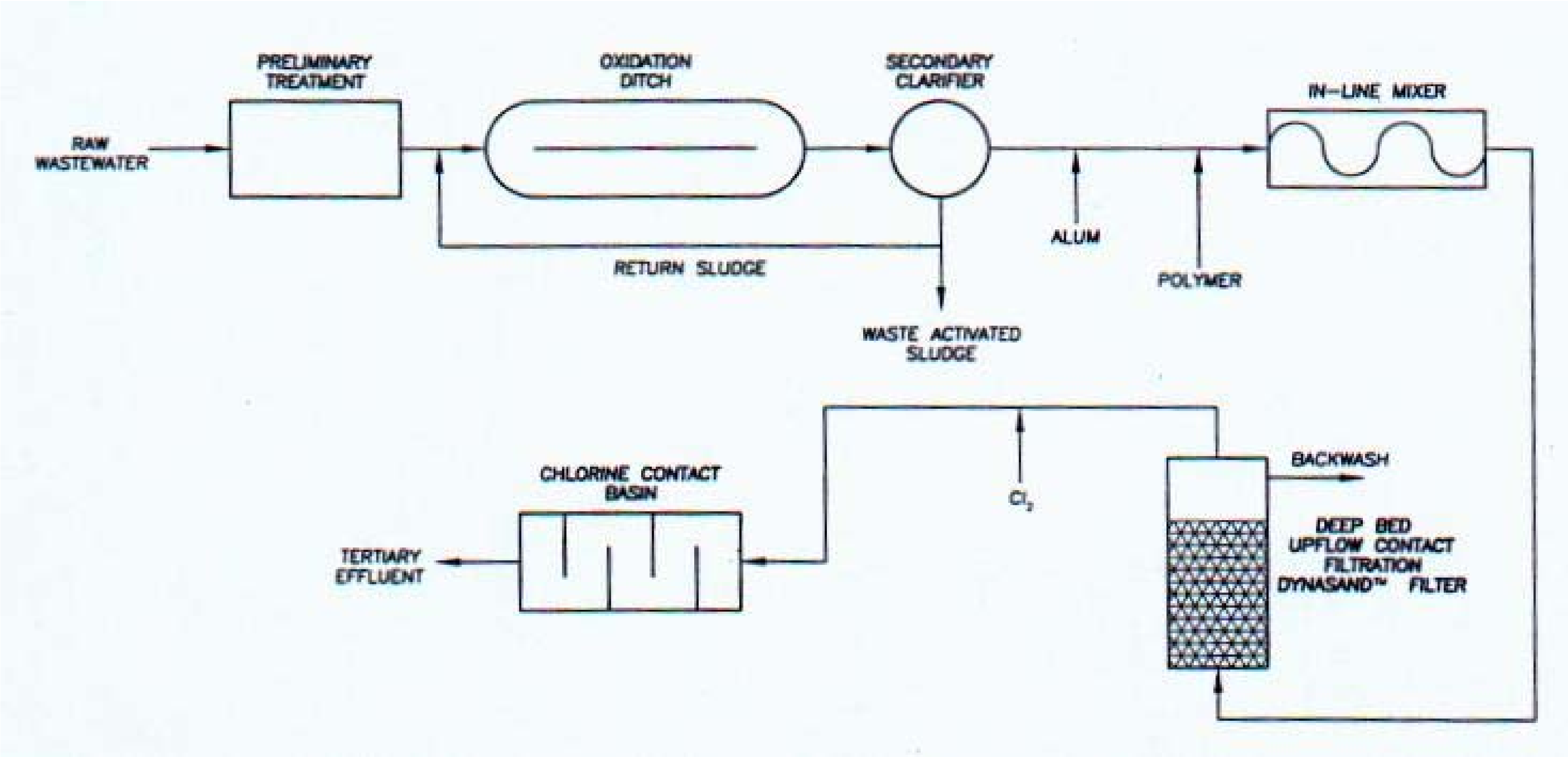

Figure 64. Treatment flow diagram number 7: secondary treatment plus contact filtration.

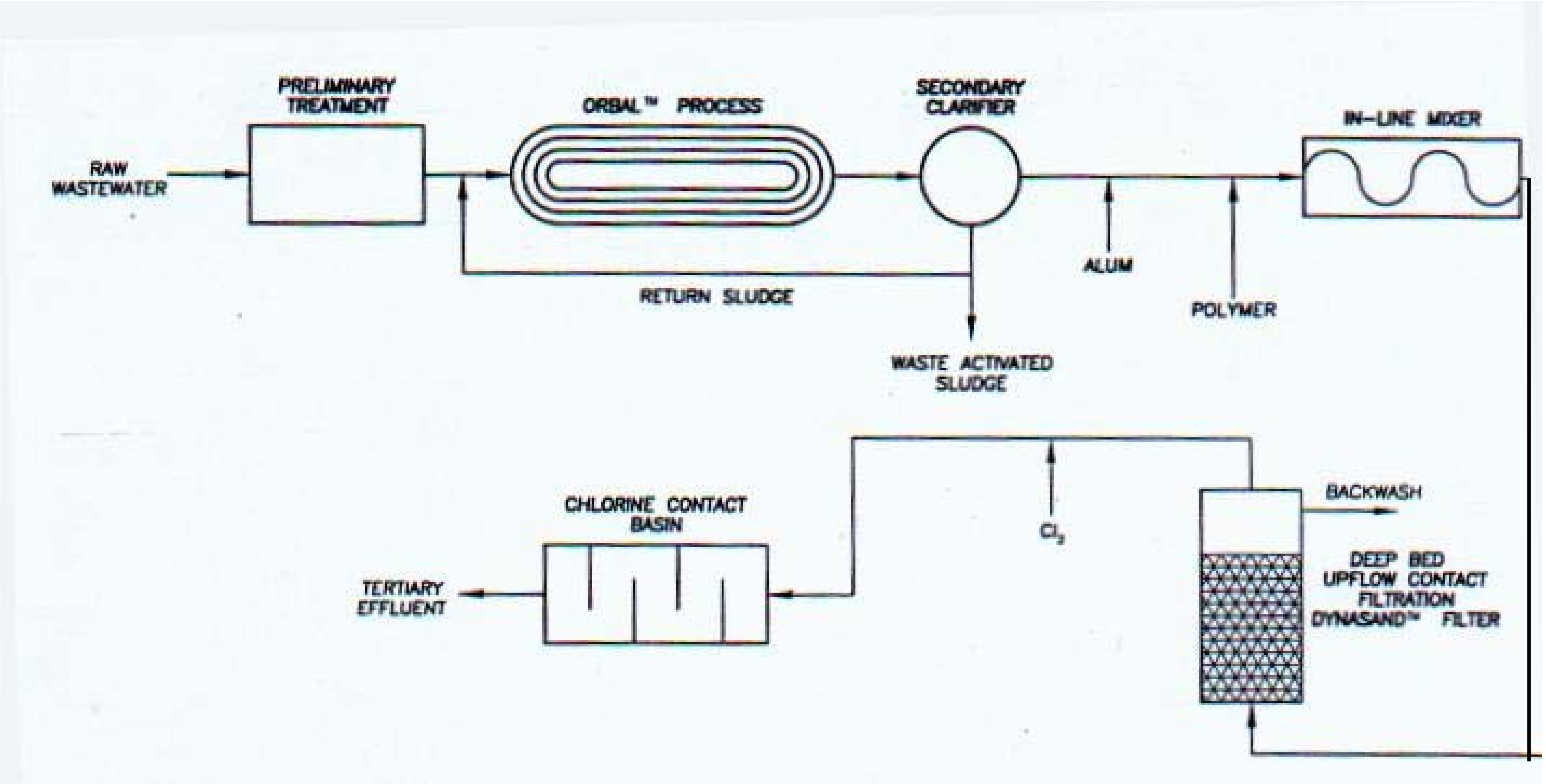

Figure 65. Treatment flow diagram number 8: secondary treatment plus contact filtration and phosphorous removal.

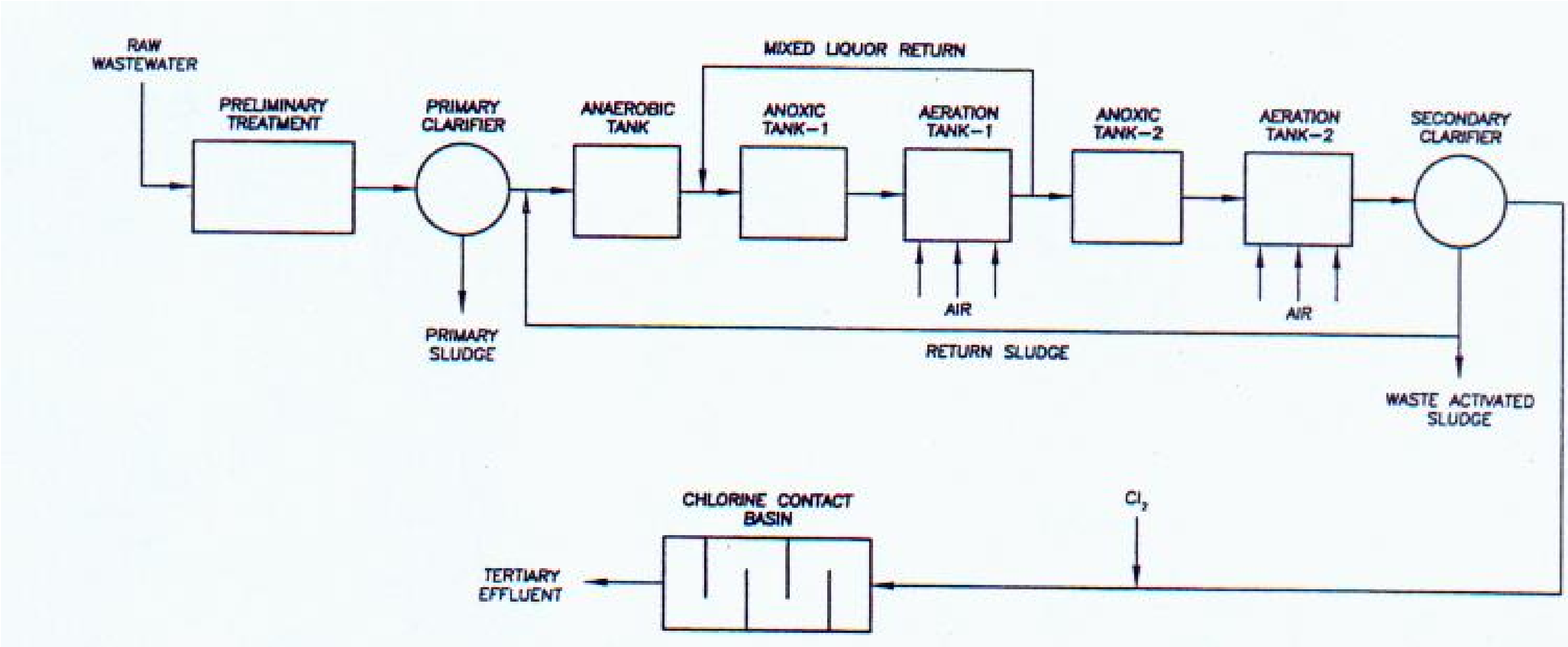

Figure 66. Treatment flow diagram number 9: five stage process (EIMCO).

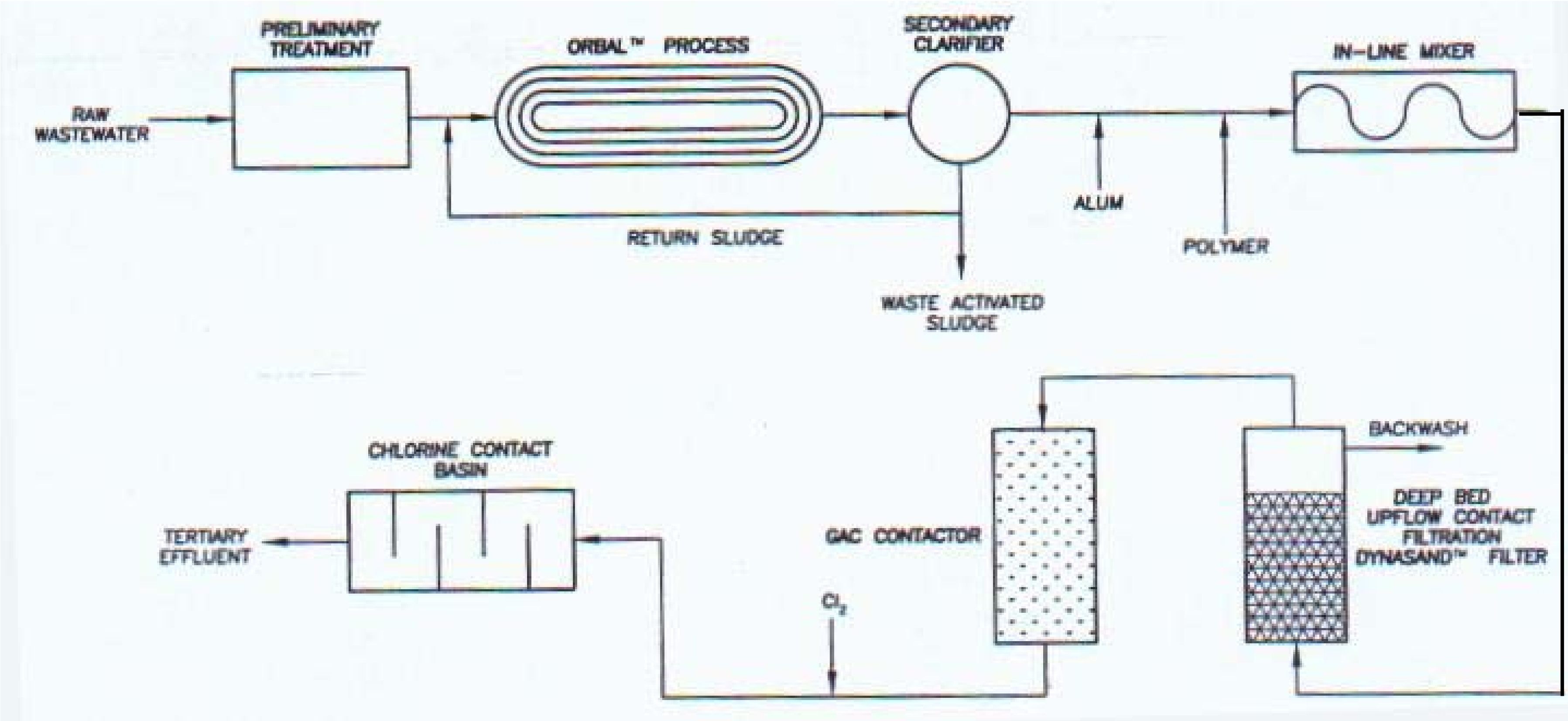

Figure 67. Treatment flow diagram number 10: secondary treatment plus contact filtration and carbon adsorption.

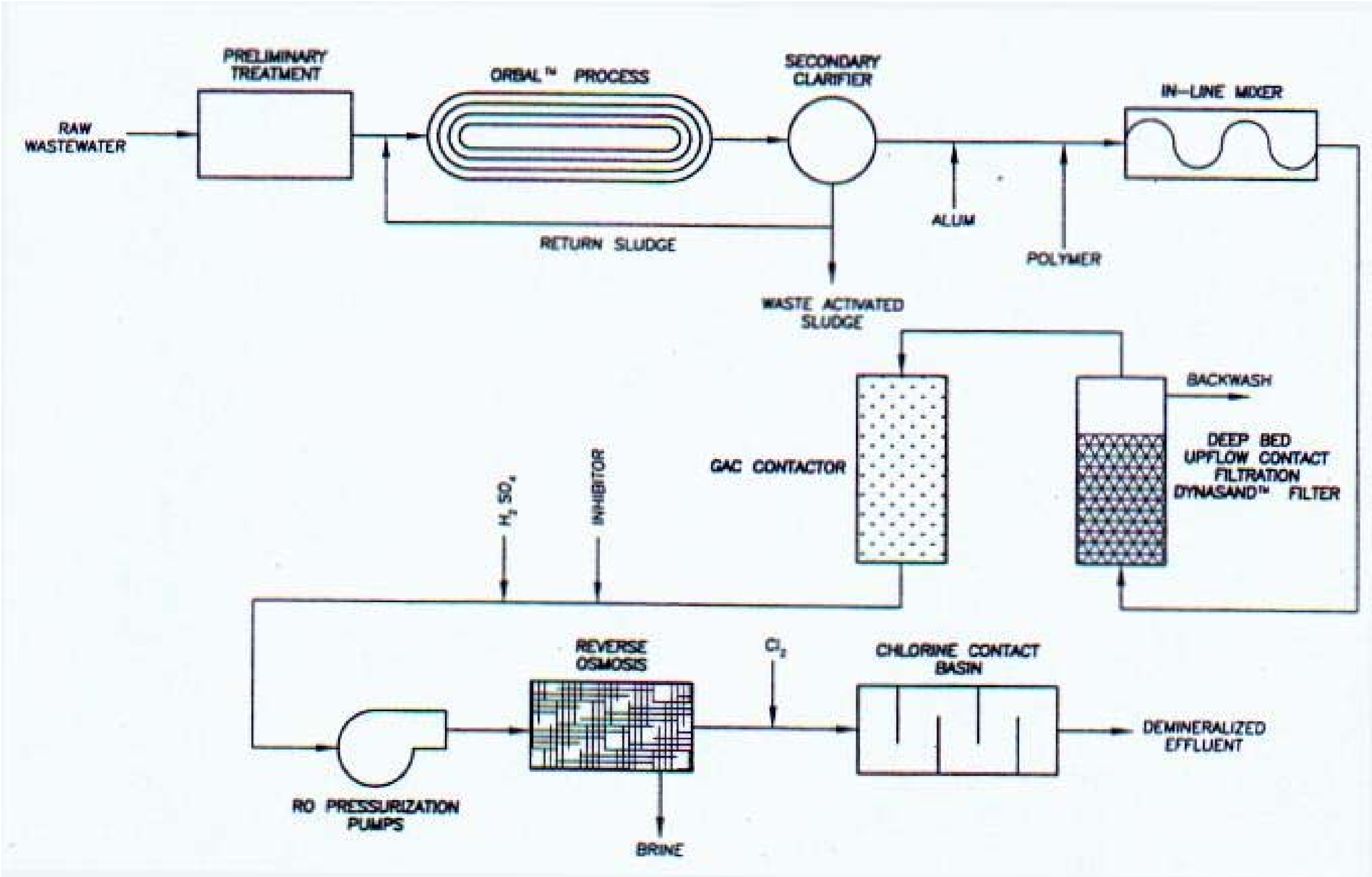

Figure 68. Treatment flow diagram number 11: secondary treatment plus contact filtration, carbon adsorption and reverse osmosis

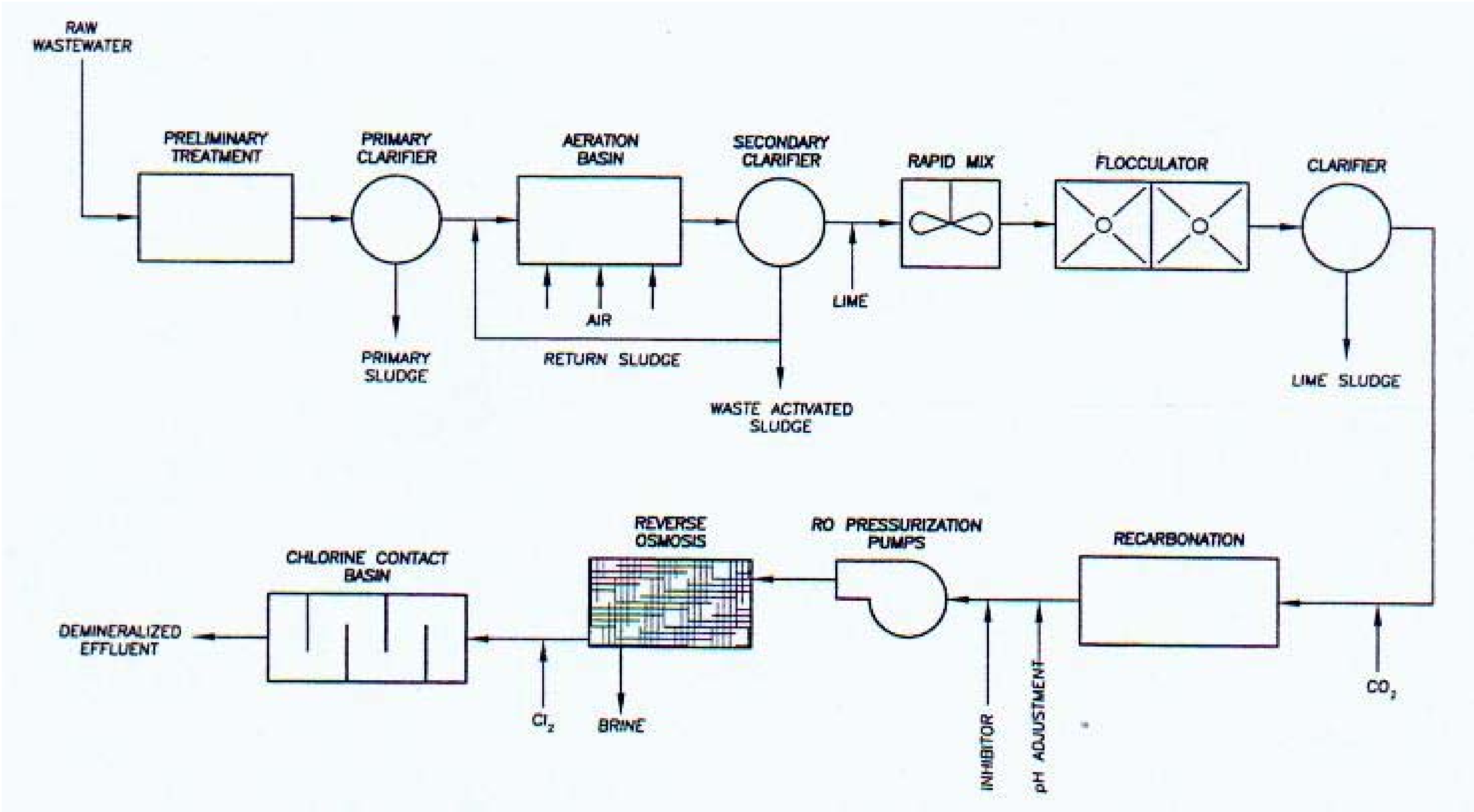

Figure 69. Treatment flow diagram number 12: secondary treatment plus lime treatment and reverse osmosis.

The effluent quality that can be expected from the flow diagrams presented in Figures 58 through 69 is shown in Table 65.

Figure 65. Projected effluent quality from alternative treatment process flow diagrams.

Flow Diagram number	Parameter concentration [a]								
	TSS	**BOD**	**NH_3-N**	**NO_3-N**	**PO_4**	**TOC**	**TDS**	**Hardness [b]**	**Coliform [c]**
1	80	120	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]
2	20	20	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]	<23
3	25	25	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]	<23
4	10	10	5	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]	<23
5	10	10	5	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]	<2.2
6	10	10	5	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]	<2.2
7	10	10	5	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]	<2.2
8	10	10	1	2	2	NA [d]	NA [d]	NA [d]	<2.2
9	10	10	1	2	2	NA [d]	NA [d]	NA [d]	<2.2
10	<2	<2	1	2	2	<5	NA [d]	NA [d]	<2.2
11	<1	<1	<1	<1	2	<2	<50	<10	<2.2
12	<1	<1	<1	<1	2	<2	<50	<10	<2.2

[a]: mg/l unless indicated otherwise
[b]: mg/l as $CaCO_3$
[c]: total coliform / 100 ml
[d]: NA (Not Applicable), treatment process not designed typically for specific constituent removal
Source: Adapted from *Asano et al*., 1998

<u>Treatment flow diagram number 1 - primary treatment</u>: For fodder, fibre, seed crops and orchards and vineyard irrigation, primary treatment will consist of screening, grit removal (preliminary treatment) and sedimentation.

<u>Treatment flow diagram number 2 - conventional activated sludge</u>: To satisfy secondary treatment requirements, a conventional activated sludge system coupled with chlorine disinfection will be employed. The alternatives pasture for milking animals, golf course, cemetery, freeway median and greenbelt irrigation, restricted recreational impoundment, landscape impoundment and livestock and wildlife watering will require as a minimum secondary wastewater effluent.

<u>Treatment flow diagram number 3 - combined biofilter-activated sludge process</u>: As a secondary treatment alternative, a combined biological process that links a high-rate biofilter and a suspended-growth aeration basin will be considered in a similar application to Treatment flow diagram number 2.

<u>Treatment flow diagram number 4 - extended aeration</u>: Nitrification is typically the initial unit process in any nutrient management scheme. Although ammonia conversion alone is generally not a requirement for a specific reuse option, an extended aeration system will be analysed nonetheless, because of its importance in a total nitrogen removal system. Also, extended aeration represents a popular derivative of the high-rate activated sludge process, particularly in the oxidation ditch mode. Because of the number of installations worldwide, extended aeration systems to be evaluated will include the ENVIREX Orbal™ process and EIMCO Carrousel ™ process.

Treatment flow diagram number 5 - secondary treatment plus flocculation-coagulation and filtration: Wastewater oxidation (extended aeration), chemical addition, coagulation, sedimentation, filtration and disinfection will be provided to produce essentially a pathogen-free effluent. Agricultural food crops, parks, playgrounds and schoolyards irrigation alternative as well as non-restricted recreational impoundments will require the described level of treatment.

Treatment flow diagram number 6 - secondary treatment plus direct filtration: As an alternative to the previous treatment, direct filtration following secondary treatment will be considered for restricted and non-restricted recreational impoundments, agricultural food crops and fodder, fibre, seed crops, orchards and vineyards irrigation. In direct filtration, the tertiary sedimentation process is deleted with coagulation-flocculation occurring in a separate reactor immediately upstream of the filters.

Treatment flow diagram number 7 - secondary treatment plus contact filtration: As a third option for satisfying the criteria for the production of a pathogen-free effluent, upflow contact filtration in a deep bed sand filter, following secondary treatment (extended aeration) and chemical addition-coagulation will be analysed also for reuse alternatives abovementioned (treatment number 6). Similar to the direct filtration alternative, the contact filtration process configuration does not include an intermediate clarification step. Unlike treatment flow diagram 6, chemical addition-coagulation is accomplished through an in-line mixer mechanisms with flocculation and aggregation occurring subsequently in the lower layers of the deep bed filter.

Treatment flow diagram number 8 - secondary treatment plus contact filtration and phosphorous removal: Combining a single tank nitrification-denitrification process with chemical addition and upflow contact filtration, complete nutrient management (nitrogen and phosphorous) will be assessed for fisheries habitat reuse.

Treatment flow diagram number 9 - five stage process (EIMCO): Biological nutrient removal in a compartmentalized treatment process will be evaluated as an alternative to contact filtration (treatment number 8) for nitrogen and phosphorous reductions.

Treatment flow diagram number 10 - secondary treatment plus contact filtration and carbon adsorption: For the groundwater recharge alternatives injection wells and surface spreading basins, nutrient and organic removal will be required. Addition of carbon adsorption to the contact filtration flow scheme will provide the desired effluent polishing.

Treatment flow diagram number 11 - secondary treatment plus contact filtration, carbon adsorption and reverse osmosis: To produce the high quality demineralised water required for industrial reuse, reverse osmosis will be added to contact filtration-carbon adsorption flow diagram (treatment number 10).

Treatment flow diagram number 12 - secondary treatment plus lime treatment and reverse osmosis: Lime treatment-reverse osmosis will be presented as an alternative to treatment number 11 for the industrial reuse options.

In the design of a reclamation treatment and reclamation plant, raw wastewater characteristics and hydraulic-organic loading parameters must be considered. The potential deterioration in process performance under minimum and maximum conditions will determine the likely governing criteria to be utilized in the sizing of individual treatment components (Table 66).

Table 66. Governing criteria used in the sizing of reclamation unit processes.

Unit process or operation	Governing criteria in process sizing
Preliminary treatment	Performance during peak hour wastewater flow
Primary treatment (sedimentation)	Hydraulic loading rate during peak hour wastewater flow
Secondary treatment	
High-rate activated sludge	
Aeration basin volume	Detention time at average daily wastewater flow Food to microorganisms (F/M) ratio at average daily organic loading
Aeration equipment	Maximum daily organic loading
Secondary clarification	Hydraulic loading rate during peak hour wastewater flow Solids loading rate at average daily wastewater flow with 100 % recycle
Oxidation ditch	
Ditch volume	Detention time at average daily wastewater flow F/M ratio at average daily organic loading
Aeration equipment	Maximum daily organic loading
Secondary clarification	Hydraulic loading rate during peak hour wastewater flow Solids loading rate at average daily wastewater flow with 100 % recycle
Trickling filter	
Filter medium volume	Maximum daily organic loading
Coagulation, flocculation sedimentation	
Chemical addition-flash mix	Detention time at peak hour wastewater flow
Flocculation	Detention time at peak hour wastewater flow
Sedimentation	Hydraulic loading rate at peak hour wastewater flow
Filtration	Filtration rate at peak hour wastewater flow with one unit out of service
Carbon adsorption	Hydraulic loading rate at peak hour wastewater flow
Lime treatment	Hydraulic loading rate at peak hour wastewater flow
Reverse osmosis	Hydraulic loading rate at peak hour wastewater flow
Disinfection	
Chlorination	Detention time at peak hour wastewater flow
UV light	UV dose at maximum day wastewater flow

Source: Adapted from *Asano et al*, 1998

From the point of view of operation, a reclamation facility must include alarms to alert operator to emergency conditions or poor effluent quality. Because chemical addition is an integral component of typical reclamation plants, sufficient instrumentation must be provided to allow for automatic chemical dosing either through flow pacing or in response to other system variables (e.g., chlorine residual, wastewater turbidity). A typical list of water quality parameters, controls and alarms for a reclamation plant designed to satisfy an effluent requirement of <2.2 total coliforms / 100 ml is presented in Table 67.

The number and potential complexity of alarms and controls required in a reclamation plant is apparent. Because of the emphasis placed on reliability and product quality, costs for instrumentation and alarms in a reclamation facility are generally 20% higher than in a conventional wastewater treatment plant.

Table 67. Recommended process parameters and alarm conditions to be monitored in a water reclamation plant (limited to chemical addition-flocculation, sedimentation, filtration and disinfection unit process in reclamation facility).

Category	Characteristic Monitored
Water quality parameters	Filter influent turbidity Filter effluent turbidity (composite and individual filters) Effluent chlorine residual Wastewater transmittance (UV systems)
Treatment process characteristics	Influent flow Effluent flow Filter backwash rate Filter surface wash rate UV intensity UV dose
Alarm conditions	High filter influent turbidity High filter effluent turbidity Chlorine contact tank bypass (high filter effluent turbidity) Low chlorine residual Low chemical supply High chlorine supply Multiple UV lamp failure Low UV intensity Low UV transmittance Pump/equipment failure Power failure Chemical feeder malfunction

Source: Adapted from *Asano et al*, 1998

The most attractive usages of reclaimed water include irrigation of edible crops or golf courses, but these uses require disinfection of wastewater so as to comply with relevant regulations.

The purpose of disinfection is to reduce the population of organism in the wastewaters to levels low enough to ensure that pathogenic organisms will not be present in sufficient quantities to cause disease when discharged or reuse. However quality standards are also affected by the irrigation option chosen, for example, a lower microbiology quality can be accepted if spray irrigation is used only for crops not to be raw-consumed, while in this situation no-contact irrigation has to be implemented for other crops.

There are a number of chemicals and processes that will disinfect wastewater, but none are universally applicable. The disinfection methods generally considered for use consist of chemical methods (chlorine, chlorine dioxide, peracetic acid and ozone), physical methods (UV irradiation and membrane microfiltration) and biological methods (ponds).

Disinfection systems are known to be very sensitive to wastewater quality, as we can see in Tables 67 through 70. Suspended solids concentration in the effluent is a critical parameter and effluents can be classified according to that parameter in a first approach in order to choose the better disinfection system in each situation.

Table 68. Impact of wastewater characteristics on UV disinfection.

Ammonia	Nor or minor effect
BOD, COD, etc	Nor or minor effect
Hardness	Effects solubility of metals that may absorb UV light. Can lead to the precipitation of carbonates of quartz tubes
Humic materials	Strong absorber of UV light
Iron	Strong absorber of UV light
Nitrite	Nor or minor effect
Nitrate	Nor or minor effect
pH	Can affect solubility of metals and carbonates
TSS	UV absorption and shielding of embedded bacteria

Source: Adapted from *Crites* and *Tchobanoglous* (1998)

Table 69. Impact of wastewater characteristics on Chlorine disinfection.

Ammonia	Combines with chlorine to form chloramines
BOD, COD, etc	Organic compounds that comprise the BOD and COD can exert a chlorine demand. The degree of interference depends on their functional groups and their chemical structure
Hardness	Nor or minor effect
Humic materials	Reduces effectiveness of chloride
Iron	Nor or minor effect
Nitrite	Oxidized by chloride
Nitrate	Nor or minor effect
pH	Effects distribution between hypochlorous and hypochlorite ion
TSS	Shielding of embedded bacteria

Source: Adapted from *Crites* and *Tchobanoglous* (1998)

Table 70. Impact of wastewater characteristics on Ozone disinfection.

Ammonia	Can react at high pH
BOD, COD, etc	Organic compounds that comprise the BOD and COD can exert an ozone demand. The degree of interference depends on their functional groups and their chemical structure
Hardness	Nor or minor effect
Humic materials	Affects the rate of ozone decomposition ant the ozone demand
Iron	Nor or minor effect
Nitrite	Oxidized by ozone
Nitrate	Can reduce effectiveness of ozone
pH	Affects the rate of ozone decomposition
TSS	Increase ozone demand and shield embedded bacteria

Source: Adapted from *Crites* and *Tchobanoglous* (1998)

Poor quality effluents or incomplete nitrification can cause extremely high chlorine demands. In addition, high concentrations of solids prevent chlorine-organism contact.

Current regulations for domestic treatment systems limit use of ozonization to filtered effluents unless the system effectiveness can be demonstrated prior to installation.

Many states limit the use of UV disinfection to facilities that can reasonably be expected to produced an effluent containing less than 30 mg/l of BOD and TSS.

Apart from wastewater quality, there are many factors that can affect disinfection procces efficiency. Some of these factors are drawn in Table 71.

Table 71. Factors affecting disinfection process.

Main factors affecting disinfection	Effects	Good practices
Effluent quality	Affect disinfection products demands and UV disinfection effectiveness. If the wastewater quality is poor, the UV light will be unable to penetrate the solids and the effectiveness of the process decreases dramatically.	Injection of fresh water saturated in dissolved oxygen (DO) that improves reclaimed wastewater quality during transportation (reduction in salinity and organic matter content). The DO injected with the fresh water provokes a nitrification-denitrification process. The appearance of oxidized nitrogen compounds inhibits the generation of sulphide, and the reduction in ammonia nitrogen content results in a less chemical products requirement for disinfection.
Mixing	In order to be effective, chemical disinfectant chlorine must be in contact with the organism; poor mixing results in poor product distribution.	Installing of baffles and using a high length-to-width ratio ratio will improve mixing and contact.
Residual levels	Some chemical disinfection processes are residual concentration dependent.	The concentration of residual must be sufficient to ensure the desired reactions occur. For example, 1 mg/l of chloride residual concentration for chlorination
Contact time	Some chemical disinfection processes as well as UV disinfection are time dependent. As the contact time decreases, process effectiveness decreases.	A minimum of time of contact must be fixed. For example, 30 minutes for chlorination. A contact tank with greater than 10 minutes contact time at design average daily for is required for ozonation.
UV light intensity	Affects process effectiveness.	The tubes must be cleaned regularly. Periodic acid washing is also required to remove chemical buildup.

Source: Adapted from *Hidalgo* et al. (2004)

A good practice in this case is the injection of fresh water saturated in dissolved oxygen (DO) that improves reclaimed wastewater quality during transportation (reduction in salinity and organic matter content). The DO injected with the fresh water provokes a nitrification-denitrification process. The appearance of oxidized nitrogen compounds inhibits the generation of sulphide, and the reduction in ammonia nitrogen content results in a less chemical products requirement for disinfection (*Delgado et al*., 2001).

Chlorination/dechlorination has been the most widely used disinfection technology until now but following the discovery that chloride may produce harmful by-products, alternative disinfectants are being considered worldwide for meeting the sanitary standards required for wastewater discharge and reuse. UV radiation is becoming a more and more accepted alternative to conventional chemical disinfection. UV-light has proved cost-effective and environmentally friendly in many projects but there are cases when ozonation should be considered as a competitive alternative.

The abovementioned conventional disinfection procedures are fairly effective, but in the Mediterranean countries, low technology techniques, such as lagooning and infiltration-percolation, are sometimes more reliable because of the lower cost that these systems suppose. The effluent microorganisms are eliminated here by mechanical filtration, adsorption and microbial degradation. The major disadvantage of these techniques is the big amount of space required.

Table 72 shows a comparison of data contained in the WAWTTAR program (*Finney* and *Gearheart*, 1998) for two water reclamation treatment trains. The high technological train represents the technology standard required by the State of California to meet its Title 22 water reclamation guidelines for high value users (groundwater injection, landscape irrigation, etc). Performance standards for unrestricted water reclamation is less than 5 mg/l BOD and TSS, less than 5 NTU turbidity and less than 2 CFU/100 ml. The low technological train includes natural processes plus UV disinfection. UV disinfection is considered an appropriate technology based upon its a lack of need for a continuous chemical supply, its ability to be operated with photovoltaic cells (w/wo batteries), and its relative ease of operations. The compared land requirements for a 4,000 m^3/day flow is 0.7 ha for the high tech versus 10 ha for the low tech system. The total cost for the two systems are seventeen million dollars for the high tech system and seven million dollars for the low tech system. The unit cost for cubic meter of reclaimed water is 17.00 US$/month for the high tech versus 7.00 US$/month for the low tech system. Ancillary benefits favour the low tech system with approximately 20 days of available storage.

Table 72. Comparison of a high tech and low tech water reclamation train.

	Technological Intensive Treatment Train			Low Technological / Sustainable Treatment Train		
Constituents	**Process**	**Removal efficiency**	**Retention (days)**	**Process**	**Removal efficiency**	**Retention (days)**
Settleable solids	Grit / Primary clarification	100% SS	0.08	Primary cell Oxidation pond	100% SS	10
Flocculant solids	Primary clarification	70% SS	0.08	Primary and Secondary Ox. pond cell Wetland cell 1	90% SS	10
Oxidizable organics	Activated sludge	90% BOD 90% FC	0.25	Secondary and Tertiary Ox. pond cell Wetland cell 1	80% BOD 75% TSS 99.9% FC	20
Oxidizable Nitrogen	Activated sludge	80% TN 95% FC	0.15	Minimum in Tertiary Ox. pond cell Wetland 2&3	80% TIN Denitrification	10
Small particles DOCs	Chemical addition filtration	98% BOD 99% TSS 99.9% FC	0.025	Wetland cell 3 Slow sand filters	98% BOD 98% TSS 99.99% FC	
Disinfection	UV / Chlorination	99.99% FC		Wetland cells UV Disinfection	99.99% FC	10
HRT (days)			0.5			40
Total cost O&M and Capital	17,106,000 US$			6,736,000 US$		
$/m³/month	17.50 US$			7.00 US$		

The cost of wastewater reclamation and reuse

(adapted from "Wastewater reclamation and reuse" Ed. T. Asano, Chapter 29 by David Richard)

Several risks can be associated with the reuse of treated wastewater. First the receiving soil can be contaminated if the water content is inappropriate. Accidents have already happened in the past. In fact the directive on sludge reuse does give content limits in heavy metal and several recommendations of water reuse refer to sludge content as a base for contamination warning. However, the most important risk is for human health. Indeed wastewater contains a very high level of microbiology (e.g. coliform) that can have serious adverse health effects. Furthermore, chemical contamination can also have effects on human health as well as on the ecosystem. Finally another risk with water reuse is economic aspect. To be viable, treated wastewater to be reused must have at least a comparable cost as freshwater. However, the wastewater treatment plants are rarely close to agriculture area, consequently there is an additional transport cost and storage cost. Additionally, the technology to produce clean water to achieve quality targets set in guidelines is not cheap (*Junger*, 2000).

Wastewater reclamation can be defined as a treatment or processing of wastewater to make it reusable. Unfortunately, wastewater reclamation cost are not well-documented. The first studies about reclamation cost were carried out in the late 1950s as part of planning studies for the California State Water Project.

Reclaimed wastewater can be used for a number of options including agricultural irrigation, landscape irrigation, groundwater recharge and industrial processes. Water quality requirements for reuse alternatives vary depending on the extent of potential public exposure. The development of a cost estimate includes projections of capital costs, annual operation and maintenance costs and life cycle cost. Life cycle costs are useful in comparing the economic feasibility of alternative water resources projects over a specific time period.

Wastewater reclamation system costs are presented as a function of facility capacity, end-use option and treatment process configuration. Costs have been identified by Richards (1998) estimating facility construction costs, equipment purchases and operation and maintenance fees. Initially, reclamation systems are analysed in terms of individual components based on design criteria. Cost data are derived for each element of a reclamation system at various capacity levels and unit sizes. Data are developed for reclamation systems ranging in production capacity from 4,000 m^3/d to 40,000 m^3/d. Common unit costs for construction materials and activities employed in the development of system capital cost are summarized in Tables 73 and 74. Site development and electrical cost are assumed as 10 and 15 percent of the total facility costs respectively.

Table 73. Summary of unit costs utilized in the development of reclamation system capital costs.

Item	Basis	Unit cost
Grading	€/m^3	5
Structural excavation / backfill	€/m^3	10
Structural concrete		
Foundations	€/m^3	419
Walls	€/m^3	471
Slabs on grade	€/m^3	366
Elevated slabs	€/m^3	524
Grating	€/m^2	344
Handrail	€/m	131
Building cost	€/m^2	1,292
Asphalt concrete paving	€/m^2	17
Piping		
8 in. diameter	€/m	92
10 in. diameter	€/m	105
12 in. diameter	€/m	118
18 in. diameter	€/m	157
24 in. diameter	€/m	210
30 in. diameter	€/m	262
36 in. diameter	€/m	315
42 in. diameter	€/m	367
48 in. diameter	€/m	420
Fencing	€/m	26

Source: Adapted from *Richard* (1998)

Table 74. Summary of tank station and storage tank cost.

Delivery system component		Capital cost (€)
Pump stations		
4,000 m^3/d	TDH = 6-15 m	80,000
	TDH = 15-90 m	160,000
	TDH > 90 m	320,000
20,000 m^3/d	TDH = 6-15 m	200,000
	TDH = 15-90 m	420,000
	TDH > 90 m	880,000
40,000 m^3/d	TDH = 6-15 m	300,000
	TDH = 15-90 m	680,000
	TDH > 90 m	1,400,000
Reclaimed water storage tanks		
2,000 m^3 capacity		600,000
3,800 m^3 capacity		760,000
7,500 m^3 capacity		1,000,000
15,000 m^3 capacity		1,600,000

TDH = total dynamic head

Source: Adapted from *Richard* (1998)

Reclamation system annual cost are comprised of treatment and distribution facility personnel salaries, operating fees (recurring power and chemical cost) and maintenance cost (equipment repairs and replacements). Personnel requirements are a function of facility size and complexity. Operating cost depend upon energy usage and chemical consumption. Maintenance cost (spare parts, replacements) are estimated generally as a percentage of equipment first cost (e.g., 5 percent). For pipelines and storage tanks, maintenance costs are projected as two percent of capital costs. Each of these annual cost components are analysed for various reclamation options based on the guidelines presented in a technical literature and actual operating experience (*Culp* et al., 1980; *Nolte* et al., 1994). Typical unit cost employed in the evaluation of these annual costs are enumerated in Table 75.

Table 75. Summary of unit cost for reclamation systems operation.

Item	Basis	Unit cost
Plant operator	€/h	14.4 [a]
Utility maintenance worker	€/h	12.0 [a]
Electrical power	€/kWh	0.08
Chemicals		
Alum	€/kg	0.79
Polymer	€/kg	2.65
Chlorine	€/kg	0.35
Sulphuric acid	€/kg	0.88
Lime	€/kg	0.35
Sodium hexametaphosphate	€/kg	1.77
Sodium hypoclhoride	€/m^3	0.84
Granular activated carbon replacement	€/kg	1.94

(a) Labour cost do not include fringe benefits, insurance and administrative overheads
Source: Adapted from *Richard* (1998)

Total reclamation system life cycle cost are estimated by combining amortized capital cost with annual operation and maintenance costs and converting to €/m^3 (by dividing the estimated life cycle cost, €/yr, by the reclamation facility capacity, m^3/yr). The life cycle analysis is based on a 20-year facility life and return rate of 10%.

Capital cost include cost incurred for wastewater treatment, storage and distribution. Capital cost for wastewater treatment and water reclamation are estimated by summing individual unit process cost with required supporting facilities fees. Ancillary facility costs reflect the following:

1. Site development costs including grading, paving, fencing and landscaping
2. Process piping and liquid stream conduit costs linking reclamation facility unit processes.
3. Administration – operations building costs
4. Standby generation costs.

Operation and maintenance costs for a total reclamation system are analysed in a similar manner to capital costs. Solids management costs are also added to the total reclamation system annual costs. Solids refer to primary sludges, waste secondary sludges and tertiary chemical sludges. In all the cases, an average solid management cost of 120 €/dry ton of solids produced is assumed. The stated sludge “handling cost reflects some type of solid digestion, sludge pumping, dewatering and beneficial agricultural reuse application. The 120 €/dry ton includes amortized capital costs and operational and maintenance fees.

Historically, one of the first efforts to develop a rationale basis for projecting reuse costs were technical information published in the report “Wastewater reuse and recycling technology” (*Culp* et al., 1980). Eighteen beneficial reuse options were identified ranging from agricultural irrigation to groundwater recharge. Thirteen levels of wastewater treatment comprising twenty-four different unit process configurations were developed and analysed subsequently in terms of life cycle costs. Assuming certain water quality requirements for each reuse alternative, specific treatment schemes were then linked with the respective beneficial use. A summary of the costs estimated in the mentioned study is presented n Table 76.

Table 76. Summary of estimated water reclamation treatment process life cycle costs.

Reuse alternative	Recommended treatment process	Annual costs (€/m^3) [a, b]
Agricultural irrigation	Activated sludge	0.16-0.44
Livestock and wildlife watering	Trickling filter	0.17-0.46
Power plant and industrial cooling	Rotating biological contactors	0.25-0.47
Urban irrigation – landscape	Activated sludge, filtration of secondary effluent	0.19-0.59
Groundwater recharge – spreading basins	Infiltration – percolation	0.07-0.17
Groundwater recharge – injection wells	Activated sludge, filtration of secondary effluent, carbon adsorption, reverse osmosis of advanced wastewater treatment effluent	0.76-2.12

(a): Costs are estimated for facility capacities ranging from 4,000 to 40,000 m^3/d. Lower cost figure within each treatment process category represents cost for a 40,000 m^3/d reclamation plant while the upper cost limit is presented for a 4,000 m^3/d facility.
(b): Annual costs include amortized capital costs based on a facility life of 20 years and a return rate of 7 %.
Source: Adapted from *Richard* (1998)

The wide variation in projected reuse costs both as a function of treatment level and facility capacity is shown in Table 77. Life cycle cost (including sludge disposal but excluding storage and distribution costs) ranged from 0.07 to 2.12 €/m^3 depending upon specific reclamation requirements.

Following the methodology presented previously, reclamation facility costs have been estimated for the twelve process flow diagrams described in Table 64. Capital, operation and maintenance and life cycle cost are summarized in Tables 77 through 79 for reclamation plants with capacities of 4,000, 20,000 and 40,000 m^3/d. Distribution system costs are also described along with a comparison of alternative disinfection systems.

Table 77. Estimated capital cost for reclamation treatment facilities.

Treatment flow diagram		Capital cost, € [a]		
		4,000 m^3/d	20,000 m^3/d	40,000 m^3/d
1	Primary treatment	2,360,000	4,240,000	6,040,000
2	Conventional activated sludge	4,880,000	11,520,000	19,920,000
3	Combined biofilter-activated sludge	5,200,000	12,160,000	20,880,000
4	Extended aeration	4,560,000	10,560,000	19,960,000
5	Secondary treatment plus flocculation-coagulation and filtration	6,720,000	14,720,000	28,240,000
6	Secondary treatment plus direct filtration	5,520,000	12,560,000	24,000,000
7	Secondary treatment plus contact filtration	5,640,000	13,320,000	24,720,000
8	Secondary treatment plus contact filtration and phosphorous removal	5,680,000	14,480,000	27,600,000
9	Five stage process (EIMCO)	6,080,000	16,640,000	30,560,000
10	Secondary treatment plus contact filtration and carbon adsorption	7,240,000	20,440,000	39,480,000
11	Secondary treatment plus contact filtration and carbon adsorption plus reverse osmosis	10,760,000	35,040,000	67,320,000
12	Secondary treatment plus lime treatment and reverse osmosis	9,680,000	28,360,000	52,360,000

(a) Cost presented in June 1996 referring USA reclamation plants
Source: Adapted from *Richard* (1998)

Table 78. Summary of reclamation facility Life Cycle Costs.

Treatment flow diagram		Life cycle costs, €/m^3 [a]		
		4,000 m^3/d	20,000 m^3/d	40,000 m^3/d
1	Primary treatment			
	Capital [a]	0.20	0.07	0.05
	Operation and maintenance	0.09	0.06	0.06
	Total	0.29	0.13	0.11
2	Conventional activated sludge			
	Capital [a]	0.42	0.20	0.17
	Operation and maintenance	0.16	0.11	0.10
	Total	0.57	0.31	0.27
3	Combined biofilter-activated sludge			
	Capital [a]	0.45	0.21	0.18
	Operation and maintenance	0.18	0.12	0.12
	Total	0.62	0.33	0.29
4	Extended aeration			
	Capital [a]	0.39	0.18	0.17
	Operation and maintenance	0.17	0.12	0.11
	Total	0.56	0.30	0.28
5	Secondary treatment plus flocculation-coagulation and filtration			
	Capital [a]	0.57	0.25	0.24
	Operation and maintenance	0.30	0.23	0.22
	Total	0.88	0.48	0.46
6	Secondary treatment plus direct filtration			
	Capital [a]	0.47	0.21	0.20
	Operation and maintenance	0.20	0.14	0.13
	Total	0.67	0.35	0.34
7	Secondary treatment plus contact filtration			
	Capital [a]	0.48	0.23	0.21
	Operation and maintenance	0.20	0.14	0.13
	Total	0.68	0.37	0.34
8	Secondary treatment plus contact filtration and phosphorous removal			
	Capital [a]	0.49	0.25	0.24
	Operation and maintenance	0.39	0.32	0.31
	Total	0.87	0.56	0.55
9	Five stage process (EIMCO)			
	Capital [a]	0.52	0.28	0.26
	Operation and maintenance	0.16	0.12	0.12
	Total	0.68	0.40	0.38
10	Secondary treatment plus contact filtration and carbon adsorption			
	Capital [a]	0.52	0.35	0.34
	Operation and maintenance	0.47	0.40	0.39
	Total	1.09	0.75	0.73
11	Secondary treatment plus contact filtration and carbon adsorption plus reverse osmosis			
	Capital [a]	0.92	0.60	0.57
	Operation and maintenance	0.72	0.58	0.56
	Total	1.64	1.24	1.13
12	Secondary treatment plus lime treatment and reverse osmosis			
	Capital [a]	0.83	0.48	0.45
	Operation and maintenance	0.61	0.49	0.47
	Total	1.44	0.97	0.92

(a) Capita cost are amortized based on a facility life of 20 years and a return rate of 10%.
Source: Adapted from *Richard* (1998)

Table 79. Estimated operation and maintenance costs for reclamation treatment facilities.

Treatment flow diagram		Operation and Maintenance cost, €/y[a]		
		4,000 m^3/d	20,000 m^3/d	40,000 m^3/d
1	Primary treatment	120,000	424,000	768,000
2	Conventional activated sludge	216,000	744,000	1,384,000
3	Combined biofilter-activated sludge	240,000	848,000	1,592,000
4	Extended aeration	240,000	824,000	1,560,000
5	Secondary treatment plus flocculation-coagulation and filtration	416,000	1,568,000	3,048,000
6	Secondary treatment plus direct filtration	280,000	960,000	1,832,000
7	Secondary treatment plus contact filtration	272,000	960,000	1,824,000
8	Secondary treatment plus contact filtration and phosphorous removal	528,000	2,184,000	4,272,000
9	Five stage process (EIMCO)	224,000	832,000	1,696,000
10	Secondary treatment plus contact filtration and carbon adsorption	656,000	2,720,000	5,344,000
11	Secondary treatment plus contact filtration and carbon adsorption plus reverse osmosis	992,000	3,968,000	7,680,000
12	Secondary treatment plus lime treatment and reverse osmosis	848,000	3,384,000	6,480,000

(a) Cost presented in June 1996 referring USA reclamation plants
Source: Adapted from *Richard* (1998)

Facility capital costs include construction costs for individual unit processes, operations-laboratory building, maintenance building, electrical distributions-control, site development, process-yard piping, instrumentation and electrical service. Operation and maintenance costs include personnel charges, power costs, spare parts, chemicals and sludge handling fees.

Life cycle costs are computed by combining amortized capital costs with operation and maintenance costs. Amortization of capital costs is based upon a design life of 20 years and a return rate of 10%.

Referring to disinfection, agricultural food crops, parks, playgrounds and schoolyard irrigation and non-restricted recreational impoundments reuse options, require a pathogen-free effluent. To upgrade secondary wastewater treatment pants to produce the desired product quality, chemical addition, coagulation, filtration and disinfection facilities must be provided.

Table 80. Estimated incremental capital costs associated to produce reclaimed water for unrestricted use.

Advanced process beyond secondary treatment	Capital cost, €[a]		
	4,000 m^3/d	20,000 m^3/d	40,000 m^3/d
Flocculation-coagulation and filtration	2,120,000	4,040,000	7,640,000
Direct filtration	1,160,000	2,360,000	4,360,000
Contact filtration	1,240,000	2,920,000	4,880,000

(a) Cost presented in June 1996 referring USA reclamation plants
Source: Adapted from *Richard* (1998)

Table 81. Estimated incremental operation and maintenance costs associated to produce reclaimed water for unrestricted use.

Advanced process beyond secondary treatment	Operation and Maintenance cost, €/y[a]		
	4,000 m^3/d	20,000 m^3/d	40,000 m^3/d
Flocculation-coagulation and filtration	192,000	776,000	1,544,000
Direct filtration	56,000	168,000	336,000
Contact filtration	52,000	172,000	320,000

(a) Cost presented in June 1996 referring USA reclamation plants
Source: Adapted from *Richard* (1998)

Table 82. Estimated incremental life cycle costs associated to produce reclaimed water for unrestricted use.

Advanced process beyond secondary treatment	Life cycle costs, €/m^3 [a]		
	4,000 m^3/d	20,000 m^3/d	40,000 m^3/d
Flocculation-coagulation and filtration			
Capital [a]	0.18	0.07	0.07
Operation and maintenance	0.14	0.11	0.11
Total	0.32	0.18	0.18
Direct filtration			
Capital [a]	0.10	0.04	0.04
Operation and maintenance	0.04	0.02	0.02
Total	0.14	0.06	0.06
Contact filtration			
Capital [a]	0.11	0.05	0.04
Operation and maintenance	0.04	0.02	0.02
Total	0.14	0.07	0.07

(a) Capital costs are amortized based on a facility life of 20 years and a return rate of 10%.
Source: Adapted from *Richard* (1998)

The advanced wastewater treatment elements included in treatment flow diagrams number 5 (secondary treatment plus flocculation-coagulation and filtration, Figure 62), number 6 (direct filtration, Figure 63) and number 7 (contact filtration, Figure 64) will satisfy disinfection requirements when constructed downstream of typical secondary process components. Upgrading costs for each filter alternative are summarized in Tables 80 through 82.

Historically, gaseous chlorine has served as the principal disinfectant in wastewater reclamation plants. The low cost of gaseous chlorine coupled with its efficacy in pathogen destruction versus alternate chemical disinfectants or techniques. However, in the last years, safety concerns and restrictions regarding the storage and handling of hazardous materials have prompted a re-evaluation of gaseous chlorine use. Capital costs for gaseous chlorine systems have increased significantly because of these recent requirements for containing, scrubbing and neutralization. As an alternative, many communities are considering the use of sodium hypochlorite for the disinfection of reclaimed wastewater. Liquid sodium hypochlorite storage and delivery system are similar to other wastewater treatment chemical supply and metering arrangements with storage tanks, metering pumps and distribution piping. Capital cost for sodium hypochlorite systems are 25-40 percent less than comparable gaseous chloride systems, however operating cost are significantly higher. In a recent study of life cycle costs for alternative disinfection systems (*Richard* et al., 1996), any savings in capital costs associated with liquid sodium hypochlorite are offset within 3-5 years by higher chemical costs as compared for gaseous chlorine.

The use of ultraviolet irradiation for wastewater disinfection is also receiving increased attention as an alternative to gaseous chlorine. UV disinfection is an effective disinfectant with no residual toxicity. Depending on wastewater characteristics and effluent quality requirements, significant capital and operating cost savings could be realized with UV system compared to a conventional chlorination-dechlorination process.

The influence of water on production costs is not enough focused in the most of the countries. In Italy, for example, the majority of water distributors are public authorities and water fees are usually not based on consumption, but on the farm's irrigable surface: for instance in a large irrigation district, supplied by Ticino river, the farmers are charged with an irrigation fee of about 100 €/ha per year (for spray irrigation, which is the most common practice), regardless of the volume of water effectively used. Fees for farmers are mainly due to operation and maintenance costs for water distribution: in fact, the charge asked by the State to withdraw public waters for irrigation purposes is very low (~ 36 €/y at a 100 l/s flow). The amount of water usually withdrawn during the irrigation season is 2,500–6,000 m^3/ha (thus giving for natural waters a 0.012–0.03 €/m^3 range), depending on crop, climate and farmers' habits. In the case of corn, the cost of water will be roughly 8% of the average selling price for farmers: as a consequence the economic impact of water prices is to be taken into account, especially considering that the current EU agricultural policy will lead to reduce farmer's profits. Similar considerations can be made for reclaimed water, thus the control of polishing costs appears to be a primary target.

Recently, *Nurizzo et al.* (2001), on the basis of the current Italian situation, have evaluated the construction and operation cost increases due to a polishing section, downstream a standard municipal WWTP. A simple treatment train, based on contact filtration followed by four different disinfection agents (ozone, chlorine, UV rays or peracetic acid) has been studied (see Figure 70) and the four different options have been analysed from the economic point of view to achieve the following microbiological quality standards: A: Total Coli <2.2 /100 ml; B: Total Coli <23 /100 ml; C: Total Coli <200 /100 ml; D: Total Coli <1,000 /100 ml.

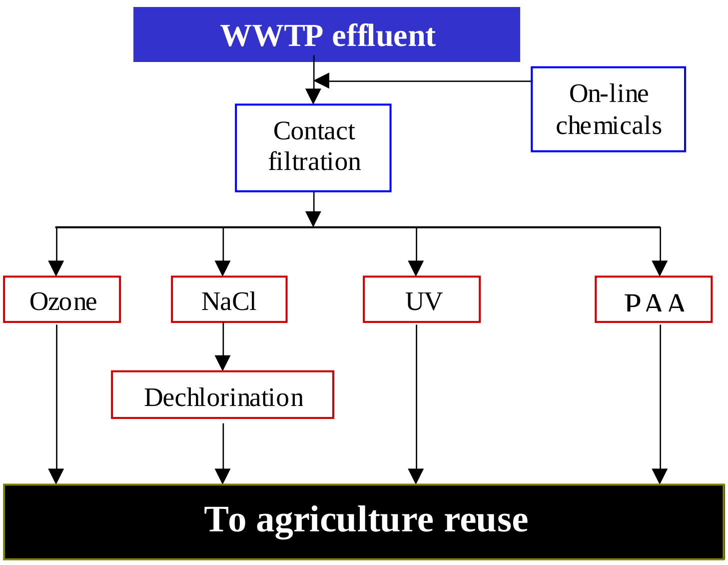

Figure 70. General layout of the polishing trains taken in consideration for the cost evaluation made by *Nurizzo* et al., (2001).

Operation costs appear to be strongly influenced by different disinfection options and quality targets. The increase of operation costs induced by a reclamation section is given in Table 83.

Table 83. Operation costs increases (as % of the ones for a standard nitro-denitro municipal WWTP), (Source: *Nurizzo et al*., 2001).

Scenario	Contact filtration NaClO	Contact filtration UV	Contact filtration PAA	Contact filtration O_3
A: 2.2 T.Coli/100 ml	18.2 %	17.7 %	N/A	60.6 %
B: 23 T.Coli/100 ml	16.0 %	15.4 %	64.4 %	41.6 %
C: 100 T.Coli/100 ml	15.3 %	14.1 %	42.2 %	33.1 %
D: 1,000 T.Coli/100 ml	14.9 %	13.7 %	27.4 %	N/A

N/A: not applicable

The economic impact of operation with different disinfection agents is evident:
- The use of ozone appears to be limited to very peculiar situations (cost are supposed to be smaller with new generation ozonators).
- Peracetic Acid is very expensive.
- Operation cost using NaClO and UV are very similar.
- Construction cost differences are less significant (except for ozone disinfection).

The compliance with stringent microbiological standards significantly affects overall wastewater treatment costs. With reference to a standard nitro-denitro municipal WWTP, even a simplified polishing step (contact filtration followed by disinfection) can increase operation costs by 15–20%, for the more economically feasible polishing trains based on UV or NaClO disinfection. However both of them have to face some practical limitations: consequences of influent TSS fluctuations for UV rays and increasing concern – in some countries – for possible toxicity risks related to chlorination.

Table 84. Comparative cost of various reuse alternatives in three cities in Israel for establishing national reuse priorities (costs in US$/m^3).

	Dan Region		Jerusalem			Eilat			
	RA	NoR	RA	RDD	NoR	RA	RI	RDD	NoR
Baseline treatment	0.22	0.22	0.24	0.24	0.24	0.26	0.26	0.26	0.26
Extra treatment	0.09	-	0.07	0.17	-	0.03	0.09	0.17	-
Final disposal	-	0.06	-	-	0.19	-	-	-	0.17
Pumpage and conveyance	0.14	0.14	0.36	0.21	0.36	0.08	0.04	0.16	0.03
Cost of fresh water as source	-	0.29	-	-	0.29	0.35	-	-	0.48
Comparative National cost	0.45	0.71	0.76	0.62	1.08	0.72	0.39	0.59	0.94

RA: reuse in agriculture; NoR: No reuse; RDD: Reuse in dual distribution; RI: Reuse for irrigation of parks, golf courses, etc. (Source: Adapted from *Shelef* and *Azov*, 1996).

Summarizing, the cost of water reuse involves: (a)the extra treatment needed to reach the reuse quality requirement above and beyond the mandatory baseline treatment required to protect the community safety, health and environment, and (b) extra conveyance of the effluent to reuse sited (in case of dual distribution this will include its cost). The benefit of reuse includes: (a) the value of fresh water saved (including pumpage and conveyance), and (b) the cost of the alternative safe final disposal of the effluent (including extract treatment) when reuse is not practised. Table 84 analyses the alternative estimated costs of various proposed types of reuse versus not reuse, in three cases in Israel, namely: the Dan Region (Greater Tel-Aviv), the City of Jerusalem and the City of Eilat.

The Dan Region project (Greater Tel-Aviv) has been abovementioned in this document. If not reuse has been practised, alternative fresh water resources with source water value (based on potential alternative demand of this source) would have been used to supply the agricultural demand of Southern Israel with the same conveyance costs and with the need to find a safe alternative for final disposal of the wastewater.

In the case of Jerusalem, fresh water is pumped to an elevation of 860 m from the coastal plane. Any saving of fresh water to the city itself (by using dual distribution reuse) would save both the basic value of freshwater as source, high conveyance and pumping costs (estimated at 0.36 US$ per cubic meter), as well as the final disposal of the coty´s effluent, which in this inland city is quite high. The other reuse alternative is to convey the final effluent to an agricultural irrigation site 38 km away.

The City of Eilat´s water supply is solely dependent, at present, on reverse osmosis desalination of brackish waters pumped from the Sabcha wells costing 0.48 US$ per cubic meter. Since this source of brackish water has reached its full capacity, the future desalination source will be seawater, where the cost of desalinated waters will be about 0.80 US$ per cubic meter.

As conclusion from all the mentioned in this section, it can be extracted the following *Asano et al.,* (1998):

- The production of reclaimed water for fodder, fibre, seed crops, orchards and vineyards irrigation requires the lowest level of treatment and generates the least reclamation costs. Life cycle costs for primary treatment range from 0.11 to 0.29 €/m^3 for facilities wit a capacity of 4,000 to 40,000 m^3/d respectively.
- Secondary effluent suitable for pasture for milking animals, golf course, cemetery, freeway media and greenbelt irrigation and landscape impoundment is produced for either, the conventional activated sludge, activated biofilter or extended aeration process configurations. Capital costs for the extended aeration alternative are 10-15 percent lower than similar costs for the conventional activated sludge and activated biofilter options. Life cycle cost are comparable for extended aeration and conventional activated sludge systems.
- Effluent from three advanced wastewater treatment configurations can satisfy common criteria for reclaimed water suitable for unrestricted use. Secondary effluent that is treated through either flocculation-coagulation and filtration plant, direct filtration plant or contact filtration process can be utilized for agricultural food crops, parks, playgrounds and schoolyard irrigation and non-restricted recreational impoundments.
- Incremental capital costs for flocculation-coagulation and filtration facility are 1.5-2.0 times as great as those associated with either a direct filtration or contact filtration alternative. The higher capital costs are the result of the requirement for tertiary sedimentation equipment and additional chemical handling inherent with this option.
- Incremental operation and maintenance costs for a direct filtration or contact filtration process configuration are 20-30 percent of the annual costs incurred with the flocculation-coagulation and filtration facility. The large difference in operation and maintenance costs is

due primarily to higher chemical usages associated with a flocculation-coagulation and filtration plant.

- Certain economics of scale may be realized for reclamation plants in the 4,000 to 40,000 m^3/d capacity range. Incremental unit capital costs for small reclamation plants (capacity less than 4,000 m^3/d) are 2-2.5 times as great as larger facilitates. Because ancillary equipment costs do not increase linearly with plant size, the cost of supporting facilities is a major component for small reclamation plants, thereby contributing to the disproportionately high unit costs.
- Life cycle costs for the direct filtration and contact filtration alternatives vary less than10 percent. Specific equipment characteristics and other factors (filter head loss, reliability under varying influent loads, operator preference, compatibility with existing equipment, flexibility, etc.) will govern ultimate systems selection.
- Incremental treatment costs for the additional treatment processes beyond secondary treatment required to produce reclaimed water suitable for unrestricted use will range from 0.06-0.14 €/m^3 depending upon facility capacity for either a contact filtration or direct filtration process configuration.
- Nutrient management (nitrogen and phosphorous removal) may be accomplished through utilization of either contact filtration-phosphorous removal (treatment flow diagram 8) or five stage process EIMCO (treatment flow diagram 9). Life cycle costs for the EIMCO alternative, however, are 30 percent lower than the contact filtration option because of chemical cost associated with contact filtration-phosphorous removal treatment.
- The production of reclaimed water for groundwater recharge will require a high degree of treatment including nutrient removal, filtration and carbon adsorption.. Reclamation costs for the contact filtration-carbon adsorption process configurations vary from 0.73-0.75 €/m^3.

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