RESEARCH REVIEW OF TECHNOLOGICAL PERSPECTIVES FOR WATER RESOURCES MANAGEMENT IN THE MEDITERRANEAN REGION

By

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1 INTRODUCTION

Water management is related to the development, allocation and use of water resources of a country or region, that is, the water volume used compared to the natural water resources available from rainfall. However, the traditional water management, based on modifying the hydrological cycle through the construction of small scale or massive engineering projects, is changing towards a new paradigm of integrated water management system involving new sources of water such as: surface and ground waters, reused waters, desalinated waters or any other available resource, and managing demand in order to respect ecosystems and in close harmony with the territory, the energy available, and the socio-economic system.

The new feature of these times is the high value attributed to the respect of the integrity of the ecosystem when using water resources. Efforts are now underway to rethink water planning and management, putting emphasis on the principles of integration between water policy and the three main dimension of sustainable development: environmental, socio-cultural and economic, as an alternative to new massive infrastructures. In this sense, the technologies that contribute to a rational use of water resources play an important role in the integrated water management.

Over the last decade of the 20th century, new strategies for the management of water resources have been promoted. These strategies are recommended in several chapters of Agenda 21 and they are also confirmed in the First Paragraph of the UN Program on Integrated Water Resources Development and Management, which states that the development of appropriate water management requires the application of new sustainable technologies both in terms of analysis and engineering.

This report analyzes the actual situation of water technologies for a rational use of water, and proposes an approach to a conceptual frame for the available water technologies in the Mediterranean area. It is based on the results of the MELIA partners dialog, the background documents uploaded in the MELIA Knowledge Base, and the research papers presented at the second Workshop of MELIA project focused in measures and different technologies for a rational use of water resources. Many key techniques in water management have been identified. They range from reducing the amount of water losses in agriculture to other technologies related to reservoirs, surface-groundwater conjunctive use, re-use of wastewater and water desalination. In the following, a description of the conditions of water scarcity in the Mediterranean Region is presented, followed by a analysis of the water management technologies employed in different economic and social sectors.
2 WATER SCARCITY IN MEDITERRANEAN AREA

Water of good quality availability has become one of the most significant problems in the world, especially in the Mediterranean region. The major aspects of this water crisis are overall scarcity of potable water and water pollution. There are several causes for the water crisis, including the overexploitation of surface and groundwater, overuse and pollution of water resources harming biodiversity, and inadequate access to safe drinking water for 1.1 billion people in the world (WHO, 2004), www.unwater.org , http://web.worldbank.org .

Most of the Mediterranean basin countries in North Africa, Middle East and Southern Europe has many similarities in terms of growing water shortage, increased drought events, increased pollution threats, increased overexploitation of groundwater resources and increased threat of sea water intrusion, rapid population growth and rapid tourism growth . In addition, natural surface and groundwater resources do not recognize frontiers, and many of them are shared by more than one country, incorporating another complication to the sustainable management of water. The common feature of the Mediterranean area is that water is one of the limiting factors for sustainable development, increased quality of life, and peace.

Natural and renewable water resources are unequally distributed between Mediterranean countries with more water in the North and less water in the South and East. But within each country water resources are also unequally distributed. In Spain, 81% of resources are located in the Northern half of the country; in Tunisia, the North provides the 80% of the country’s water resources; in Algeria, 75% of renewable resources are concentrated in 6% of the land in the Mediterranean coastal border. Some hydrological basins are crossed by national borders, making the resource common to several countries. Furthermore, some considerable water volumes stored in large deep aquifers in Libya, Tunisia, Algeria and Egypt are non-renewable resources and their use is consequently not sustainable (Kayamanidou, 1998).

Water is a scarce commodity in Eastern Mediterranean Region (EMR) and its availability is declining to a crisis level. According to the World Bank (1996), Middle East and North Africa (MENA) is the driest region in the world with only 1% of the world’s fresh water resources.

The regional average annual per capita renewable water dropped significantly over the last 40 years from 3,300 m³ in 1960 to 1,250 m³ in 1995 and is projected to drop to 650 m³ in 2025. Projections of the World Resources Institute (1996) suggest that by 2025 some EMR countries will be among the 45 countries worldwide which will suffer chronic water stress. An increasing proportion of surface and groundwater resources in the region are polluted mainly due to inappropriate disposal of municipal wastewater, infiltration from onsite sanitation facilities, and excessive use of fertilizers and pesticides in agriculture. Due to severe shortages in agricultural water, reuse of wastewater has become unavoidable in many countries such as Jordan, Syria and Israel. Untreated wastewater was and still is used sometimes in agriculture without adequate health safeguards .
Due to the water scarcity, water supplies are intermittent, unreliable and insufficient, and water consumption rates are still comparatively very low.

Trends in most European countries indicate that the supply of water to the population is threatened by man-made pressures and that water ecosystems are undergoing severe processes of quality deterioration (Berbel et.al., 2004). About 20% of all surface water in the European Union is seriously threatened with pollution. Groundwater supplies around 65% of all Europe drinking water, and 60% of European cities overexploit their groundwater resources. Furthermore, 50% of Europe’s wetlands have “endangered status” due to groundwater over-exploitation and the area of irrigated land in Southern Europe has increased by 20% since 1985 (European Commission 2002). In recent years, there has been a growing concern throughout the EU regarding drought events leading to water scarcity problems, especially in the Mediterranean countries. Here, the semi-arid/arid climate enhances water scarcity and rainfall is the main source of recharge. The competition between various uses, especially agriculture and tourism, which are major components of this area’s economy, make trade off allocation decisions very often too difficult. Hence, conflicts over water are increasing and they are becoming more complex, involving competition among alternative uses, among geographical regions with disparate water endowments, and between water resource development and other natural resources lost due to that development.

The challenge of water use and allocation is already a major political concern and will most likely amplify in the coming years. This is why integrated water resource management (IWRM) and the search for appropriate technologies is coming high on the policy agenda to help overcome such long list of problems. Such technologies will certainly range from the supply side to the demand side management, and addresses both quantity and quality of water. The identified relevant technologies have certainly to look into the enhancement of available supply through the use and reuse of available resources in the most efficient way, and develop management techniques that are integrated and comprehensive.

The legal and institutional aspects of integrated water resources management are also of prime importance to the country’s efforts toward overcoming their water problems and help reduce poverty; attain food security and economic growth, while maintaining sustainable ecological system. (Gbadegesin, 2008).

3 AGRICULTURE

Agriculture is the activity that demands higher quantities of water. In arid and semi-arid regions, water availability is a serious limitation for crop production due to poor and irregular rainfall, high evaporative demand and inadequate management. Some authors suggest measures and technologies applied to a rational use of water in agriculture (El Quosy, 2005):

- Use of modern irrigation systems in reclaimed land.
- Use of sprinkler and drip irrigation systems in the desert lands converted into agricultural production through reclamation.

- Change the irrigation system to drip irrigation.
- Precise land levelling, having a positive impact on the reduction of water supply since it reduces surface run-off to a minimum.
- Special attention must be paid to the opportunity of major water consuming crops like sugar cane and rice. Modification of the cropping pattern, principally of crops those need a lot of water, should be envisaged, but taking into account factors such as: population needs for food, the export requirement, the availability of land and water, the employment needs, the climatic conditions, status of soil salinity, etc…
- Night irrigation, since it reduces evaporation losses.
- Introduction of short cycle varieties of crops, rising crops which stay shorter period in the fields by reducing their growing age (avoiding high loss of water in the summer). Example are crops of some varieties of rice, wheat, maize, cotton and legumes.
- Some countries as Egypt present problems of irrigation in alluvial soils, and support the improvement of surface irrigation in old lands. The alluvial soils reduce the possibility of changing the existing gravity irrigation into modern and sustainable systems, due principally to:
  - Very low permeability of the soils.
  - High possibility of soil salting.
  - High initial costs of materials, cost of energy and maintenance.
  - Need for acquainted farmers those to do skilled labour required in this kind of lands.

In this sense, to improve the surface irrigation in the old lands, water and energy saving techniques can be implemented by:

- Change from the earth field ditches into canals or pipelines, which reduce seepage, aquatic weeds and evaporation from free water surface.
- Change from multi points abstraction of water from the ditches into one point lift on the top end of a raise ditches.

- Change the distribution system control from upstream to downstream control. In some countries as Egypt, the traditional head regulators operated manually or mechanically on the basis of upstream control are replaced by regulators equipped with automatic gates capable of providing the required flow when demand is in progress, reduced flow when demand decreases and complete shut off when demand is stopped. In the mean time, this type of system allows for a storage build up during periods of no abstraction to permit heavy abstraction afterwards.
• The use of operational models (indirect and direct) to determine crop evapotranspiration of crop cultivated, since this factor is very important and must be controlled in regions where the shortage of water is a serious problem.

• Use of accurate measurements of heat and water fluxes to optimize water management, and to validate models simulating crop water consumption (for example using the eddy-covariance system).

• In Turkey, some experiments on the deficit irrigation of crops have been done, resulting in approaching the problem in a different way:
  
  o To spread water deficiencies equally through the growing season. Different approaches are being considered such as:
    • Use different soil depth for wetting, to decrease irrigation water as control treatment.
    • Use different plant-pan coefficients.
    • Use different irrigation intervals.
    • Use different furrow spacing in surface, lateral and trickle spacing in drip irrigation systems.
    • Use line source sprinkler irrigation technique.
  
  o A better knowledge of crops responses to drought in order to concentrate water in critical periods e.g. olive irrigation in early autumn is the most productive period.

• Use of non-conventional water such as brackish water (treated waste water, drainage water) and saline water supply. Such water occurs extensively in the arid and semi-arid parts of the Mediterranean, Central and Southeast Anatolia regions, and are being used for irrigating some summer crops which are tolerant to salinity. Sometimes saline water is blended with fresh water with different quantity and used to irrigate the salt sensitivity crops.

• Use of drip method, mini-sprinklers, low capacity sprinklers, etc. In some countries, such as Cyprus, there are different uses of this methods according:

  o Permanent low sprinkler system is recommended for irrigation of densely spaced field vegetables like potatoes, carrots, beans, etc. In case, however, of limited financial resources the portable sprinkler system can be used instead, although it requires more labour.
  
  o Drip irrigation is the only applicable method for irrigation of row vegetables grown in greenhouses, low-tunnels and in the open field, spaced at a relatively great distance on the row and between rows. One nozzle is usually installed to deliver water to each plant.

  o Among permanent plantations, drippers are mainly recommended for banana, grapes and several other crops, like aromatic plants. Generally, unless there is a particular problem, drippers with larger nozzle opening are preferred, because they are not easily blocked by
impurities, therefore, they require less filtering and they are characterized by higher uniformity in flow.

- For irrigation of permanent trees plantations both drippers and mini-sprinklers can be successfully used. Mini-sprinklers are generally preferred and are more widely used due to their lower installation cost.

- Modern irrigation technologies.
  - Control and automation of the frequency and amount of water application using programmable computer-based systems, and including such devices as sequential metering valves and sensors to monitor weather and soil moisture variables.
  - Drip-irrigation systems with wastewater in both agricultural and garden settings. The rubber tubes of these pipes have a labyrinth “toothed” water passage, which facilitates superior filtration.

- Use of local materials (perlite, pumice, almond shells and pine bark) for some soilless cultures.
- Hydroponic systems.
  - Open hydroponic system. In some dry countries this kind of system for soilless cultures is the most favored commercially due to its technical simplicity based in managing the nutrient solution. However there are problems such as: pollution of the environment (underground water), waste of fertilizers and water and the final disposal of the hydroponic substrate (e.g. rock wool). The leach is usually collected in a reservoir, and it is used for the fertigation of open cultures or greenhouse cultivations in the soil.
  - Closed hydroponic system. This kind of system uses locally available inert substrates, like crashed gravel produced in a copper mine (Cyprus). The leach from the substrates is collected in a tank and it is re-circulated after being sterilized by a UV lamp. A well managed closed system reduces the evapotranspiration level of the plants and the water consumption. The system requires water of very good quality which is difficult to find in some countries. An open system using a mixture of locally available organic materials with perlite or peat moss as substrate is being studied for floriculture in Cyprus.

In designing and operating such a closed hydroponic system the following main parameters are to be considered:

- Crop related matters such as the life span of the crop, the water and nutrient requirements (recipe) and the cultural practices needed.
- Method for fertilizer mixing and supply of irrigation water (using simple volumetric fertilizer injectors or automatic fertilizer mixing units).
- Use of locally available inert substrates like perlite, coarse sand, crashed gravel vs. imported inert materials like rock wool.
- Climate control in greenhouses, like monitoring the aerial climate requirements (temperature, relative humidity, light, CO₂, etc.), the root zone requirements (root temperature and O₂ supply in the root zone).

- Rainwater harvesting. Collection of rain water from the roofs of greenhouses for irrigation purposes. This is achieved by installing a simple rain harvesting system next to the greenhouse. The water falling on the greenhouses is collected and stored in a water reservoir for later use. The reservoir is dug in the soil and a UV stabilized plastic membrane is used for preventing water leakage. The good quality water harvested can be used for leaching the salts from the soil, or for irrigation of the crops.

4 AQUIFERS MANAGEMENT

Integrated water management must take into account the artificial recharge of groundwater reservoirs. The water to be recharged can be clean water (storm water, water surpluses, surface water, imported water etc.), saline/brackish water, or treated effluent. Artificial recharge has been practiced for a number of years in many countries and for a wide variety of water resources management purposes, e.g.:

- Restoring groundwater levels (which have dropped due to over-exploitation).
- Providing a barrier for seawater intrusion in coastal aquifers.
- Usage of the aquifer as a reservoir facility for both seasonal and long term storage.
- Prevention of floods, by deviating peak flows.

There are several artificial recharge techniques, which have been widely employed, primarily in arid and semi-arid zones. Main recharge methods are: infiltration basins, bank filtration, sink-pits and canals, and injection wells. Their use depends on the type of water or effluent, on the soils and ground geologic profile, on hydraulic underground characteristics, on the availability of land for such projects, on the proximity of contamination sources, risk of seawater in coastal aquifers, etc.

Some authors (Teijón, G., et al, 2008) have reported an interesting use of treated wastewater: a hydraulic barrier for seawater intrusion control at a delta deep aquifer (Llobregat River, Barcelona, Spain). The hydraulic barrier consists of injecting treated recycled water to conform a pressure ridge along the coast, therefore stopping the sea water from entering the aquifer.
Other authors (Briuni, J. et al, 2008) have reported information regarding the preservation of aquifers. In areas in the influence zone of phosphate mining, such as Khouribga in Morocco, some technical management options for reducing the water necessary for washing plant of phosphate, to preserve the aquifer, have been evaluated:

- Use of water dams.
- Use of nitrated water.
- Optimization of water in the phosphate washing plant, increasing the recycling rate in the mine by maximizing recycling in decanters and dikes. Technician can play on the morphology of dikes / depths / surfaces and optimize the flocculation by the choice of flocculent, the concentration of flocculent and the flocculent point of injection, and optimize the rate of recycling of spreading basins.
- Use of treated wastewater. This has been the more economic water coupling with optimization of the cycle water in the washing plant.

### 5 RESERVOIRS

Today there are 45,000 large dams around the world, and the largest share with 20,000 of them belongs to China. In Mediterranean Area, Spain is the champion with 1,196 dams. Turkey comes second with 625 dams and thirdly France with 566. The life-time of a reservoir depends on several natural factors, climatic parameters and geographic-geological factors are the most important. These two factors determinate the sediment production.

Today, we need better tools to manage the basins which are already mature. From a technological perspective, while considering the rational use of water, keeping the basin water storage on its original level has great significance. Some technological alternatives help to improve this management. Table 1 shows the worldwide storage and sedimentation in dams.

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of large dams</th>
<th>Storage (km³)</th>
<th>Annual loss due to sedimentation (% of residual storage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worldwide</td>
<td>45571</td>
<td>6325</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Europe</td>
<td>5497</td>
<td>1083</td>
<td>0.17-0.2</td>
</tr>
<tr>
<td>North America</td>
<td>7205</td>
<td>1845</td>
<td>0.2</td>
</tr>
<tr>
<td>South and Central America</td>
<td>1498</td>
<td>1039</td>
<td>0.1</td>
</tr>
<tr>
<td>North Africa</td>
<td>280</td>
<td>188</td>
<td>0.08-1.5</td>
</tr>
<tr>
<td>Sub Saharan Africa</td>
<td>966</td>
<td>575</td>
<td>0.23</td>
</tr>
<tr>
<td>Middle East</td>
<td>895</td>
<td>224</td>
<td>1.5</td>
</tr>
<tr>
<td>Asia (excluding China)</td>
<td>7230</td>
<td>861</td>
<td>0.3-1.0</td>
</tr>
<tr>
<td>China</td>
<td>22000</td>
<td>510</td>
<td>2.3</td>
</tr>
</tbody>
</table>
In order to attain a Sustainable Development of Basin Water Storage Capacity, three instructions should be followed:

- **Prevent sediment inflow:**
  - Watershed management, aiming at conserving soil and, consequently, conserving water by using some techniques such: forestation, prevention of erosion by vegetation and tillage management, sediment tramp and change in land usage.
  - Upstream check structures (debris dams), which are dams smaller than the main dam provided by spillway structures, stopping sediment coming from tributaries to the reservoir of a main dam used to supply either power or water. It can extend the life of the dam, but the debris dam itself will require reservoir sediment management program.
  - If the sediment concentration in the tributary is large, the lifetime of the dam is short. In addition, debris dam are not active in design flood reduction. In this situation, increasing the main dam capacity weighed against debris dam capacity is more economical and useful than to build a new additional dam. However, if accumulated sediment in the debris dam is used for construction purposes by making arrangements in institutional and legal procedures according to this purpose, debris dam’s usage will be cost effective.
  - Reservoir bypass is a system very hard to apply. It should be design correctly, and its operation should be planned carefully since it is very expensive system. In order get a feasible bypass system some special conditions should be provided at the same time (topography conditions and size distribution of sediment load). Furthermore, bypassing sediment-laden water from channel is not acceptable for arid areas where need water seriously.

- **Sustainable management of the reservoir:**
  - Evacuation of sediments from reservoir.
  - Flushing: sediment removal technique, where the deposited sediment are removed from the reservoir by increasing flow velocity, and then transported through low level outlets. It can be operated in two ways (Fan, J. and Morris, G.L., 1997).
    - Flushing under pressure. The water is released through the bottom outlets by keeping reservoir water level high. For semiarid regions this applicability is suitable because of water scarce.
    - Free-flow flushing. Water is released by emptying reservoir and also by inflowing water from upstream, depending on riverside conditions.

The advantages and disadvantages of other types of flushing are showed in Table 2.
Table 2. Types of flushing

<table>
<thead>
<tr>
<th>Type of flushing</th>
<th>Advantages and disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment routing during floods</td>
<td>Useful at many types of sites. Can utilize excess water during floods for sediment control; can not stop sedimentation.</td>
</tr>
<tr>
<td>Drawdown flushing</td>
<td>Under proper conditions, capable or arresting sedimentation.</td>
</tr>
<tr>
<td>Emptying &amp; flushing</td>
<td>The only strategy which can recover lost capacity, but it requires emptying the reservoir in a regular basis</td>
</tr>
<tr>
<td>Venting density current</td>
<td>Does not require drawdown of reservoir pool level</td>
</tr>
</tbody>
</table>

- Sediment sluicing. It is an operational design where the reservoir is drawn down in flood season, and the sediments carrying inflow directly passed through the reservoir. So that sediment does not settle down after flood season, clear water will be stored and the reservoir capacity will be raised for the next season usage. In the worldwide usage, generally sluicing and flushing are used together.

- Mechanical removal.
  - Dredging. Sustainable method for medium and small size reservoirs, which do not have enough water for flushing. The method is removing accumulated in the reservoir mechanically from a reservoir bed by pumping or mechanical equipment without emptying the reservoir and then dumping the dredged sediment at a suitable area.
  - Trucking. It is the excavation of the accumulated sediment from reservoir like dredging but it requires drawdown of reservoir. Then the excavated solids transport to a suitable disposal area using traditional moving equipment. This method is not widely used because it is very expensive.
  - Hydrosuction Removal System (HRS). It is a siphon and airlift system, which uses the potential energy stored by hydraulic head at the dam, removes the sediments through a floating or submerged pipeline to an outlet. This method has some advantages than traditional dredging (lower operating costs, there is no need for any equipment to produce energy, sediments gone to the downstream end of the reservoir).

- Operational rules can affect how the sediment deposition occurs. For example, during flood season if the reservoir water level is high the sediment is mostly deposited in the upper reaches of reservoir. If the reservoir is drawdown, the sediments tend to deposit in the dead storage zones.

- Tactical dredging. It is the same as traditional dredging. It consists in the removal of accumulated sediment in reservoir locally, being an effective tool to prolong the reservoir life.
• **Search lost storage replacement or decommissioning of dam.**
  
  o Raising dam height, increasing the reservoir capacity in order to compensate the storage loss due to sedimentation. Nevermore, in the long term period this is not a solution for the sediment problem. In addition this method requires very careful engineering.
  o Building new dam. In some countries, such as Turkey, this is used to replace the lost storage capacity, but this is a temporary solution.
  o Decommissioning (retirement of dam). It is not a reservoir sediment technique; on the contrary it is an economical option if the dam useful life is finished and the operation costs of the reservoir are higher than the benefits gained.

• **Reduction of gully erosion hazards in mountainous and semi-arid areas.**

In mountainous and semi-arid countries, such as Algeria, there are severe problems of erosion. Some projects propose the use of anti-erosive structures in the protected basins, such as gabions, metallic weirs or tires dams.

• **River restoration.**

  Some authors suggest sustainable measures that restore natural conditions of the aquatic ecosystem, enhancing the landscape and ecological quality of riparian vegetation strips and reducing the transport of fine sediments in the channel:
  
  - Implementation of a horizontal subsurface flow constructed wetland, to treat the wastewaters.
  - Implementation of wooded buffer zones and plantation of these.

### 6 WASTEWATER TREATMENT

The access to adequate sanitation and wastewater treatment has a double benefit: it improves the life conditions of the affected population (poverty, hygiene, healthiness, etc), and it is a conservation strategy of the good ecological status of water resources.

In many Southern Mediterranean countries, sanitation tends to receive less attention and fewer financial resources than water supply. This leads to a lack of maintenance even for existing wastewater treatment plants (WWTP). For example, in Morocco and Algeria more than half of the WWTP are not functioning properly (Saghir *et al.*, 2000). In many small-to-medium-sized communities, wastewater treatment requirements are met using conventional on-site septic tanks, with effluent being disposed into the groundwater.

In Cyprus, the total number of main WWTP currently in operation is 25, however, more than 175 small WWTP are located in hotels, hospitals, on military bases and in small villages. In Jordan there are currently 19 WWTP
that serve big cities. In Morocco, on the other hand, the number of WWTP operating in small communities or rural areas amounts to 23 out of the total 31 that are in full operation. However, these plants serve only about 7% of the total population of Morocco (MEDAWARE Report, 2003). About 68 WWTP out of 129 are located in small-to-medium-sized communities in Turkey. Other countries in the region that practice wastewater treatment and reuse include Kuwait, Saudi Arabia, Oman, UAE, Egypt, Jordan, Israel, Tunisia and partially Palestine.

From these examples it is evident that many small-to-medium-sized communities are lacking sufficient and appropriate wastewater treatment.

Analysing the situation under a global overview, it can be said that the problem is more or less solved in large and medium cities and in those areas with adequate social, economic and technological development. On the contrary, the population most affected in terms of lack of basic services (drinking water and sanitation) is concentrated on rural and scattered areas, as well as in the marginal zones of the large cities in less developed countries. It is in this context where the main economic and technical limitations occur, where it is necessary to have solid and adjusted solutions that guarantee the elimination and adequate treatment of wastewater with minimum implementation costs and affordable service costs for the beneficed population. Decentralized systems at a small scale, as well as the non-conventional or extensive wastewater treatments, are a solution to this situation, given their resemblance with natural purification processes and the fact that their simplicity regarding their management and exploitation considerably reduce infrastructure and service costs.

Extensive technologies include many of the treatment processes used in conventional sewage treatment (settlement, filtration, absorption, chemical precipitation, ion exchange, biodegradation, etc.), in addition to natural treatment processes (photosynthesis, photo-oxidation, absorption by vegetation, etc.). However, contrarily to conventional technology, where the process take place sequentially in tanks and reactors and at high rates of flow (thanks to the application of energy), the processes in non conventional technologies take place at a natural speed (without the application of energy) and in a single reactor-system where the energy saving is offset by the fact that a larger surface area is utilised. (Martín, I. et al., 2007).

At present, both intensive and extensive technologies are used for the treatment of the sewage generated in small settlements. The practice proves that both types of technologies are valid for the treatment of effluent in small settlements, but the practice has also shown that, due to the special characteristics of these sites, priority should be given to robust treatment technologies with low operating and maintenance costs.

The advantages and disadvantages of extensive and intensive wastewater technologies, commonly used at present in the Mediterranean small settlements, as well as two commonly used Primary Treatment processes, are showed in Table 3:
Table 3. Wastewater technologies commonly used in the Mediterranean small settlements.

<table>
<thead>
<tr>
<th>Primary Treatment:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Septic Tank</strong></td>
<td><strong>Imhoff Tank</strong></td>
</tr>
<tr>
<td>Scope of application (p.e.)*: 300-500</td>
<td>Scope of application: 300-500</td>
</tr>
<tr>
<td><strong>Advantages:</strong></td>
<td><strong>Advantages:</strong></td>
</tr>
<tr>
<td>- Low installation and operation cost. The operational tasks consist mainly of the periodic extraction of the digested sludge.</td>
<td>- Low installation and operation cost. The operational tasks consist mainly of the removal of the digested sludge and floating debris.</td>
</tr>
<tr>
<td>- Easy installation of prefabricated units.</td>
<td>- Zero energy consumption.</td>
</tr>
<tr>
<td>- Low energy consumption.</td>
<td>- Absence of electromechanical failures.</td>
</tr>
<tr>
<td>- Low visual impact: underground installation.</td>
<td>- Subsurface installation is possible.</td>
</tr>
<tr>
<td>- It constitutes pre-treatment for many extensive technologies.</td>
<td>- The possibility of utilising prefabricated units facilitates installation.</td>
</tr>
<tr>
<td><strong>Disadvantages:</strong></td>
<td><strong>Disadvantages:</strong></td>
</tr>
<tr>
<td>- Low performance in terms of the reduction of organic load and elimination of pathogens, with the result that secondary treatment is required.</td>
<td>- Low performance, with the result that secondary treatment is required.</td>
</tr>
<tr>
<td>- Lack of stability when faced with peak flows.</td>
<td>- Lack of stability when faced with peak flows.</td>
</tr>
<tr>
<td>- Accumulation of fats and oils on the surface.</td>
<td>- Accumulation of fats and oils on the surface.</td>
</tr>
<tr>
<td>- Generation of bad smells in the absence of adequate maintenance.</td>
<td></td>
</tr>
<tr>
<td><strong>Extensive technology:</strong></td>
<td><strong>Filtration Trench</strong></td>
</tr>
<tr>
<td><strong>Advantages:</strong></td>
<td><strong>Scope of application</strong>: Isolated dwellings or small groups of dwellings</td>
</tr>
<tr>
<td>- Low operating and maintenance costs.</td>
<td></td>
</tr>
<tr>
<td>- Zero energy consumption.</td>
<td></td>
</tr>
<tr>
<td>- Absence of electromechanical failures.</td>
<td></td>
</tr>
<tr>
<td>- Contact of people or animals with the sewage is avoided.</td>
<td></td>
</tr>
<tr>
<td>- High treatment efficiencies.</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages:</strong></td>
<td></td>
</tr>
<tr>
<td>- Stringent surface requirements for installation.</td>
<td>- The application of this system depends on the nature of the soil, especially its permeability and the existence of shallow aquifers.</td>
</tr>
<tr>
<td>- The application of this system depends on the nature of the soil, especially its permeability and the existence of shallow aquifers.</td>
<td>- If the trenches are not correctly designed and maintained, it may lead to contamination of groundwater</td>
</tr>
<tr>
<td>- If the trenches are not correctly designed and maintained, it may lead to contamination of groundwater</td>
<td></td>
</tr>
</tbody>
</table>
### Extensive technology: Filtration Beds

**Scope of application:** Isolated dwellings or small groups of dwellings

**Advantages:**
- The total surface area required to service a given population size is smaller than that required for Filtration Trenches.
- Low operating and maintenance cost.
- Zero energy consumption.
- Absence of electromechanical failures.
- Contact of people or animals with the sewage is avoided.
- High treatment efficiency.

**Disadvantages:**
- Stringent surface requirements for installation.
- The application of this system depends on the nature of the soil, especially its permeability and the existence of shallow aquifers.
- If the filtration beds are not correctly designed and maintained, it may lead to contamination of groundwater sources.
- More susceptible to clogging than Filtration Trenches.

### Extensive technology: Filtration Wells

**Scope of application:** Isolated dwellings or small groups of dwellings

**Advantages:**
- The surface area required for installation is smaller than that required for other subsurface systems, such Filtration Trenches and Beds.
- Low operating and maintenance cost.
- Zero energy consumption.
- Absence of electromechanical failures.
- High treatment efficiency.

**Disadvantages:**
- The application of this system depends on the nature of the soil, especially its permeability and the existence of shallow aquifers.
- If the filtration wells are not correctly designed and maintained, it may lead to contamination of groundwater sources.

### Extensive technology: Intermittent Buried sand Filters

**Scope of application:** Isolated dwellings or small groups of dwellings

**Advantages:**
- Low operating and maintenance cost.
- Zero energy consumption.
- Absence of electromechanical failures.
- High treatment efficiency.
- Contact of people or animals with the sewage is avoided.

**Disadvantages:**
- Stringent surface requirements for installation.
- If the sand filters are not correctly designed and maintained, it may lead to contamination of
groundwater sources.
- If the sand filter should become clogged, it will be necessary to construct a new filter.
- Limited capacity to process effluent overloads.

### Extensive technology:

**Green Filter**

**Scope of application:** ≤ 500

**Advantages:**
- Simplicity of operation.
- Absence of mechanical failures.
- The operation costs of the treatment plant can be defrayed in part by selling the wood produced.
- The system can operate without any energy consumption.
- No sludge is produced in the purification process.
- Perfect environment integration.
- Very high levels of purification are achieved.
- It is perfectly able to absorb increases in effluent flow caused by increases in summer populations.
- Absence of odours.

**Disadvantages:**
- It requires a very large surface area, with the result that installation cost is directly related to land cost.
- The terrain cannot be very steep, there must be no shallow aquifers and the soil must have a certain level of permeability.
- Not suitable for high rainfall areas.

### Extensive technology:

**Constructed Wetlands**

**Scope of application:** ≤ 2,000

**Advantages:**
- Simplicity of operation.
- Absence of mechanical failures.
- The system can operate without any energy consumption.
- The system is sensible and not very sensitive to variations in influent flows and organic loads.
- The vegetation biomass acts as insulator for the sediment, which ensures that microbial activity continues throughout the year.
- Zero acoustical impact on the environment.
- No odours are generated.
- Perfect integration into the rural environment.
- Creation and restoration of wetland areas those are suitable for improving biodiversity, environmental education and recreational areas.

**Disadvantages:**
- It requires a larger surface area that intensive treatment technologies (3-5 m²/p.e.).
- The generation of sludge in the primary treatment process, although the sludge removal is spread out over time if Septic or Imhoff Tanks are used.
- It takes 2 or 3 growth phases of the vegetation before the best performance is achieved.
- Flow losses through evaporation and transpiration, which causes increased salinity of the treated effluent.

### Extensive technology:

**Stabilisation Ponds**
### Peat Filter

**Scope of application:** ≤ 2,000

**Advantages:**
- Simplicity of operation.
- Absence of mechanical failures.
- No sludge is generated and the dry crust is easy to handle.
- Capacity to adapt to variations in influent flows and organic loads.
- Less stringent terrain requirements for installation (0.5 m²/p.e.)
- Easy aesthetic adaptation to the environment.

**Disadvantages:**
- Dependence on rainfall figures which affect the time for the surface crust to dry, resulting in varying surface area required according to the rainfall figures. This technology is not suitable for areas with very high rainfall.
- Greater labour requirements than other extensive technologies, given that the depleted filters need to be regenerated after each filtration cycle.
- The peat layer needs to be replaced every 6-8 years of operation.

### Trickling Filter

**Scope of application:** ≤ 5,000

**Advantages (compared to intensive technologies):**
- Lower energy consumption.
- It is not necessary to control dissolved oxygen levels or the concentration of suspended solids in the bacterial filter.
- No aerosols are formed, which eliminates the danger of micro-drop inhalation by operators.
- Low noise levels due to the low energy requirements of the installation.

**Disadvantages (compared to extensive technologies):**
- The installation costs are high due to the cost of the plastic filter material.
- The process generated sludge, which needs to be stabilised.
Technologies with intermediate characteristic between extensive and intensive technology.

### Rotating Biological Contactors (RBC)

<table>
<thead>
<tr>
<th>Scope of application:</th>
<th>≤ 5,000</th>
</tr>
</thead>
</table>

**Advantages (compared to intensive technologies):**
- Lower energy consumption.
- It is not necessary to recycle the sludge in a secondary settling tank to the biological area, as the concentration of the bacterial biomass which has adhered to the substrate is sufficient.
- Improved performance in the presence of toxins, as the bacterial flora does not remain immersed in the water continuously, which allows it time to recover during the extended time for which it is in contact with the air.
- It is not necessary to control dissolved oxygen levels or the concentration of suspended solids in the biological reactor, which makes the operation of the plant much simpler.
- Lends itself to gradual construction. The modular nature of the system makes it possible to expand the treatment plant gradually in accordance with the treatment requirements.
- No aerosols are formed, which eliminates the danger of micro-drop inhalation by operators.
- Low noise levels due to the low energy requirements of the installation.
- Given that RBC units are generally installed in covered containers, the temperature of the sewage being treated is maintained at a higher level, which improves the plant’s purification capacity during cold periods.

**Disadvantages (compared to extensive technologies):**
- The installation costs are high.
- The process generates sludge, which needs to be stabilized.
- Makes use of patented equipment.

### Intensive or conventional technology:

#### Extended Aeration

| Scope of application: | The extended aeration system is generally used in populations that do not exceed 10,000 p.e. Pre-manufactured plants are usually installed underground and are used for the treatment of the effluent generated by small population centres (such as housing complexes, schools, camping sites, etc). |

**Advantages:**
- Less stringent land surface requirements.
- Low environmental impact, if the aeration tanks are installed underground.
- Large capacity for the elimination of organic matter and suspended solids.
- The sludge flowing from the biological tank is stabilised.

**Disadvantages**
- High energy consumption.
- Limited flexibility when faced with changes in flow rates and organic load.
- If surface aerators are used, aerosols are formed which may carry pathogenic agents. This problem can be eliminated by covering the tanks.
- Low capacity for the elimination of nutrients and pathogens.
- More complex control process than with extensive or non conventional technologies.

*p.e.: population equivalent.*
7 MUNICIPAL WASTEWATER RECYCLING

New concepts which are separating the wastewater into urine (yellow water), feces (brown water) and grey water emerge during the last 10 years. The separated and adapted treatment of these flows allows the utilization of their energy and their valuables.

**Organic waste and faeces.** Are treated an-aerobically. The produced biogas can be used to provide electric energy for the treatment processes and the population as well as for heating (combined heat and power units, fuel cells etc.). The produced sludge will be dewatered, stored and transported to a central processing station. Anaerobic treatment requires a minimum size/capacity because the basic investment costs are comparably high.

**Urine.** Separated urine should be stored and transported to central treatment stations as the volume is small (1.6 L p.e.-1 day-1) and the utilization of valuables requires an advanced treatment.

**Grey water.** Approximately 38,000 L of grey water per person and year has to be treated with the goal to reuse most of the water. The safe reuse of grey-water requires the removal of germs and viruses, carbon, nutrients and salts. Aerobic membrane bioreactors followed by reverse osmosis can be applied, but have the drawback of high costs. Anaerobic membrane bioreactors are a possibility to overcome the high energy consumption and sludge production of aerobic systems. Nevertheless, sludge and salt brines have to be discharged for further treatment and utilization (Figure 2).

![Figure 2](image.png)

*Fig. 2.* Anaerobic membrane bioreactor-system for grey-water recycling. (Sven-Uwe Geissen, 2008. 2nd Workshop Melia).

**Emerging contaminants.** Anthropogenic substances like pharmaceuticals, diagnostics, pesticides, drugs, etc. are detected worldwide in the water cycle. During the treatment at wastewater treatment plants (WWTP) they are either partially retained in the sludge, or metabolized to a more hydrophilic but still persistent form that passes...
the wastewater treatment plant and ends up in the receiving waters. The removal of pharmaceuticals in WWTP is variable and depends on the properties of the substance and process parameters (i.e. sludge retention time, hydraulic retention time, temperature) 10. (Clara et al, 2005; Vieno et al. 2005).

There are some technical measures to reduce the concentration of this king of substances:

- **Membrane Bio-reactor.** The nominal porosity of the membranes is 0.4 µm (microfiltration) a fouling layer formed on the surface of the membranes out of proteins and microorganisms brought up the effective porosity of 0.01 µm, which put the filtration type into the range of ultra-filtration.

- **Nano-filtration and Reverse Osmosis.** The system works with three treatment lines operating in parallel, one equipped with Nano-filtration, and two lines equipped with Reverse Osmosis membrane filtration racks (see Figure 3). All three lines are fed from groundwater wells.

![Figure 3](image)

**Fig. 3.-** Scheme of Nano-filtration ad Reverse osmosis treatment lines at the Drinking Water Treatment Plant of Besós (NE-Spain).

- **Conventional activated sludge.** The treatment consists of a pre-treatment, preliminary treatment, primary sedimentation unit and a secondary (biological) treatment. Pre-treated wastewater goes through a physical process of settling in a primary clarifier. Secondary treatment is consisted of a pre-denitrification (anaerobic) and nitrification (aerobic) tank, and two secondary clarifiers. Secondary sludge is being re-circulated to a primary clarifier which improves settling characteristics of primary sludge and also increases sludge age. Mixture of primary and secondary (activated) sludge is being processed (thickening, dewatering) and anaerobically digested, and biogas produced is being used for heating of a digester.

- **There are other techniques dealing with the elimination of these substances in the effluent of the municipal wastewater treatment plants that demonstrated that with ozone doses of approx. 5-10 g O3 m-3 the removal of the target substances is possible for most**
pharmaceuticals. Mineralization of the target compounds will require much higher doses and therefore, higher costs as the concentration is low and the flow rate is high. Figure 4 shows the treatment of urine with ozone, a process that will destroy most of the pharmaceuticals and, with the XRC (x-ray contrast), bacteria and viruses.

![Diagram showing the treatment of urine with ozone](image)

Fig. 4.- Elimination of pharmaceutical from separated urine in hospitals; x-ray contrast media as example. (Sven-Uwe Geissen, 2008, 2nd Workshop Melia).

8 **REUSE OF TREATED WASTEWATER**

It is widely recognized that the increasing strain being put on freshwater resources will place further emphasis on the development of sustainable, reliable and cost-effective technologies, capable of treating and reclaiming wastewater for reuse. This is made very challenging by virtue of the extreme fluctuations in wastewater quality, coupled with the demand for reliably pure water that most reuse applications demand. According to the World Bank, “The greatest challenge in the water and sanitation sector over the next two decades will be the implementation of low cost sewage treatment that will at the same time permit selective reuse of treated effluents for agricultural and industrial purposes” (Looker, N., 1998).

Since the public health is essential, the quality of reused water must satisfy the recommended standards in each region. Accordingly, close monitoring for both the effluent, soil and crops need to be tested in order to assess the level of potential impact of the reused effluent.

Although there is an absence of common guidelines or regulations about wastewater reuse both at European Community level and between the Mediterranean countries, there are several countries or federal regions that have published their own standards or regulations. In Spain, for example, the current Royal Decree 1620/2007 regulates the legal regime for reuse of treated wastewaters according to different uses. The quality criteria for reclaimed water are shown in Table 3, which differentiates 14 uses under five main headings: 1) Urban, 2) Agricultural Irrigation, 3) Industrial, 4) Recreational and 5) Environmental.
The reuse of treated wastewater is forbidden for the following purposes: a) for human consumption, except in situations of declared disasters; b) for the specific uses of the food industry; c) for use in hospital installations; and other similar uses; d) for the breeding of filtering molluscs in aquaculture; e) for recreational use as swimming waters; f) for use in fountains and ornamental waters in public spaces or inside public buildings; g) for any other use that the Health Authorities may deem to be a hazard to human health. Use in refrigerating towers and evaporation condensers, is subject to very stringent requisites, and forbidden in urban areas and in places with public or commercial activities.

Minimum acceptable limits are established for each type of use under the following parameters: intestinal nematode eggs, Escherichia coli, suspended solids and turbidity. Furthermore, the following parameters have been added: a) *Legionella spp.* for use in industrial refrigerating systems or in case of hazards due to aerosols; b) *Taenia saginata* and *Taenia solium*, in the case of irrigation of pastureland for milk or meat-producing animals; c) total phosphorus for environmental and recreational uses (pools, water bodies and running watercourses); d) total nitrogen in the case of groundwater recharge.

The implementation of these regulations, which impose rigorous quality requirements for reclaimed water, will make it necessary to adapt an important part of the current reuse systems (Ortega, E., and Iglesias, R. 2008).

**Table 4. Quality criteria for the reuse of treated effluent reuse. Maximum allowed values (Spanish Royal Decree 1620/2007)**

<table>
<thead>
<tr>
<th>Wastewater reclamation Uses</th>
<th>Maximum allowed values</th>
<th>Other Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intestinal nematode eggs</td>
<td>Escherichia Coli CFU/100 ml</td>
</tr>
<tr>
<td>1.- URBAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QUALITY 1.1 Residential:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Private garden watering.</td>
<td>1 egg /10 L</td>
<td>0</td>
</tr>
<tr>
<td>b) Discharge of bathroom appliances</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QUALITY 1.2 Urban services:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Watering of urban green areas (parks, sports grounds, etc.)</td>
<td>1 egg /10 L</td>
<td>200</td>
</tr>
<tr>
<td>b) Hosing down streets.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Fire-fighting systems.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) Industrial car wash</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.- AGRICULTURAL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Foundation Center for New Water Technologies (CENTA).SPAIN
Palestinian Hydrology Group (PHG). PALESTINE
QUALITY 2.1
a) Irrigation of fresh food crops for human consumption, through water application systems allowing for direct contact of regenerated water with edible parts.

<table>
<thead>
<tr>
<th>Pathogens</th>
<th>Maximum Limit</th>
<th>Other Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legionella spp.</td>
<td>1000 CFU/L (in the case of aerosol hazards)</td>
<td>Presence/absence of pathogens</td>
</tr>
</tbody>
</table>

QUALITY 2.2
a) Irrigation of crops for human consumption, through water application systems not avoiding direct contact of regenerated water with edible parts, but not for consumption as fresh food since there is subsequent industrial treatment.
b) Irrigation of pastureland for milk or meat-producing animals.
c) Aquaculture

<table>
<thead>
<tr>
<th>Pathogens</th>
<th>Maximum Limit</th>
<th>Other Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taenia saginata and Taenia solium</td>
<td>1 egg / L (In irrigation of crops for consumption by meat producing animals)</td>
<td>Presence/absence of pathogens</td>
</tr>
</tbody>
</table>

QUALITY 2.3
a) Localised irrigation of ligneous crops impeding contact of regenerated water with food for human consumption.
b) Irrigation of ornamental flowers, greenhouses and nurseries with no direct contact of regenerated water with crops.
c) Irrigation of industrial crops, greenhouses, fodder stored in silos, cereals and oleaginous seeds.

<table>
<thead>
<tr>
<th>Pathogens</th>
<th>Maximum Limit</th>
<th>Other Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legionella spp.</td>
<td>100 CFU/L</td>
<td>Presence/absence of pathogens</td>
</tr>
</tbody>
</table>

3. - INDUSTRIAL

QUALITY 3.1
a) Process and cleaning water except in food industry.
b) Other industrial uses

<table>
<thead>
<tr>
<th>Pathogens</th>
<th>Maximum Limit</th>
<th>Other Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legionella spp.</td>
<td>100 CFU/L</td>
<td>Presence/absence of pathogens</td>
</tr>
</tbody>
</table>

QUALITY 3.1
b) Process and cleaning water for use in food industry.

<table>
<thead>
<tr>
<th>Pathogens</th>
<th>Maximum Limit</th>
<th>Other Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legionella spp.</td>
<td>100 CFU/L</td>
<td>Presence/absence of pathogens</td>
</tr>
</tbody>
</table>

QUALITY 3.2
a) Refrigeration towers and evaporation condensers

<table>
<thead>
<tr>
<th>Pathogens</th>
<th>Maximum Limit</th>
<th>Other Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legionella spp.</td>
<td>Absence CFU/L</td>
<td>Industrial use exclusively far from urban areas. Authorization is subject to the approval of the Health Authority responsible for the relevant control under RD 865/2003</td>
</tr>
</tbody>
</table>

4. - RECREATIONAL
### QUALITY 4.1

<table>
<thead>
<tr>
<th>a) Irrigation of golf courses</th>
<th>1 egg /10 L</th>
<th>200</th>
<th>20</th>
<th>10</th>
</tr>
</thead>
</table>

If irrigation water is applied directly onto the soil (drip, micro-spray) the QUALITY 2.3 criteria are applicable.

*Legionella spp.*

100 CFU/L

(in the case of aerosol hazards)

**Other contaminants (1)**

### QUALITY 4.2

<table>
<thead>
<tr>
<th>a) Ponds, bodies of water and running water with no public access</th>
<th>No limit set</th>
<th>10,000</th>
<th>35</th>
<th>No limit set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total phosphorus: 2 mg P/L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(in stagnant water)

**Other contaminants (1)**

### 5.- ENVIRONMENTAL

#### QUALITY 5.1

<table>
<thead>
<tr>
<th>a) Recharge of aquifers by localised seepage through the soil</th>
<th>No limit set</th>
<th>1,000</th>
<th>&lt; 35</th>
<th>No limit set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total nitrogen: 10 mg N/L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{NO}_3$: 25 mg $\text{NO}_3$/L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### QUALITY 5.2

<table>
<thead>
<tr>
<th>a) Recharge of aquifers by direct injection</th>
<th>1 egg /10 L</th>
<th>0</th>
<th>10</th>
<th>2</th>
</tr>
</thead>
</table>

Art. 257 to 259 of Royal Decree 849/1986

#### QUALITY 5.3

<table>
<thead>
<tr>
<th>a) Irrigation of forests, green zones and similar areas with no public access</th>
<th>No limit set</th>
<th>No limit set</th>
<th>35</th>
<th>No limit set</th>
</tr>
</thead>
</table>

**Other contaminants (1)**

#### QUALITY 5.4

<table>
<thead>
<tr>
<th>a) Other environmental uses (maintenance of wetlands, minimum flows and similar uses)</th>
<th>The minimum quality required is studied on a case by case basis</th>
</tr>
</thead>
</table>

**NOTE (1):**

The liberation into the environment of the Other Contaminants contained in the wastewater discharge authorisation must be limited (See Annex II of Royal Decree 849/1986, of 11 April). In the case of hazardous substances (See Annex IV of Royal Decree 849/1986, of 11 April, modified by Royal Decree 606/2003, of 23 May), compliance with the Environmental Quality Regulations must be ensured (See Article 245.5 of Royal Decree 849/1986, of 11 April, modified by Royal Decree 606/2003, of 23 May).

In some countries, there has been a significant development of water reclamation technologies and these have substantially improved both the reliability of treatment and the quality of effluent. New technologies have appeared especially in the field of membranes and advanced filtration systems. Proven technologies from other fields, such as desalination and disinfection, have been developed so that they can be used efficiently with reuse systems (Ortega, E., and Iglesias, R., 2008). Some of the most widely-used water reclamation technologies are:
Physical-chemical treatment. It is an excellent buffer against possible irregularities of the treated effluent. It can also reduce sulphide, phosphorus or heavy metals, if necessary. An interesting innovation which is appearing in some countries such as Spain with good results is the use of micro-sand to improve flocculation and settling, allowing clarification basins to operate under high loads for short retention times.

Filtration systems. One of the most common filtration systems are pressure or gravity sand filters, which are well-known and reliable, with low installation and operating costs. To improve the efficiency rates, more complex systems like pulsating bed filters and moving bed filters have been developed. The former have been operating efficiently for many years, but their installation and operating costs are the highest.

Two emerging systems in Spain are worth mentioning since they offer high performance: the Dualsand double filtration system and Sieving Filters (Ortega, E., and Iglesias, R. 2008):

1. Dualsand double filtration system consists of two filters in series with a recirculation device from the second back to the first filter.

2. Sieving Filters consist of discs with polyester fabric panels with an absolute porosity of 10-500 µm. The filtration, by gravity, is carried out from the inside to the outside of the discs and cleaning is against the current.

Membrane treatments. The technologies implemented, depending on whether they were used as filtration or salt elimination systems, are micro-filtration (0.2 µm pore size) and ultra-filtration (< 0.1: 0.02-0.04 µm) for filtration and the Electrodialysis reversal (and Reverse osmosis for desalination).

Desalination systems. In view of the salination problems in aquifers, structural water deficit and the need for non conventional resources, some desalination techniques for sea or brackish waters are:

1. Reverse Osmosis. It is an electrochemical process of salt separation where ions are transferred through membranes from a lesser concentrated solution to a higher concentration as a result of a difference of potential.

2. Reverse Electrodialysis, is a robust system which is easy to operate. A decisive factor as regards the operating cost is the replacement of protective cartridge filters.
Disinfection systems

In terms of health, disinfection is the most important phase of the water reclamation treatment systems since it removes the pathogenic micro-organisms (bacteria, viruses and protozoa) through physical (ultraviolet radiation) and chemical processes (sodium hypochlorite or ozone).

Extensive or non conventional technologies. These kinds of technologies are those which apply parameters and kinetics which are normally found in the nature (European Commission 2001). Their energy input requirement is much lower than that of intensive or conventional technologies but the land requirement is much higher and so it is used only for small communities. The principal extensive technologies used by wastewater reuse are: infiltration-percolation, stabilization ponds and constructed wetlands. These treatments are mainly in the field of the reclamation of purified effluents for environmental purposes (riverbank improvement, landscape or wetland recovery), as a method to improve the secondary treatment and the ligneous and industrial non-food crops

Case studies from Mediterranean Region:

- Irrigation of Serres de Pals Golf Course with treated effluent, Girona – Spain

The main aim of this case study (Candela, L. et al, 2007) is to evaluate if the soil and the aquifer underneath are affected by the utilization of this type of water. Analyses have been performed for total coliforms, aerobic bacteria, soil water pressure and soil water content as well as chemical analyses of the irrigation water, aquifer and water of the vadose zone. As a result of the agricultural management of the golf course and the quality of the treated urban wastewater, the soil and aquifer chemical characteristics of the area have been changed by water irrigation. Although no associated microbiological risk has been observed in the aquifer due to the effective soil filtration, the soil–water interaction may render water quality of the aquifer inappropriate for its final use due to the salinity increase. However, the most important risk is associated to soil Stalinization which may impair cultivation in the long term.

- Low tech wastewater treatment and reuse technology application in Palestine

Several small scale low technology wastewater treatment plants have been implemented in Palestine. They serve small rural communities partially or fully. The total population served by each plant range from couple of hundred households to entire villages of around 5000 people. The treatment plants are based on low-cost technology consisting if anaerobic treatment phase (up-flow anaerobic sludge blanket) followed by constructed wetlands and effluent storage tank that can allow treated effluent flow to the downhill agricultural area. The system removal efficiency can reach 90% as shown in Table 5, (PHG, 2005). In Figure 5 is showed the scheme of these treatment plants.
Table 5: Removal Efficiency of Low Cost Wastewater Treatment Technologies in Palestine

<table>
<thead>
<tr>
<th>Parameter</th>
<th>In</th>
<th>Out</th>
<th>Removed%</th>
<th>WHO guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Oxygen Demand COD (mg/L)</td>
<td>1200</td>
<td>&lt; 100</td>
<td>92%</td>
<td>100&gt; &lt;150</td>
</tr>
<tr>
<td>Biological Oxygen Demand BOD (mg/l)</td>
<td>546</td>
<td>&lt; 20</td>
<td>96%</td>
<td>25</td>
</tr>
</tbody>
</table>

Grey wastewater forms about 80% of the total water used at household level. At least 60% of grey wastewater can be recovered, treated and reused. The general shortage of water and the high grey wastewater generation from households requires careful consideration of solutions that can be locally applied, considering environmental elements, health issues and the socio-economic situation.

One experience has demonstrated that simple treatment units can be built per household or school in order to help save more water that can be treated and reused easily for irrigating home gardens and school gardens. The technology simply involves a Septic tank up flow gravel filter followed by aerobic filter system as shown in Figure 6. The removal efficiency of nutrients can be as high as 90% as well, (PHG,2008).
Figure 6: Implemented grey water treatment units in schools and households in Palestine

- Ecological sanitation.

Ecological sanitation represents a different approach - an ecosystem approach to sanitation. An ecosystem approach prevents disease by destroying pathogens prior excreta are returned to the terrestrial environment, and it recovers and recycles plant nutrients and organic matter, thus closing the nutrient loop.

Ecological toilets are designed with these goals in mind. In addition, there is no water use to flush away human excreta. So water is conserved and pollution is prevented. In contrast, the conventional toilet systems (e.g. flush toilets and pit latrines) are designed to dispose off excreta, flushing them away with water or burying them in deep pits. Such approach is converting human excreta from soil cycle to water cycle. This entails further step and costs to bring them back to the soil cycle. This is why the ecological toilet is an important part of the ecosystem approach since it allows for direct use of the nutrients at the soil cycle with some natural and simple treatment.

Ecological (dry) sanitation can be defined as on-site disposal of human excreta without the use of water as a carrier. The technology of dry toilets has been used successfully for decades in many developing countries e.g. Vietnam, China, Mexico, El Salvador and other Central American states. Even in highly developed countries such as Sweden there is a great deal of interest in this technology. All ecological toilets should be designed to prevent diseases, recover and recycle nutrient and reduce wastage of water and also reduce contamination of water.

One case of study have been reported from Palestine. It is a dry sanitation pilot project in four villages and one refugee camps in Palestine to test the viability of this technology and its performance in this region, which is characterized by its particular climatic and cultural environment (PHG, 2003). The pilot includes the
construction of thirty units of ecological toilets in these areas as shown in Figure 7. After monitoring the performance of these units in terms of bacterial as well as viral removal, it was realized that there is a dramatic reduction in pathogen count.

![Structure of Dry Toilet](image)

**Figure 7: Structure of Dry Toilet**

9 **REUSE OF DRAINAGE WATER**

Some countries such as Egypt return back a high quantity of drainage waters to the River Nile raising its salinity from about 200 ppm to less than 300 ppm. On the other hand, four more billion cubic meters of drainage water generated in the southern part of the Delta are mixed with fresh water and reused for different purposes.

10 **INDUSTRIAL WASTEWATER**

Olive oil production industries. Olive mill wastewaters (OMW) are a significant source of environmental pollution related to olive oil production industries. Olive oil extraction processes generate three phases: olive oil, solid residue and aqueous liquor which averagely represent 20, 30 and 50% respectively of the total weight of the processed olives. In Spain since the 90’s the technology of ‘two phases’ for extracting oil that is now the most widely used system avoid the production of water in the process of extraction generating only a ‘wte’ residual with 60%-70% humidity and oil.
The advantage of the new technology is to avoid extra water addition (therefore saving water use) and avoid OMW (Uceda, M. et al., 2006).

OMW cause serious environmental deteriorations such as colouring of natural waters, alteration of soil quality, phytotoxicity and odour nuisance. Conventional methods for the removal of phenolic compounds from OMW can be divided into three main categories: biological, chemical and physical treatment. Adsorption has been found to be superior to other techniques for water reuse in terms of initial cost, flexibility and simplicity of design, ease of operation and insensitivity to toxic pollutants.

Many sorbents based on low cost agricultural by-products had been used for dye sorption from wastewater, which included: banana pith, orange peel, wheat straw, sawdust, powdered waste sludge, wheat shells, and wheat bran and hen feathers. Some authors have reported that banana peel has proven to be a promising material for the removal of contaminants from OMW.

11 RAIN WATER HARVESTING

Traditionally, rainwater harvesting has been practiced in arid and semi-arid areas, and has provided drinking water, domestic water, water for livestock, and water for small irrigation. Also it’s a way to replenish groundwater levels.

Harvesting of rainwater is achieved through the effective use of runoff that occurs only when the rainfall rate exceeds the infiltration capacity of the natural soil. It is a function of soil type, slope, rainfall amount and intensity.

In most urban areas, population is increasing rapidly and the issue of supplying adequate water to meet social needs and to ensure equity in access to water is one of the most urgent and significant challenges faced by decision-makers. Rain water is valued for its purity and softness which can avoid many environmental problems often caused in conventional large-scale projects using centralized approaches. It has a neutral PH, free from salts, manmade contaminants and any disinfectant.

Methods of Rainwater Harvesting:

Rain water harvesting is a technology used in collecting and storing rainwater from rooftops, the land surface or rock catchments using simple technique such as jars and pots as well as complex techniques such as underground check dams. These techniques are found all over the world, with different level of technology comprising, even, practices employed by ancient civilizations and still serving as a major source of drinking water in rural areas.

Commonly used systems consist of three principal components:
1. Catchment Areas

- Rooftops Catchments: in this technique, rainwater is collected in vessels at the edge of the roof. Variations on this basic approach include collection of rainwater in gutters which drain to the collection vessel through down-pipes constructed for this purpose, and/or the diversion of rainwater from the gutters to containers for settling particulates before being conveyed to the storage container for the domestic use. As the rooftop is the main Catchment area, the amount and quality of rainwater collected depends on the area and type of roofing material. Reasonably pure rainwater can be collected from roofs constructed with galvanized corrugated iron, aluminium or asbestos cement sheets, and tiles and slates. Roofs with metallic paint or other coating are not recommended as they may impart tastes or colour to the collected water. Roof catchments should also be cleaned regularly to remove dust, leaves and bird droppings so as to maintain the quality of the product water.

- Land surface catchments: Rainwater harvesting using ground or land surface Catchment areas is a simple way of collecting rainwater. It involves improving runoff capacity of the land surface through various techniques including collection of runoff with drain pipes and storage of collected water. Compared to rooftop Catchment techniques, ground Catchment techniques provide more opportunity for collecting water from a larger surface area.

- Clearing or altering vegetation cover: Clearing vegetation from the ground can increase surface runoff but also can induce more soil erosion. Use of dense vegetation cover such as grass is usually suggested as it helps to both maintain a high rate of runoff and minimize soil erosion.

- Soil compaction by physical means: This involves smoothing and compacting of soil surface using equipment such as graders and rollers.

2. Collection Device:

Storage Tanks: Storage tanks for collecting rainwater harvested using guttering may be either above or below the ground.

3. Conveyance Systems

Conveyance systems are required to transfer the rainwater collected on the rooftops to the storage tanks. This is usually accomplished by making connections to one or more down-pipes connected to the rooftop gutters.

**Advantages of Rain Water Harvesting**

- Rainwater harvesting techniques are simple to install and operate.
- Running cost is almost negligible.
- Rainwater is relatively clean and the quality is usually acceptable for many purposes with little or even no treatment.
- Rainwater harvesting has few negative environmental impacts compared to other water supply project technologies.
- Rainwater provides a water source when groundwater is unacceptable or unavailable, or it can augment limited groundwater supplies.
- Rainwater can be a continuous source of water supply for both the rural and poor.

**Rainwater Harvesting Examples from Mediterranean Region**

Rainwater harvesting is an old technology in collecting of rainwater in rainy season to use it in dry seasons. Extensive rainwater harvesting apparatus existed 4000 years ago in the Palestine, Jordan and Greece. Ancient Rome residences were built with individual cisterns and paved courtyards to capture rain water to augment the water supply from city's aqueducts.

**a. Water Harvesting in Jordan**

Jordan is a country of with scarce water resources, due to low and erratic behaviour of rainwater. 92% of the water evaporates and only 8% is available in the form of flood flow and groundwater. Historically, agriculture using surface runoff and rain harvesting technique were extensively practiced as early as 4000 years ago in Jordan through cisterns, pools, and hafirs found in all ruins and archaeological sites in the country. The Nabatean culture showed beautiful examples of water harvesting form condensation on rocks.

Many activities of rainwater harvesting were implemented in Jordan in order to control the erosion, combat desertification and to ensure better utilization of the limited water resources and minimize the stress on the water demand.

**b. Water Harvesting in Palestine**

Similar to Jordan, and other Mediterranean countries, water harvesting in Palestine has been practiced from thousands of years ago. Many cisterns from the Roman times still exist. The water harvesting practices implemented in Palestine aims at maintaining soil moisture and preventing soil erosion through constructing of traces and also building storage facilities such as cistern and ponds to collect rainfall directly and use it for potable use. It is good to mention that 40% of the rural areas in Palestine are still lacking proper water supply source and they depend on rain water harvesting to satisfy their domestic water needs. Traditional techniques used are collecting the rainfall from the roof tops of households and store it in Cisterns adjacent to the house.
The rainfall is conveyed to the cistern through a pipe and then the water is pumped back into a roof water tank to be circulated to the house in a closed loop to avoid any pollution. Figure 8 shows the system used in Palestine.

![Figure 8: Water Harvesting Cisterns used in Palestine](image)

**12 DESALINATION (BRACKISH AND SEAWATER)**

Today, desalination is becoming a serious option for the production of drinking and industrial water as an alternative to traditional surface water treatment and long distance conveyance. In some countries, desalination has long been confined to situations where no other alternatives were available to produce drinking water (some coastal towns, islands, remote industrial sites, etc.), or where energy is abundantly available (power stations, gas and oil production fields).

Nanotechnologies and membrane technologies represent central assesses for the future of all our societies in terms of health, environment, energy, industrial market, etc. This is particularly true for the Mediterranean area due to scarcity of the water resource. In the field of desalination two groups of technologies must be distinguished:

- Thermal or distillation processes which involve some form of boiling or evaporation with steam generators, heat boilers (Multiple Effect –MED- and Multiple Stage Flash –MSF- distillation)
- Membrane / Reverse Osmosis processes (ordinarily isothermal operations with a significant energy saving, but which produce brines).

Each approach has its advantages and disadvantages, the choice of any approach depend on the requirements and the restrictions faced at the site.

Some research groups are working with new promising membrane material such as:
- Mixed-matrix membranes (MMMs), those are merely hybrid membranes consisting of nanoparticles imbedded into polymeric matrix as represented on Figure 9. The presence of nanoparticles allows getting much higher selectivity without compromising the flux. Different concepts are being developed involving zeolites, carbon molecular sieves, other porous particle or non-porous fillers. The selectivity is linked to the polymer free volume, the particle size and surface, the presence of covalent bonding.

![Microporous material](image)

Fig. 9. Scheme of an MMM. (Ríos, G. 2008, 2nd Workshop Melia).

- Example of reverse Osmosis membrane (E. Hoek et al., 2007) from the University of California to reduce the cost of sea-water desalination and waste-water reclamation. It is a uniquely cross-linked matrix of polymers and nanoscale engineered particles, which creates molecular tunnels through which water flows much more easily than nearly all the contaminants. The highly porous nanoparticles are soaking up water like a sponge, while repelling dissolved salts and other impurities such as organics and bacteria. As a result, driven-pressure are lower than in conventional systems. The overall cost of desalination is considerably reduced (25%), including energy demand and environmental issues.

- Molecular self-assembly is another way to obtain new kind of membrane materials. Block copolymers represent one class of self assembling materials attractive to fabricate well ordered nanometer-scale structures (spheres, cylinders and lamellae…, depending on the volume fractions desired). With them it can be envisaged to manufacture membranes, with an extremely narrow pore size distribution, leading to superior selectivity without flux decrease.

Nanofiltration is a quite new technology (Handbook of Membrane separations,2008) which allows the removal from a liquid of:

- Nanoscale uncharged molecules by size exclusion and/or from differences in diffusion rates.
- Ions (mainly multivalent) by electric charge effects.

Abatement of fluoride ions to prevent fluorose disease, or the separation of arsenic, lead, aluminium and uranium. It is a new very promising project of technological developments, today focused to drinking water.
Another project has developed autonomous desalination units for fresh water supply in remote rural areas (Reverse Osmosis units which is powered by a photovoltaic plant. Figures 10 and 11 show the diagram of the Photovoltaic (PV) plat and the diagram of the Reverse Osmosis (RO) plant. The RO units are automatically operated for a preset time fixed by a timer mounted in the control panel.

![Figure 10. Schematic diagram of the PV plant. (Outzourhit, N. et al., 2008, 2\textsuperscript{nd} Workshop Melia)](image1)

In some countries, such as Spain, the desalination of seawater is increasingly being used, particularly in the Canary Islands. With the appearance of new, low-energy desalination technologies such as reverse osmosis, the international desalination sector, both in the plant construction industry and in the operation of desalination plants, is booming. The application of the WFD regulations in Spain has give priority to water saving, efficiency and re-use, and has used the desalination of seawater to meet local needs for a new source of water which cannot be covered by any other means. The installation of desalination capacity express the commitment to cope with the demand of water, but also with a realistic water price policy (Estevan, 2009)
13 TOOLS FOR MONITORING AND MODELLING

Satellite observations are used to support water management. Some authors have present different applications in this frame:

- Estimated of evaporation
- Reservoir storage
- River and lake levels
- Soil moisture

Other authors report computing spatial data (SAMIR), that estimates the evapotranspiration and irrigation water budget on large areas based on the use of satellite images. Remote sensing offers a synoptic view of vegetation development, which is key information for reliable computing of evapotranspiration. Thanks to the information regularly provided, this is a particularly valuable data source for the water budget monitoring of irrigated areas.

The use of Earth Observation (EO)-derived information is used in operational irrigation scheduling at farm and field scale. Space-assisted Irrigation Advisory Services (IAS) at community level provides the EO-derived irrigation scheduling information to farmers, interacting with water management. EO, in combination with Geographical Information Systems (GIS), is naturally destined to fill such a gap. In parallel, last-generation Information and Communication Technologies (ICT) open vast possibilities to transmit spatial information to users in a personalized way using internet and mobile phones. It is also useful for decision makers at river basin level, and serving as a potential policy instrument.

There is other essential tool in calculating the real water use of a country, or its water footprint: the virtual water (impeded water). This is the amount of water that is embedded in food or other products needed for its production. It is very important to take this concept in consideration when the issue of water rationalization is discussed.

There are other methods based on secondary data covering hydrology indicators of the spring system and primary data via interviewing farmers and agricultural extension agents. It showed possible causes of water use inefficiency, among which is the water supply driven irrigation (linked to water rights) rather than decisions based on crop water requirements, and lack of informed decisions at farm and policy making levels.
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