Guide for the treatment of urban wastewater in small settlements

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Improving effluent quality

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CENTRO DE LAS NUEVAS TECNOLOGIAS DEL AGUA

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Table of Contents

Letters from authorities

The territory of the Autonomous Community of the Canary Islands is unique in terms of its biodiversity, fragmentation and distance from the continental territory. The Canarian Archipelago has been one of the main tourist destinations during recent decades and its geographical proximity to three continents, together with its historic links with America, lends it unparalleled value from a cultural, social and economic point of view. The unique nature of the Canary Islands gives rise to a certain fragility in all its developmental sectors, which places enormous environmental and socio-economic pressures on its narrow coastal region and rural areas, as well as the sparse rural population.

Faced with this scenario, the Autonomous Community of the Canary Islands has committed itself to an environmental policy that seeks to reduce the tensions that arise through the interaction of economic activity with the physical and natural environment. This policy consists of a set of guidelines, regulations and courses of action that essentially integrate the Water, Energy and Environmental sectors. The aim is to develop a society that is more attuned to the rational and sustainable use of resources and the reduction of pollution, while also engendering an increased awareness and knowledge of our environmental and territorial reality.

These aspects, especially the issues of water quality and the conservation and improvement of our coastline, constitute a priority for the Canary Islands. The optimal management of the coastal areas and the implementation of quality control programmes create, in terms of the development of tourism, a competitive advantage vis- -vis other tourist destinations, thereby promoting economic growth in the Islands and helping to provide users with indisputable proof of water safety.

The Water Department of the Instituto Tecnol gico de Canarias (ITC), in pursuit of its mission to foster innovation and the transfer of technology to strategic sectors as a means of promoting competitiveness as well as the sustainable development of the Canary Islands and its geographical and cultural environment, participates in and provides leadership for trans-national cooperation projects, which involve the evaluation and protection of water quality, the sustainable development there of and the productive utilisation of wastewater in order to provide incentives for the industrial development of the Canary Islands in the field of water treatment technology and the sustainable management of the water cycle.

The participation of ITC in the ICREW project, which is jointly financed through the INTERREG IIIB European Community initiative for the Atlantic Area, represents a commitment to trans-national cooperation as a valuable tool for the integrated development of ultra-peripheral regions with the countries on the continent. It is an opportunity to establish new and strong relations between the participating institutions, while also being a starting point for collaboration in all water matters.

The trans-national cooperation between national, regional and local authorities is aimed at promoting a larger degree of territorial integration in large regional groupings in an effort to achieve lasting, harmonious and balanced development as well as increased territorial integration between countries.

Marisa Tejedor Salguero

Island Councillor of Industry, Commerce and New Technology and Chirperson of ITC

When the powers relating to water matters were devolved to the Government of Andalusia in 1984, it quickly became aware of two important water treatment issues: firstly, the large number of small rural settlements that exist in our autonomous community and, secondly, the proven failure of conventional treatment systems when installed in these types of settlements, a failure owing mainly to a lack of technological and economic resources that is common in such areas.

In the light of this situation, it is taken for granted that no single approach can provide all the answers for the issues arising in the context of wastewater treatment, but that it is necessary to investigate sustainable solutions for specific situations. It is at this stage of the search when we begin to become aware of the enormous potential that the application of so-called Non-Conventional Technologies (NCT's) have in our region. Its versatility and adaptability, its integration into the environment and the reduced installation and running costs make these especially suitable for the treatment of the sewage generated in rural areas, where, as has been stated, the effectiveness of sewage treatment could be seriously jeopardised by technical and financial limitations.

However, these advantages are countered by serious questions, such as the enormous dispersal of information relating to NCT's, discrepancies in the technical design criteria available in the literature and contradictory opinions on the efficiency of such systems, etc.

In order to avoid jeopardising any programme for the implementation of NCT's and with the aim of gaining the greatest possible knowledge in this regard, the Government of Andalusia followed a pragmatic approach and formulated a research plan aimed at gaining detailed knowledge of the design, maintenance, running and installation of these types of technologies: the Non-Conventional Technologies R&D Plan.

Central to the implementation of this plan was the Carri n de los C spedes Experimental Sewage Treatment Plant, which has provided indispensable support for the installation of NCT's in various rural settlements in Andalusia, thereby becoming a national reference with regard to these technologies. Since 1999, the management of this plant has been the responsibility of the Centro de las Nuevas Tecnolog as del Agua (CENTA).

This guide is testimony of the a foregoing and aims to become part of the collection of instruments that CENTA wishes to put at society's disposal in order to achieve good management of wastewater treatment.

Hermelindo Castro Nogueira

Chairman of CENTA

Introduction

The sustainable management and integral treatment of water resources is a priority issue in the society in which we live. It is important to have access to water of sufficient quality and in sufficient quantity in order to support developmental activities, which make it possible to improve the environment, health and quality of life.

It is generally in the small population settlements where we find the greatest deficiency in water management, being due mainly to the sensitive nature of such areas as well as their decentralised location, limited financial resources and, in certain instances, lack of specialised personnel. These factors contribute to a lack of control over effluent quality, which leads to the pollution of water resources through the discharge of raw sewage into the environment or the discharge of sewage that has been treated in treatments plants that operate incorrectly or that simply do not function at all.

Within the context of urban wastewater legislation, Directive 91/271/EEC on Wastewater Treatment provides that all settlements with more than 2,000 population equivalent should have a wastewater treatment system by the end of 31 of December 2005, while the rest should have systems for the collection and adequate treatment of wastewater. Although there has been considerable improvement in the treatment of wastewater since the implementation of the said directive, with numerous urban settlements currently utilising some type of technology for the treatment of effluent, the reality remains that some urban settlements, mainly small and dispersed communities, still do not have systems for the treatment of their sewage and, where such systems are in place, a large percentage of treatment plants work poorly or not at all.

In addition to the situations mentioned above, we find in many instances that simplicity of operation and maintenance has incorrectly been confused with simplicity of design and construction, with the result that insufficient attention has been given to the capacity of the treatment system or the subsequent construction phase. These failures have had the result that many installations do not perform according to specification and, consequently, end up not operating or operating deficiently.

The Spanish partners of the ICREW (Improving Coastal and Recreational Waters) Project, which is financed by the Interreg IIIB Atlantic Area Operational Programme, are publishing this GUIDE with the aim of providing an additional tool in the field of urban wastewater treatment. It is hoped that it will provide answers and/or prove useful for all interested technical staff, especially those directly involved with small urban settlements, where, as has been stated above, there are still many aspects that require improvement.

This Guide contains a general overview of the characteristics of urban wastewater and the basic terminology in use, independently of the size of the settlement, before dealing with the importance of correctly treatming the effluent generated by small urban settlements is addressed. The main characteristics of the effluent generated in small settlements are identified, indicating how it differs from the effluent generated in large cities, by reason of which different forms of treatment are required, and, lastly, a detailed description is given of the considerable range of conventional and non-conventional technologies and processes proposed for the correct treatment of the type of sewage in question.

The authors

Acknowledgements

The authors of this Guide wish to thank all the technical field and laboratory staff of ITC and CENTA who have participated in the ICREW project, for their meticulous and committed research of treatment technologies and for preparing an inventory of the same in the Canary Islands and Andalusia.

The authors also wish to thank all the authorities that collaborated in the project for their time and dedication, with special thanks to:

Instituto Andaluz del Agua - Department of Environmental Affairs, Government of Andalusia

Island Water Council of Gran Canaria

Municipality of San Juan de La Rambla, Tenerife

AENA Arrecife, Lanzarote

Aguas Filtradas de Lanzarote

Island Council of Gran Canaria - Environmental Area

El ctrica de Maspalomas S.A.-ELMASA

Association of Municipalities of the Southeast of Gran Canaria

Lastly, the authors wish to acknowledge the participation of the members of the ICREW project's Pilot Action 6 and especially its coordinator, Phil Heath of the Environment Agency for England and Wales. .

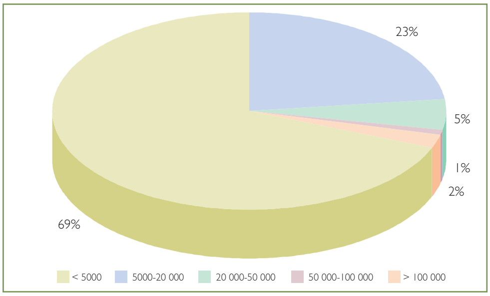
Why this guide?

According to the survey of water supply and treatment (Spanish National Institute of Statistics 2003), more than nine million cubic metres of sewage is collected daily in Spain, of which only approximately eight million cubic metres are treated, representing approximately 89% of the total volume of sewage generated. In the Autonomous Community of Andalusia, 88% of the total volume of sewage is treated, while only 65% of the sewage generated in the Autonomous Community of the Canary Islands is treated. Every year, approximately 300,000 effluent discharges are made, of which 240,000 take place inside the urban sewerage networks, while the rest is discharged directly into receiving waters. Of the latter, approximately 50,000 are generated by industrial activities, while 10,000 are generated by urban settlements (Sainz, 2005).

Of the more than 8,100 municipal areas in Spain, some 6,000 have less than 2,000 inhabitants. In the specific case of Andalusia, 69% of its 770 municipal areas have less than 5,000 inhabitants, while 85% of population settlements do not exceed 2,000 inhabitants (Spanish National Institute of Statistics, 2001; Department of Environmental Affairs, Government of Andalusia, 2001). In the Canary Islands, on the other hand, 52% of the total number of municipal areas have less than 5,000 inhabitants, while 83% of population settlements do not exceed 2,000 inhabitants (Spanish National Institute of Statistics, 2001).

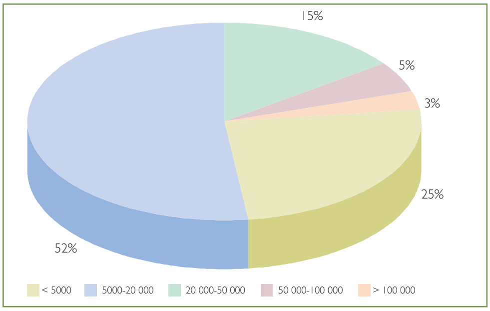
Given this demographic distribution, it is in the small settlements where we find the greatest deficiency in the treatment of sewage, mainly due to the fact that sewage treatment plants are, more often than we would desire, conceived and designed as mere scaled-down versions of larger conventional treatment plants. The direct consequence

Figure 1.1. Municipal areas in Andalusia according to size



Source: Spanish National Institute of Statistics, 2001

Figure 1.2. Municipal areas in the Canary Islands according to size

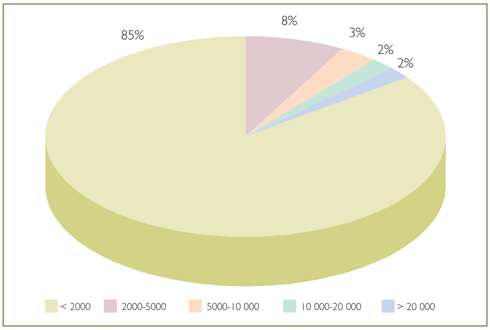


Source: Spanish National Institute of Statistics, 2001 of this modus operandi is that these plants are unable to properly treat the existing sewage load, while the responsible bodies generally find it difficult to absorb the costs of running and maintaining such plants, with the result that these sewage treatment plants fail to operate properly.

It is in areas such as these, being characteristic of rural and/or sparsely populated areas as well as recreational areas, where a strong effort is required to heighten awareness and achieve the technical commitment necessary to correct deficiencies in sanitation and treatment, in order to comply with applicable legislation and to reduce or eliminate possible problems caused by pollution.

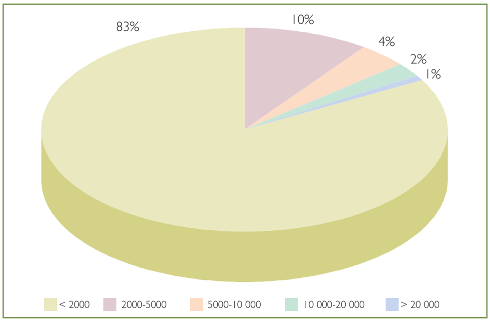
The aim of this Guide is to make a significant contribution to the achievement of the following objectives:

Figure 1.3. Population settlements in Andalusia according to size



Source: Spanish National Institute of Statistics, 2001

Figure 1.4. Population settlements in the Canary Islands according to size



Source: Spanish National Institute of Statistics, 2001

- In response to the framework within which the ICREW Project is being implemented, to serve as compendium of information on alternatives for the treatment of urban wastewater in small settlements where effluent may affect the quality of those waters in which bathing and recreational activities take place, thereby contributing to the improvement of the quality of such waters and the implementation of the Proposed Amendment to Council Directive 76/160/EEC relating to the quality of bathing waters, as approved by the Plenary Session of 10 May 2005;
- To contribute to the implementation of Directive 2000/60/EC of the European Parliament and Council, establishing a framework for Community action in the field of water policy and contributing, through the improvement of the quality of urban effluent, to the achievement of the general objective of "good ecological status" of receiving water ecosystems; and
- To impart knowledge regarding the use of those urban wastewater treatment technologies that can be installed in small settlements, with special emphasis on non-conventional technologies by virtue of its potential to be used as more sustainable and valid alternatives for the proper treatment of effluent generated by small settlements, thereby contributing to the implementation of Council Directive 91/271/EEC concerning urban wastewater treatment.

The ICREW Project

Under the leadership of the Environment Agency (EA) of England and Wales, a total of 19 organisations from Spain, the United Kingdom, France, Ireland and Portugal have participated in this project, which is financed by the INTERREG IIIB Atlantic Area Programme. The participating partners were:

Spain

- Instituto Tecnológico de Canarias (ITC).
- Centro de Investigación, Fomento y Aplicación de las Nuevas Tecnologías del Agua (CENTA).

United Kingdom

- Environment Agency.
- Mersey Basin Campaign.
- Preston City Council.
- Blackpool Borough Council.

France

- Conseil Régionale de Bretagne.
- Direction Régionale des Affaires Sanitaires et Sociales de Bretagne.
- Institut Français de Recherche pour l'Exploitation en MER.
- Centre d'Etude et de Valorisation des Algues.
- SAUR France Région Ouest.

Ireland

- University College Dublin.

Portugal

- Instituto do Ambiente.
- Instituto Nacional de Saúde Dr. Ricardo Jorge.
- Direcção Geral da Saúde.
- Instituto Superior Técnico.
- Instituto da Agua.
- Sub-Região de Saúde de Portalegre.
- Comissão de Coordenação e Desenvolvimento Regional do Alentejo.

The ICREW Project seeks the integration of strategies for the development of a sustainable economy in the various territories that comprise the Atlantic Area through the common theme of the improvement of bathing waters, which corresponds with the strategic objectives of the INTERREG IIIB Atlantic Area Programme, namely a policy of integrated spatial planning and trans-national cooperation.

It, furthermore, represents a clear work programme that provides the necessary mechanisms for successfully carrying out the terms of the Water Framework Directive of the EU (*2000/60/EEC*). Through the development of a broad trans-national programme on bathing water quality, ICREW will act as guide for public participation and the collaborative work required by the said Directive.

In short, the final objectives that are pursued through the implementation of this Project are the reduction of pollution and the improvement of bathing water quality in the Atlantic Area.

The large number of participating partners, as well as the resulting high degree of geographic representation, favours the achievement of the objectives of INTERREG IIIB, which relate to the coherence and cohesion of the Atlantic Area and the improvement of the economic competitiveness and efficiency of the areas involved.

The ICREW Project forms part of *Priority C* in terms of the Interreg IIIB Operational Programme, which deals with the *promotion of the environment and the sustainable management of economic activities and natural resources*, and of *Measure C1*, which relates to the *protection of the environment and natural resources*.

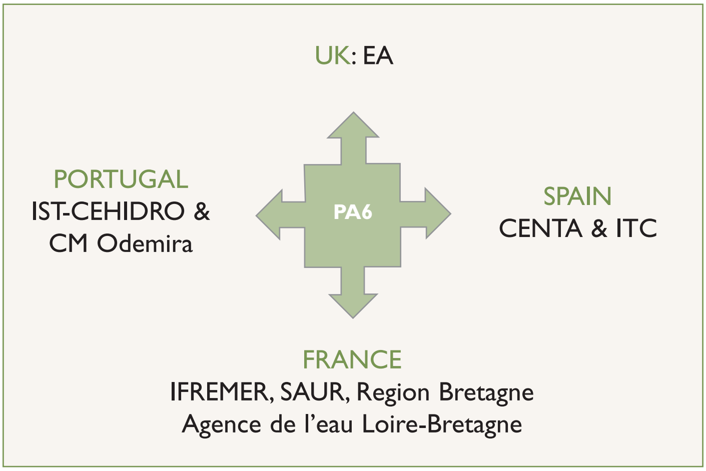
The ICREW project is structured into seven Pilot Actions:

- *Pilot Action 1*: Sampling and data review;
- *Pilot Action 2*: Resolving diffuse pollution;
- *Pilot Action 3*: Developing pollution source tracking;
- *Pilot Action 4*: Forecasting bathing water quality;

- *Pilot Action 5*: Re-identifying recreational waters;
- *Pilot Action 6*: Sustainable sewage solutions;
- *Pilot Action 7*: Understanding and managing algae.

The Spanish partners, CENTA and ITC are participating in Pilot Action nº 6 in collaboration with Portuguese, French and English partners.

Figure 2.1. Partners participating in Pilot Action 6



The basic objective of Pilot Action 6 is **to establish the most effective methods for the treatment of sewage in rural areas in order to reduce the problems of pollution and to promote the economic and social development of these areas.**

The partners participating in this pilot action have approached this objective from various points of view. In the case of the Spanish partners (CENTA and ITC), the work is focused on **studying the efficiency of small-scale urban wastewater treatment plants in rural and coastal areas, as regards the removal of bacteria and nutrients, with the aim of-**

- Establishing the degree of abatement of pathogenic micro-organisms (*E. coli* and intestinal enterococci) and nutrients through the use of the various technologies that can be applied in small urban settlements and through various combinations thereof;

- Establishing the best conditions for the installation, maintenance and operation of such technologies in rural areas; and
- Providing certain basic guidelines in respect of the considerations and criteria that need to be taken into account when installing treatment plants for small urban settlements in the regions of Andalusia and the Canary Islands, which could further be extrapolated into the Mediterranean Area, where the geo-climatic and territorial conditions are similar to the abovementioned Spanish regions.

General overview of urban wastewater treatment

3.1. Definition and source of urban wastewater

According to the definition contained in *Royal Decree-Act 11/1995* of 28 December (Official Government Gazette nº 312 of 31-12-95), which was enacted for the purposes of incorporating *Council Directive 91/271/EEC* on the treatment of urban wastewater into internal legislation, **urban wastewater** is understood to refer to *domestic effluent or a mixture of the same with industrial effluent and/or rain run-off*.

The following further definitions are contained in the said Directive:

> Domestic sewage consists of the wastewater flowing from residential and services areas, which are generated mainly through human metabolism and domestic activities.
>
> Industrial sewage consists of the wastewater flowing from premises used for the purposes of any commercial or industrial activity, other than domestic effluent or rain run-off.
>
> The contribution of industrial effluent to the composition of urban wastewater depends mainly on the degree of industrialisation in the relevant urban centre and the characteristics of the effluent discharged into the municipal sewerage network, with the result that the composition thereof may vary greatly depending on the type of industry.
>
> Rain run-off can represent a lesser or greater proportion of urban wastewater, depending mainly on the type of existing sewerage network as well as the relevant rainfall figures.

Domestic effluent includes kitchen, washing machine and bathwater as well as the black water generated by human metabolism.

Industrial effluent is generated by industrial activities and is discharged into the municipal sewerage network, the composition thereof varying greatly according to the nature of the industry.

Rain run-off or stormwater carries particles and pollutants that are present in both the air and roadways. Most urban centres have a single sewerage system, which means that rainwater is collected by the same system that is used for the collection and transport of domestic and industrial effluent. During the first 15 to 30 minutes of precipitation, a significant amount of pollution can be carried to the treatment plant. To this is added the intermittent flow of effluent, which, in certain instances, makes it necessary to release a certain amount of raw sewage into the receiving waters.

3.2. Characteristics of urban wastewater

Urban wastewater is characterised by its physical, chemical and biological composition, there being an interrelationship between many of the component parameters. It is vitally important, for the proper handling of urban wastewater, to have the most detailed information possible regarding its nature and characteristics. The main physical, chemical and biological characteristics of urban wastewater are explained below.

The most important **physical characteristics** of urban wastewater are as follows:

- Colour: the colouration of urban wastewater determines its qualitative age. In general, the colour varies from clear beige to black. If the effluent is recent, it usually presents a clear beige colour, becoming darker with the passage of time, until it becomes grey or black in colour. This change in colour is due to the effects of anaerobiosis, which is caused by the bacterial decomposition of organic material.
- Smell: the smell is mainly caused by certain substances that are released through the anaerobic decomposition of organic material, such as hydrogen sulphide, indole, scatole, mercaptans and other volatile substances. There are no disagreeable or intense odours in recent, or fresh, effluent, but the smell increases with the passage of time due to the production of gases (such as hydrogen sulphide and ammonia compounds) through anaerobic decomposition.
- Temperature: the temperature of urban effluent varies between 15°C and 20°C, which is hospitable to the propagation of existing microorganisms.
- Solids: this generally refers to all elements or compounds, other than water, that are present in urban wastewater. Some of the negative effects of these on water resources that require special mention are the reduction of photosynthesis due to increased water turbidity, deposits on plants and the gills of fish, which could lead to clogging and asphyxia, the formation of deposits on the beds of watercourses through sedimentation, which facilitate the development of anaerobic conditions, and increased salinity and osmotic pressure.

The **chemical characteristics** of urban wastewater are defined by the organic, inorganic and gaseous components thereof.

The **organic components** can be of plant or animal origin, although urban wastewater is also starting to contain increasing concentrations of synthetic organic compounds. Proteins, carbohydrates and lipids, as well as derivatives of these, are the main types of organic compounds that are found in this type of water. These compounds are biodegradable and it is a fairly simple matter to eliminate them through oxidisation.

- Proteins account for between 40 and 60% of the organic matter present in sewage, which, together with urea, are the main sources of nitrogen in sewage. The existence of large quantities of proteins in sewage can lead to disagreeable odours, which are caused by the decomposition processes.

- Carbohydrates account for between 25 and 50% of the organic matter. Cellulose is the most important carbohydrate found in sewage, in terms of volume as well as resistance to decomposition.
- Urban wastewater without any industrial component usually has a fat and oil content of less than 10%, but this does not mean that the fat and oil content cannot cause problems in sewage networks and treatment plants. If the fat content is not eliminated before the effluent is discharged, it may interfere with the organisms that live on water surfaces, creating films and disagreeable accumulations of floating material, which sometimes impedes certain processes, such as photosynthesis, respiration and transpiration.
- In addition to proteins, carbohydrates, fats and oils, urban wastewater also contains small amounts of synthetic organic molecules, with structures that range from very simple to extremely complex. One of the most important of these synthetic organic molecules is surfactant agents.

  Surfactant agents consist of large molecules that are lightly water-soluble and are responsible for the appearance of foam in treatment plants and on the surfaces of the receiving waters. These substances are the main ingredients of detergents and any foam on the surface of urban sewage is an indicator of their presence. The formation of this type of foam leads to increased pollution by dissolved organic materials that occur through the emulsification and/or dissolution of the fats and oils present in the water. The foam, furthermore, causes serious problems in treatment plants as it interferes with the necessary biological processes as well as the coagulation-flocculation and settling systems.

Inorganic compounds include all solids that are generally of mineral origin, such as mineral salts, clay, mud, sand and gravel, as well as certain other compounds, such as sulphates and carbonates, which could undergo certain transformations through processes such as oxidation-reduction reactions, amongst others.

The **gaseous component** of urban wastewater includes various gases in varying concentrations, some of the most important being::

- Dissolved oxygen, which is essential for the respiration of the aerobic organisms that live in wastewater. By monitoring the concentration of this gas over time, we obtain essential information concerning the state of the wastewater. The concentration of oxygen in water depends on many factors, which are mainly related to temperature, biological and chemical activity.
- Hydrogen sulphide, being a gas that forms in an anaerobic environment through the decomposition of certain organic and inorganic substances that contain sulphur. The presence of this gas manifests mainly in the characteristic unpleasant odour that it produces.
- Carbon dioxide, which is produced through the fermentation of organic compounds in the sewage.
- Methane, which is formed through the anaerobic decomposition of organic material, especially in certain types of treatment plants that utilise anaerobic processes for the stabilisation of

sludge (there is scope for taking advantage of the combustive properties of methane for energy production).

- Other gases, referring mainly to malodorous gases, such as volatile fatty acids, indole, scatole and other derivatives of nitrogen.

The **biological characteristics** of urban effluent are the product of a large variety of living organisms that have high metabolic capacities and enormous potential to decompose and break down organic and inorganic material.

The organic component of effluent is a culture medium which supports the growth of those microorganisms that close the biogeochemical cycles of elements such as carbon, nitrogen, phosphorous and sulphur.

The main organisms found in urban wastewater are algae, moulds, bacteria, viruses, flagellates, ciliates, rotifers, nematodes, annelids and larvae, etc.

3.3. Main pollutants and characteristic parameters

The main compounds in urban wastewater that need to be controlled and eliminated can be summarised as follows:

Large objects: pieces of wood, cloth and plastic, which are discharged into the sewerage network.

Sand: this term covers sand in the strict sense as well as grit, gravel and mineral, or organic particles that are relatively large.

Fats and oils: which include substances that fail to mix with the water, remaining on the surface where it forms films. These substances are of both domestic and industrial origin.

Substances that require oxygen: including organic matter and inorganic compounds that are easily oxidised, this leads to the consumption of the oxygen present in the medium in which these substances occur.

Nutrients (nitrogen and phosphorous): the presence of nutrients in wastewater is mainly due to detergents and fertilisers. Human excrement contributes organic nitrogen. The nutrients, nitrogen, phosphorous and carbon are essential for the growth of plants and when these elements are discharged into the aquatic environment, it can promote the growth of undesirable aquatic life. If excessive quantities are discharged onto land, it can lead to the pollution of groundwater.

Pathogens: which include certain organisms that occur in larger or smaller concentrations in sewage and which can cause or transmit diseases (such as viruses, bacteria, protozoa, fungi, etc).

Emerging or priority pollutants: consumer habits in today's society generate a series of pollutants that did not exist previously. These substances mainly consist of additives in personal hygiene, domestic cleansing and pharmaceutical products (residues of antibiotics, hormones, etc.). These substances, the majority of which are not removed in conventional urban sewage treatment plants, are referred to by the generic term, emerging pollutants.

Sewage is characterised by reference to a group of parameters that enable us to quantify the pollutants defined above. The parameters most commonly used are as follows:

Suspended Solids: are solids that cannot pass through a filter membrane of a given size (0.45 micron). Suspended solids include settleable solids, which settle out by virtue of their own weight, and non-settleable solids.

Oils and fats: the fat and oil content of sewage is determined by first extracting the same with an appropriate solvent, after which the solvent is evaporated and the residue weighed.

Biochemical Oxygen Demand (BOD_5): the amount of dissolved oxygen (mg O_2/l) required to biologically oxidise the organic material in sewage when a sample is incubated for 5 days at 20ºG. During the course of the five-day period approximately 70% of the biodegradable matter is consumed.

Chemical Oxygen Demand (COD): the amount of oxygen (mg O_2/l) required to completely chemically oxidise the organic water constituents.

The BOD_5/COD ratio is an important indicator of the *biodegradability* of urban wastewater, biodegradability being defined as an attribute of certain chemical substances which enables it to be used as substrate for microorganisms, which utilise the same to produce energy (through cellular respiration) and create other substances, such as amino acids, new tissue and new organisms.

Table 3.1. Biodegradability of urban wastewater according to the BOD_5/COD

BOD_5/COD	Biodegradability of sewage
0,4	High
0,2-0,4	Normal
0,2	Low

Source: Metcalf & Eddy, 2000

Nitrogen: in sewage, this element essentially appears in the form of ammonia and, to a lesser extent, as nitrates and nitrites, being quantified with spectrophotometric methods;

Phosphorous: This element mainly appears in sewage in the form of organic phosphates and polyphosphates and is also quantified with spectrophotometric methods; and

Pathogens: coliform bacteria (total and faecal) are normally used as an indicator of faecal contamination.

The following table shows the normal values of these parameters in respect of urban wastewater comprised mainly of domestic sewage.

Table 3.2. Typical values of the main pollutants in urban wastewater (raw domestic)

Parameter	Strong Contamination	Medium Contamination	Light Contamination
Suspended Solids (mg/l)	350	220	100
BOD_5 (mg O_2/l)	400	220	110
COD (mg O_2/l)	1000	500	250
Nitrogen (mg N/l)	85	40	20
Phosphorous (mg P/l)	15	8	4
Fats (mg/l)	150	100	50
Faecal Coliform (ufc/100 ml)	10^6-10^8	10^6-10^7	10^6-10^7

Source Metcalf & Eddy, 2000

3.4. The need for the treatment of urban wastewater

In many instances, the volume of the urban wastewater being discharged exceeds the dilution and self-purification capacity of the receiving waters, which leads to a progressive deterioration of water quality, making it impossible to subsequently reuse such water.

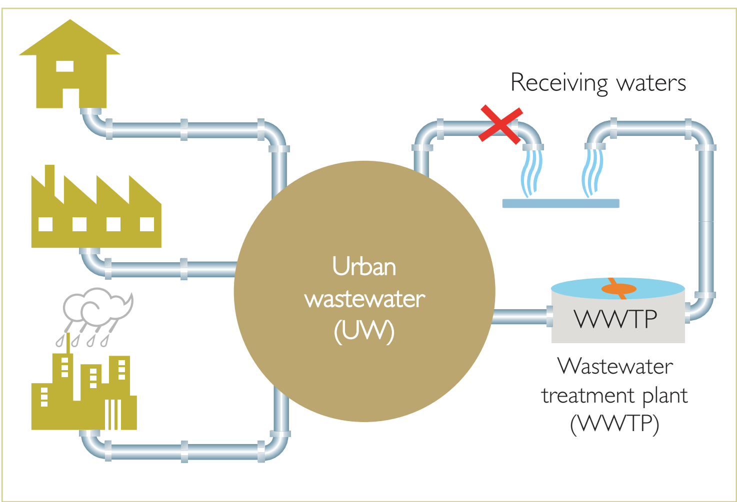
Urban wastewater needs to be treated adequately before being discharged or reused, regardless of its origin and characteristics, in order to:

- Protect the ecological condition of the receiving waters (lakes, rivers, ravines, aquifers, ocean, etc.) from a major portion of the organic pollution in urban wastewater.
- Avoid public health risks.
- Produce effluent that is suitable for reuse in terms of its physical, chemical and microbiological characteristics.

These days, sewage treatment plants are artificial and essential complements of aquatic ecosystems, although it is also true that the level of sewage treatment that is required depends to a large degree on the knowledge that we have of the receiving waters, as this enables us to determine the pollution load that the receiving waters can absorb without causing irreversible or large-scale environmental imbalances. Consequently, the level of sewage treatment should accord with the:

- Characteristics of the receiving waters and their status.
- Flow ratio between the effluent and the receiving waters.
- Utilisation of water by downstream users, as well as the possibility of use of groundwater or close water sources.
- The hydrological balance of the area.
- Fauna and flora present in both the receiving and surrounding environment.

Figure 3.1. Urban wastewater cycle



Untreated urban wastewater has a series of constituents which, depending on its nature and concentration, can alter the physicochemical and biological balance of the receiving ecosystem. By treating the effluent, the negative effects are reduced in accordance with the degree of completeness of the treatment. Some of the most important negative effects are:

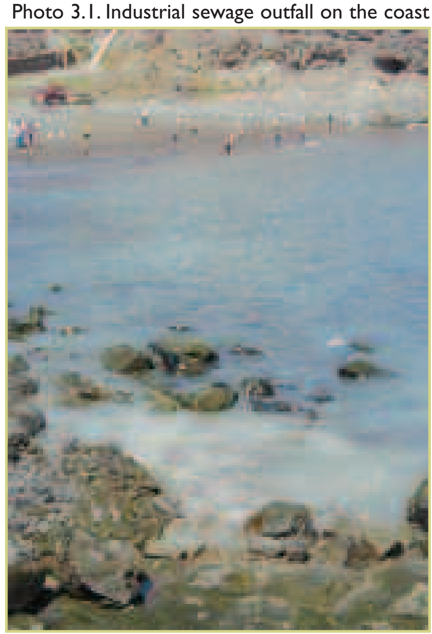
Appearance of sludge and floating debris: if untreated sewage is discharged, the coarse solid waste content (plastic, food residues, etc.) and settleable solids (sand and organic matter) can lead deposits on the bed or the accumulation of large amounts of solids on the surface and/or the shores of the receiving waters, forming layers of floating debris. The sludge and floating debris depositss are not only visually disagreeable, but the organic pollutants can also lead to a depletion of the dissolved oxygen in the water and the emission of bad odours.

Depletion of water oxygen content: aquatic organisms need oxygen to survive. If easily oxidisable waste (organic matter and ammonia compounds) is discharged into the receiving waters, bacteria begin to feed, thereby consuming the oxygen in the water. If the rate of consumption is excessive, the oxygen content of the water will drop below the minimum levels necessary to sustain aquatic life, leading to the death of the organisms that live in the water. In addition, anaerobic processes are activated, which produce disagreeable odours.

Eutrophication phenomena in the receiving waters: this phenomenon is caused mainly by excessive amounts of nutrients (mostly nitrogen and phosphorous), which provoke massive growth of algae and other plants in the receiving waters. Such growth can eventually render the water unsuitable for domestic and industrial use.

Damage to public health: an increased concentration and propagation of pathogens, consisting mainly of viruses and bacteria, can cause illness in humans, which can be transmitted through water that is contaminated with urban wastewater. Some of the most important illnesses that can be transmitted in this way are typhus, cholera, dysentery, polio and hepatitis (A and E).

Photo 3.1. Industrial sewage outfall on the coast



Source: Leopoldo O'Shannahan

Detrimental effects on the microbiology of the natural receiving waters: when urban wastewater is discharged into an aquatic ecosystem, the concentration of eubacteria (which has a similar chemical composition to that of eukaryotes and represents the bulk of the ecosystem's bacterial content) and algae diminish, while there is a multiplication of other types of bacteria that live in sewage with high organic content. One such bacterium is Sphaerotilus natans (which falls into the category of so-called mud fungi and causes bulking in activated sludge processes). After sewage is discharged, we can detect increases in the concentration of protozoa and, eventually, of algae.

Industrial sewage spills, which, depending on their nature, can lead to the pollution of organisms through toxic or inhibitory chemical compounds.

3.5. Urban wastewaters flows

When designing an urban wastewater treatment plant, which will include collection, treatment and discharge systems, the first phase will consist of determining the volume and composition of the water that needs to be treated, as well as the management of flow. These three elements represent the starting point and any error in these will have the result that the future installation will fail to fulfil the initial projections.

All sewage has its own unique characteristics. However, it is possible to establish certain normal ranges of variation in terms of flow and the physicochemical properties of effluent, which depend on the size of the population, the sewerage system used, the degree of industrialisation and the amount of rainwater.

The amount of effluent to be treated is measured in terms of the volume of water that arrives at the treatment plant during any given time unit.

The amount of effluent produced by a community is proportional to the amount of municipal water that is consumed and is influenced by the degree of economic and social development of the community, in the sense that a higher degree of development brings with it a greater and more diverse utilisation of water in human activity.

The factors that influence the amount of sewage generated are as follows:

- The consumption of municipal water supplies.
- Rainfall.
- Losses, which could be caused by leaks in pipes or by the fact that part of the consumed water fails to reach the sewerage network, being used for other purposes, such as the irrigation of gardens or small-scale agricultural uses.
- Gains, due to discharges into the sewerage network or the intrusion of other water into the collection network.

According to the instructions for the drafting of projects for water supply and sanitation, as laid down in 1995 by the Ministry of Public Works, Transport and Environmental Affairs (Referred to by its Spanish, MOPTMA), water consumption in the various population brackets is as shown in Table 3.3.

Table 3.3. Urban consumption (l/inhab/day), according to usage and population size

Population (Inhabitans)	Domestic Municipal	Industrial	Services	Leaks in networks and various	TOTAL
1000-6000	70	30	25	25	**150**
6000-12 000	90	50	35	25	**200**
12 000-50 000	110	70	45	25	**250**
50 000-250 000	125	100	50	25	**300**
> 250 000	165	150	60	25	**400**

Source: MOPTMA, in Hernández, A. (1995)

In the majority of instances, the daily flow of urban wastewater that arrives at a treatment plant is estimated on the basis of the municipal water supply capacity and the size of the population in question, the formula being as follows:

$$Q = \frac{D \times P}{1000}$$

Where:
Q = Daily flow (m^3/d).
D = Supply Capacity (l/inhab/day)
P = Population (inhab.)

In practice, between 60 and 85% of the consumed municipal water is converted into sewage, but this can vary according to the utilisation of water for specific activities, such as the irrigation of green areas, the existence of leaks, the utilisation of water in production processes, etc. This percentage should be applied to the results of the calculations done with the aforementioned formula.

Variations in the flow of sewage that arrives at the treatment plants are a faithful reflection of the activities that take place in the area. These variations are usually significant and follow the variations in the consumption of municipal water and electricity, although there is a delay of a few hours in respect of variations in municipal water consumption, especially in instances where external and uncontrolled flows into the sewerage network are minimal.

During the night and the early hours of the day, the consumption of water is low, with the result that the flow of sewage is also low, consisting mainly of infiltration water and small amounts of domestic sewage. The first peak flow occurs approximately during midmorning, when the water corresponding to the first period of peak consumption reaches the treatment plant. The second peak flow usually occurs in the evening, between 19:00 and 21:00 (National Association of Spanish Chemists , 1994).

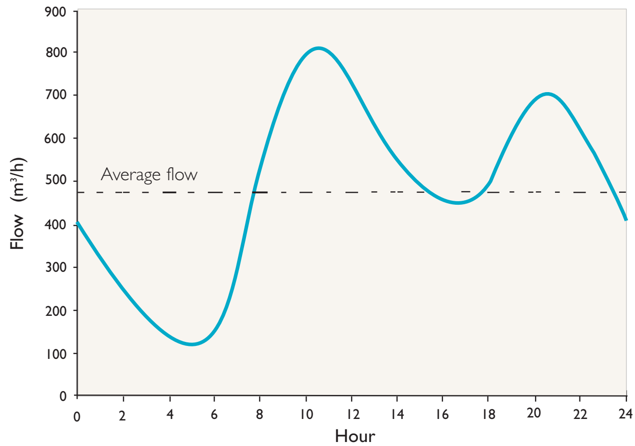
These flow variations are shown in the following diagram.

It is important to determine the maximum (Q_{max}), minimum (Q_{min}) and average (Q_{av}) values, as well as the peak factor (F_p) of the relevant sewage flows.

The average flow (Q_{av}) is defined by:

$$Q_{av}\ (m^3/h) = \frac{Q}{24}$$

Figure 3.2. Daily urban wastewater flow rates.



The maximum flow can be determined on the basis of a series of empirical mathematical formulas, the following being one of the most commonly used formulas:

$$Q_{max} = Q_{av} \times (1{,}15 + 2{,}575 / (Q_{av})^{0{,}25})$$

The relationship between the maximum and average flows is defined as F_p, as illustrated:

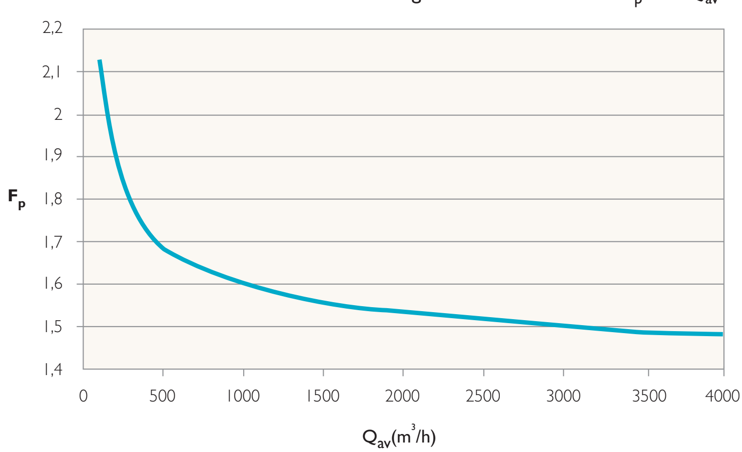
$$F_p = \frac{Q_{max}}{Q_{av}}$$

In this type of sewage, the ratio between the maxium and average flows varies between 1.5 and 2.5

In Figure 3.3, the values of Fp are presented as a function of the various values of Q_{av}.

The foregoing diagram demonstrates that the peak factor is highest in small settlements, due to

Figure 3.3. Ratio between F_p and Q_{av}



the fact that the differences between maximum and average flows are larger in these areas than in large settlements, where flow variations are less accentuated and sewage is produced at a constant rate throughout the day.

3.6. Legislative framework

The following section contains an overview of the most important aspects of Spanish water legislation insofar as it relates to urban wastewater treatment. There are five legislative tiers at which legislation is adopted to regulate the water sector.

- International: International treaties.
- European Community: Regulations, Directives and Community Decisions.
- State: Acts of Parliament, Regulations and Ministerial Decrees.
- Autonomous Communities: Acts, Autonomous Decrees.
- Local: Municipal Decrees.

European Community Legislation

The European Community has adopted water legislation which covers obligations and courses of action for Member States and which have the aim of protecting water resources and, by extension, the environment. A number of closely interrelated directives, promulgated within the context of this framework for action, require special mention:

- **European Parliament and Council Directive 2000/60/EC** passed on 23 October 2000, establishing a framework for community action in relation to water policy and creating a new and modern approach to water policy for all Member States of the European Union. This Directive, which is also referred to as the Water Framework Directive (WFD), was incorporated into Spanish legislation through **Act 62/2003**, published in the Official Spanish Government Gazette of 31 December 2003.

  A novel aspect of the WFD is that it deals with all waters, including continental (surface and groundwater), transitory and coastal water, regardless of size or characteristics.

  The main objective of this directive is to achieve "good status" for all waters by 2015, protecting the same and preventing deterioration. In order to achieve this objective, great importance is given to hydrological planning, river basin management, economic analyses and public participation. Interim objectives include:

  - Establishing concrete measures for the reduction of spills, emissions and losses of priority substances and the stopping or gradual reduction of spills, emissions and losses of priority dangerous substances. Priority substances are identified in Annex X of the Directive;
  - Guaranteeing the progressive reduction of groundwater pollution as well as the sustainable use of groundwater.

Another important aspect of the Directive is the use of pricing in water policy. Before 2010, the Member States must guarantee, firstly, that water pricing policy will provide proper incentives for the efficient use of water resources and, secondly, that the various sectors of water use, broken down at least into industry, household and agriculture, each contribute adequately to the cost of water-related services on the basis of the "Polluter-pays" principle.

- **Council Directive 91/271/EEC**, adopted on 21 May 1991, relating to the treatment of urban wastewater (amended by Council Directive 98/15/EEC, adopted on 27 February 1998), establishes the objective of protecting the environment against deterioration caused by the discharge of urban sewage generated in urban settlements and of biodegradable sewage generated by the agrifood industry, requesting the Member States to make provision for the collection and treatment of such wastewater.

  To gain a better understanding of this Directive, it is necessary to be familiar with a series of definitions relating to urban wastewater treatment.

Urban settlement: geographic area formed by one or more municipalities, or by part of one or more municipalities, in which the population or economic activity create a focal point of sewage generation that justifies the collection and transport of the same to a treatment plant or a final point of discharge.

Eutrophication: increase in nutrients in the water, mainly consisting of nitrogen and phosphorous compounds, which promotes accelerated growth of algae and higher vegetation species, resulting in undesirable disruptions of the balance between organisms that live in the water and the deterioration of the quality of the affected water.

Sensitive area: surface water bodies where there is limited exchange of water or that receive nutrients and become eutrophic or that may become eutrophic in the near future if protective measures are not adopted; fresh surface water destined for the production of potable water and which could contain a higher concentration of nitrates than stipulated in the legislative provisions applicable to this type of water, if no protective measures are adopted.

Less sensitive area: a marine or freshwater area can be catalogued as less sensitive if the discharge of sewage has no negative environmental effects due to the conditions existing in the area.

Normal area: all areas not included in the categories of sensitive or less sensitive areas.

Primary treatment: the treatment of sewage through a physical or physicochemical process, which includes the sedimentation of suspended solids and other processes through which the BOD_5 of the influent is reduced by at least 20%, and the total concentration of suspended solids in the sewage is reduced by at least 50% before discharge.

Secondary treatment: the treatment of urban sewage through a process that includes biological treatment with secondary sedimentation, or other processes that comply with the requirements set out in Table 3.5.

Adequate treatment: the treatment of sewage through any process or system that ensures that the receiving waters comply with the quality parameters stipulated in the applicable legislation after the treated sewage has been discharged.

Population equivalent: in order to measure the biodegradable pollution in sewage, a standard has been adopted that is referred to as "population equivalent (p.e.)", which establishes a relationship between the flow and quality of sewage and is defined as "the biodegradable organic load with a 5-day biochemical oxygen demand (BOD_5) of 60 grams of oxygen per day".

The calculation of **population equivalent** is an extremely important factor in the context of sewage treatment, having significant impact on:

- The flow and quality of wastewater generated.
- The technology to be applied for the treatment of the wastewater.

The volume and quality of sewage is related partly to population size, but is especially closely related to the type of water consumed.

Once the flow of sewage (Q) generated by an urban settlement and its BOD_5 are determined, the population equivalent (p.e.) is determined with the following formula:

$$p.e. = \frac{Q\ (m^3/d) \times BOD_5\ (mg/l)}{60\ g\ BOD_5/d}$$

In those urban settlements where no or insignificant amounts of non-domestic biodegradable sewage is generated, the population equivalent will be very similar to the actual population of the settlement. The usual estimated ratio of population equivalent to actual population is 1.5 to 2.

The following practical case may be presented as an example of the calculation of the population equivalent of a settlement:

Population of **2,500 inhabitans**, which generates a flow of **300 m^3/d**, with a **BOD_5 of 508 mg/l.**

The resultant value for population equivalent will be:

(300 m^3/d x 508 mg/l) / 60 g= **2,540 p.e.**

The Directive establishes a timetable within which Member States are expected to install sewage collection and treatment systems for their urban settlements in compliance with the criteria stipulated in the Directive. The main dates for compliance stipulated in the Directive are as follows:

Table 3.4.Timetable for compliance with Direcive *91/271/EC*

<table>
<tr><th rowspan="2">Designation of Area</th><th colspan="5">Population equivalent</th></tr>
<tr><th>< 2000</th><th>2000-10 000</th><th>10 000-15 000</th><th>15 000-150 000</th><th>> 150 000</th></tr>
<tr><td>Sensitive</td><td rowspan="4">If a collection system exists, 31.12.2005, adequate treatment</td><td rowspan="2">Collection system, 31.12.2005 secondary treatment (**)</td><td colspan="3">Collection system, 31.12.1998, most advanced treatment</td></tr>
<tr><td>Normal</td><td rowspan="2">Collection system, 31.12.2005 secondary treatment</td><td colspan="2" rowspan="2">Collection system, 31.12.2000, secondary treatment</td></tr>
<tr><td rowspan="2">Sensitive (Coastal Waters)</td><td rowspan="2">Collection system, 31.12.2005 adequate treatment</td></tr>
<tr><td>Collection system, 31.1.2005, secondary or primary treatment</td><td>Collection system, 31.1.2000, secondary or primary treatment</td><td>Collection system, 31.1.2000, primary (exceptional) or secondary treatment</td></tr>
</table>

(**): Adequate treatment, if the sewage is discharged into coastal waters.

Source: Europan Council, Environment Directorate-General, 2000.

The Member States are required to draw up a list of sensitive and less sensitive areas into which the treated effluent is discharged, on the basis of the provisions contained in Annex II of the Directive. This list must be revised regularly and at least every four years in the case of sensitive areas.

The Directive, furthermore, lays down specific requirements in respect of the discharge of industrial and biodegradable sewage generated by certain industrial sectors and which are not treated in urban sewage treatment plants before being discharged into the receiving waters.

As far as the construction of urban sewage treatment plants are concerned, the Member States must ensure that they are designed, constructed, used and maintained in such a manner as to ensure that they perform adequately in all the normal climatic conditions of the area.

The Directive further establishes the following requirements for the treatment of urban sewage, in accordance with the characteristics of the receiving waters:

Table 3.5. Binding requirements for the treatment of urban sewage according to the characteristics of the receiving waters

LESS SENSITIVE AREAS (Primary Treatment)		
Parameter		% reduction
BOD_5 (mg O_2/l)		20
Suspensed solids (mg/l)		50
NORMAL AREAS (Secondary Treatment)		
Parameter	Concentration of discharge	% reduction
BOD_5 (mg O_2/l)	25	70-90
COD (mg O_2/l)	125	75
Suspensed solids (mg/l)	35	90
SENSITIVE AREAS (Tertiary or Advanced Treatment)		
Parameter	Concentration of discharge	% reduction
Total Nitrogen (mg N/l)	15 mg/l (between 10 000 and 100 000 p.e.) 10 mg/l (> 100 000 p.e.)	70-80
Total Phosphorous (mg P/l)	2 mg/l (between 10 000 and 100 000 p.e.) 1 mg/l (> 100 000 p.e.)	80

Source: *Directive 91/271/CE, Royal Decree-Act. 11/1995, Royal Decree 509/1996* amendeb by *Royal Decree. 2161/1998*

- **Directive 86/278/EC**, of 12 June 1986, on the protection of the environment and soil in particular from the use of sewage sludge in agriculture, which directive establishes the physicochemical requirements with which these by-products need to comply before it can be used in agriculture.
- **Council Directive 76/160/EC**, which lays down binding standards for bathing waters througout the European Union. Bathing waters, insofar as they are considered as receiving waters for the urban effluent generated by settlements that are situated in proximity to such waters, need to be protected from the risk of pollution by the effluent in question.

  Sewage has an impact on the quality of bathing waters, given that it carries biodegradable matter and nutrients that contribute to the phenomenon of eutrophication, while also releasing pathogens that endanger public health.

  This Directive is a clear reflection of the status of social and technical knowledge and expertise during the 1970's, which is why the Commission presented the Proposed European Parliament and Council Directive on the quality of bathing waters on 24 October 2002.

In the Proposal it is suggested that bathing water quality should not be seen merely as a question of quality control, but that it should embody a comprehensive understanding of the processes involved in determining the quality of the water as well as the variability thereof.

Regarding control parameters, the Proposal provides for visual inspections of bathing sites as well the control of two types of bacteria which have been scientifically demonstrated to constitute reliable indicators of faecal contamination, namely Escherichia coli and Intestinal Enterococci, as compared to the 19 control parameters established by the 1976 Directive.

National Legislation

The Spanish Constitution of 1978 contains certain provisions that deal with the environmental rights of citizens:

- Recognition of the right of all Spanish citizens to live in an acceptable environment.
- The obligation to conserve and maintain the environment for proper utilisation by future generations.
- The obligation on all, and especially the public authorities, to ensure the rational utilisation of natural resources in order to protect and improve quality of life.

The **Water Act** of 2 August, nº 29/1985, amended by Act 46/1999 of 13 December, which provides for the protection of the public domain:

- Through the treatment and recovery of water in order to preserve its quality and priority uses.
- By requiring authorisation for all discharges of sewage.
- By promoting the reuse of water for secondary uses, thereby saving better quality water.
- By establishing a system of fines and legal liability for loss and damage.

The incorporation of Directive 91/271/EC into national legislation: In accordance with Article 19 of *Directive 91/271/EC*, the Member States are obliged to adopt such legislative and administrative provisions as are necessary to comply with the terms of the Directive in question. The contents of the said Directive have been incorporated into Spanish legislation through:

- *Royal Decree-Act 11/95* of 28 December, in terms of which regulations governing the treatment of urban wastewater have been promulgated.
- *Royal Decree 509/96* of 15 March, adopted pursuant to *Royal Decree-Act 11/1995*, which completes the incorporation of the Community Directive into Spanish legislation, while also completing the regulations applicable to the collection, treatment and discharge of urban wastewater.
- Resolution *of 25 May 1998* of the Secretariat for the Status of Waters and Coasts, in terms of which "*sensitive areas*" in intercommunity river basins are designated.

- *Royal* Decree *2116/98* of 2 October, which amends Royal Decree 509/96, setting out regulations governing the treatment of urban wastewater.

The incorporation of Directive 86/278/EC into national legislation::

- *Royal Decree 1310/1990* of 29 October, which regulates the utilisation of sewage sludge in the agricultural sector.
- *Order 1993/26572* of 26 October, on the utilisation of sewage sludge in the agricultural sector, which provides that, "in order to conduct a census of treatment plants and of local agencies and other owners of sewage treatment plants, a document setting out the characteristics of the treatment plant and the sewage treated therein must be sent to the competent authority within the relevant Autonomous Community before 31 December 1993".

The National Sanitation of Wastewater Treatment Plan (1995-2005), adopted in terms of the Resolution of 28 April 1995. The text was approved by the Cabinet of Ministers on 17 February 1995 and was subsequently endorsed by the Autonomous Communities after an Environmental Sectoral Meeting. The Plan in question was updated in 1998.

The National Sanitation and Wastewater Treatment Plan is not only limited to the construction of new infrastructure, but also deals with a series of complementary actions, which need to be formulated and carried out within the same framework and timetable stipulated in Directive 91/271, the following being some of the most important aspects:

- The expansion, improvement and rehabilitation of collection and discharge systems.
- The modification and improvement of treatment plants in order to achieve compliance with the requirements set out in the Directive.
- The adaptation of sanitation and treatment systems to cope with increases in pollution loads.
- The incorporation of secondary treatment in those treatment plants that only provide primary treatment, as required by the Directive.
- The elimination of nutrients in treatment plants that discharge effluent into areas that have been declared as "sensitive areas".
- The improvement of treatment plants in order to reduce and avoid environmental impact (smells, noise, visual impact, etc.).

Legislation regarding the reuse of treated effluent

At present there is a vacuum in the european legislation regulating the reuse of treated effluent. At the beginning of 2006, Spain commenced inter-ministerial discussions on draft national legislation. Autonomous Communities, such as Andalusia, the Balearic Islands and Catalonia have promulgated legislation for the use of such water.

In 1994, the Ministry of Health in Andalusia drafted the "Criteria for the reuse of treated effluent", which determine the physicochemical and microbiological requirements with which treated effluent need to comply before it may be used for the irrigation of agricultural land and green areas.

At national level in 1998, CEDEX (Ministry of Environmental Affairs) drafted a "Proposal for minimum quality requirements for the reuse of treated effluent" according to the various possible uses, also covering aspects such as sample methodology and frequency as well as the criteria with which such analyses need to comply. This proposal, which was intended to be incorporated into national legislation, sets out the physicochemical and biological requirements with which treated effluent needs to comply for different uses (agricultural irrigation, industrial refrigeration, recreational uses, fish farming and replenishment of aquifers).

The National Sewage Sludge Plan (2001-2006), which is aimed at protecting the environment and especially the quality of soil through the proper management of sewage sludge and the pursuit of the following ecological objectives:

- Reduction sewage sludge pollution at origin.
- Characterisation of sewage sludge generated in Spain before 2003.
- Assessment (valorisation) of at least 80% of sewage sludge before 2007.
- Reducing the disposal of sewage sludge in landfill sites to a maximum of 20% before 2007.

Legislation of the Autonomous Communities

Each Autonomous Community has a legal framework that follows the provisions of national and EU legislation and which needs to be taken into account when doing sewage treatment viability studies, in addition to legislation dealing with the sludge that is generated during the treatment process. The following legislation is in force in the Autonomous Communities of Andalusia and the Canary Islands:

- *Andalusia:*
  - *Order of 22 November 1993*, in terms of which the provisions of Royal Decree 1310/1990 and the Order of 26 October 1993 of the Ministry of Agriculture, Fisheries and Food, on the utilisation of sewage sludge in the agricultural sector are implemented within the territory of the Autonomous Community of Andalusia.
  - *Decree 54/1999* of 2 March of the Government of Andalusia, in terms of which sensitive, normal and less sensitive areas are designated in the coastal waters and intercommunity river basins of the Autonomous Community of Andalusia.
  - *Decree 310/2003* of 4 November of the Government of Andalusia, in terms of which urban settlements in Andalusia are demarcated for the purposes of sewage treatment and the territorial scope for integral water cycle service delivery by the Local Authorities is established for the priority action of the Government of Andalusia.

- *The Canary Islands:*
  - *Water Act 12/1990* of 26 July.
  - *Decree 174/1994* of 29 July, approving the Effluent Control Regulations for the Protection of the Public Water Domain (Official Gazette of the Canary Islands nº 104 of 24 August 1994).
  - *Decree 49/2000* of 10 April, in terms of which water bodies polluted by nitrates of agricultural origin, as well as areas that are vulnerable to such pollution, are identified (Official Gazette of the Canary Islands nº 48 of 19.04.00).
  - *Order of 27 October 2000*, in terms of which the Action Plan referred to in Section 6 of Royal Decree 261/1996 of 16 February, is adopted in order to prevent and reduce pollution by nitrates of agricultural origin (Official Gazette of the Canary Islands nº 149 of 13.11.00).

Local Legislation

A series of local ordinances have been adopted in relation to sewage matters, in order to ensure the biodegradability of what is considered to be domestic effluent and to avoid any disturbance of those treatment plants that are based on biological processes. The controls that have been established are generally based on i.a. the following:

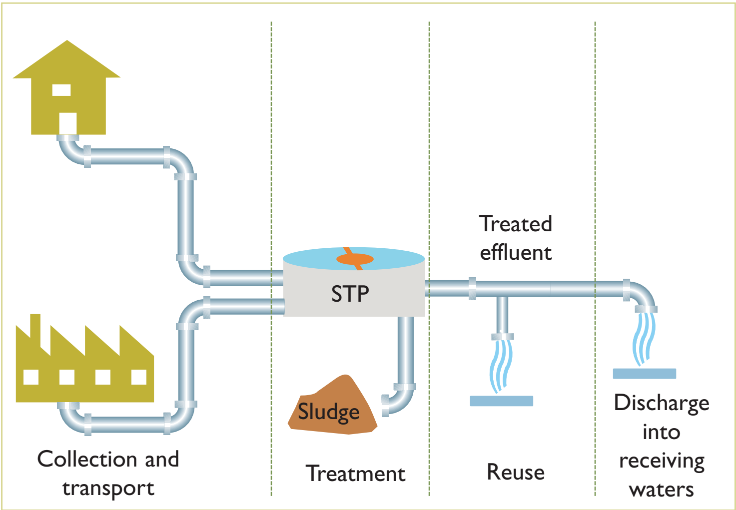
- Controlling the discharge of sewage into the sewerage network.
- Establishing maximum concentrations of the various industrial parameters in order to maintain an optimal degree of treatment.
- Fixing all connection tariffs in accordance with flows and concentrations.

3.7. Basic principles of urban wastewater treatment

Urban wastewater treatment facilities are comprised of three main elements:

- **Collection and transport** of effluent to the treatment plant.
- **Treatment** of effluent.
- **Disposal** of the by-products, treated effluent and sludge resulting from the treatment process.

Figure 3.4. The elements comprising urban sewage treatment facilities



3.7.1. Collection and transport

The collection and transport of urban sewage from the settlement in which it is generated to the treatment plant takes place through a complex pipe network (sewage collection system or sewerage network). Depending on the topography of the terrain, the sewage flows to the treatment plant under force of gravity, although it may be necessary, in certain instances, to utilise pumps.

Normally there is a single collection system, i.e. the sewerage network collects sewage as well as rainwater. Sometimes, the collection network only transports sewage to the treatment plant, with rainwater being collected in an independent network (separate sewer system).

In order to ensure that the flow remains within the capacity of the treatment plant, overflows discharging excess flows are installed in the sewerage system. Excess flows mainly occur during high rainfall periods.

Photo 3.2. Inlet pipe. Almonaster la Real Sewage Treatment Plant, Huelva.

Similarly, if it should be necessary in the event of malfunction, to divert all the sewage before it reaches the treatment plant, a general bypass is installed at the inlet pipe.

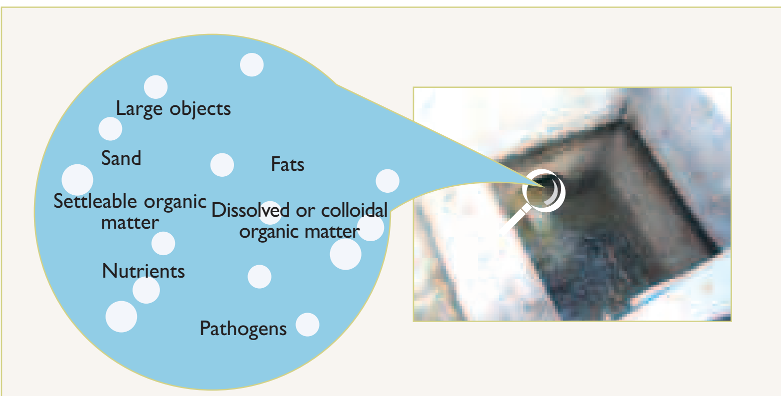
Partial bypasses are also installed after each treatment stage, making it possible to discharge the effluent without passing through the following phase when so required by operational incidents. These bypasses normally discharge the effluent into a single pipeline, being the same one used for the general bypass and the discharge of purified effluent.

3.7.2. Treatment

The treatment of urban sewage involves physical, biological and chemical processes, which ensure that the resultant pollution levels of treated effluent are within the applicable legal limits and that it can be assimilated in a natural manner by the receiving waters.

Two factors need to be taken into account during the sewage treatment process, namely the constituents of the sewage and the order in which they are eliminated during the treatment process.

Figure 3.5. Constituents of urban sewage



The order in which the constituents of sewage are eliminated during the treatment process is: large objects, sand, fats, sedimentable organic matter, dissolved or colloidal organic matter, nutrients and pathogens.

Two treatment processes can be distinguished in conventional urban sewage treatment plants:

- Aqueous treatment, which includes all the processes or treatments that reduce the pollution content of the sewage.
- Sludge treatment, which treats most of the by-products generated by the water treatment process.

Aqueous Treatment

The various stages of the sewage treatment process are as follows: Pre-treatment and Primary, Secondary and Tertiary Treatment.

Before the sewage is treated, it is submitted to a **pre-treatment** process. This involves a series of physical and mechanical processes aimed at removing as much as possible materials whose size or nature could cause problems during the later stages of the treatment process. The correct design and subsequent maintenance of the pre-treatment stage is extremely important, as any shortcomings in this process can create problems in the rest of the equipment in the facility, including the obstruction of pipes, valves and pumps and excessive wear or crusting of equipment, etc.

The pre-treatment stage normally involves the following processes: *screening. sieving sand removal and fat removal*.

Screening: This consists of the removal of large and medium-sized solid objects (such as pieces of wood, cloth and roots, etc), as well as fine solids, which could block or damage the mechanical equipment and obstruct the water flow. The most usual method consists of passing the water through bar grids, which are classified according to the size of the openings between the bars:

- Large object screening: the openings between the bars are 50 to 100 mm.
- Fine object screening: the openings between the bars are 10 to 25 mm.

Photo 3.3. Screening channel.
Almonte Sewage Treatment Plant, Huelva

Sieving: This process is aimed at reducing the concentration of suspended solids in the sewage by straining the same through a thin material equipped with openings through which the water can pass. For the purposes of the pre-treatment of urban sewage, sievers are used with openings of between 0.2 and 6 mm. There are two types of sievers:

- Static: These consist of meshes made of horizontal bars, which are installed with the flat side facing the flow direction. The angle of the mesh decreases progressively from top to bottom, approximately between 65° and 45°. The sewage flows onto the upper part of the strainer and solids that exceed the size of the openings are retained by the mesh, rolling down into a container below.

• Rotating: These consist of cylindrical meshes that rotate slowly around a horizontal axis, being driven by a geared motor. The sewage is fed through the strainer from the outside and solids that exceed the size of the openings are retained on the external part of the cylinder, being removed through the action of a scraper and the movement of the cylinder itself.

Photo 3.4. Static sieve.
Fondón Sewage Treatment Plant, Almería

Photo 3.5. Rotating sieve. AENA Sewage Treatment Plant. Arrecife, Lanzarote-Las Palmas.

Sand removal: The objective of this process is to remove as much sand as possible from the sewage. The term "sand" includes sand in the true sense of the word, as well as grit, gravel and mineral or organic particles that are relatively large. The purpose of this process is to protect mechanical equipment from abrasion and excessive wear and to avoid the accumulation of heavy materials. Sand removal equipment (detritors or sand traps) is normally designed to remove particles that are bigger than 0.2 mm.

Fat separation: During this process, fats and other low density floating debris are removed from the water. Normally the sand and fat removal processes take place simultaneously in treatment units referred to as aerated detritors and fat separators.

Royal Decree-Act 11/95 defines **Primary Treatment** as "the treatment of urban wastewater through a physical or physicochemical process that includes the sedimentation of suspended solids or other processes that reduce the BOD_5 of the raw sewage by at least 20% and the total concentration of suspended solids in the raw sewage by at least 50%, before being discharged".

The most common Primary Treatment processes are as follows:

Primary sedimentation: The objective of this process is to eliminate most of the setteable solids through gravitational action alone. It is extremely important to remove these solids, as it would otherwise create extremely high oxygen demands during later treatment processes.

Physicochemical treatment: Through this type of treatment, chemical reactions are used to further reduce the concentration of suspended solids and to further eliminate colloidal solids. The size and density of these solids are increased through a coagulation-flocculation process. This type of process is used mainly:

- When the sewage contains industrial effluent that could inhibit the biological treatment process.
- To avoid excessive loads during the subsequent biological treatment.
- When there are strong seasonal flow variations.
- In order to reduce the phosphorous content.

Royal Decree-Act 11/95 defines **Secondary Treatment** as "the treatment of urban wastewater through a process that includes biological treatment with secondary sedimentation or another process, in compliance with the regulatory requirements".

Photo 3.6. Detail of aerated detrior-fat separator. El Bobar Sewage Treatment Plant, Almería.

Photo 3.7. Primary settling tank detail. Arroyo de la Miel Sewage Treatment Plant, Malaga.

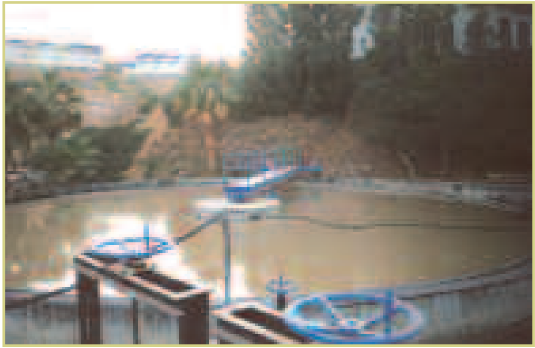


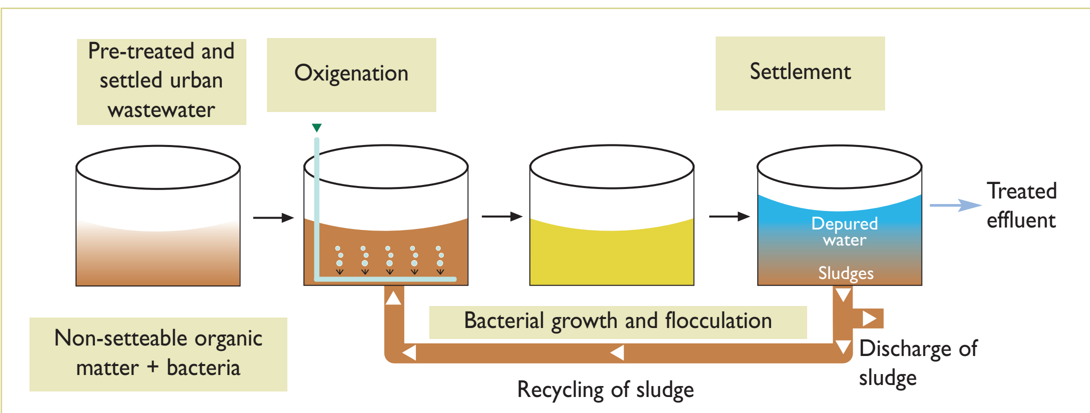
Photo 3.8. Detail of physicochemical treatment (flocculation-coagulation chamber). El Rompido Sewage Treatment Plant, Huelva.

The purpose of these processes is to reduce organic matter pollution and to coagulate and remove non-settleable colloidal solids. The biological processes involve the use of microorganisms (essentially bacteria), which act on the organic material in the sewage under aerobic conditions. In order to maintain the biological reactions (oxidisation, synthesis and endogenous respiration), oxygen is added by introducing air into the containers in which these reactions are taking place. These containers are known as *biological reactors or aeration chambers*. The most common methods for introducing oxygen into biological reactors involve the use of mechanical aerators or diffusers.

The new bacteria that start to appear in the reactors have the tendency to bind together (flocculate), forming aggregates of higher density than the surrounding water, with surfaces that absorb colloidal matter. In order to separate these aggregates, which are known as *sludge* or *slurry*, the contents of the biological reactor (*mixed liquor*) is put through a further sedimentation phase (Secondary Sedimentation or Clarification), which involves the separation of the sludge from the purified effluent through gravitational action.

A fraction of the settled sludge is purged as excess sludge, while the remaining portion is recycled to the biological reactor in order to maintain a specified concentration of microorganisms in the biological reactor.

Figure 3.6. Schematic diagram of Secondary Treatment for he purification of urban sewage



The process described above is known as the *activated sludge* process and was developed in England in 1914 by Ardern and Lockett. Today, the various forms of this technology (conventional, contact-stabilisation, prolonged aeration, etc) are the most widely used for the treatment of urban wastewater throughout the world.

Photo 3.9. Detail of a biological reactor.
El Rompido Sewage Treatment Plant, Huelva

Photo 3.10. Detail of the Southeastern Gran
Canaria Sewage Treatment Plant, Las Palmas

Tertiary Treatment, which is also referred to as advanced, more rigorous or supplementary treatment, makes it possible to achieve greater BOD_5 reduction and elimination of suspended matter, while also reducing other pollutants, such as nutrients and metals, which makes it possible to subsequently reuse the treated effluent. Any suspended particles and colloidal matter remaining in treated effluent can be removed through physicochemical treatment (coagulation-flocculation).

Biological processes are also increasingly being used to eliminate nutrients (phosphorous and nitrogen). However, in the case of phosphorous, chemical precipitation processes involving dosing with iron and aluminium salts continue to be the most widely used.

The biological elimination of nitrogen involves sequential processes in oxic and anoxic conditions, with the nitrogen finally being released into the atmosphere in gaseous form.

In order to remove phosphorous with biological processes, reactors operating under anaerobic, aerobic and anoxic conditions are combined, causing the phosphorous to be absorbed and stored in the microorganisms, which are later extracted as excess sludge. It is possible to combine the aforementioned processes in order to achieve the simultaneous removal of both nutrients.

Due to the inherent nature of urban effluent and the contamination thereof with saltwater during collection and transport to treatment plants, the salinity of effluent increases considerably, which renders it unsuitable for direct irrigational purposes. In these cases it is necessary to desalinate the effluent through a tertiary treatment processes. Due to the brackish quality of this effluent, which usually has a salinity of less than 5 g/l, reverse osmosis or reversible electrodialysis technology is used to desalinate the same.

Photo 3.11. Detail of tertiary treatment. Maspalomas Sewage Treatment Plant, Gran Canaria - Las Palmas

Foto 3.12. Detail of tertiary treatment. Southeastern Gran Canaria Sewage Treatment Plant, Las Palmas

It is normal practice to apply filtration techniques, such as ultra-filtration (UF) and micro-filtration (MF), before this step.

Chlorine has been and continues to be the standard treatment for disinfecting sewage. In the light of increasingly strict requirements that limit the residual chlorine in treated effluent to very low or undetectable concentrations, it is necessary to apply subsequent de-chlorination processes, or to utilise alternative disinfection systems, such as UV radiation, ozone treatment or the use of membranes.

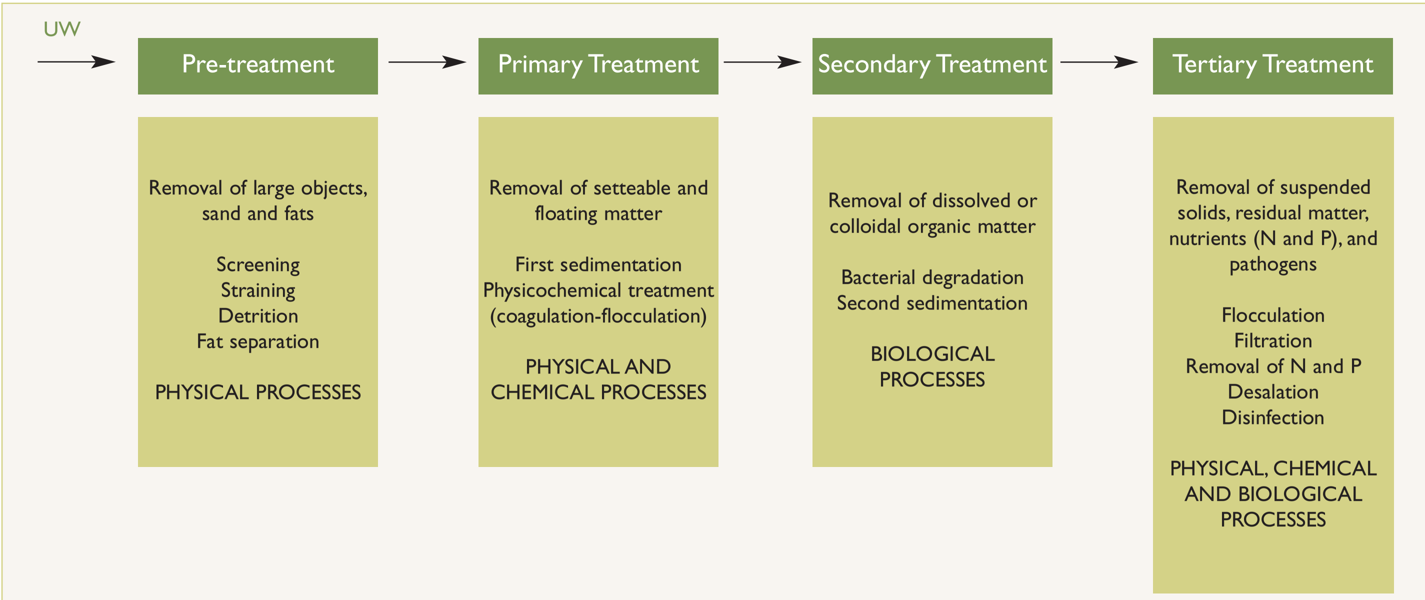
Table 3.6 shows the efficiencies achieved with each type of urban sewage treatment.

Table 3.6. Efficiencies (%) for the stages of urban sewage treatment

Stage	Suspended solids	BOD_5	*E. coli*
Pre-treatment	5 – 15	5 – 10	10 – 25
Primary Treatment	40 – 70	25 – 40	25 – 70
Secondary Treatment	80 – 90	80 – 95	90 – 98
Tertiary Treatment	90 – 95	95 – 98	98 – 99

By way of summary, Figure 3.7 shows the different stages for the aqueous processes in the treatment of urban wastewater.

Figure 3.7. Aqueous processes stages in the treatment of urban wastewater



Sludge treatment

The treatment of urban wastewater produces certain by-products, known as sludge or slurries, or more recently, biosolids, with two types being distinguished:

- *Primary sludge*, being the settleable solids resulting from primary treatment.
- *Secondary or biological sludge*, being the solids that are retained in the settling tank after the water has passed through the Biological Reactor.

The treatment of the sewage sludge generated during the treatment of urban wastewater consists of a series of stages, namely:

- **Thickening**: The density of the sludge is increased by eliminating its water content. The most usual methods involve gravitational force or flotation, the latter being the most appropriate for the thickening of secondary or biological sludge.
- **Stabilisation**: The biodegradable content of the sludge is reduced in order to avoid putrefaction and the consequent release of unpleasant odours. Stabilisation can be achieved through:

Photo 3.13. Sludge thickening equipment. Manilva Sewage Treatment Plant, Málaga

Photo 3.14. Anaerobic stabilisation of sludge. Manilva Sewage Treatment Plant, Málaga

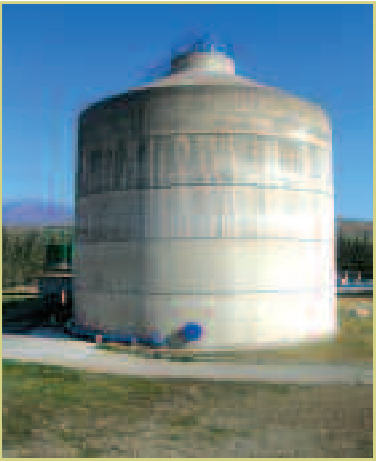


Photo 3.15. Mechanical dehydration of sludge: Belt Filters. Manilva Sewage Treatment Plant, Málaga

   - *Aerobic and anaerobic digestion*, which eliminates approximately 40-50% of the organic matter in the sludge.
   - *Chemical stabilisation*, which involves increasing the pH by dosing lime.
   - *Thermal* treatment.
- **Conditioning**: Greater dehydration is achieved by adding chemical products which facilitate water elimination.
- **Dehydration**: Part of the water content of the sludge is eliminated in order to obtain a solid material that can be handled and transport more easily. The usual methods are:
   - *Centrifuging*.
   - *Filtration* (band, *vacuum*, pressure, etc.).
   - *Thermal* dehydration.
   - *Sludge drying pans*.

Figure 3.8 shows the various stages of sludge treatment in the treatmentpurification of urban wastewater.

Treatment of stormwater

In cases where there is a single sewerage system, effluent flow can sometimes be increased by stormwater to the extent that the single collection system overflows, with the result that it becomes necessary to implement measures to avoid the consequent pollution of the receiving waters. These measures can include:

- The installation of spillways that have a higher dilution ratio .
- The installation of screening equipment at spillway gates, in order to separate and remove large solids.
- The construction of stormwater basins or reservoirs in order to store and regulate extraordinary influent at the primary treatment facilities of treatment plants.

3.7.3. Discharge and reuse

The treatment processes at a sewage treatment plant separate the influent into two streams, namely effluent and sludge. The treatment process is finalised with the evacuation of both effluent and sludge.

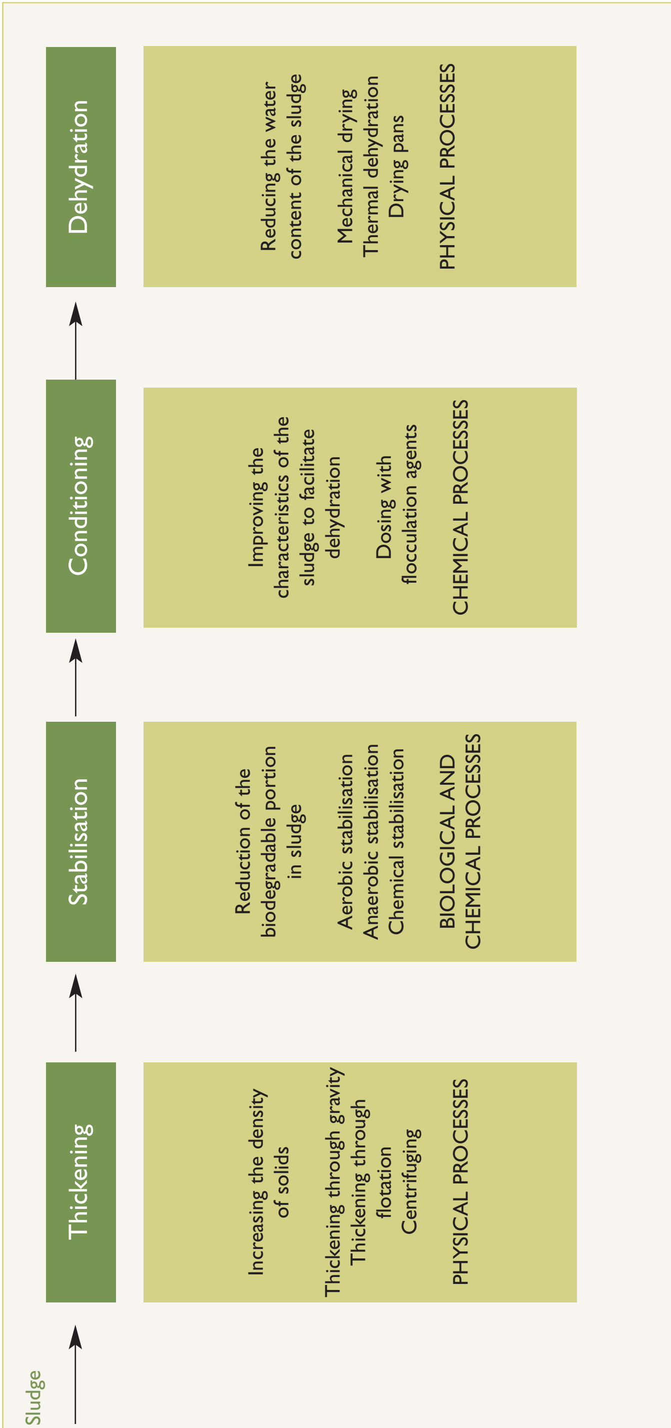


Figure 3.8. The Sludge treatment phase in the purification of urban wastewater

The treated effluents can be discharged into a receiving waters close to the treatment plant, provided that the required level of purification has been achieved in each instance. However, there are ever-increasing alternatives for reuse, some of the most important (adapted by the EPA, 1992), being as follows:

- Urban reuse:
    - Irrigation of public parks, sports fields, gardens, green areas of public buildings, industrial properties, shopping centres and roadways.
    - Irrigating gardens of single- and multifamily housing units.
    - Ornamental uses; fountains and lakes.
    - Street cleaning.
    - Fire protection.
    - Flushing water for public urinals and urinals in commercial and industrial buildings.
- Industrial reuse:
    - Refrigeration.
    - Industrial processes.
    - Construction.
- Agricultural irrigation.
- Replenishment of aquifers in order to limit the percolation of seawater.
- Restoration of natural habitats and improvement of the environment.
- Municipal and recreational uses (irrigation of publicly owned forests, irrigation of public parks and gardens, washing of streets, storage for use in fighting municipal and forest fires and the creation of artificial lakes).
- Transport and cleansing (primary materials: coal, sugar factories; finished and semi-finished products: pulps in paper mills, lamination products, leather tanning, fabric in dyeing-mills, maintenance cleaning: vehicles, properties, streets in industrial areas, building facades, etc.).
- Production of animal and plant biomass (forest and agricultural irrigation, production of micro-algae, fish farming, etc.).
- Supplementing potable water resources.

In the case of sewage sludge, the following alternatives to dumping can be considered:

- Agricultural use: sludge has an organic content between 40 and 80%, including nitrogen and phosphorous, which are essential nutrients for vegetation growth.
- Incineration: by converting the sludge into energy, the volume of the sludge is reduced to its maximum extent, while also destroying pathogens and toxic compounds. However, this process is costly and the emission of gasses and ash has a negative impact on the environment.

Wastewater treatment in small urban settlements

There are more than 8,000 municipalities in Spain, of which 6,000 have less than 2,000 inhabitants. In the case of Andalusia, 85% of the total number of settlements have less than 2,000 inhabitants, the percentage being similar in the Autonomous Community of the Canary Islands, 83% of the total.

In terms of **Royal Decree-Act 11/95**, all urban settlements with less than 2,000 equivalent inhabitants, which discharge their effluent into continental or estuarine waters, are required to provide adequate wastewater treatment by 1 January 2006, adequate wastewater treatment being defined as: "the treatment of wastewater through any treatment process or system which ensures that the receiving waters complies with the quality objectives stipulated in the applicable legislation after the purified effluent has been discharged into it".

At present, it is in these small settlements where we find the greatest shortcomings in sewage treatment and a great effort will be required in the near future to rectify the deficient sanitation and sewage treatment systems of rural and dispersed settlements, in compliance with the applicable legislation.

Until now, and more often than we would desire, treatment plants for wastewaters generated by small urban settlements have been conceived and designed as mere scaled-down versions of larger conventional treatment plants. The direct consequence of this modus operandi is that the responsible bodies, which usually have limited access to technical and financial resources, find it difficult to absorb the operating and maintainance costs of such plants.

When it comes to sewage treatment, small settlements require actions that will make it possible to achieve the legislative standards for treated effluents with simple tecnologies and with affordable operating and maintenance costs.

4.1. Characteristics of wastewater in small urban settlements

Small urban settlements, having a different degree of social and economic development, generate effluent with unique characteristics (strong fluctuations in flow and load, as well as high concentrations), which differ significantly from the effluent generated in large settlements. This fact needs to be taken into account when designing treatment facilities.

4.1.1. Flow

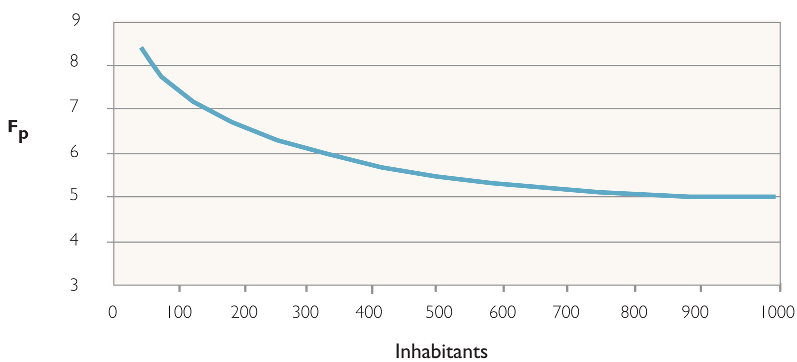
The smaller the settlement, the higher the fluctuations in the volume of sewage generated, with the flow varying from almost zero during the early hours of the morning to eight times the average flow during peak hours, in the case of individual residences.

When designing sewage treatment plants for very small settlements, the term "average daily flow" is used, this is the average flow that is assumed to be produced in a period of only 16 hours (Sainz, 2005).

$$Q_{avarage} = \frac{Q_{daily}}{16}$$

The minimum flow is estimated to be around 30% of the average flow. The ratio between peak flow and the average flow (peak factor - Fp) according to population size is shown in Figure 4.1.

Figure 4.1. Peak factor (Fp) and the number of settlements with less than 1,000 inhabitans



4.1.2. Effluent quality

The sewage that is generated in small urban settlements mainly consists of domestic effluent, with a small industrial component, although the industrial component generated by agrifood and livestock farming activities sometimes requires special attention, as the high organic load of this type of sewage is more problematic in terms of treatment than domestic sewage.

The fact that less municipal water is supplied in small urban settlements impacts directly on sewage concentrations, as a smaller municipal water supply leads to lesser dilution, or greater concentration, of the pollutants generated.

Table 4.1 contains the average ranges for the main parameters that characterise the effluent generated in small urban settlements, in the case of effluent consisting mainly of domestic sewage.

Table 4.1.Average values for sewage generated in small settlements

Parameter	Small Settlements in Andalusia	Small Settlements in the Canary Islands
Suspended solids (mg/l)	300 – 500	350-3300
BOD_5 (mg/l)	400 – 600	480-1500
COD (mg/l)	800 – 1200	1200-4500
Nitrogen (mg N/l)	50 – 100	60-160
Phosphorous (mg P/l)	10 – 20	20-65
Fats (mg/l)	50 – 100	60-120
Total coliform (ufc/100 ml)	10^7-10^8	10^6-10^7

Regional discrepancies between the values of the parameters can be explained by the characteristics of the settlements themselves, as well as varying trends in the consumption of potable water and differences in livestock farming activities. In rural parts of the Canary Islands, agricultural and livestock farming activities usually take place in the settlements themselves, without special treatment for each type of effluent generated for the different activities .

Given the disparate and wide-ranging values of the parameters, the design parameters for the treatment of sewage generated in small settlements should not be based on bibliographical values, it being even more vitally important to conduct assessment and sampling campaigns in order to establish the correct characteristics of the effluent in question before commencing the design of any given treatment plant. It is also necessary to determine the impact of the sewage collection model on the quality of the effluent being generated, given that settlements such as these generally have single sewerage networks that collect domestic and industrial effluent as well as rainwater.

4.2. Technologies for wastewater treatment in small settlements

The geographical location and level of development of small settlements present very specific problems that make it difficult to provide sanitation and sewage treatment services.

Some of the most important problems are:

- The treated effluent needs to comply with very strict legislative standards.
- It is impossible to take advantage of economies of scale due to the small size of treatment plants, which translates into high per capita installation, operation and maintenance costs. Furthermore, sanitation costs increase sharply in dispersed settlements.
- The shortage of technical and financial resources necessary to operate and maintain sewage treatment plants..

For these reasons, it is necessary, when selecting sewage treatment solutions in small settlements, to give preference to technologies that:

- Require minimal energy consumption, avoiding, where possible, the use of electromechanical equipment and making principal use of natural oxygenation processes.
- Have simple operating and maintenance requirements.
- Guarantee effective and stable operation, despite the large fluctuations in influent flow and load that are common in small settlements.
- Simplify the management of the sludge generated by the treatment processes.
- Have low acoustic environmental impact and are properly integrated into the environment.

Technologies for the treatment of domestic urban sewage that comply with these characteristics are referred to by the generic term, "**non-conventional technology" (NCT)**. This type of technology needs to operate with low environmental impact, while successfully reducing the relevant pollution load with lower operating costs than that of conventional treatment plants and with maintenance requirements that do not present great technical difficulties, thereby enabling unspecialised personnel to operate the plant.

Non-conventional treatment technologies include many of the treatment processes that are used in conventional sewage treatment (settlement, filtration, adsorption, chemical precipitation, ion exchange, biodegradation, etc.), in addition to natural treatment processes (photosynthesis, photo-oxidation, absorption by vegetation, etc.). However, contrary to conventional technology, where the processes 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.

At present, both conventional and non-conventional technologies are used for the treatment of the sewage generated in small settlements. Practice has proven that both types of technologies are valid for the treatment of effluent in small settlements, but practice has also shown that, due to the special characteristics mentioned above, priority should be given to robust treatment technologies with low operating and maintenance costs.

However, while "simplicity" of operation and maintenance should be uppermost in mind when installing this type of technology, we find in many instances that simplicity of operation and maintenance has incorrectly been confused with "simplicity" of design and construction, with the result that insufficient attention has been given to the capacity of the treatment system as well as the subsequent construction phase. These failures have had the result that many installations do not achieve projected outputs.

4.3. Essays on technologies for the treatment of urban sewage in small settlements

In this section, each of the various conventional and non-conventional technologies that are most commonly used at present for the treatment of sewage in small settlements, as well as two commonly used Primary Treatment processes, are discussed in detail:

- **Primary Treatment**: *Septic Tanks and Imhoff Tanks.*

- Non-conventional technologies:
  - Systems using soil as a treatment agent.

    Subsurface systems: *Filter Trenches, Filter Beds, Filter Wells and Intermittent Buried Sand Filters*.

    Surface systems: *Plant Filters*.
  - Systems that simulate conditions unique to natural wetlands.

    The various forms of *Artificial Wetlands*: *Free Flow* and *Subsurface Flow* (*Vertical* and *Horizontal*).
  - Systems that imitate natural treatment processes in rivers and lakes: *Lagooning*.
  - Systems based on the filtration of water through natural carbon: *Peat Filters*.

- Technologies with intermediate characteristics between conventional and non-conventional technology:
  - Biological filters.
  - Rotating Biological Contactors.
- Conventional technologies
  - *Extended aeration.*

Essays

PRIMARY TREATMENT: SEPTIC TANKS

A *Septic Tank* is a watertight tank that is usually buried below ground and in which the sedimentable organic matter in the wastewater to be treated settles and is mineralised.

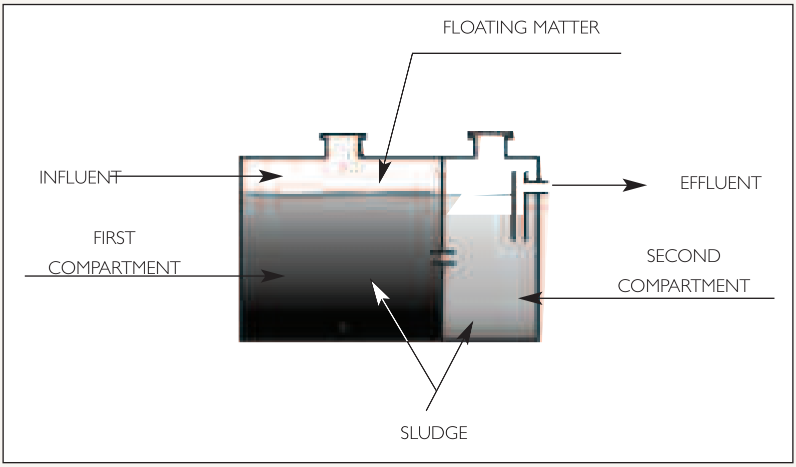
The septic tank is divided into a varying number of compartments, with two sequential compartments being the most common design. The sedimentation, digestion and storage of the suspended solids take place in the first compartment. The clarified water then passes to the second compartment, where further, albeit lesser, sedimentation and crusting takes place due to the fact that some of the organic matter escapes the first stage.

In cases where the septic tanks are equipped with a third compartment, a certain degree of *Secondary Treatment* is achieved in the latter compartment.

The sludge that is retained on the bottom of the various compartments undergoes anaerobic degradation, thereby reducing in volume, which enables the septic tank to continue functioning for long periods of time without any need to remove the sludge.

While the sludge is undergoing anaerobic degradation, gas bubbles are produced which impede the normal sedimentation of the suspended solids in the influent, which is why there is a second compartment in which the conditions are more favourable for the sedimentation of lighter particles.

Schematic diagram of a twin-compartment septic tank process



Desing parameters

- As a general rule, the total volume of the septic tank varies between 250 and 300 l/ p.e.
- When the septic tank consists of two compartments, it is recommended that the first occupies 66% of the total volume, When there are three compartments the first compartment should not occupy more than 50% of the total volume with the remaining volume being divided equally between the second and third compartments.
- The usable water level inside the two compartments varies between 1.2 and 1.7 metres, leaving a clearance of 0.3 m above the water level.
- The total length of the septic tank should be between two and three times the width of the compartments.

Scope of application

Septic tanks can be utilised for populations of up to 300-500 p.e, although it does not constitute an urban sewage treatment system in itself, which is why it is advisable to supplement it with an additional treatment technology.

Average treatment efficiency

Parameter	% Reduction
SS	50-60
BOD_5	20-30
COD	20-30
N	10-20
P	0-5
Faecal Coliform	50-75

Key operational requirements

- The *structure* of the tank must remain watertight.
- The septic *tank* must not be overloaded with organic pollution.
- Large *quantities* of fats/oils and detergents and/or bleaches must be avoided.
- It is *necessary* to remove the sludge periodically. The quantity of sludge produced is normally 0.2 m^3/inhab./year.
- Any *filters* or grids in the septic tanks need to be cleaned periodically.
- In order *to* avoid possible contamination, septic tanks must always be installed below and at a distance of least 30 m from any potable water wells and nearby springs.
- Periodic removal of the digested sludge and floating debris.

Advantages

- Low *installation* and operation cost. The operational tasks consist mainly of the periodic extraction of the digested sludge.
- Easy *installation* of prefabricated units.
- Zero *energy* consumption.
- Low visual impact: underground installation.
- It constitutes pre-treatment for many non-conventional systems.

Disadvantages

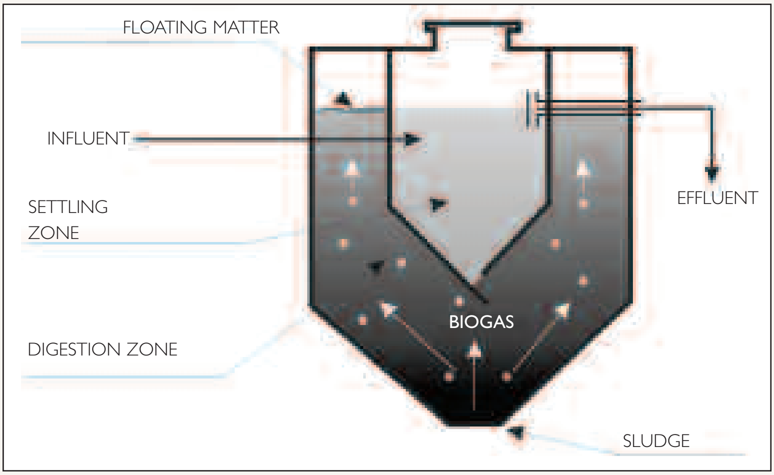
- Low *performance* in terms of the reduction of organic load and elimination of pathogens, with the result that secondary treatment is required.
- Lack of stability when faced with peak flows.
- *Accumulation* of fats and oils on the surface.
- *Generation* of bad smells in the absence of adequate maintenance.

PRIMARY TREATMENT: IMHOFF TANKS

An *Imhoff Tank* is a unit that can be used for the Primary Treatment of urban wastewater by eliminating sedimentable organic particles and floating solids. The organic component of the settled solids is mineralised through anaerobic action.

It consists of a single unit, in which the sedimentation zone, settling chamber, is separated from the zone in which the settled solids are digested, digester section, the former being located in the upper part of the unit, while the latter is located in the lower part. The opening between the two parts is designed in such a way as to prevent gases and sludge particles from passing from the digestion area into settling zone, with the result that the gases cannot interfere with the settlment of the suspended solids.

Schematic diagram of an Imhoff Tank process



Desing parameters

- *Settlement zone*: The size of this part of the tank is calculated to ensure that the maximum hydraulic retention time of the effluent is 90 minutes.
- *Digestion zone*: To achieve a 6-month sludge digestion period, the size of the digestion area is typically calculated on the basis of 0.07 m^3/ p.e.
- Although *Imhoff Tanks* sometimes have cylindrical designs, they are more usually built in rectangular shapes, the length being 3 to 5 times the width.

Scope of application

Imhoff Tanks are used as a pre-treatment system before land application systems and as a *Primary Treatment* system before *Artificial Wetlands*, *Rotating Biological Contactors* and *Biological Filters*.

The utilisation of *Imhoff Tanks* is usually limited to a maximum of 300-500 inhabitants, although it is possible to install several modules to increase its range of application. Furthermore, it is advisable to supplement the *Imhoff Tank* installation with an additional treatment technology, as it does not constitute an urban sewage treatment system in itself.

Average treatment efficiency

Parameter	% Reduction
SS	60-70
BOD_5	30-40
COD	30-40
N	10-20
P	0-5
Faecal Coliform	50-75

Key operational requirements

- The Imhoff Tank must be installed below ground with a 25-35 cm layer of soil covering the structure.
- In order to avoid possible contamination, Imhoff Tanks must always be installed below and at a distance of least 30 m from any potable water wells and nearby springs.
- Periodic removal of the digested sludge and floating debris.

Advantages

- Low installation and operation cost. The operational tasks consist mainly of the removal of the digested sludge and floating debris.
- Zero energy consumption.
- Absence of electromechanical failures.
- Subsurface installation is possible.
- The possibility of utilising prefabricated units facilitates installation.
- It constitutes pre-treatment for many non-conventional systems.

Disadvantages

- Low performance, with the result that secondary treatment is required.
- Accumulation of fats and oils on the surface.
- Lack of stability when faced with peak flows.

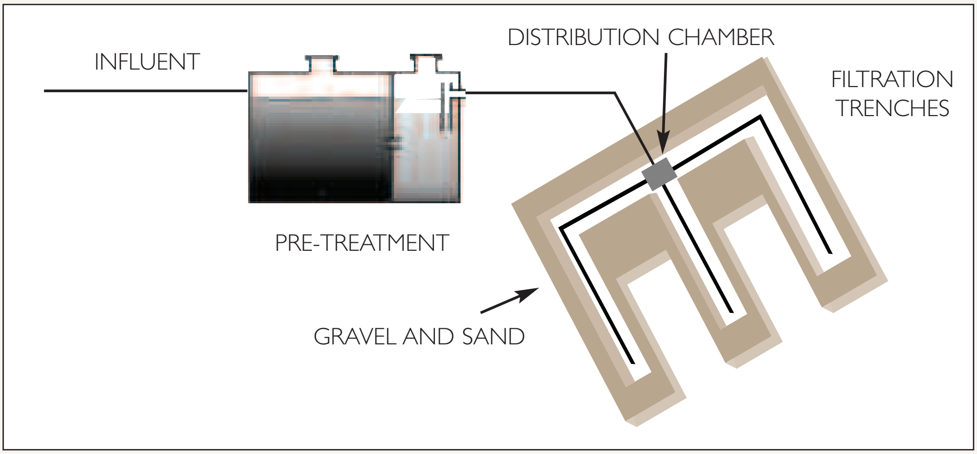
FILTRATION TRENCHES

Filtration Trenches is a Land Suburface System for the treatment of urban sewage.

It consists of shallow (< 1 m) and narrow (0.45-0.80 m) trenches excavated on the land surface, in which the pre-treated effluent (coming from Septic Tanks and Imhoff Tanks) is collected and distributed by means of a perforated pipe system, which is placed on a bed of sand and covered by gravel. The gravel is covered with a vegetation fill, taking care that the vegetation fill does not mix with or obstruct the gravel layer. In this case, the bed of the trench constitutes the percolation surface, although the vertical walls can assist with percolation in the event of clogging.

The pre-treated effluent is discharged into a distribution box, which makes it possible to alternate the feed to the various trenches.

Schematic diagram of the Filtration Trench process in plan and section



Desing parameters

Parameter	Value
Hydraulic load (m^3/m^2d)	0,02-0,05
Trench depth (m)	0,50-0,70
Trench width (m)	0,45-0,80
Trench length (m)	< 20 ó 30
Distance between trench axes (m)	1,0-2,50
Depth between bed and watertable (m)	> 0,6 ó 1,2
Thickness of covering (m)	> 0,15

Source: EPA, 1980

Scope of application

Filtration Trenches are suitable for the treatment of effluent generated by isolated dwellings or by small groups of dwellings.

Average treatment efficiency

Parameter	% Reduction
SS	80-90
BOD_5	80-90
COD	75-85
N	50-80
P	40-70
Faecal Coliform	99-99,9

Key operational requirements

- The terrain must be suitable for the percolation of the effluent coming from the Primary Treatment process.
- Alternation between the trenches in use in order to maintain aerobic conditions in the percolation area as far as possible.

Advantages

- Low operating and maintenance costs.
- Zero energy consumption.
- Absence of electromechanical failures.
- Contact of people or animals with the sewage is avoided.
- High treatment efficiencies.

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 trenches are not correctly designed and maintained, it may lead to contamination of groundwater sources.

Filtration Beds constitute a subsurface system for the treatment of urban sewage.

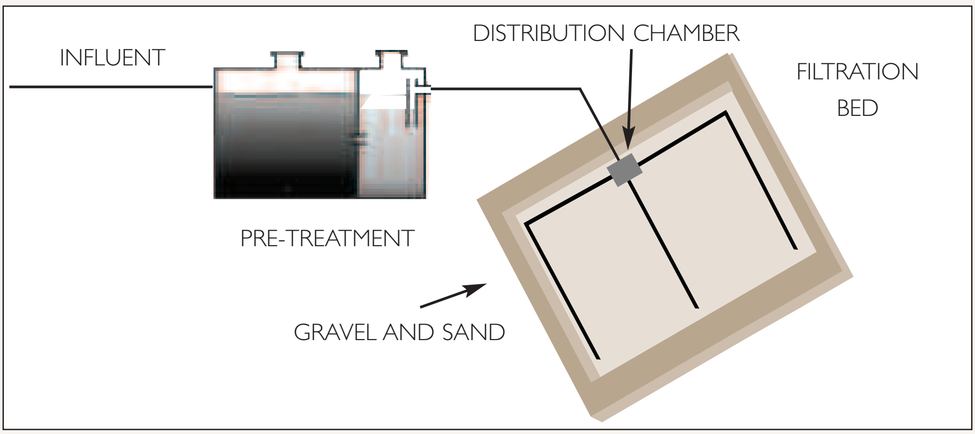
The process is similar to that of Filtration Trenches, with the difference that wider trenches (0.9-2.0 m) are excavated in order to create gravel beds with perforated piping at the bottom.

The subsurface land application of the effluent coming from the Septic or Imhoff Tanks takes place via the excavated beds, with the water being treated as it percolates into the soil.

A layer of sand, approximately 5 cm thick, is spread over the bottom of the bed, which is covered with a layer of gravel approximately 60 cm deep. The gravel layer is covered with a layer of vegetation fill, which is approximately 20-30 cm thick.

Parallel drains are inserted into the gravel layer, through which the effluent is distributed in the bed. The pre-treated effluent is discharged into a distribution chamber, which makes it possible to alternate the feed between the various drains.

Schematic diagram of the Filtration Bed process



Desing parameters

Parameter	Value
Hydraulic load (m^3/m^2d)	0,02-0,05
Depth of Trench (m)	0,50-0,70
Width of Trench (m)	> 0,9
Length of Trench (m)	< 30
Number of pipes per Bed	> 2
Depth between bed and watertable (m)	> 0,60 ó 1,20
Thickness of covering (m)	> 0,15

Source: EPA, 1980

Scope of appication

Filtration Beds are suitable for the treatment of effluent generated by isolated dwellings or by small groups of dwellings.

Average treatment efficiency

Parameter	% Reduction
SS	80-90
BOD_5	80-90
COD	75-85
N	50-80
P	40-70
Faecal Coliform	99-99,9

Key operational requirements

- The terrain must be suitable for the percolation of the effluent coming from the Primary Treatment process; and
- Alternation between the drains in use in order to maintain aerobic conditions in the percolation area as far as possible.

Advantages

- The total surface area required to service a given population size is smaller than that required for Filtration Trenches.
- Low operating and maintenance costs.
- 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.

FILTRATION WELLS

Filtration Wells constitute a *subsurface land application System* for the treatment of urban sewage.

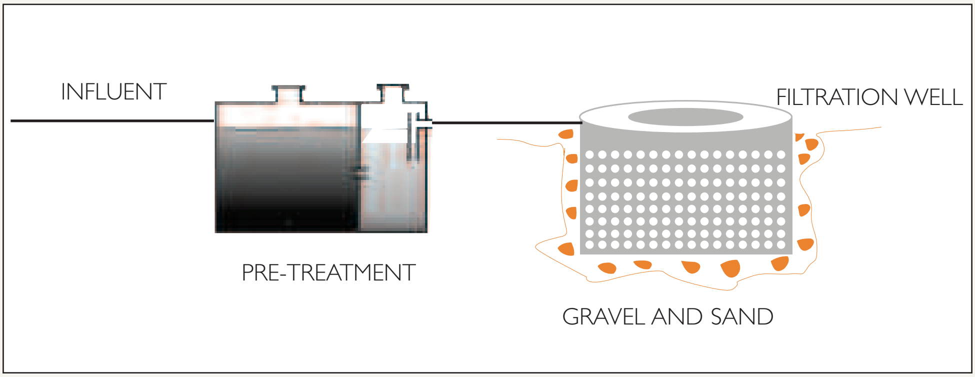
These systems can be used when the water table is low (> 4 m), it being possible to construct *Wells* with a large vertical surface area in relation to the horizontal surface area.

The interior of the wells is reinforced with concrete rings, while a layer of gravel, approximately 20 cm thick, is spread on the bottom surface and in the space between the external wall and the concrete rings, through which the effluent is dispersed into the soil.

The pre-treated effluent (coming from Septic of Imhoff Tanks) is applied to the land by percolation through the lower part of the *Well*. While passing through the well, the effluent is purified through aerobic action and suspended solids are retained.

The pre-treated effluent is discharged into a distribution chamber, which makes it possible to alternate the feed to the various *Wells*.

Schematic diagram of the Filtration Well process



Desing parameters

Parameter	Value
Hydraulic load (m^3/m^2 d)	0,025-0,05
Depth of Well (m)	3-6
Diameter of Well (m)	2,5-3,5
Depth between bottom of well and watertable (m)	> 1,2
Distance between centre points of wells (m)	> 4 Ø

Source: Rohuart, 1986

Scope of application

Filtration wells are suitable for the treatment of effluent generated by isolated dwellings or by small groupings of dwellings.

Avarage treatment efficiency

Parameter	% Reduction
SS	80-90
BOD_5	80-90
COD	75-85
N	50-80
P	40-70
Faecal Coliform	99-99,9

Key operational requirements

- The terrain must be suitable for the percolation of the effluent coming from the *Primary Treatment* process; and
- Alternation between the wells in use in order to maintain the aerobic conditions in the percolation area as far as possible.

Advantages

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

Disadvantages

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

INTERMITTENT BURIED SAND FILTERS

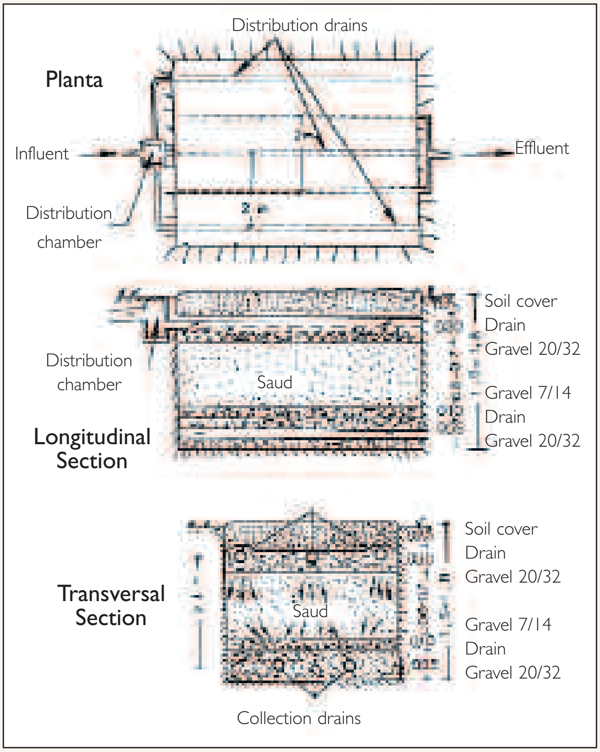
When the nature of the terrain (excessive permeability or impermeability) makes it impossible to install *Subsurface Infiltration* systems, recourse can be had to a *Sand Filter Percolation System*.

The *Sand Bed* is between 0.6 and 1 m thick and rests on a layer of gravel, in which pipes are inserted to collect the treated effluent.

After the effluent has been pre-treated (normally with a *Septic* or *Imhoff Tank*), it is distributed across the surface of the filter by means of perforated pipes.

In order to maintain aerobic conditions during operation, the effluent is fed intermittently onto the *filter*.

Schematic diagram of the Buried Sand Filter Process



Source: Rohuart, 1986

Desing parameters

Parameter	Value
Pre-treatment	Septic tank or similar process
Hydraulic load (m^3/m^2d)	< 0,040
Depth (cm)	60-90
Slope (%)	0,5-1,0
Dosing	Periodic flooding of filter (> 2 twice/d)

Source: EPA, 1980

Scope of Application

Intermittent Buried Sand Filters are *suitable* for the treatment of effluent generated by isolated dwellings or by small groupings of dwellings.

Average treatment efficiency

Parameter	% Reduction
SS	80-90
BOD_5	80-90
COD	75-85
N	50-90
P	40-80
Faecal Coliform	99-99,9

Key operational requiremenst

- Alternation of effluent feed in the operation cycle.
- Proper grading of the filter media.

Advantages

- Low operating and maintenance costs.
- 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.
- 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.

GREEN FILTERS

The effluent treatment technology referred to as Green Filters involves the use of an area of land surface on which a tree plantation has been established, with the effluent normally being introduced through trenches or by flooding.

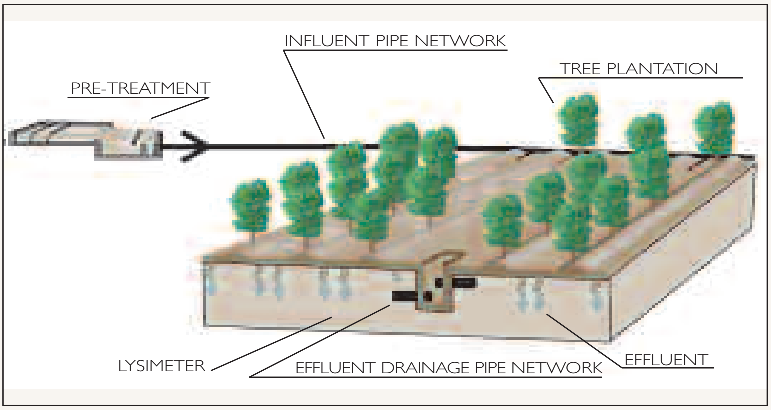
The black poplar is the most commonly used vegetation type, although eucalyptus is also starting to be used in Green Filters.

With this treatment technology, the treated effluent is not reused immediately, but percolates through the soil to be incorporated into the aquifers. In order to control the quality of the percolating water, a series of lysimeters are installed in the soil where the Green Filter is established, which makes it possible to collect samples at different depths.

The influent to be applied to the Green Filter should at least be put through a screening process in order to avoid obstructions in the piping.

The terrain on which the Filter is established is subdivided into a series of plots, which are irrigated on a rotational basis, generally through controlled flooding.

Schematic diagram of the *Green Filter* process



Desing parameters

In order to determine the surface area that is required for the establishment of an effluent purification system based on *Green Filter* technology, it is necessary to know the relevant *Hydraulic Load*.

The *Hydraulic Load* is determined in accordance with the most unfavourable of the following two conditions:

- The *Permeability* of the soil.
- The *Concentration of nitrogen in the percolated water*, as it is necessary to establish a balance between the nitrogen that is added to the terrain through the application of effluent, and the elimination of this nutrient by various means, such as the processes of nitrification and denitrification, volatilisation of ammonia, absorption by vegetation, etc.

The frequency of irrigation varies between once every 4 days for sandy soil and once every 14 days for soil with high clay content, it being relatively common to establish the frequency at once per week.

Scope of application

This type of technology is applied most frequently for populations not exceeding 500 p.e.

Average treatment efficiency

Parameter	% Reduction
SS	85-95
BOD_5	85-95
COD	80-90
N	50-90
P	40-90
Faecal Coliform	99-99,9

Key operational requirements

- *Installation:*
  - For the installation of a Green Filter, the terrain and effluent need to fulfil a series of conditions, namely:
    - It is necessary to have detailed knowledge of the hydrological and nutrient balance on the terrain, using the most unfavourable conditions to determine the requirements of the terrain;
    - The terrain needs to have specific soil conditions in terms of permeability and granule size. The most suitable terrains consist of sandy loam or clay loam. Clayey, sandy or very sandy soils are not suitable;
    - The piezometric level must be more than 1.5 m from the surface (although this value should normally be doubled or tripled);
    - A surface area of approximately 1 Ha is required for every 250 inhabitants, which amounts to approximately 40 m^2/inhab, although this can vary between 10 and 90 m^2/inhab depending on the climate (mainly rainfall) and the characteristics of the terrain; and
    - The influent must not contain substances that are noxious for the tree species being cultivated;
- *Maintenance and operation:*
  - The periods of flooding need to accord with the type of soil, in order to avoid prolonged water stagnation that could lead to anaerobic conditions;
  - The terrain needs to be harrowed on a quarterly basis in order to re-aerate the soil, break crusts (mainly in the areas surrounding the outlets of the effluent feed) and remove undergrowth;
  - The soil should not be harrowed to a depth of more than 10 cm in order to avoid damage to tree roots and it should never be done during the period when the trees are without leaves, as the undergrowth between the trees is necessary to absorb the nutrients in the sewage during this period;
  - The trees should be pruned before they start budding in spring, in order to ensure that the tree stems grow as straight as possible;
  - The appearance of possible diseases that may endanger the trees needs to be controlled; and
  - The entire operational process needs to be monitored on a continuous basis.

Advantages

- Simplicity of operation, given that the operational and maintenance activities are limited to the removal of residues from pre-treatment, the periodic rotation of the plot into which the effluent is applied and a quarterly harrowing of the soil, in order to re-aerate the soil and break the crusts that may have formed;
- Absence of mechanical failures, due to the absence of mechanical equipment;
- The system can operate without any energy consumption;
- The operation costs of the treatment plant can be defrayed in part by selling the wood produced;
- No sludge is produced in the purification process;
- Perfect environmental integration;
- Very high levels of purification are achieved;
- It is perfectly able to absorb increases in effluent flow caused by increases in summer populations; and
- Absence of odours.

Disadvantages

- It requires a very large surface area (more than any other non-conventional technology), 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; and
- Not suitable for high rainfall areas

ARTIFICIAL WETLANDS

Artificial Wetlands are treatment systems that consists of shallow channels or lagoons (normally less than 1 m deep), in which typical wetland vegetation (aquatic macrophytes) is planted and in which the treatment process takes place through simultaneous physical, chemical and biological action.

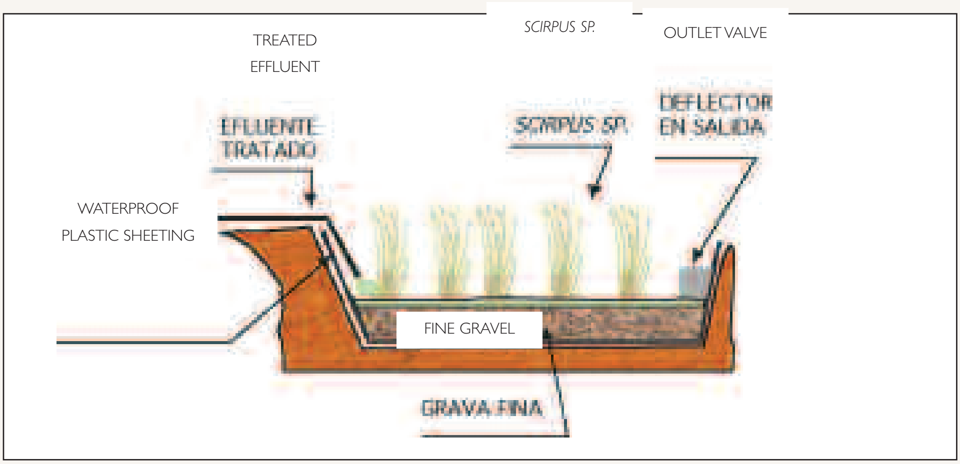
The influent generally first undergoes a *Screening* and *Primary Treatment* process (generally in *Septic or Imhoff Tanks*).

Artificial Wetlands can also be used to restore ecosystems, in which case effluent purification can be a secondary objective.

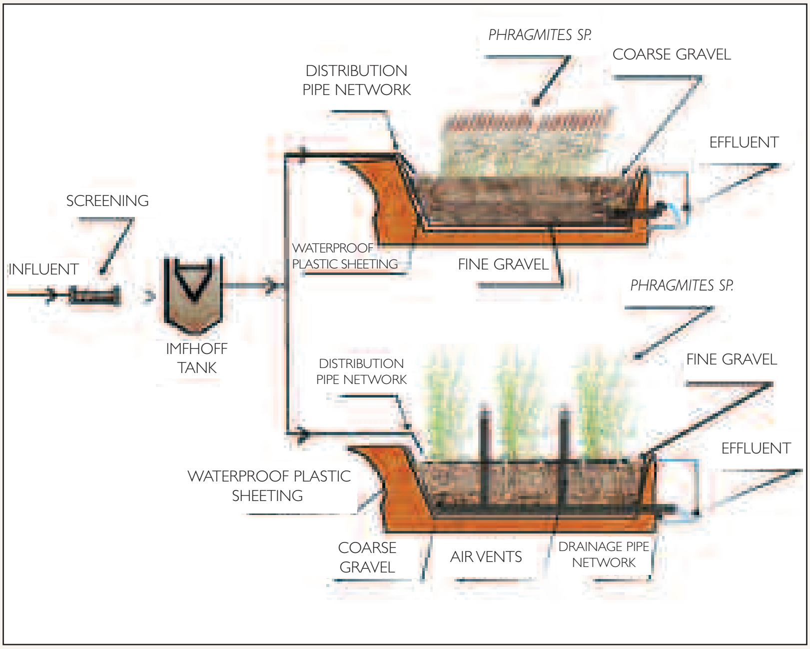
Types of processes

- *Free Flow Artificial Wetlands (FF)*, which are usually used as a form of *Advanced Effluent Treatment*. It consists of a number of marshes or parallel channels, with emergent vegetation and shallow water levels (0.1-0.6 m). The *effluent* feed is normally continuous.
- *Artificial Wetlands with Horizontal Subsurface Flow (HSF)*, which can be used as a form of both *Secondary* and *Advanced Treatment*. After the effluent has been *Screened* and submitted to *Primary Treatment*, it flows horizontally through a porous medium (stone chippings or gravel), being confined to an impermeable channel, in which emergent vegetation, preferably wild reeds, is planted. The effluent feed is continuous.
- *Artificial Wetlands with Vertical Subsurface Flow (VSF)*, which can be used as a form of both *Secondary* and *Advanced Treatment*. After the effluent has been *Screened* and submitted to *Primary Treatment,* it flows vertically through a porous medium (sand or grit), after which it is collected in a drainage network on the bed of the *Wetland*, which is connected to aeration vents.

Schematic diagram of the Free Flow Artificial Wetland (FF) Process



Schematic diagram of the *Horizontal Subsurface Flow (HSF)* and
Vertical Subsurface Flow (VSF) Artificial Wetland processes



Desing parameters

Parameter	Free Flow Wetland
Hydraulic retention time (d)	4-15
Water depth (m)	0,1-0,6
Organic load (kg BOD/Ha d)	< 67
Hydraulic load (m^3/m^2d)	0,014-0,046
Specific surface area ($Ha/10^3\ m^3\ d$)	7,1-2,2

Parameter	Horizontal Subsurface Flow Wetland	Vertical Subsurface Flow Wetland
Organic load (g BOD_5/m^2 d)	10-15	20-30
Average depth of substrate (m)	0,3-0,6	0,8-1,0
Granule size of active substrate (mm)	5-12	2-6

Scope of Application

This type of technology is applied most frequently for populations not exceeding 2,000 p.e.

Average treatment efficiency

Parameter	% Reduction
SS	80-90
BOD_5	80-90
COD	75-85
N	35-50
P	20-35
Faecal Coliform	99-99,9

Key operational requirements (Wetlands with Subsurface Flow)

- *Commissioning:*
    - In a Horizontal Subsurface Flow Artificial Wetland, the effluent feed is started as soon as the vegetation has been planted in order to stimulate growth.
    - The level of flooding of the substrate is lowered periodically, thereby altering the exit level of the purified effluent in order to stimulate more rapid development of the plant roots.
    - When a number of years have passed after the planting of the vegetation, the level of flooding is increased until it is slightly below the surface of the substrate, avoiding the formation of puddles on the substrate.
- *Maintenance and operation:*
    - Maintenance of Overflows, *Bypasses and Pre-treatment systems*.
    - Periodic cleaning of the distribution systems at the entrances to the channels.
    - Preventing animals that feed on the Wetland vegetation from gaining access to the Effluent Treatment Plant.
    - Avoiding, as far as possible, stepping on the substrate of the *Wetland* in order to avoid compaction and any reduction of the substrate's hydraulic conductivity.
    - Cutting the dry plants when they have reached the end of their lifecycles.
    - Removing weeds that may compete with the *Wetland* vegetation, especially during the first two months of operation.
    - Controlling any diseases that may appear in the *Wetland* vegetation.
    - If any *Septic* or *Imhoff Tanks* are in use, the periodic removal of accumulated sludge.
    - Continuous monitoring of the entire operation process.
- *Most common problems and their solutions:*
    - The main problem that can occur In a *Subsurface Flow Wetland* is the clogging of the substrate. Assuming that the correct substrate has been used, the main cause of clogging can be found in the poor functioning of the pre-treatment process. It is advised to interrupt the effluent feed for approximately two weeks.

- In winter it is normal to find dead leaves and stems. If this should happen in any other part of the year and it is established that the water level is sufficient, the cause may be the presence of toxic substances in the effluent.

Advantages

- Simplicity of operation, being limited to the removal of residues from Pre-treatment and the cutting and removal of dry vegetation.
- Absence of mechanical failures, due to the absence of mechanical equipment.
- The system can operate without any energy consumption.
- The system is flexible and not very sensitive to variations in influent flows and organic loads.
- The vegetation biomass acts as insulator for the sediment, which ensures that the microbial activity continues throughout the year.
- Given that the effluent circulates below the substrate surface in Subsurface Flow Wetlands, no bad odours are generated and no proliferation of mosquitoes occurs.
- Zero acoustical impact on the environment.
- No odours are generated.
- Perfect integration into the rural environment.
- Creation and restoration of wetland areas that are suitable for improving biodiversity, environmental education and recreational areas.

Disadvantages

- It requires a larger surface area than *Conventional Treatment Technologies* (approximately 5 m^2/ 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.
- Proliferation of mosquitoes In *Free Flow Artificial Wetlands* where the water circulates above the substrate surface.

LAGOONING

The wastewater treatment technology referred to by the generic term of *Lagooning*, involves the construction of artificial ponds in which the phenomenon of self-purification, which occurs naturally in rivers and lakes, is reproduced.

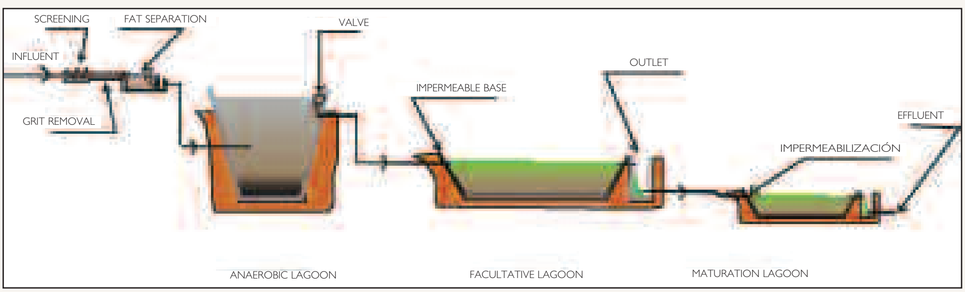
Types of lagoons

There are essentially three types of lagoons:

- *Anaerobic Lagoons*. Due to the high organic content of the effluent, anoxic conditions predominate, with the result that the microorganisms which proliferate in the lagoon are almost exclusively anaerobic bacteria. The depth of this type of lagoon varies between 3 and 5 m.
- *Facultative Lagoons*. These are characterised by the existence of three clearly defined strata, namely an anaerobic bottom layer, an aerobic top layer and a middle layer in which the conditions vary greatly and in which facultative bacteria predominate, hence the name of this type of lagoon. The depth of this type of lagoon varies between 1.5 and 3 m.
- *Maturation Lagoons*. Due to the fact that the effluent that is treated in these types of lagoons contains low organic loads and that the conditions permit solar penetration, while favouring the growth of micro-algae, the predominant oxygen levels are sufficient to sustain the proliferation of aerobic organisms in the water. The depth of this type of lagoon is usually between 0.8 and 1 m.

The Lagooning system that could be categorised as the classical system, is comprised of a Pre-treatment system (Screening grid, Detritor and Fat Separator), which is followed sequentially by the three types of Lagoons described above, i.e. Anaerobic, Facultative and Maturation.

Schematic diagram of the *Lagooning* system



Desing parameters

The *Lagooning* system encompasses a great variety of methods, which reflect the variety of conditions in which these systems have operated (different types of effluent feed, geographic location, climatic conditions, etc.). The dimensions of these types of *Lagoons* are calculated in accordance with the following guidelines:

Parameter	Anaerobic L.	Facultative L.	Maturation L.
Retention time (d)	2-3	20-30	5
Volumetric load (g BOD_5/m^3 d)	150-200	-	-
Superficial organic load (kg BOD_5/Ha.d)	-	< 100	< 100
Depth (m)	3-5	1,5-2	0,8-1

Source: Bibliographic compilation

Scope of application

This type of technology is applied most frequently for populations not exceeding 2,000 p.e.

Average treatment efficiency

Parameter	% Reduction		
	Anaerobic L.	Facultative L.	Maturation L.
SS	50-60	0-70	40-80
BOD_5	40-50	60-80	75-85
COD	40-50	55-75	70-80
N	5-10	30-60	40-80
P	0-5	0-30	30-60
Faecal Coliform	30-70	99,5-99,8	99,9-99,99

The performance is determined with reference to the influent.

Key operational requirements

- *Commissioning:*
    - The commissioning of a *Lagooning* project can be problematical, given that the microorganisms responsible for the purification process do not appear spontaneously, requiring a gestation period that can vary according to ambient conditions;
    - It is advisable to commission the *Lagooning* system during spring or summer, given that the micro-organisms grow at a faster rate during this period;
    - The system needs to be commissioned in sequence: Firstly, the *Anaerobic Lagoons* are commissioned, followed by the *Facultative Lagoons* and, lastly, the *Maturation Lagoons*; and
    - Each lagoon requires a waiting period during which the appropriate conditions for the ecosystems that needs to develop in each, are activated, i.e. anaerobic conditions (*Anaerobic* Lagoon) and the development of micro-algae (*Facultative* Lagoon).
- *Maintenance and operation:*
    - Maintenance of Overflows, *Bypasses and Pre-treatment systems;*
    - *Anaerobic Lagoons*:

      Periodic removal of matter floating on the surface of the *Lagoons*;

      Periodic removal of the sludge that accumulates on the beds of the *Lagoons* in operation, normally every 5-10 years;

Inspection of the earth embankments, repairing any damage; and

Any breaches of the waterproof lining that may be detected (in the case of *Lagoons* lined with plastic sheeting) need to be repaired immediately.

- *Facultative* and *Maturation* Lagoons:

  It is necessary to remove the accumulated sludge and floating debris from the collection basins on a regular basis in treatment plants where the effluent from the anaerobic stage is brought together in channels for distribution to the *Facultative Lagoons*, in addition to checking that the sluice gates function properly and are watertight. The same maintenance tasks need to be carried out in the channels that transport the effluent from the *Facultative Lagoons* to the *Maturation Lagoons*;

  Periodic removal of any floating debris appearing on the surface of the *Lagoons;*

  The earth embankments and waterproof linings require the same maintenance tasks as the ones specified for *Anaerobic Lagoons*; and

  Prevention of any spontaneous vegetation growth in *Lagoons* that do not have waterproof linings and on earth embankments.

- Continuous monitoring of the entire operation process of the *Lagooning* system.

• *Most common problems and their solutions:*

- The types of problems that can arise in a *Lagooning* system are sometimes due to problems with the influent (flow or composition) or incorrect maintenance and operation;
- An excessive increase in flow can lead to reduced purification capacity. The impact on the anaerobic stage can be corrected by increasing the number of *Anaerobic Lagoons*. If there is only one *Facultative* and *Maturation Lagoon*, we can change the level of the weir, thereby increasing the retention time. If this is not feasible, the only solution is to draw off the excess effluent from the anaerobic stage; and
- Excessive increases in the organic load of the effluent can overload the *Lagoons*, which leads to the release of bad odours and a change of the water colour in the *Anaerobic Lagoons* from greenish to pinkish-brown, while bubbling and the release of bad odours occur in the *Facultative* and *Maturation Lagoons*. These problems can be solved by reducing, and even completely interrupting, the flow into the *Lagoons* until the initial conditions are re-established.

Advantages

- Low investment cost, especially if the terrain is sufficiently impermeable, and easy construction;
- Zero energy consumption, in cases where it is possible to transport the effluent to the treatment plant under gravitational force;
- Absence of mechanical failures, due to the absence of mechanical equipment;
- Low or simple maintenance, being limited to removing residues from *Pre-treatment* and keeping the surface of the *Lagoons* free of floating debris, in order to avoid the proliferation of mosquitoes;
- Low production of sludge; The sludge undergoes a high degree of mineralisation due to the extended retention time of the sewage, which greatly facilitates the handling and removal of the sludge;
- Long retention time, which makes it easy to adapt to variations in flow and organic load; and
- Highly effective for the elimination of pathogens.

Disadvantages

- Large surface areas are required for the construction of *Facultative* and *Maturation Lagoons*;
- Due to its strong dependence on climatic conditions, the application of this type of purification system may be limited in cold climates or areas where there are low levels of solar radiation;
- *Anaerobic Lagoons* release disagreeable odours, which make it necessary to situate them far away from inhabited areas;
- Recovery is slow after any deterioration of the biological system;
- The purified effluent has a high concentration of suspended solids (micro-algae); and
- Water losses through evaporation.

This treatment system is based on the filtration of urban wastewater through filter beds in which *peat* is used as filtration medium. *Peat* is a form of humus that is formed in the anaerobic conditions that occur in soil which is saturated with water.

Peat Filters consist of enclosures containing a series of filtration layers, namely (from top to bottom) peat, sand, grit, stone chippings and gravel. The treatment action takes place in the peat layer, while the only function of the remaining layers is to support the upper peat layer.

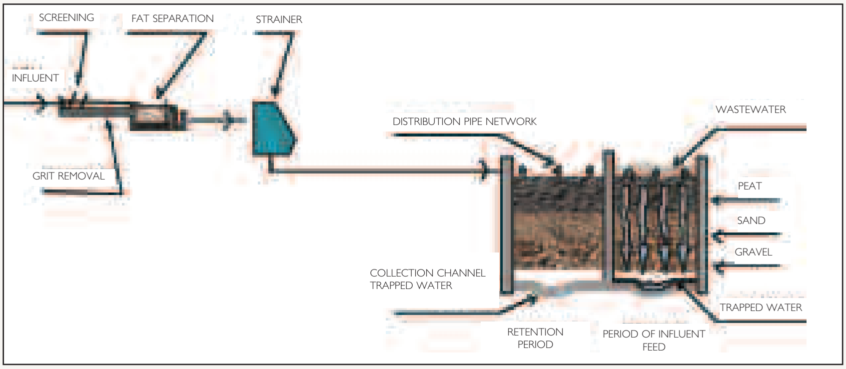
The effluent to be treated in the *Peat Filter* should have undergone pre-treatment with *Screening* and *Fat Separation* processes. It is advisable, furthermore, to strain the influent, or alternatively to treat it with a sedimentation-digestion process, before being applied to the peat filter, in order to prevent the rapid clogging of the pores in the peat. All these tasks are extremely important due to the fact that this technology is based on a filtration process.

After the sewage has been *Pre-treated*, the influent is fed into the *Filters* through a series of pipes that distribute the water as evenly as possible on the surface of the *Peat Bed*.

The *Filters* operate sequentially, periodically alternating between being in operation or being left to regenerate. Each operational cycle usually lasts between 10 and 12 days.

The treated effluent is collected in drainage pipes or channels after it has passed through the peat, sand, grit, stone chippings and gravel, after which it is discharged through the outfall.

Schematic diagram of the Peat Filter process



Design parameters

Parameter	Value
Hydraulic load (m^3/m^2 d)	0,6
Organic load (kg BOD_5/m^2 d)	0,3
Load of solids (kg SS/m^2 d)	0,24
Duration of cycles (days) (d)	10-12
Ratio of total surface/active surface	2:1

Source: CENTA

The main design parameter of *Peat Filters* is the *Hydraulic Load.* The recommended value of 0.6 $m^3/m^2.d$ was obtained through experiments conducted on wastewater with a BOD_5 of 500 and suspended solids of 400 mg/l, which means that, if the organic load and concentration of suspended solids of the wastewater to be treated is higher than the recommended values, it will be necessary to operate with lower *Hydraulic Loads* than that recommended.

The following table contains the values that are acceptable in respect of the various parameters that need to be considered when determining whether the physicochemical characteristics of the relevant peat are suitable for the treatment of urban wastewater.

Parameter	Value
pH (extract 1:5)	6 – 8
Conductivity (extract 1:5) (dS/cm)	< 5
Humidity (%)	50 – 60
Ashes (%)	40 - 50
Organic matter through calcination (%)	50 - 60
Total Humic Extract (%)	20 - 30
Humic Acids (%)	10 - 20
Ion exchange capacity (meq/100 g)	> 125
C/N Ratio	20 – 25
Kjeldhal Nitrogen (% N)	1,2 –1,5
Iron (ppm)	< 9000
Hydraulic Conductivity (l/m^2 h)	25

Note: Except for pH, Conductivity and Humidity, all figures relate to dry materials

Source: CENTA

Scope of application

This type of technology is applied most frequently for populations not exceeding 2,000 p.e.

Average treatment efficiency

Parameter	% Reduction
SS	80-90
BOD_5	75-85
COD	70-80
N	30-50
P	15-35
Faecal Coliform	90-99

Key operational requirements

- *Commissioning:*
  - Once the required number of *Filters* have been installed in accordance with the project specifications, the effluent can immediately be passed through the various *Pre-treatment* processes and, thereafter, the filter beds, as no waiting period is required.
  - If the effluent is pre-treated with an *Anaerobic Lagooning* process, the plant will be commissioned by first filling the lagoons, which will then require 4-5 days for the required anaerobic conditions to develop (darkening of the water and commencement of bubbling in the water mass). When this period has passed, the sewage will be fed into the *Lagoons* according to the flow rates stipulated in the design specifications, the effluent from the *Lagoons* being used as influent for the *Peat Filters*.
- *Maintenance and operation:*
  - Maintenance of Overflows, *Bypasses and Pre-treatment systems*;
  - It is recommended that the effluent be strained (*Static Self-cleaning Strainers* with a hole size of approximately 1 mm are normally used for these purposes) and the fat separated before being fed into the *Peat Filters*. In some *Peat Filter* plants, the *Straining and Fat Separation* processes are substituted by *Anaerobic Lagooning or by Septic or Imhoff Tanks*, which need to be properly maintained and operated in order to ensure that they function correctly;
  - *Peat Filters* need to be operated in alternating sequence, with some being in operation while others are inactive;
  - The inactive *Filters* should be left to dry out. The resulting crust that forms on the surface needs to be removed when dry, the rate of drying depending on the prevailing climatic conditions, after which the *Filters* have to be prepared for a new operational cycle;
  - The peat layer needs to be replenished periodically to its recommended thickness. The thickness of the peat layer reduces by approximately 2 cm per year; and
  - The entire operation process needs to be monitored on a continuous basis.
- *Most common problems and their solutions:*
  - The formation of preferential furrows on the peat surface can lead to reduced purification efficiency. This problem can be corrected through the correct rotation between filters and proper raking of the peat surface; and
  - A malfunction of the system that distributes influent between the units in operation can cause the rapid clogging of the *Filters*. It is necessary to properly achieve a correct distribution of the influent between the filters in operation.

Advantages

- Simplicity of operation, given that operational and maintenance tasks are limited to the regeneration of the depleted filter beds (every 10-12 days) by raking the peat surface once it has been dried out, in order to remove the dried crust that has formed on the surface and to scarify the surface;
- Absence of mechanical failures, due to the absence of mechanical equipment, being able, further, to operate without any expenditure on energy;
- 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; and
- Easy aesthetic adaptation to the environment.

Disadvantages

- Dependence on rainfall figures, which affect the time it takes for the surface crust to dry, with the result that the required surface area can vary according to the rainfall figures. This technology is not suitable for areas with very high rainfall;
- Greater labour requirements than other non-conventional technologies, given that the depleted filters need to be regenerated after each filtration cycle; and
- The peat layer needs to be replaced every 6-8 years of operation.

BACTERIAL FILTERS

BacterialFilters, which are also known as Trickling or *Percolation Filters*, consist of tanks or containers that are filled with a material with a high specific surface area, on which a biological film is formed. The influent is distributed evenly through the upper part of the filling material and slowly percolates through the filtration bed. The Filter is ventilated (in order to obtain the oxygen necessary for the oxidisation of the organic matter) through vent in the lower part of the tank or container. The ventilation process takes place naturally due to the difference in temperature between the inside and outside of the *Filter*.

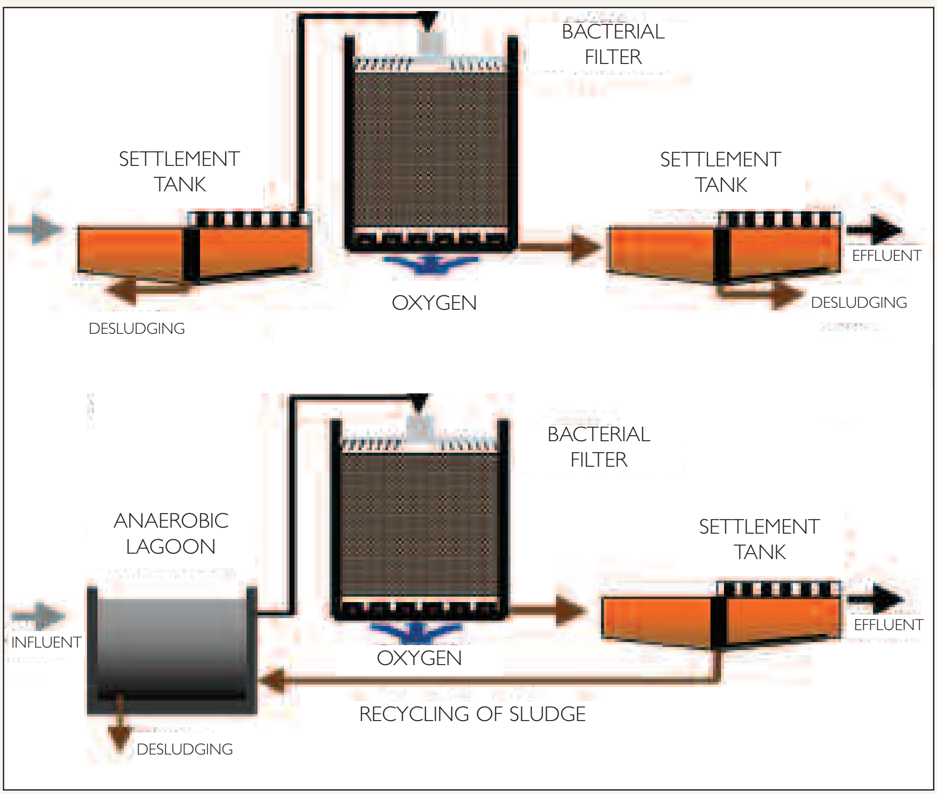
The treated effluent, which contains the bacterial floc that is separated from the substrate, is collected at the bottom of the system, after which it passes through a *Secondary Settling Tank*, in which the purified effluent is separated from the sludge that is generated in the process.

At present, plastic materials are used as filling, on which the bacterial film is formed.

The following types of *Bacterial* Filters require special mention:

- For *low organic loads*: simple treatment systems for obtaining stable effluent with a high level of nitrification; able to deal with large load variations in the raw sewage, with high capacity for the elimination of organic loads; and
- For *high organic loads*: Recirculation is required, which can be done with the final effluent of the system or the effluent of the *Filter* itself. The purpose of this recirculation is to self-clean the *Filter*, to seed the sewage with microorganisms before entry into the Filter and to dilute the concentration of the influent.

Schematic diagram of Bacterial Filter process with Primary Treatment (Primary Settling Tank) or Anaerobic Lagoon:



Sewage treatment plants which are designed to operate with *Bacterial* Filters do not differ much in outline from the designs of plants that utilise *Conventional Technology*. The processes for *Pre-treatment (Screening, Detrition and Fat Separation)* and *Primary Treatment (Primary Settling Tanks)* are similar, although it is possible to substitute the *Primary Treatment* with *Straining*, *Imhoff Tanks or Anaerobic Lagoons* in small installations. The *Anaerobic Lagoons* and *Imhoff Tanks* can be used, in turn, to stabilise the sludge generated in the *Secondary Settling Tanks.*

Desing parameters

Parameter	Low Load	Medium Load	High Load
Organic load (kg BOD_5/m^3 d)	0,08-0,4	0,25-0,50	0,50-0,90
Hydraulic load (m^3/m^2 d)	1,2-3,5	3,5-9,4	9,4-37,5
Circulation ratio	0	0-1	1-2

Scope of application

This type of technology is applied most frequently for populations not exceeding 5,000 p.e.

Average treatment efficiency

Parameter	% Reduction
SS	80-90
BOD_5	80-90
COD	75-85
N	20-35
P	10-35
Faecal Coliform	80-90

Key operational requirements

- *Commissioning:*
  - In order to activate the process, it is necessary to establish a continuous flow of effluent into the *Bacterial* Filter from the *Primary Settling Tank* or *Anaerobic Lagoon*, as the case may be;
  - Verify, after 2-3 weeks, that a biological film has formed on the plastic material used as filling; and
  - If the sewage is pre-treated in an *Anaerobic Lagoon*, the lagoon must be filled, after which the flow is interrupted for 4-5 days until the establishment of anaerobic conditions is observed, following which the anaerobic system is fed with the correct flow of sewage in accordance with design specifications, with the effluent from the anaerobic phase being used as influent for the *Bacterila Filter*.

- *Maintenance and Operation:*
  - Maintenance of *Overflows, Bypasses, Pumps and Pre-treatment systems*; and
  - Monitoring the operation of the *Primary Settling Tank*. The typical capacity of a *Primary Settling Tank* is:

Parameter	% Reduction
Settleable Solids	90-95
Suspended solids	40-60
BOD_5	25-35

  - In cases where the *Primary Settling Tank* is substituted by an *Anaerobic Lagoon*, the anaerobic system will need to be maintained and operated in accordance with the requirements set out in the *Lagooning* section;
  - Monitoring the operation of the *Bacteria Bed*, ensuring that the influent feed to the *Bed* is not interrupted for prolonged periods, as this could cause the biomass in the upper layers to deteriorate, thereby reducing the purification capacity of the system;
  - Monitoring of the operation of the *Secondary Settling Tanks*;
  - Proper electromechanical maintenance; and
  - Continuous monitoring of the entire operation process.
- *Most common problems and their solutions:*
  - Wastewater treatment plants, which utilise Anaerobic Lagooning to pre-treat the sewage before being fed into the Bacterial Filters and which operate at loads that are very different from the design specifications, may function abnormally due to insufficient or excessive loads. This is remedied by adjusting the influent load of the treatment plant.
  - Any bubbling that is observed on the surface of the Settling Tanks is an indication of high sludge levels, which is remedied by desludging more frequently.
  - If excessive separation of the bio-film from the substrate is observed, it may indicate the presence of toxins or agents that inhibit bacteria growth or the hydraulic load may be excessive.
  - Any reduction in purification capacity may be caused by decreases in the ambient temperature, excessive hydraulic or organic loads, changes in the usual characteristics of the sewage, etc.

Advantages (compared to *Conventional 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; and
- Low noise levels due to the low energy requirements of the installation.

Disadvantages (compared to *Non-conventional Technologies*)

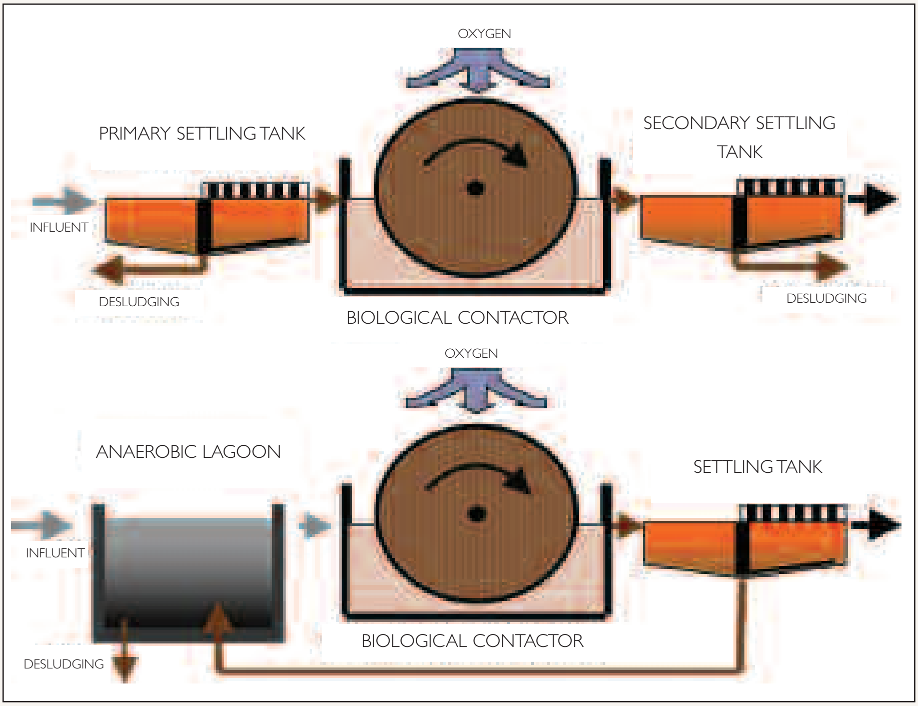
- The installation costs are high due to the cost of the plastic filler material; and
- The process generates sludge, which needs to be stabilised.

Rotating Biological Contactors (RBC's) are wastewater treatment systems in which the microorganisms responsible for degrading the organic matter adhere to a substrate which turns semi-submerged in the sewage requiring treatment. The rotational movement brings the biomass in alternating contact with the sewage being treated and the oxygen in the atmosphere.

The following types of RBC's can be distinguished:

- *Biodiscs*: The substrate to which the bacteria adhere consists of a set of plastic discs which are between 2 and 4 metres in diameter. The discs are installed parallel and in close proximity to each other, being mounted on a central shaft that passes through the centre of each disc; and
- *Biocylinders*: This is a modification of the *Biodisc* system and consists of a rotor, which is a cylindrical perforated cage that contains the plastic filler material to which the bacterial biomass adheres.

Schematic diagram of the Rotating Biological Contactor process, with Primary Treatment (Primary Settling Tank) or Anaerobic Lagoon



RBC's operate in enclosures to avoid damage to the biomass through meteorological action.

Wastewater treatment plants that are designed to function with RBC's include *Pre-treatment (Screening, Detrition and Fat Separation)* and *Primary Treatment* (Settling) processes. In small plants, the *Primary Treatment* process can be substituted by *Straining systems, Imhoff Tanks* or *Anaerobic Lagoons*. The *Anaerobic Lagoons* and *Imhoff Tanks* can be used, in turn, to stabilise the sludge generated in the *Secondary Settling Tanks*.

Desing parameters

The annexed table shows the typical values for the design parameters of RBC's, distinguishing between installations that operate with Secondary Treatment or with combined Nitrification.

Parameter	Secondary	Combined Nutrification
Hydraulic load	(m^3/m^2 d)	0,08-0,16 0,03-0,08
Organic load:		
g BOD_{5S} /m^2 d	3,7-9,8	2,45-7,35
g BOD_{5S}/m^2 d	9,8-17,5	7,35-14,70
Maximum load in the primary stage:		
g BOD_{5S}/m^2 d	19,6-29,4	19,6-29,4
g BOD_{5T}/m^2 d	39,2-58,8	39,2-58,8
NH_3 load(g/m^2 d)	-	0,74-1,47
Hidraulic retention time (h)	0,7-1,5	1,5-4,0

Scope of application

This type of technology is applied most frequently for populations not exceeding 5,000 p.e.

Avarage treatment efficiency

Parameter	% Reduction
SS	80-90
BOD_5	80-90
COD	75-85
N	20-35
P	10-30
Faecal Coliform	80-90

Key operational requirements

- *Commissioning:*
  - Initially, it will be necessary to establish a continuous effluent feed from the *Primary Settling Tank* (or the *Anaerobic* Lagoon, as the case may be) into the RBC. During the next 2-3 weeks a biofilm will form on the rotor. The biomass adhering to the substrate will have a filamentous appearance with a brownish colour.
  - The effluent that is purified while the biofilm is forming will be of inferior quality.

- *Maintenance and operation:*
  - Maintenance of *Overflows, Bypasses, Pumps and Pre-treatment systems*;
  - Monitoring the operation of the *Primary Settling Tank*. The typical capacity of a *Primary Settling Tank* is:

Parameter	% Reduction
Sedimentable Solids	90-95
Suspended Solids	40-60
BOD_5	25-35

  - In cases where the *Primary Settling Tank* is substituted by an *Anaerobic Lagoon*, the anaerobic system will need to be maintained and operated in accordance with the requirements set out in the *Lagooning* section;
  - It is necessary to maintain the rotor in continuous motion for the RBC to function correctly, as the biomass deteriorates very quickly outside of the water;
  - The biomass film that forms on the rotor is vital for the correct functioning of the system, with the result that it may **never** be cleaned;
  - Monitoring of the operation of the *Secondary Settling Tanks*
  - Proper electromechanical maintenance; and
  - Continuous monitoring of the entire operation process.
- *Most common problems and their solutions:*
  - Wastewater treatment plants, which utilise *Anaerobic Lagooning* to pre-treat the sewage before being fed into the RBC and which operate at loads that are very different from the design specifications, may function abnormally due to insufficient or excessive loads. This is remedied by adjusting the influent load of the treatment plant;
  - Any bubbling that is observed on the surface of the Settling Tanks is an indication of a high sludge levels, which is remedied by desludging more frequently;
  - If excessive separation of the bio-film from the substrate is observed, it may indicate the presence of toxins or agents that inhibit bacteria growth in the sewage being treated; and
  - Any reduction in purification capacity may be caused by decreases in the ambient temperature, excessive hydraulic or organic loads, changes in the usual characteristics of the sewage, etc.

Advantages (compared to *Conventional Technologies*)

- Lower energy consumption;
- It is not necessary to recycle the sludge in the 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; and
- Given that the 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 *Non-conventional Technologies*)

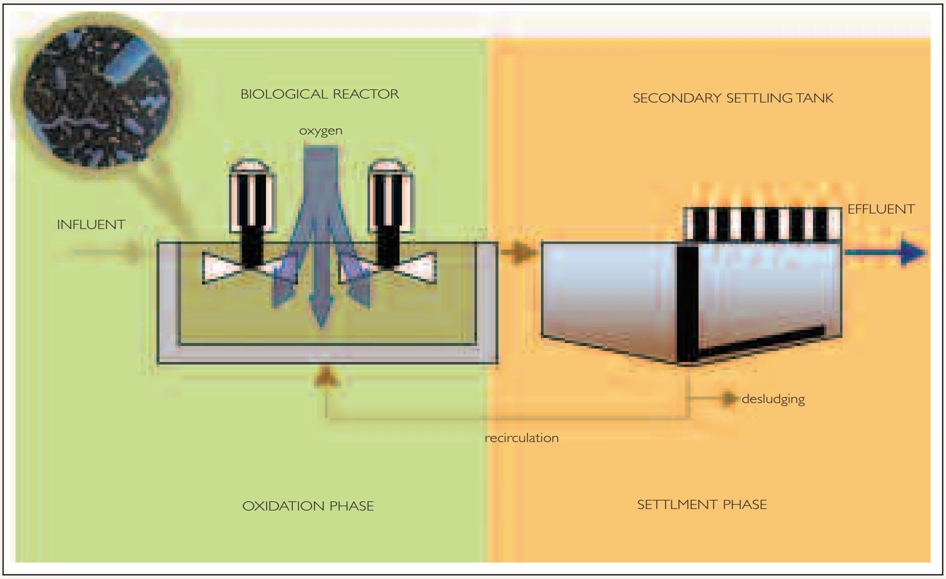
- The installation costs are high;
- The process generates sludge, which needs to be stabilized; and
- Makes use of patented equipment.

EXTENDED AERATION

Extended Aeration is a modification of the Activated Sludge process, involving the biological treatment of wastewater in aerobic conditions, and falls in the category of so-called *Conventional Technology*.

This technology is most commonly supplied in prefabricated units consisting of *Aeration Tanks* or *Biological Reactors* into which the *Pre-treated* sewage is fed. A bacteria culture, consisting of a large number of microorganisms in the form of floc clusters (*Activated Sludge*), is kept in suspension in the sewage, the mixture being referred to as *"mixed liquor"*.

Schematic diagram of a Extended Aeration process



The aerobic conditions in the *Reactor* are achieved by making use of mechanical aerators or diffusers, which homogenises the *mixed liquor*, thereby preventing the floc from settling in the *Reactor*.

After the *mixed liquor* has remained in the *Reactor* for a certain time, it is fed into a *Settlement Tank or Clarifier,* which can stand adjacent to the *Reactor Tank* or be installed within the same, the aim being to separate the purified effluent from the sludge (new cells). A portion of the sludge is recirculated to the *Reactor* in order to maintain a certain concentration of microorganisms, while the rest is removed periodically.

We can distinguish, therefore, between two different processes:

- The biological oxidation, which takes place in the *Reactor* or *Aeration Tank*.
- The separation of the solids from the liquid, which takes place in the *Settling Tank* or *Clarifier*.

Extended Aeration works with very low organic loads and long aeration periods, requiring no *Primary* Settlement process, and generates stabilised sludge, which require only dehydration before disposal.

Desing parameters

Biological Reactor

Parameter	Value
Mass load (kg BOD_5/kg SSLM. d)	0,05-0,1
Volumetric load (kg BOD_5/ m^3 d)	0,1-0,4
Hydraulic retention time (h)	18-36
Suspensed solids in tank (g/l)	3,0-6,0
Age of sudge (d)	20-30
Recycling ratio (Q_r/Q) (%)	75-150

SSML: Suspended solids in mixed liquor, Qr: Volume of recycled sludge (m^3/d),
Q: Flow of effluent requiring treatment (m^3/d)

Biological Reactor

Parameter	Value
Surface load (m^3/m^2 h)	Q_{av} 0,4-0,6
	Q_{max} 0,8-1,2
Concentration of solids (kg SS/m^2 h)	Q_{av} 1,5-2,0
	Q_{max} 3,0-4,0
Hydraulic retention time (h)	Q_{av} 3-5
Flow of purified effluent (m^3/ml h)	Q_{av} 4-6
	Q_{max} 8-12

Sludge production (kg dm/kg BOD_5 eliminated): 0.6-0.8; where dm = dry matter

Scope of application

The *Extended Aeration* system is generally utilised in populations that do not exceed 10,000 inhabitants Pre-fabricated 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.).

Average treatment efficiency

Parameter	% Reduction
SS	80-90
BOD_5	85-95
COD	80-90
N	30-40
P	20-30
Faecal Coliform	85-95

Key operational requirements

The key principles on which the *Prolonged Aeration* process is based, relate to the correct sizing of the installation and proper control of the process.

The process is controlled by assessing and acting on certain interrelated factors that promote the effective treatment of wastewater. These factors are essentially as follows:

- The characteristics of the wastewater to be treated: flow, quality, presence of toxins, etc.;
- The quality of the purified effluent: percentage of suspended solids, organic matter, nutrients and pathogens eliminated;
- The concentration of dissolved oxygen in the *Aeration Tanks*; The introduction of oxygen needs to be adjusted in accordance with the organic load requiring treatment;
- The volume of sludge that needs to be retained in the system in accordance with the organic load of the influent; To achieve the desired performance it is essential to maintain a certain *biological load*;
- The settling capacity of the sludge in the *Secondary Settling Tanks*. Settling capacity can be determined by reference to the *Volumetric Sludge Index* (V.S.I.), i.e. the ratio between the *volume* of *sludge settled* in 30 minutes (V30) and the SSML;
- The volume of sludge recycled to the *Aeration Tanks* from the *Secondary Settling Tanks*. Sludge is recycled to regulate the SSML level in the said *Tanks*;
- Removal of excess sludge, which makes it possible to regulate the age *of the sludge* and SSML levels in the *Biological Tanks*; and
- Monitoring the quality of the sludge that is recycled to the beginning of the treatment process.

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; and
- 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; and
- More complex control process than with *Non-conventional Technologies*

4.4. Criteria for the selection of the appropriate technology for the treatment of wastewater in small urban settlements.

The selection of the type of technology for the treatment of the wastewater generated in small urban settlements depend on a number of factors that render them suitable, partly suitable or unsuitable for each specific case. The main factors that need to be taken into consideration are set out below.

4.4.1.Population size

Each technology has a different range of optimal population sizes, which depends mainly on the requirements of the terrain on which the treatment plant is to be constructed. The average values of these requirements (per population equivalent) are as follows:

Table 4.2. Ranges of optimal population sizes for the application of the various urban wastewater treatment technologies

Technology	m^2/p.e.
Green Filters (plantation area)	30 – 50
Artificial Wetlands (Wetland surface)	3 – 5
Lagooning (surface of water layers)	7 – 10
Peat Filters (total peat surface)	0,5 – 1,0
Bacteria Beds (total surface area)	0,1 – 0,3
Rotating Biological Contactors (total surface area)	0,1 – 0,3
Prolonged Aeration (total surface area)	0,1 – 0,3

Due to the extensive surface requirements of non-conventional technologies, its normal scope of application will usually be limited to small settlements, although this is no impediment to finding treatment plants based on these types of technologies, which operate in much larger urban centres.

4.4.2. Climatic conditions of the area where the treatment plant will be constructed

Green Filters, Artificial Wetlands and Lagooning, being based on natural processes, are the most susceptible to reigning climatic conditions.

High rainfall mostly affects the *Green Filter*, given that it limits the amount of effluent that can be applied to the plantation, and the Peat Filter, as it prolongs the periods required for the surface crust to dry out.

High evaporation indices favour the installation of Green Filters, given that it increases the amount of effluent that can be applied to the plantation. However, in the case of *Lagooning* it results in significant losses of stored water and increased salinity of the purified effluent.

Solar radiation is especially important for Lagooning, as it has a direct impact on the photosynthetic action of the micro-algae in the *Facultative* and *Maturation Lagoons*.

The main climatic factor to take into consideration in respect of *Bacterial Filters, Rotating Biological Contactors* and *Extended Aeration* is temperature, although *Biological Contactors* that operate in enclosures are less affected by prevailing climatic conditions.

4.4.3. Environmental impact of the treatment plant

Special attention needs to be given to the possible environmental impact (aesthetic, olfactory, acoustic, etc.) that may be caused by the construction of the treatment plant.

The technologies that integrate best into the environment are *Green Filters, Artificial Wetlands* and *Lagooning*.

Bacterial Filters, Rotating Biological Contactors and Extended Aeration require the installation of motors, the required horsepower increasing in the order in which the three technologies are listed. These motors have an acoustic impact on the environment, which varies in accordance with the size of the motor.

Bacteria Beds, being comprised of tanks that stand approximately 5 m tall, cause significant visual impact on the environment, which can be reduced by painting or covering it with creepers.

4.4.4. Operational and maintenance costs

In view of the limited resources available to the local authorities of small urban settlements, it is in the field of operating and maintenance costs that non-conventional wastewater treatment technologies present the biggest advantages in comparison with conventional treatment technologies.

These costs are comprised of the following:

- **Personnel costs**, being one of the biggest components of the total operating cost:
  The *Green Filter, Artificial Wetland, Lagooning* and *Peat Filter* technologies all require very simple operational and maintenance tasks that can be performed by personnel without special qualifications, which translates into a resulting reduction in labour cost;

Although *Bacterial Filters* and *Rotating Biological Contactors* entail more complex operational tasks, requiring more highly trained staff than that required by the natural treatment systems, the degree of complexity involved is less than in the case of *Extended Aeration*;

- **Electromechanical maintenance costs**: *Green Filters, Artificial Wetlands* and *Peat Filters* have no electromechanical maintenance costs, as they function without any electromechanical equipment, while *Bacterial Fiters, Rotating Biological Contactors* and *Extended Aeration*, on the other hand, do entail costs of these nature.
- **The cost of electrical energy**, together with labour cost, contributes the most to operating costs.

  Green Filters, Artificial Wetlands, Lagoons and Peat Filters are able to function without any electricity consumption whatsoever, provided that the wastewater can be fed to the treatment plant under gravitational force and without the use of pumps;

  The *Bacterial Filter* and *Rotating Biological Contactor* systems do require electricity to operate, but their consumption is lower than that of *Extended Aeration*, while Bacterial Filters consume less electricity than Rotating Biological Contactors;

  Non-conventional technologies do not require any chemical dosing for correct functioning, with the result that there is no cost in this regard;

  Bacterial Filters, *Rotating Biological Contactors* and *Extended Aeration* involve the mechanical drying of the sludge that is generated by the treatment processes, which requires chemical dosing before it is dehydrated.
- **The cost of treating, transporting and disposing of the sludge generated in the treatment process** also constitutes a significant running expense of a treatment plant. The cost-effectiveness of the various Non-conventional Technologies in this regard is as follows:
  - *Green Filters* do not generate sludge, but instead a crust forms around the outlets of the effluent feed. One of the maintenance tasks is to periodically break this crust and mix it into the soil, where it biodegrades;
  - With *Lagooning*, the intervals between the evacuation of excess sludge are extremely long (5 - 10 years) and, given the long retention periods, the evacuated sludge is perfectly mineralised and considerably reduced in volume.
  - No sludge is generated in *Peat Filters*, the treatment residue forming a dry crust instead, which is easy to handle;
  - With *Artificial Wetlands* it is necessary to periodically remove the sludge that settles in the pre-treatment process, while the dry plants that have completed their growth cycles need to be cut and removed on an annual basis;

Fresh sludge is generated in the *Bacteria Bed* and *Rotating Biological Contactor* processes. In order to minimize the problems that this entails, recourse is often had to utilising *Septic Tanks*, *Imhoff Tanks* or *Anaerobic Lagoons* for pre-treatment. The excess sludge that is generated during the treatment process is recycled to the beginning of the treatment process, with the digested sludge being removed as often as is necessary.

In the case of *Extended Aeration*, the sludge that is removed from the *Settling Tanks* is already stabilised, due to the long retention time of the sludge, with the result that it is only necessary to concentrate the sludge before dehydration. In small treatment plants, the sludge can be dehydrated in *Drying Beds*.

Photo Gallery

The following section contains a gallery of photos of the various processes for the treatment of urban wastewater in small settlements, based on both *Conventional* and *Non-conventional Technologies*.

5.1. Pre-treatment

Photo 5.1. Screening grid. Las Tablas Sewage Treatment Plant, Cadiz.

Photo 5.2. Screening grid. Casa Aguilar Sewage Treatment Plant, Gran Canaria - Las Palmas.

Photo 5.3. Manual cleaning of screening grid.

Photo 5.4. Manual cleaning of sand traps. Evacuation extracted sand.

Photo 5.5. Extraction of fats in the Fat Separator.

Photo 5.6. Static strainer.

Photo 5.7. Parshall Channel. AENA Arrecife Sewage Treatment Plant, Lanzarote - Las Palmas.

5.2 Primary Treatment

Photo 5.8. Primary Settling Tank. Baza Sewage Treatment Plant, Granada.

5.3 Secondary Treatment

Photo 5.9. Green Filter. Carrión de los Céspedes Experimental Plant, PECC, Seville.

Photo 5.10. Artificial Wetland with Vertical Subsurface Flow. PECC.

Photo 5.11.Artificial Wetland with Horizontal Subsurface Flow.
Área Recreativa Las Niñas Sewage Treatment Plant, Gran Canaria - Las Palmas.

Photo 5.12. Maintenance tasks of an Artificial Wetland.

Photo 5.13. Anaerobic Lagoons. Centro de Transferencia Tecnológica, Tetuan.

Photo 5.14. Facultative and Maturation Lagoons. Centro de Transferencia, Tetuan.

Photo 5.15. Removal of floating debris on the surface of an Anaerobic Lagoon.

Photo 5.16. Detail of Peat Filters in operation (flooded) and regeneration (drying of surface crust) phases. PECC.

Photo 5.17. Bacterial Filters. La Iruela Sewage Treatment Plant, Cadiz.

Photo 5.18. Detail of plastic media and rotating distributor arm of Bacteria Bed.

Photo 5.19. Rotating Biological Contactor.

AENA Arrecife Sewage Treatment Plant, Lanzarote - Las Palmas.

Photo 5.20. Detail of Rotating Biological Contactor.

Photo 5.21. Biological Reactor. El Rocío Sewage Treatment Plant, Huelva.

Photo 5.22. Secondary Settling Tank. El Rocío Sewage Treatment Plant , Huelva.

Photo 5.23. Compact Activated Sludge Plant.Casa Aguilar Sewage Treatment Plant, Gran Canaria - Las Palmas.

Photo 5.24. Compact Activated Sludge Plant. La Coruña Sewage Treatment Plant, Gran Canaria - Las Palmas.

5.4 Tertiary Treatment

Photo 5.25. Sand Filters. AENA Arrecife Sewage Treatment Plant, Lanzarote - Las Palmas.

Photo 5.26 Diatomaceous Filters. Southeastern Gran Canaria Sewage Treatment Plant, Las Palmas.

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Annex. Glossary of photos, diagrams and tables

Figures

Tables

Photos

Diagrams

Schematic diagram of the Horizontal Subsurface Flow (HSF) and Vertical Subsurface Flow (VSF) Artificial Wetland processes. (CENTA)

Schematic diagram of the Horizontal Subsurface Flow (HSF) and Vertical Subsurface Flow (VSF) Artificial Wetland processes. (CENTA)

Schematic diagram of the Lagooning process. (CENTA)

Schematic diagram of the Peat Filter process. (CENTA)

Schematic diagram of Bacterial Filter process with Primary Treatment (Primary Settling Tank) or Anaerobic Lagoon. (CENTA)

Schematic diagram of the Rotating Biological Contactor process, with Primary Treatment (Primary Settling Tank) or Anaerobic Lagoon. (CENTA)

Schematic diagram of a Prolonged Aeration process. (CENTA)

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