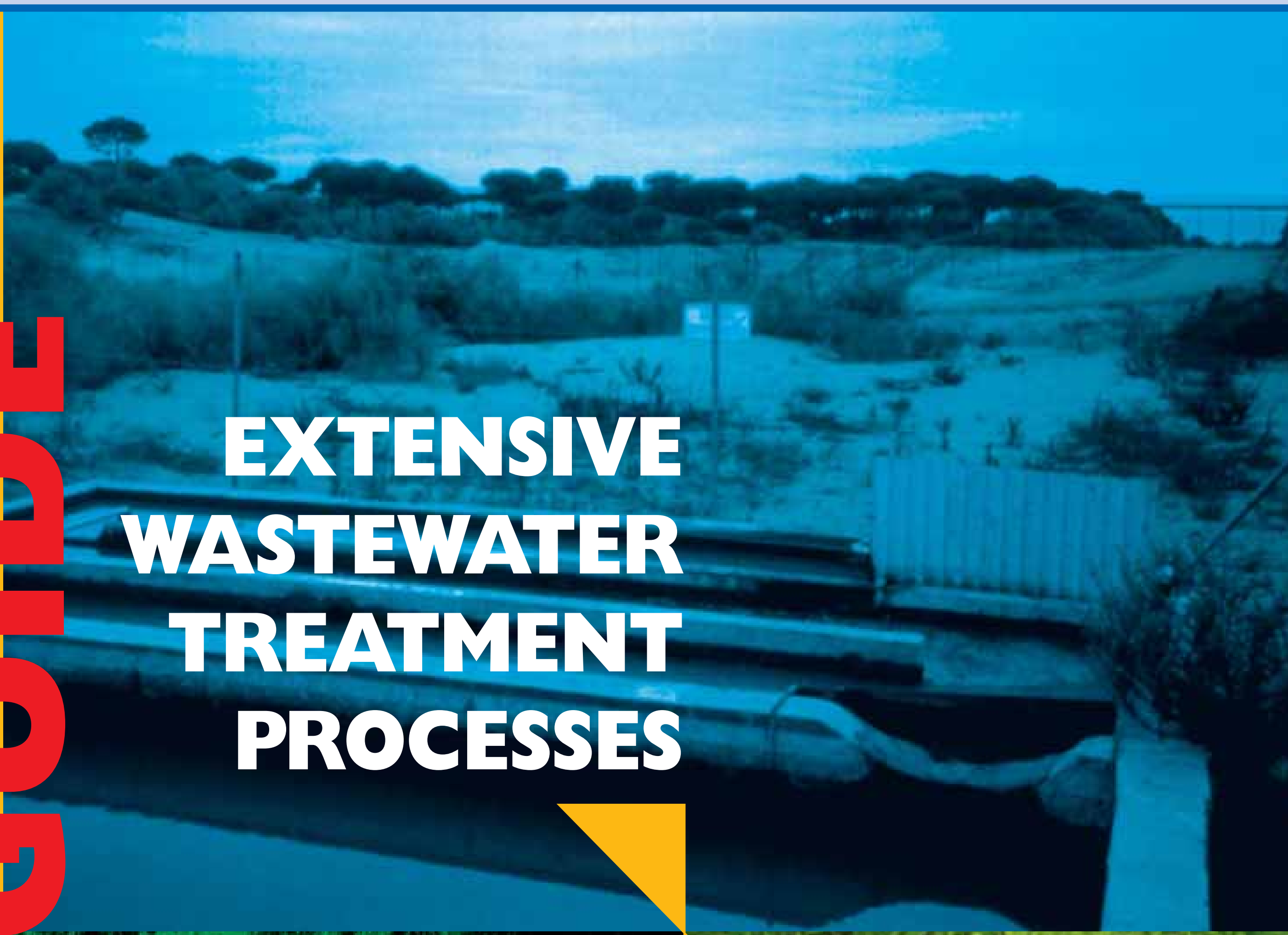
European Commission

GUIDE



EXTENSIVE WASTEWATER TREATMENT PROCESSES

ADAPTED TO SMALL AND MEDIUM SIZED COMMUNITIES

(500 to 5,000 population equivalents)

Implementation of Council Directive 91/271 of 21 May 1991 concerning urban waste water treatment

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
MINISTÈRE
DE L'AMÉNAGEMENT
DU TERRITOIRE ET
DE L'ENVIRONNEMENT

Agences de l'Eau

PREFACE

Spearhead of Europe's environmental policy, sustainable development implies for man the mastering of his urban and domestic wastewater, using techniques that are as natural and energy saving where possible. The "urban wastewater treatment" Directive from 21 May 1991, and very recently the Water Framework Directive have come to remind us of the necessity of appropriate treatment for these discharges with the objective of a good ecological status of our water.

In the 1970s France developed an ambitious rural and urban treatment policy supported financially by the Agences de l'Eau (Water Agencies). Today it has 15,500 treatment plants, more than 6,000 of which are sized at less than 2,000 population equivalents, often equipped with extensive treatments processes because of their low financial and technical constraints and their good ecological integration. Bearing in mind the varied soil conditions that exist, it has vast experience in almost all situations that exist in Europe climatically and geographically speaking and also in terms of land characteristics.

For its part, the Commission's Environment-Directorate General wanted to benefit from the experience and, if possible by the exchange of advice from its use in small communities, and from similar experiences carried out throughout the European Union, certain of which are supported within Life-Environment operations.

In this context, the value of these experiences through co-operation between the Commission's Environment-Directorate General, and on the French side, the Water Directorate of Ministry of Ecology and of Long-Term Development and of the Environment and the water Agencies, is an idea that grew during the recent French presidency. This guide represents the fruits of work accomplished since then.

We sincerely hope that this guide proves to be useful to elected officials and those responsible for technical departments of small and medium sized European agglomerations, so that the latter can determine their choices on the best possible technical and financial bases, with a concern for ecological integration and sustainable development. This guide can therefore be an illustration, among others, of the spirit of the 6th European Action Program for the Environment 2001-2010: "Our Future, Our Choice".

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A wealth of other information on the European Union is available on the Internet via Europa server (***http://europa.eu.int***).

A bibliography appears at the end of the work.

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WHAT IS THE PURPOSE OF THIS GUIDE?

One of the roles of the Commission is to help technicians in agglomerations of between 500 p.e. and 5000 p.e. (population equivalent, see glossary) to implement Commission Directive n°91/271 of 21 May 1991 concerning urban wastewater treatment (see glossary) by the end of 2005. **Indeed, agglomerations with less than 2000 p.e. which have a collection network, must also set up appropriate treatment [Article 7 of the "Urban Waste water" directive, (see glossary)].** An effort of awareness and information is all the more necessary as the municipalities and local authorities involved in the carrying out of projects are not structured, organised and equipped as well as those of larger agglomerations.

The Commission's Environment-Directorate General helps in the perfecting and production of adapted extensive devices for these agglomerations in particular, via the LIFE-Environment financial instrument. The purpose of this tool is to facilitate the implementation of the directive by the development of demonstration efforts and innovative technologies adapted to environmental problems that need to be resolved. Furthermore, the Environment-Directorate General supports the distribution of these techniques, via the development of technical exchanges and advisories. This document and the development of aids such as structural funds and cohesion funds are examples of this.

This guide will simply mention intensive techniques and will concentrate, above all, on extensive treatment techniques. These techniques, by definition, use more land than traditional intensive processes developed for large agglomerations. However, the investment cost for extensive processes are generally lower, and the operating conditions of these extensive processes are simpler, more flexible and allow more energy to be saved. Finally, these techniques require a lower amount of manpower and less-specialised manpower than intensive techniques.

They can be applied in the various European configurations that do not exceed population equivalents of a few thousands. One must bear in mind when reading this document that the techniques that we are going to cover cannot be used for capacities greater than 5,000 p.e. except in exceptional circumstances.

After a reminder of the objectives to be met by small and medium sized agglomerations (see glossary) and a quick presentation of the different intensive approaches, we will describe the different extensive techniques in more detail.

THE REGULATORY FRAMEWORK AND IMPETUS GIVEN BY THE EUROPEAN UNION FOR THE CONSTRUCTION OF INFRASTRUCTURES FOR COLLECTING AND TREATING URBAN WASTE WATER

Deadlines

The Council directive of 21 May 1991 concerning urban waste water treatment (see glossary) is one of the key parts in the European Union's environmental policy.

One of the main measures in this text is the obligation for agglomerations (see glossary), to set up a system (see glossary) for collecting waste water that must be associated with waste water treatment plants.

These obligations are to be fulfilled in a progressive manner. Treatment systems must be provided:

- before 31 December 1998, for agglomerations of more than 10,000 p.e. that discharge into sensitive areas;
- before 31 December 2000, for agglomerations of more than 15,000 p.e. that do not discharge into sensitive areas;
- before 31 December 2005, for agglomerations from 2,000 p.e. to 10,000 p.e. or from 2,000 p.e. to 15,000 p.e. that are not concerned by the 1998 and 2000 deadlines.

Concerning the 2005 deadline, the directive requires agglomerations of 2,000 p.e. to 10,000 p.e. that discharge into a sensitive area, and up to 15,000 p.e. for those that do not discharge into a sensitive area, to set up a collecting system and secondary treatment (see glossary), for discharges to fresh water and estuaries, or a collecting system and appropriate treatment for discharges into coastal waters.

Nevertheless, where the establishment of a collecting system is not justified either because it would produce no environmental benefit or because it would involve excessive cost, the directive allows individual systems or other appropriate systems which achieve the same level of environmental protection to be used.

Furthermore, the obligation to set up treatment is not limited to agglomerations of more than 2,000 p.e. The Directive states that discharges from smaller agglomerations must be subject to an appropriate treatment whenever a collecting network exists. Finally, remember that this text stipulates that agglomerations of less than 2000 p.e., that have a collecting system must set up appropriate treatment of their discharges before 31 December 2005.

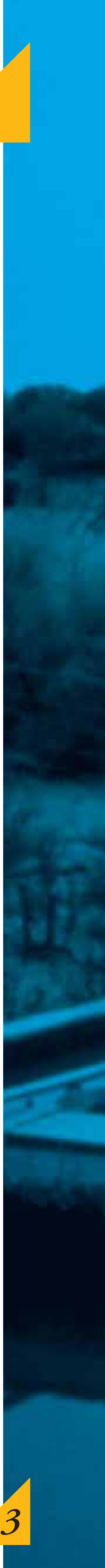
Objectives to reach in order to meet the requirements of the directive

Regulations instituted by the "Urban Waste Water Treatment" directive for those agglomerations having between 2,000 and 10,000 p.e. are summarised in the following two tables.

Table 1: Regulations concerning discharges from urban waste water treatment plants and subject to the measures of the directive from 21 May 1991(1)

Parameters	**Concentration**	**Minimum percentage of reduction(2)**
Biochemical oxygen demand [BOD_5 at 20°C (see glossary)] without nitrification(3)	25 mg/l O_2	70-90 %
Chemical oxygen demand [COD (see glossary)]	125 mg/l O_2	75 %
Total suspended solids [SS (see glossary)]	35 mg/l(3) 35 mg/l in high mountain regions for agglomerations with more than 10000 p.e. 60 mg/l in high mountain regions for agglomerations whose size falls between 2000 and 10000 p.e.	90 %(3) 90 % in high mountain regions for agglomerations of more than 10000 p.e. 70 % in high mountain regions for agglomerations whose size falls between 2000 and 10000 p.e.

(1) The values of concentration or percentage of reduction can be chosen indifferently.
(2) Reduction in relation to influent values
(3) This requirement is optional



An exception is made for lagooning. Indeed, analyses concerning discharges from this type of installation shall be carried out on filtered samples. However, the concentration of total suspended solids in unfiltered water samples must not exceed 150 mg/l.

Table 2: Regulations concerning discharges from urban waste water treatment plants carried out in sensitive areas which are subject to eutrophication (see glossary)(1)

Parameters	Concentration	Minimum percentage of reduction(2)
Total phosphorus	2 mg/l (p.e. between 10,000 and 100,000)(4)	80 %
Total nitrogen(3)	15 mg/l (p.e. between 10,000 and 100,000)(4)	70-80 %

(1) Depending on the local situation, one or both parameters may be applied. Furthermore, it is possible to apply the value of concentration or the percentage of reduction.

(2) Reduction in relation to influent values.

(3) Total nitrogen measured according to the Kjeldahl method (see glossary), plus the nitrogen contained in nitrates and nitrites.

(4) These values of concentration are annual averages. However, for nitrogen, daily averages may be used when it can be proved that the same level of protection is obtained. In this case, the daily average cannot exceed 20 mg/l of total nitrogen for all samples, when the temperature of the discharge to the biological reactor is greater than or equal to 12°C. As a substitute for the condition concerning the temperature, it is possible to apply a limited time of operation, which takes into account the regional climatic conditions.

TECHNIQUES THAT CAN BE USED TO MEET THE REGULATIONS OF THE DIRECTIVE

➔ *Traditional intensive techniques*

The most developed techniques at the level of the urban treatment plants are intensive biological processes. The principle with these processes is to operate on a reduced surface area and to intensify the phenomena of the transformation and destruction of organic matter that can be observed naturally.

Three main types of processes are used:

➔ **biological filters and rotating biological contactors;**

activated sludge;

enhanced biological filtering or biofiltering techniques.

▲ *Biological Filters*

The operating principle of a biological filter [also called biofilter, trickling filter or bacteria bed]consists in running waste water that has been previously settled through a bed of porous stone or open plastic material that serves as a support for purifying micro-organisms (bacteria) (see the drawing below).

Aeration is carried out either by natural aspiration or by forced ventilation. It is a question of supplying the oxygen that is necessary for maintaining aerobic bacteria in proper working order. The polluting matter contained in the water and the oxygen in the air are diffused, through the biological film, and assimilated by micro-organisms. The biological film has aerobic bacteria on the surface and anaerobic bacteria near the support media. By-products and carbon dioxide produced by purification are disposed of in gaseous and liquid fluids (Satin M., Belmi S, 1999).

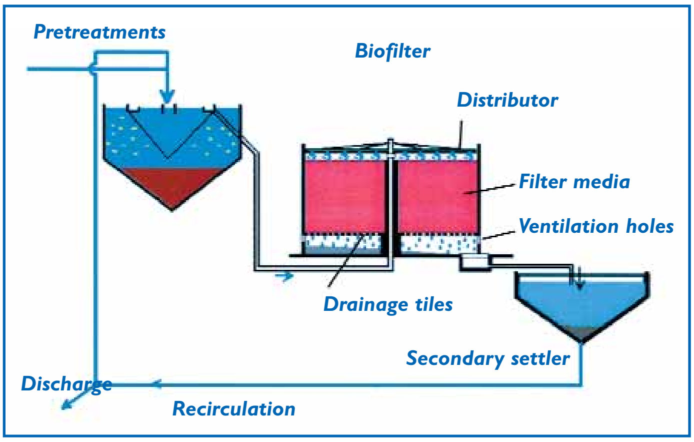


Figure 1: Synoptic of a treatment plant with a biological filter (according to a Cartel internet site - http://www.oieau.fr/ service guide section)

Table 3: Design criteria for bacteria beds are as follows (FNDAE technical document n°22):

Discharge objective	Type of media	Maximum organic load (kg BOD_5/m^3.d)	Minimum media height (m)	Minimum hydraulic load (m/h)	Minimum recirculation rate
≤ 35 mg DBO_5/l	Stone	0,7	2,5	1	2
	Plastic	0,7	4	2,2	2
≤ 25 mg DBO_5/l	Stone	0,4	2,5	0,7	2,5
	Plastic	0,4	5	1,8	2,5

Rotating Biological Contactors (also called Biodisks)

Another technique that makes use of fixed cultures consists of rotating biological disks (see the diagrams below). These are called Rotating Biological Contactors (RBCs) or Biodisks.

Micro-organisms develop and form a purifying biological film on the surface of the disks. As the disks are partially-immersed, their rotation allows the fixed biomass film to be oxygenated.

With this type of installation, the following are necessary:

- the mechanical reliability of the frame (gradual starting of the drive, support properly attached to the axis);
- the sizing of the surface of the disks (this must be made with large safety margins).

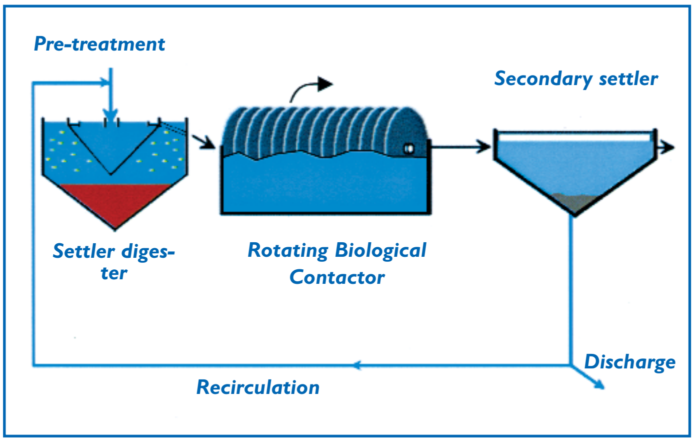


Figure 2: Synoptic of a treatment plant with an RBC (according to a Cartel internet site - http://www.oieau.fr/ service guide section)

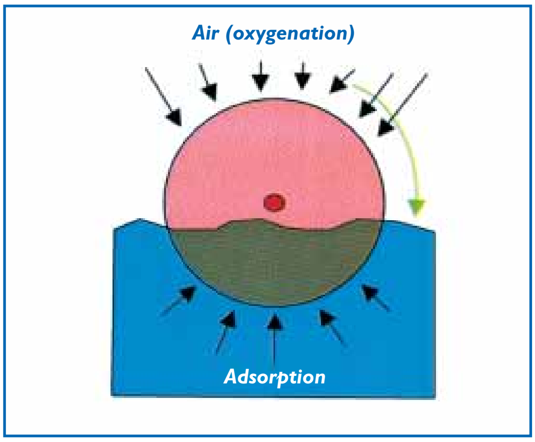


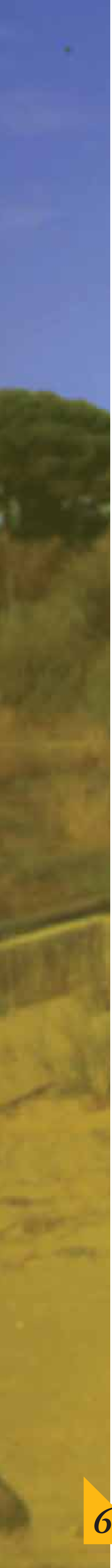
Figure 3: Diagram of the principle of an RBC.

Table 4: Design criteria of the RBC are as follows (FNDAE technical document n°22):

Discharge objective	Organic load to be applied (after primary settlement)
≤ 35 mg BOD_5/l	9 g BOD_5/m^2.j
≤ 25 mg BOD_5/l	7 g BOD_5/m^2.j

For a typical approach with 1000 p.e. and by applying an organic load of 9 g BOD_5/m^2.d, the effective developed surface is 3,900 m^2.

Other fixed film culture processes, such as high intersity "biofilters" that these of fig.1, are better adapted to the largest communities that have large human and technical means and suffer from very high demand in land. Consequently, they will not be detailed in this guide.



Activated sludge - Extended aeration

The principle of activated sludge is based upon intensification of the self-purification processes that are found in nature (see the drawing below).

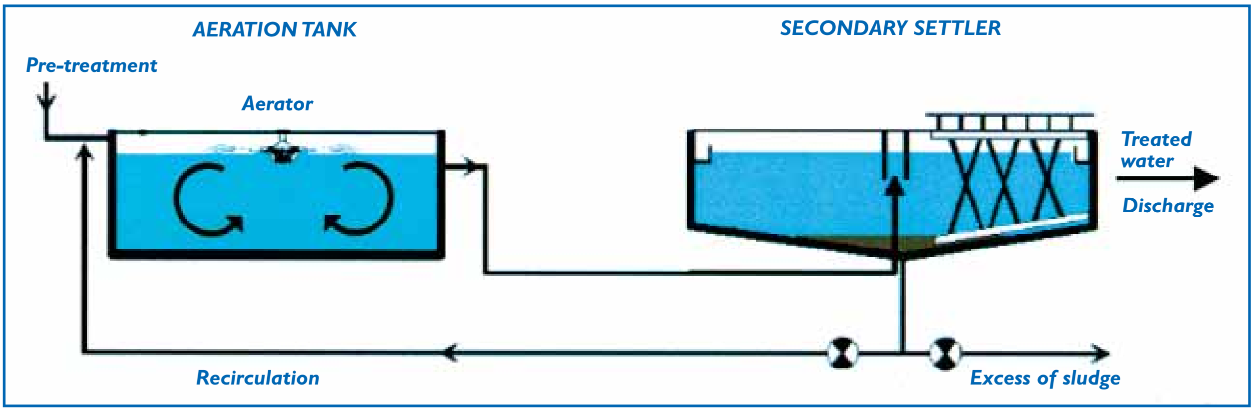


Figure 4: Diagram of activated sludge system – extended aeration (according to a Cartel internet site - http://www.oieau.fr/ service guide section)

The "activated sludge" process consists of mixing and stirring raw sewage with recycled activated sludge, which is bacteriologically very active. Aerobic degradation of the pollution takes place by thoroughly mixing the purifying micro-organisms and the influent to be treated. Then, the "purified water" and "purifying sludge" phases are separated (Agences de l'Eau , 1999).

A treatment plant of this type includes the following steps:

- preliminary and, sometimes, primary treatment;
- activation basin (or aeration basin);
- the secondary settlement tank where a part of the sludge is re-cycled;
- disposal of treated water;
- the digestion of excess sludge coming from the settlement tanks.

The design of the aeration tank is as follows (FNDAE technical document n°22):

- Mass load: < 0.1 kg BOD_5/kg MLVSS.d;
- Flow rate per volume: < 0.35 kg BOD_5/m^3.d;
- Sludge concentration: 4 to 5 g MLVSS/l;
- Retention time: approximately 24 hours (extended aeration);
- O2 demand: about 1.8 kg O_2/kg BOD_5 eliminated;
- Mixing power:
  - 30 to 40 W/m^3 for surface aerators of the turbine type;
  - 3 to 10 W/m^3 for the mixers;
  - 10-20 W/m^3 for fine bubble aeration systems.

Treatment by activated sludge with an extended aeration time allows 95 % of the BOD_5 to be removed.

Advantages and drawbacks of the different intensive approaches

**Table 5: Advantages and drawbacks of intensive approaches
(according to the Cartel internet site - http://www.oieau.fr/ service guide section)**

Filière	Advantages	Drawbacks
Biological filters and RBCs (Biodisks)	● low energy consumption; ● simple operation requiring less maintenance and monitoring than the activated sludge technique; ● good settling characteristics of the sludge; ● lower sensitivity to load variations and toxins than activated sludge; ● generally adapted to small communities; ● resistance to cold (the disks are always protected by hoods or a small chamber).	● performance is generally lower than with an activated sludge technique. This is mostly due to former design practices. A more realistic dimensioning should allow satisfactory qualities of treated water to be reached; ● rather high capital costs (can be greater by about 20% compared to activated sludge); ● requires effective pre-treatment; ● sensitivity to clogging; ● large-size structures if requirements for removing nitrogen are imposed.
Activated sludge	● adapted to any size of community (except very small ones); ● good elimination of all the pollution parameters (SS, COD, BOD5, N by nitrification and denitrification); ● adapted to the protection of sensitive receiving areas; ● partially-stabilised sludge (see glossary); ● easy to implement simultaneous dephosphatation.	● relatively high capital costs; ● high energy consumption; ● requires skilled personnel and regular monitoring; ● sensitivity to hydraulic overloads; ● the settling property of sludge is not always easy to control; ● high production of sludge that must be thickened.

Note: The low microbiological reduction achieved in the output from intensive systems (reduced by a coefficient between 10 and 100, compared with 1,000 to 10,000 for extensive lagoons and filters), could cause problems in the case of re-use of the water at a short distance downstream (drinking, irrigation, bathing, shellfish, etc.). It is sometimes necessary to consider an extensive approach or to use such a technique as a final tertiary treatment (see the decision tree structure on page 36) even for important equipment (several thousands of p.e.).

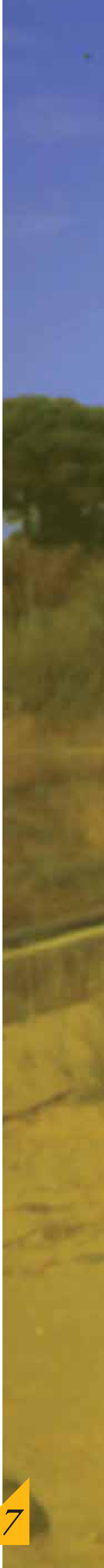
The advantages of these techniques are such that they are very successful with all types of agglomerations. Another plus, in particular for activated sludge, is that there is a lot of in-depth research done by the large water research groups and it is easy to obtain detailed publications concerning their design and innovations that allow the output of particular parameters to be improved. Nevertheless biological filters and RBCs remain, if the previously mentioned design rules are respected, techniques that are particularly adapted to small agglomerations, because they have much lower operating costs:

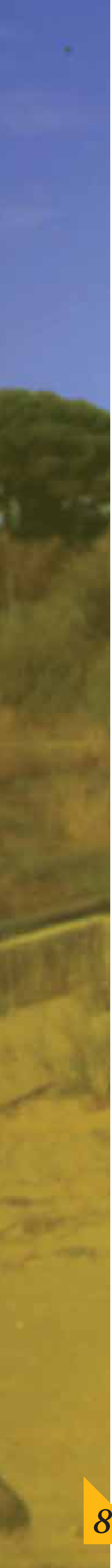
- ➔ much lower energy consumption (up to five times less compared to activated sludge),
- ➔ and requires less staff to operate this type of rural plant.

These techniques can be used in combination with extensive approaches. In particular, plants made up of a biological filters and RBCs, followed by a tertiary lagoon, can allow discharges of excellent quality to be obtained (elimination of nutrients, high reduction in pathogenic organisms).

We will not cover intensive approaches in any more detail in this guide. On the other hand we will try to describe the less well-known techniques such as extensive purifying techniques.

Furthermore, this guide covers treatment for the agglomerations connected and industrial factories: we will not cover the techniques that are specific to on-site (stand-alone) treatment (septic tanks with subsoil or sand filters, cesspool, etc.).





The techniques to be developed

The techniques that are called extensive that we are going to describe in more detail in this guide are processes that carry out the purification using fixed film cultures on small media or suspended growth cultures which use solar energy to produce oxygen by photosynthesis. It is possible to operate this type of facility without electricity, except for aerated lagooning for which an energy supply is required in order to power the aerators or air blowers.

These techniques can also be distinguished from previously mentioned techniques by the fact that the applied surface loads remain very low.

These techniques have been developed in different countries for communities that are, in general, less than 500 p.e. This is the case, in particular, in France with natural lagoons, in Bavaria with a type of natural lagooning with a design that is quite different from those found in France or those in the United Kingdom with horizontal flow reed beds filters (constructed wetlands).

The distribution of these techniques to agglomerations that exceed 500 p.e. can be considered a possibility, taking specific precautions that we will describe.

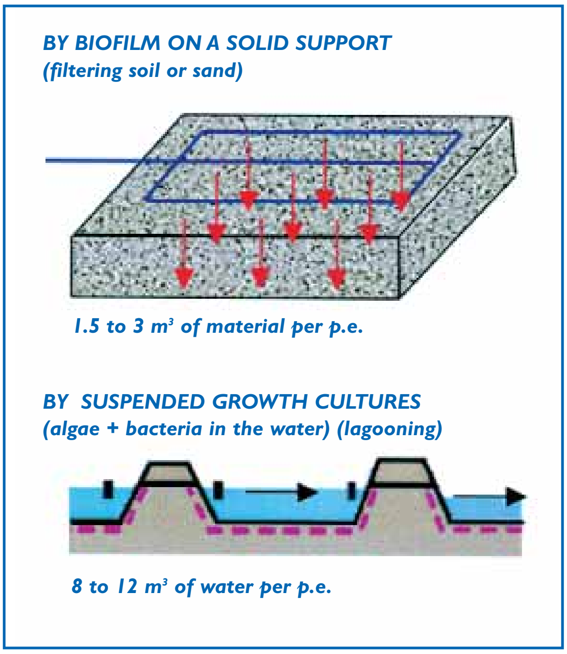
The purpose of this guide is therefore to give an impetus to this distribution and to contribute to demonstrating that extensive techniques do have their place in allowing the regulations of the "Urban Waste Water" directive to be complied with.

After describing the major operating principles of fixed film cultures and of suspended growth cultures, we will give details on the techniques according to the following plan:

➔ Fixed film cultures:
- Infiltration-percolation;
- Vertical flow reed bed filter;
- Horizontal flow reed bed filter.

➔ Suspended growth cultures:
- Natural lagooning;
- Macrophyte lagooning;
- Aerated lagooning.

➔ Hybrid systems.



BY BIOFILM ON A SOLID SUPPORT
(filtering soil or sand)

1.5 to 3 m^3 of material per p.e.

BY SUSPENDED GROWTH CULTURES
(algae + bacteria in the water) (lagooning)

8 to 12 m^3 of water per p.e.

Figure 5:
Lower intersity "natural" purification of waste water

Treatment and the role of plants in constructed wetlands

Purification systems by constructed wetlands reproduce the purification processes of natural ecosystems (Wetzel, 1993). The great degree of heterogeneity and diversity of plants, soils and types of water flow make a wide variety of methods possible:

➔ systems that flow below the ground surface (vertical or horizontal flow reed bed filters);

➔ free water surface flow systems (see natural lagooning);

➔ more rarely, irrigation of planted systems (with willows for example), of woods with frequent cutting, in order to complete the treatment by a final filtering.

For **all of the constructed wetlands,** the following different **treatment mechanisms** can be found:

Physical mechanisms:

- filtering through porous areas and root systems (see mechanisms in fixed film cultures);
- sedimentation of SS and of colloids in lagoons or marshes (see suspended growth culture mechanisms),

Chemical mechanisms

- precipitation of insoluble compounds or co-precipitation with insoluble compounds (N, P).
- adsorption on the substrate, according to the characteristics of the support that is set up, or by plants (N, P, metals);
- decomposition by UV radiation phenomena (virus and bacteria), oxidation and reduction (metals).

Biological mechanisms

- Biological mechanisms, due to fixed film or free bacterial development, allow the degradation of organic matter, nitrification in aerobic zones and denitrification (see glossary) in anaerobic zones. For free water surface systems, biological purification takes place via aerobic processes near the water surface and sometimes anaerobic process near the deeper deposits. The development of attached algae or in suspension in the water (phytoplankton) supplies via photosynthesis the oxygen that is needed by aerobic purifying bacteria and fixes a part of the nutrients ("lagooning" effect).

Fixed film cultures on small media

Operation: mechanisms that come into play

Purification processes with fixed film cultures on small media consist in running the water to be treated through several independent beds/units.

The two main mechanisms are:

- **Superficial filtering:** suspended solids (SS) are removed at the surface of the filter bed and, with them, a part of the organic pollution (particulate COD);
- **Oxidation:** the granular area makes up a biological reactor, a special large surface area support. **Aerobic bacteria** responsible for the oxidation of dissolved pollution (ammoniacal nitrogen, organic and dissolved COD) attach themselves to the support media and continue their development.

Aeration is supplied by:

- convection using the movement of water surface;
- diffusion of oxygen from the surface of the filters and aeration channels, through the porous media.

Oxidation of the organic matter is accompanied by bacterial development, which must be regulated in order to avoid internal biological clogging of the filter media and the occasional loosening of the biomass which is inevitable once the applied loads are large. Self-adjustment of the biomass is obtained thanks to the setting up of several independent beds that are alternately fed. During the inoperative phases (or while not being fed), the development of bacteria in the "food scarcity" situation is much reduced by predation, doging, etc. These inoperative phases must not last too long so that the purifying processes can quickly restart, once the new feeding phase starts. Most frequently, the "fixed film cultures on a small support media" approaches are designed on the basis of 3 beds that are fed during 3 to 4 consecutive days.

The controlled management of bacterial development avoids having to set up a specific system for separating water + sludge. Structures with fixed film cultures on a small support media are designed without settlement.

The **distribution device** for the infiltration units must provide uniform distribution of the influent (so as to make use of the entire surface area available) and the homogeneity of the unitary hydraulic loads (see glossary). The feeding may take place by temporary submersion (or by sprinkling) using a reservoir, which is emptied at high discharge rates by various means (siphons, pumps, etc.). These sequenced supplies also allow the maintaining of a high concentration of oxygen in the filter by the diffusion of air between two releases.

The **filter bed** is generally made up of sand, whether it is sand especially brought in or dune sand if already in place. The sand must meet a few precise characteristics with the aim of finding a balance between the risk of clogging (sand where it is too fine) and a floh through which is too fast (sand particles that are too big). The sand, characteristics which are shown below should offer the best compromise, according to current knowledge (Liénard et al, 2000). It seems wise during the life of these projects to keep within these few limits.

Characteristics of the sands:

- silica sand;
- washed sand;
- d10 between 0.25 mm and 0.40 mm;
- UC [degree of uniformity, (see glossary)] between 3 and 6;
- fines content less than 3 % in fines.

Infiltration-percolation through sand

Operating principles

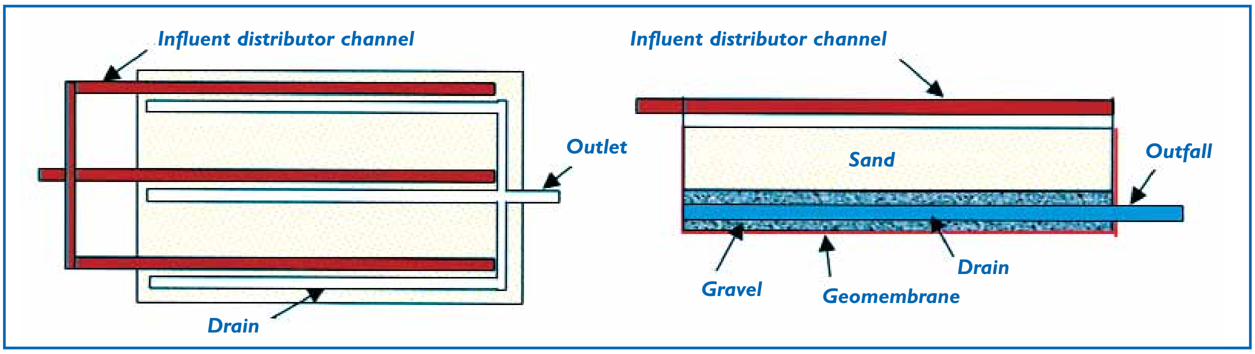


Figure 6: Watertight and drained infiltration-percolation (Agences de l'Eau, 1993)

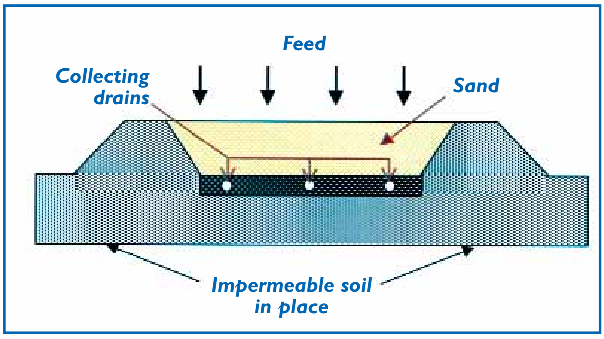


Figure 7: Drained system with impermeable soil in place (Agences de l'Eau, 1993)

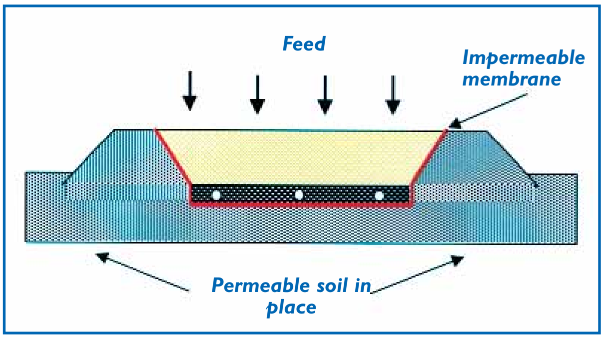


Figure 8: Drained system with a draining bed made leak-proof via an impermeable membrane (Agences de l'Eau, 1993)

Infiltration-percolation of waste water is a treatment process by aerobic biological filtering through a fine granular medium. Water is successively distributed over several infiltration units. Hydraulic loads are several hundred litres per square meter of filter bed per day. The water to be treated is evenly distributed on the surface of the filter, which is not enclosed. The distribution area for the water is maintained in the open air and is visible.

Another interesting variant of purification by the soil is made up of buried vertical or horizontal sand filters. These techniques that are used, above all, for situations involving autonomous treatment remain interesting for grouped autonomous treatment concerning a few hundred population equivalents. For a buried vertical flow sand filter, a design sizing of 3.5 m^2 / p.e. is necessary and a low pressure feed is recommended.

Basis for sizing

A plant, in which infiltration-percolation is the main method of wastewater treatment, must contain: pre-treatment, a settling system (for those agglomerations of a few hundred population equivalents, a large septic tank may be used), a storage tank, a distribution splitter system between the basins, a feeding distributor, filter bed and the return to the water table or discharge.

Infiltration percolation beds through sand must be designed as follows (FNDAE technical document n°22): **Surface = 1.5 m^2/p.e. (whether the bed is drained or not)**

Mazagon plant(Spain)
Capacity of 17 000 p.e (Photo Credits: F. Brissaud)

Note: drained and buried vertical sand filters can be suitable for the smallest-sized plants (autonomous and grouped autonomous) which require a surface of 3,5 m^2/p.e. instead of 1.5 m^2/p.e. for open-air filtering.

Determining the thickness

When bacterial removal is not one of the objectives of the plant, a filter bed thickness of 80 cm is sufficient.

In the case where infiltration-percolation has the elimination of pathogenic bacteria as an additional function, the thickness of the filter bed depends on the expected level of decontamination. The graph below provides the relationship between the reduction in faecal coliforms according to hydraulic load (h) and the thickness in the vertical sand filter (Etude Inter Agences n°9, 1993).

If the bed is in natural sand, the relationship between its thickness and decontamination is more difficult to obtain, and it is preferable to call upon laboratories in order to properly characterise the sand in question and its bacterial removal capacities

The number of units is a function of:

- the total surface area of the filter bed;
- the maximum surface of the infiltration unit compatible with an even spreading of the effluent on the very unit.

Implementation

The walls of the ditches must be vertical if possible so that, at all points along the sand filter, the vertical path of the water is sand equal to the thickness of the bed.

The height of the freeboard above the infiltration area must be around 30 cm. Safety overflow arrangements must be installed, in order to handle emergencies and dispose of the excess flow either into a receiving medium, or into other underloaded basins.

The slopes forming the sides of the basins can be protected by concrete slabs, tarred sheet piles, air-placed concrete or even vegetation.

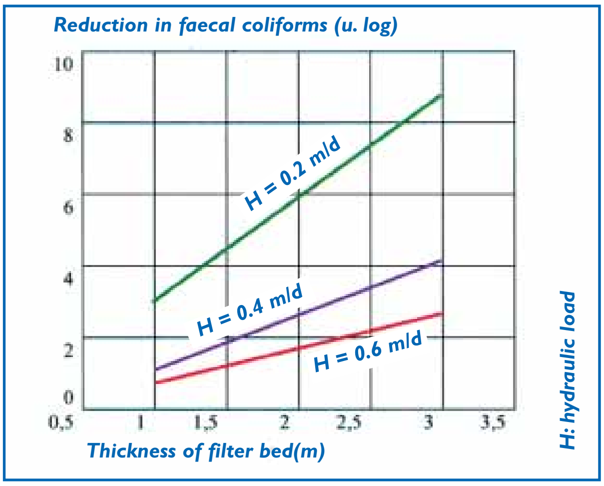


Figure 9: Reduction in faecal coliforms according to hydraulic load (H in m/d) and thickness of the filter bed

Operation

Table 6: Operation of an infiltration-percolation plant

Tasks	Observations
Normal maintenance (every 3 to 4 days)	● Valve operation; ● cleaning of the grid; ● observation of the degree of clogging of the surface of the infiltration units, and sometimes of the height of the water in the infiltration area; ● drainage time for the wastewater doses; ● in non-gravity plants, observation of pump flow; ● keep a maintenance log that notes all the tasks carried out, flow measurements (flow meter canal, pump operating time), in order to obtain a good knowledge of the flows. This will also allow operating assessments to be produced.
Regular follow-ups Inspections every 2 months	● inspection chamber, good water flow, aspect of the effluents; ● removal of floating matter (settler-digester), sludge level (anaerobic lagoon or settler digester); ● regulating level, maximum water height in the tank, feed devices (siphons, chutes, etc.); ● valves or distributing devices; ● Undermining and maintenance of levelling of the infiltration area; ● plant output (drained systems) and quality of the discharges; ● operation of sprinklers and cleaning (every month).
Other maintenance operations	● maintenance of electromechanical devices (1 to 2 times / year); ● clearing of the earth banks around the bed; ● organic accumulation that, at the end of the drying phases, are reduced to chips that can easily be detached from the sand must be raked and disposed of in a refuse collection point according to a periodicity that must be adjusted empirically; renewal of the first 5 to 10 cm of sand every 3-4 years should be scheduled; ● empty the sludge from the settler-digester (once or twice / year) or settling lagoons (once or twice / year) or alternatively from the septic tanks (once / 3 to 4 years); ● regular analyses of the nitrogen content in the discharge which gives an indication of the good condition of the equipment *.

**** A vertical flow filter that is operated in an optimal manner produces nitrates and any decrease of concentration at its outlet (on a weekly or monthly scale) reflects a lack of oxygen therefore a degradation in the treatment. This follow-up can easily be carried out using test paper.***

Performances

Excellent reduction results (in concentration) are obtained with this system:

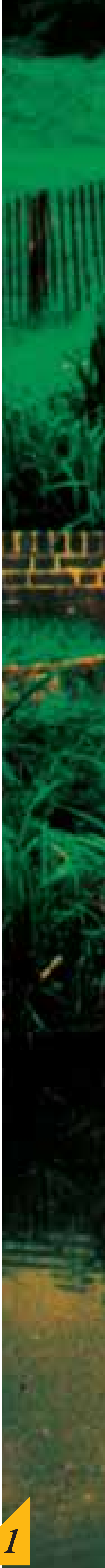
- BOD_5 less than 25mg/l;
- COD less than 90mg/l;
- SS less than 30mg/l;
- Virtually complete nitrification;
- Denitrification is limited with this type of installation. In its "autonomous purification" version, purification by the sail can allow a certain quantity of nitrogen to be eliminated. A study carried out within the Direction Départementale des Affaires Sanitaires and Sociales of Loire-Atlantique in 1993 demonstrated that it is possible to eliminate 40% of the nitrogen (sometimes even more) using a vertical flow sand filter. This reduction can reach 50% if a horizontal flow sand filter is used (Cluzel F, 1993);
- Phosphorus: high reduction during 3-4 years (60-70%), then less and then negative after 8-10 years (Duchemin J, 1994);
- Possibility of eliminating bacterial faecal contamination provided there is a sufficient material height and hydraulic operation without preferential flow (1000 times with 1 m of thickness).

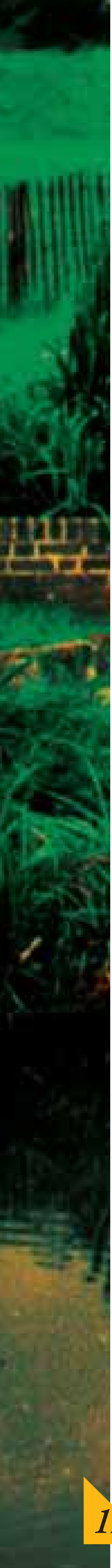
Technical advantages

- excellent results on BOD_5, COD, SS ;
- high-level nitrification ;
- surface area needed is much less than with natural lagooning ;
- an interesting capacity for disinfection.

Technical drawbacks

- requires an effective primary settling tank;
- the risk of clogging must be managed (hence the importance of the use of a "washed" sand with good sizing);
- requires great quantities of sand to be available, which could lead to high capital cost if none is available nearby;
- adaptation limited to hydraulic surcharges.





Vertical flow reed bed filters

Operating principle

The filters are excavations made to be impermeable, filled with successive layers of gravel or sand with a grading that varies according to the quality of the wastewater to be treated.

As opposed to the previously mentioned infiltration-percolation, the raw influent is distributed directly, **without prior settling**, onto the surface of the filter. During flow through it is subject to a physical (filtering), chemical (adsorption, complexing, etc.) and biological (biomass attached to small media) treatment. The treated water is drained. The filters are fed with raw sewage by tanker-loads. Within the same plant, the filtering surface is separated into several units which makes it possible to establish periods of treatment and inactivity.

The purifying principle lies in the development of an aerobic biomass attached to a reconstituted soil (see: chapter on stationary cultures on a thin support). Oxygen is supplied by convection and diffusion. The oxygen yield by the plant roots and rhizomes is, here, negligible in relation to the needs (Armstrong; 1979).

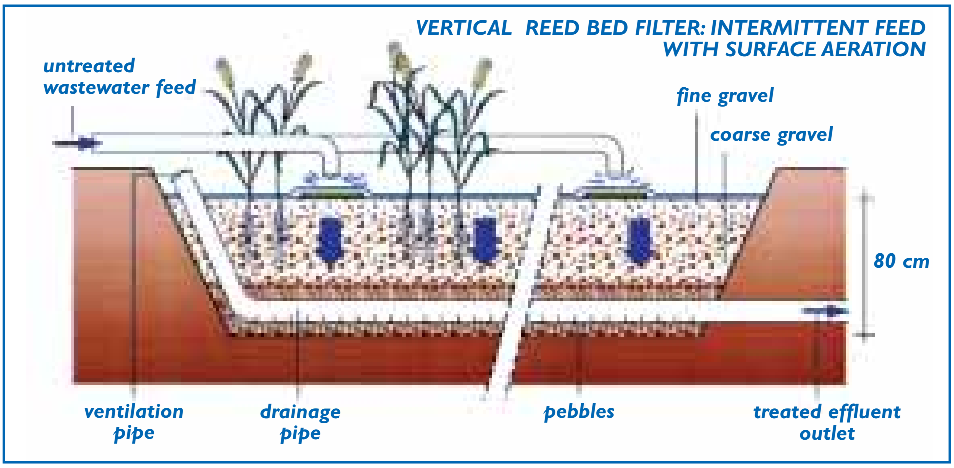


Figure 10: principle of vertical flow reed bed filters (source: CEMAGREF)

This approach is made up of:

- A bar screen;
- a first stage of vertical flow reed bed filters;
- a second stage of vertical reed bed filters.

Basis for design

The design of the vertical filters was established empirically by defining the acceptable daily limits for organic surface loads (20 to 25 g BOD_5 $m^{-2}.d^{-1}$ of the total cultivated surface).

The first stage is designed to receive about 40 g BOD_5 $m^{-2}.d^{-1}$ thus representing 60 % of the total surface, or about 1.2 m2/p.e. When the sewer network is combined or partially-combined , the design of the first stage is increased to 1.5 m2/p.e. (Agence de l'eau, 1999). This stage is divided into a number of filters which are multiples of 3, which allows rest periods for 2/3 of the time.

The surface of the second stage is generally 40 % of the total surface area or about 0.8 m^2/p.e. At this stage, the necessary rest period is equal to that of operation, thus requiring the setting up of a number of filters which are multiples of 2 and equal to 2/3 of the number of filters used for the first stage (see diagram below).

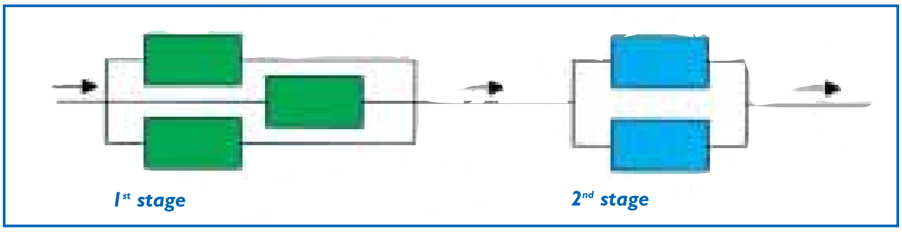


Figure 11: Design diagram for the first and second stages

Implementation

Feed

The flow of raw sewage(over the short dosing period) onto the 1st stage must be greater than the infiltration speed in order to correctly distribute the sewage over the whole bed surface. The deposits that accumulate on the surface contribute to reduce the intrinsic permeability (see glossary) of the media and thus improve the distribution of the sewage. Plants limit surface clogging, since the stems pierce the accumulated deposits. Water is distributed at several points.

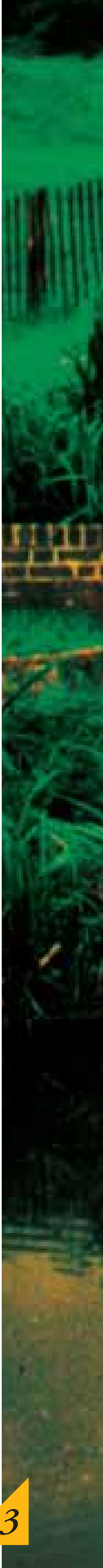
Media

The media for the first stage is made up of several layers of gravel. The active layer is gravel that has a grading of 2 – 8 mm, with a thickness of about 40 cm. The lower layers are of intermediate grading (10-20 mm) a 20 – 40 mm draining layer of gravel.

The second stage refines the treatment. The risk of clogging is less. It is made up of a layer of sand (see infiltration-percolation) of a thickness of at least 30 cm.

Drainage

The 20 – 40 mm lower layer of gravel ensures draining of the effluent. Drains made out of plastic pipes, which are rigid and equipped with wide slits, are preferably used since they are less sensitive to clogging. Each drain is connected to an aeration pipe.



Planting

Theoretically, several plant species can be used (Scirpus spp, Typha...), but reeds (of the Phragmites australis type), because of their resistance to the conditions encountered (long submerged period for the filter, dry periods, high rate of organic matter), and the rapid growth of the tangle of roots and rhizomes, are the most often used in temperate climates (Brix, 1987). The planting density is 4 plants/m^2.

Design

Choice of land

The constraints for the site are as follows:

- **Land availability:** The surface area involved for this process sometimes makes it impossible to set up these systems in average-sized agglomerations where land is at a premium.
- **Slope:** A difference in level of about 3 to 4 meters between the upstream and downstream points makes it possible to feed the filters by gravity (using siphons that do not require any type of energy supply). For communities that are sized near 3,000 / 4,000 p.e., the use of pumps may become necessary.

Operation

Maintaining these systems does not have any particular requirements, but it needs regular and frequent checks by the operator.

Table 7: Operation of vertical flow filters

Tasks	Frequency	Observations
Weeding	the 1st year	• Manual weeding of self-propagating plants (Kadlec et al,2000). Once predominance is established, this operation is no longer necessary.
Cutting	1 / year (autumn)	• Cutting down and disposal of reeds. Disposing of them stops them accumulating on the surface of the filters. With a view to reducing this maintenance time, reeds can sometimes be burned if the waterproofing does not use a geomembrane, and if the feed pipes are made of cast iron (Liénard et al, 1994).
Regular maintenance and follow-up	1 / quarter 1 / week	• Clean the feeding siphon at the first stage by pressure washing. • Periodic analyses of nitrates in the effluent will indicate the health of the plants*.
Regular maintenance	1 to 2/ week 1 / week 2 / week	• Clean the bar screen. • Regularly check the correct operation of the electromagnetic devices and detect breakdowns as quickly as possible. • Changing the valves
Other maintenance operations	Each visit	• Keep a maintenance log noting all the tasks carried out, flow measurements (flow meter canal, operating time of the pumps), to obtain good understanding of the flow. This also allows operating assessments to be produced.

*** A vertical flow reed bed filter operating in an optimal manner produces nitrates and any lowering of the concentration at its outlet (on a weekly or monthly scale) reflects a lack of oxygen, therefore a lowering of the standard in the treatment. This follow-up can easily be carried out using test paper.***

Performance

- BOD$_5$: ≤ 25 mg/l
- COD: ≤ 90 mg/l
- SS: ≤ 30 mg/l
- KjN: ≤ 10 mg/l in general with peaks that do not exceed 20 mg/l
- Phosphorus: Reduction is normally low (depends on the adsorption capacity of the substrate and on the age of the plant)
- Pathogenic bacteria: (reduced by 10 to 100 fold).

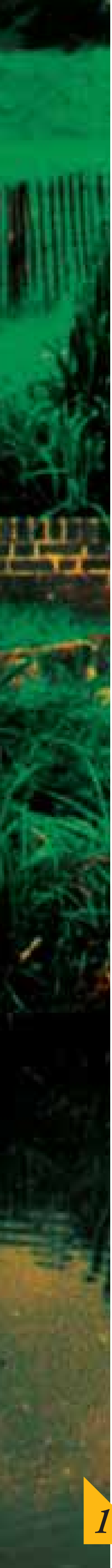
Technical advantages

- Easy to operate and low operating cost. No energy consumption if the topography makes this possible;
- Possibility of treating raw domestic sewage;
- Sludge management is reduced to a minimum;
- Adapts well to seasonal variations in population(eg. Holiday sites, camping and caravan sites, remote hotels).

Technical drawbacks

- Regular operation, annual cutting of the exposed portion of the reeds, manual weeding before predominance of reeds;
- Using this approach for capacities greater than 2,000 p.e. remains marginal for reasons of controlling costs and hydraulics compared with traditional approaches. A design for larger sizes can only be considered after serious considerations over the adaptation of the basis of design and the conditions to be fulfilled in order to ensure control of hydraulics;
- Risk of presence of insects or rodents.

Oakland parks plant (United Kingdam)
Capacity 65 P.E (Photo credits Paul Cooper)



Horizontal flow reed bed filters

Operating principle

In horizontal flow reed bed filters, the filter pack is almost totally saturated with water. The effluent is spread out over the entire inlet horizontal cross-section of the bed by a distributor system located at one end of the bed; it then flows in a direction that is practically horizontal through substrate. Most of the time, feeding takes place continuously since the supplied organic load is low.

Removal takes place via a drain positioned at the opposite end of the bed, at the bottom and buried in a trench of draining stones. This pipe is connected to a siphon which allows the height of the overflow to be adjusted, and thus the level of the water in the bed, in such a way that it is saturated during the feeding period. The water level must be maintained at approximately 5 cm under the surface of the material. In fact, water must not circulate above the surface, so as to avoid short-circuiting of treatment; therefore there is no free water surface and no risk of insect proliferation.

Design

To define the necessary surface area, the empirical values below provide the expected purification results (Vymazal et al, 1998):

- ➔ For initial concentrations of around 150 to 300 mg.l^{-1} of BOD$_5$, the planted surfaces are around **5 m^2/p.e. in secondary treatment, which corresponds to** kBOD$_5$ = 0.1m/d;
- ➔ For concentrations between 300 and 600 mg.l-1 of BOD5, **concentrations which better represent those of current urban wastewater** it seems preferable to opt for the Danish method which consists in dimensioning the filter at **10 m^2/p.e.;**
- ➔ For treating effluents from storm sewage overflows (Cooper,1996) the surface needed is **0.5 m^2/p.e.**

The **filter section** must be defined by a technical expert. It is a function of the initial permeability of the chosen material (1 to 3.10^{-3} m .s^{-1}).

The **depth of the filter** will be equal to the maximum penetration depth of the roots. This depth is 60 cm for Phragmites (Marsteiner, 1996).

The hypothesis of a notable improvement in initial hydraulic conductivity, following intense root development of the reeds, in density as well as in depth, has not been confirmed (Boon, 1986). In fact, the increase in hydraulic conductivity thanks to root development is partially compensated by the accumulation of SS and of organic matter (Cooper, 1996). It is therefore important that the chosen support has a permeability of 1 to 3.10^{-3} m.s-1. Most soils must therefore be excluded and gravel used instead.

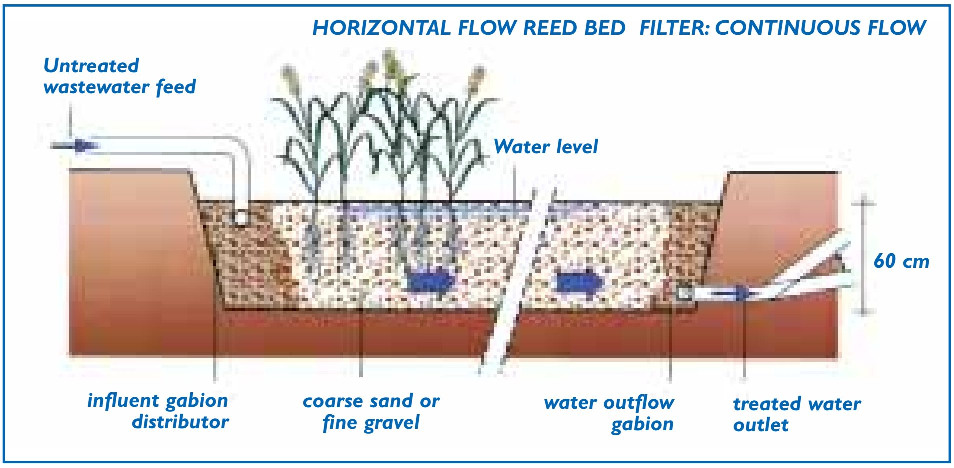


Figure 12: side view of a horizontal flow reed bed bed (Source: Cooper, 1993)

Implementation

Partitioning

For designs greater than 500 m^2, a partitioning into several units of reduced size will facilitate maintenance and improve hydraulic separation.

Slope

The bed surface is flat. The slope at the bottom of the bed must allow the filter to be completely emptied. The bottom slope must not however provoke the drying out of the roots at the output level. A variation in the bed depth equal to 10 % of the height of the material at the input area is enough (Kadlec, R.H. et al,2000).

Materials

At the outset, the process was developed using the existing soil, while endeavouring to attain, in the long run, a hydraulic conductivity of 3.10^{-3}m s^{-1}. A large number of filters were built according to hypothesis that hydraulic conductivity would increase with root development.

Following some bad experiences, it is now recommended to use washed gravel, with different degrees of grading according to the quality of the incoming water (3-6, 5-10, 6-12 mm) (Vymazal , 1998).

Plants

The most widely used variety is the Phragmites australis reed because of its rapid growth, its root development and its resistance to soil saturation conditions. Planting can take place using seeds, young shoots or rhizomes with a density of about 4 per m^2.

Design

Choice of land

The constraints concerning the site are as follows:

- Large land space needed;
- Topography: A difference in level of a 1 meter between the feeding point of the plant and downstream point makes it possible to feed the filters by gravity. The required difference in level is not very much because of the horizontal flow.
- Soil characteristics at the bottom of the filter: if the soil is clay-like, natural waterproofing can be reached by simple compaction (required conductivity of 1.10-8m.s-1). Failing this, the installation of a waterproof geomembrane is necessary.

Operation

Maintaining these systems does not have any particular requirements, but needs the operator to come and inspect the equipment regularly and frequently. For the population range that we are interested in, one must nevertheless think about the maintenance of primary settlement structures (removal of sludge) and of the biological treatment stage in the case where the reed bed filter is for tertiary treatment.

Tableau n°8 : Exploitation des filtres plantés à écoulement horizontal

Tasks	Frequency	Observations
Maintenance of pre-treatment structures	1 / week	The aim is to ensure their proper operation and that they do not discharge too many SS which could cause clogging.
Adjustment of output level	1 / week	Regular adjusting of the output water level makes it possible to avoid surface runoff. For large plants (> 500 m^{3}d-1), verifying the output level could require daily inspection. The hydraulic aspect with this type of process is a key item. The correct distribution of the effluent in the filter should be checked. Cleaning the feed distribution device should be incorporated into the design.
Vegetation Weeding	1st year	During the first year (and even during the second) it is preferable to weed the self-propagating plants manually so as not to hinder reed development (Kadlec R.H. et al, 2000). This operation can also be carried out by slightly immersing the surface of the filter (10 cm) to the detriment of purification output (Cooper, 1996). Once predominance of reeds is established, this operation is no longer necessary.
Cutting	not necessary	The absence of surface runoff makes it possible to avoid cutting. Dead plants do not hinder in any way the hydraulics of the filters and furthermore allow the filter to be thermally insulated.
Other maintenance operations	Each visit	Keep a maintenance log with all the tasks that are carried out and the flow measurements (flow meter canal, pump operating time), so as to obtain good understanding of the flows. This also allows operating assessments to be produced.

Performance

In terms of performance for BOD_5, for incoming concentrations varying from 50 to 200 mg/l, and for a sizing of 3 to 5 m^2/p.e., flow systems of the horizontal type and lined with gravel result in reductions of about 70 to 90 %. These concentrations are however too low to be considered as representative of urban waste water and it seems more prudent to follow the Danish example.

In fact, 80 Danish sites, sized at about 10 m^2/p.e., achieve removals of approximately 86 % for BOD5 and SS, 37 % for total nitrogen, and 27 % on for total phosphorus (Cooper, 1996).

Generally speaking, in secondary treatment, nitrification is limited but denitrification is very good.

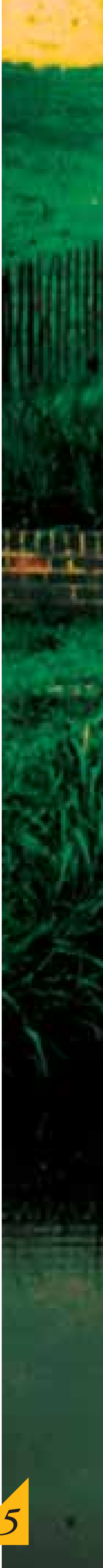
The removal of phosphorus depends of the type of soil used, but remains relatively low.

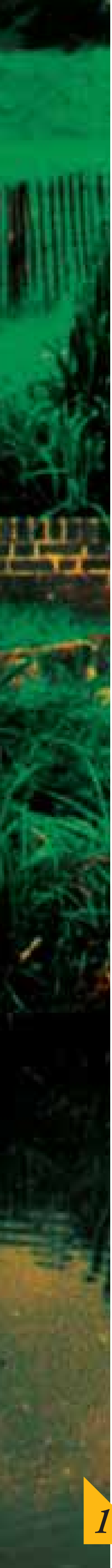
Technical advantages

- Low energy consumption;
- No highly-qualified personnel needed for maintenance;
- Does not need significant slope for gravity feeding (< 1 m);
- Reacts well to variations in load.

Technical drawbacks

- A lot of ground area is needed (as for natural lagoons);
- A plant for sizes of about 4,000 p.e. can only be considered if serious thought is given to the design parameters in particular the controlling hydraulics.





Suspended growth cultures

Operation: design principles

The purification process using "suspended growth cultures" relies on the development of bacterial cultures, mainly of the aerobic type. Oxygen comes from many sources depending on to the approaches taken.

The bacterial culture is separated from the treated water by a sedimentation structure, most often, specifically clarifier, settling lagoon, etc..

Natural lagoons (stabilisation ponds)

Operating principle

Purification is ensured thanks to a long retention time, in several watertight basins placed in series. The number of basins most commonly used is 3. However, using a configuration with 4 or even 6 basins makes more thorough disinfection possible.

The basic mechanism on which natural lagooning relies is photosynthesis. The upper water segment in the basins is exposed to light. This allows the development of algae which produce the oxygen that is required for the development and maintainance of aerobic bacteria. These bacteria are responsible for the decomposition of the organic matter. Carbon dioxide produced by the bacteria, as well as mineral salts contained in the waste water, allows the planktonic algae to multiply. Therefore, there is a proliferation of two interdependent populations: bacteria and algae, also called "microphytes". This cycle is self-maintained as long as the system receives solar energy and organic matter.

At the bottom of the basin, where light does not penetrate, there are anaerobic bacteria which break down the sludge produced from the settling of organic matter. Carbon dioxide and methane are released from this level.

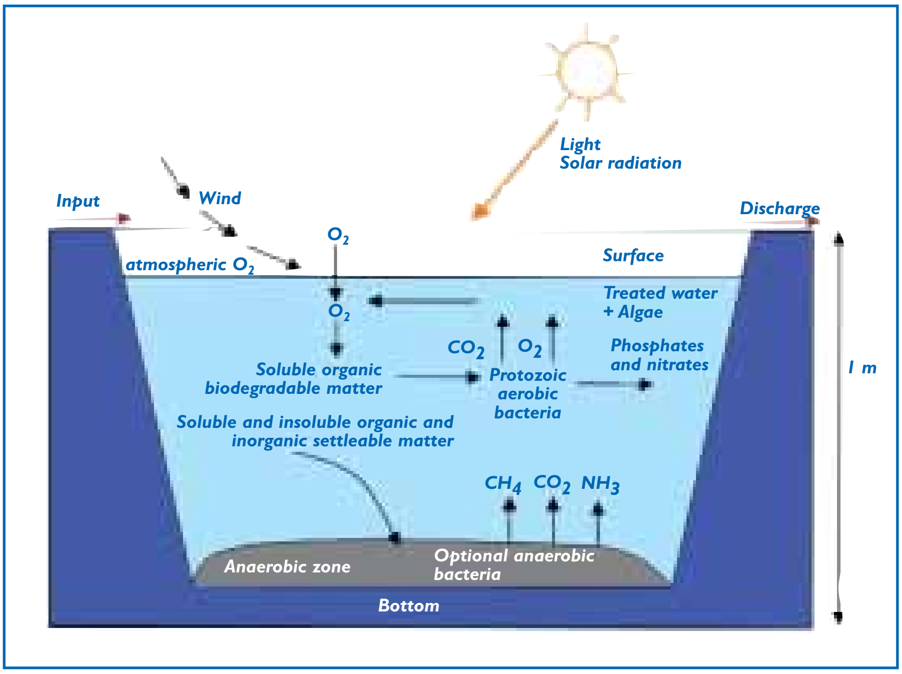


Figure 13: Mechanisms found in natural lagoon basins (according to Agences Financières de Bassin, CTGREF, 1979)

Basis for design

Natural lagooning is made up of, most often, of several watertight basins or "microphyte lagoons", operating in series.

Number of lagoons

A plant with three lagoons is common and makes it possible to ensure a good level of operating reliability for the removal of organic matter. The highest possible performance levels, as far as disinfection is concerned, are only reached with larger-sized partitioning (up to six lagoons in series).

The respective roles of each of the different basins is as follows:

- the first allows, above all, a reduction in the polluting load that contains carbon;
- the second allows nitrogen and phosphorus to be reduced;
- the third refines the treatment and makes the system reliable, in case an upstream basin malfunctions, or during maintenance work.

The daily surface load applied is approximately 4.5 g BOD_5 per m^2 of total surface area, which corresponds to a water body surface area of approximately 10 to 15 m^2/ p.e. (Vuillot et al, 1987).

The low load applied results in a long residence time in the basins. In the absence of rainwater, the retention time is around 70 days. In hot and dry climates (countries in the south of Europe), the design surface area can be halved, thanks to the temperature which accelerates the biological processes and thanks to evaporation which increases retention time (see Radoux M., Cadelli D., Nemcova M., Ennabili A., Ezzahri J., Ater M., 2000).

For this reason, the volumes to be treated are, at any given instant, completely different from the volumes discharged into the natural environment. So as to ensure proper hydraulic operation of the structures (and to detect possible infiltration from the water table or, inversely, leaks), it is thus important to always be able to compare the upstream and downstream flows by using appropriate devices (flow meters or pump operating times).

Design of the first lagoon

The value of 6m² / p.e. is successfully used, which corresponds to a nominal surface load of around 8.3 g BOD_5/m^2 per day.

For plants with a variable population, and in hot and sunny weather, design can be carried out on the basis of the maximum monthly peak flow.

The shape of the lagoon must not favour bacterial growth at the expense of algae. The balance between the two must be respected so that the oxygen yield remains sufficient. To do this, the best shape of the basin is deeper rather than long and narrow. A length to width (L/l) < 3 ratio is used in France (see the following diagram).

The depth of the basin must make it possible:

- to avoid the growth of higher forms of plant life;
- to obtain maximum penetration of light and oxygenation to the water volume;

The depth of the water in the lagoon must therefore be 1 meter (± 0.2 m). However, in order to facilitate cleaning the sludge deposits that normally develop around the feed point, a settlement zone that is deeper can be built. This zone, that has an additional depth of 1 meter maximum, covers a few dozen m². It must always be accessible from the sides or from an access ramp built for this purpose.

Design of the second and third lagoons

These two basins must be of similar dimensions and the total surface area of the two bodies of water must be equal to 5 m² / p.e.

The depth of the water must be 1 meter (± 0.2 m). The overall shape can vary to a certain extent, in accordance with particular topographical constraints and the planning permission required to obtain proper integration into the landscape.

Pre-treatment of raw sewage

A bar screen must be installed before treatment on large plants. For plants with less than 500 p.e. it is possible to use a mobile floating suction barrier. At the entrance to the first basin, a suction barrier (fat/oil collector) that is submerged 30 to 40 cm makes it possible to retain floating solids.

Space needed

The choice of land depends upon the size of the space that the lagoon system takes up on the ground. The surface area of the lagoons includes the bodies of water as well as the approaches which must be designed to facilitate maintenance. For example, approximately 15 m²/p.e. of total surface area is needed to construct the 4,400 m² of basins required to treat the waste water generated by 400 p.e. 0.6 hectare is therefore necessary (see the drawing below).

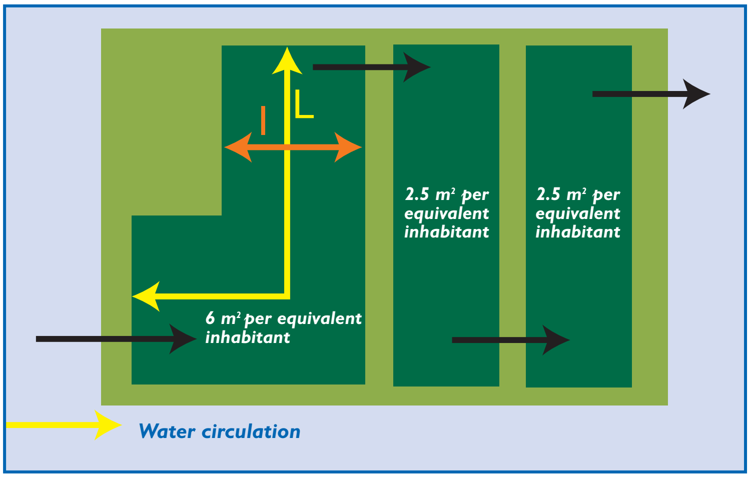


Figure 14: Ground space taken up by natural lagoons (Agence de l'eau Seine-Normandie, CEMAGREF – 1998)

Location

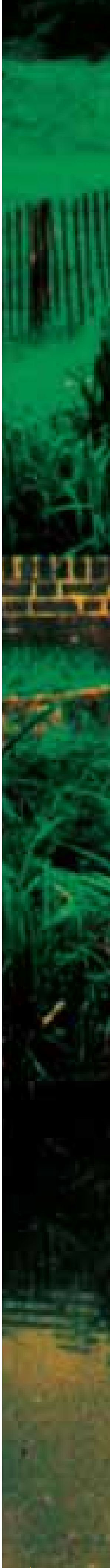
The structure should generally be located at a lowest point, at a position where prevailing winds contribute to aerating the watersurface. But, if more watertight (silt/clay) soils are available at higher positions pumping can be considered.

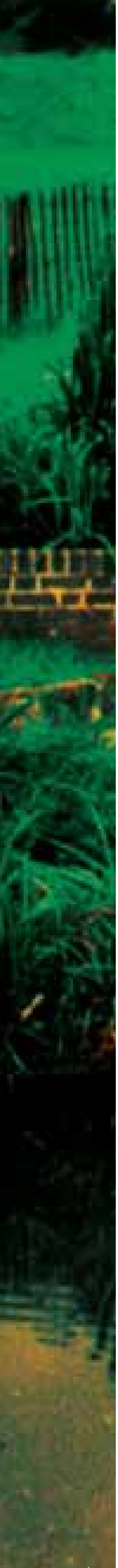
There must not be any trees closer than 10 metres, since their roots could create preferential paths through the dikes. Furthermore, their leaves could fall into the basins and cause an organic overload as well as a risk of obstructing connecting structures.

The land must be of the clay-silt type. The substratum must absolutely not be karstic or fractured.

Topography

The land must be chosen in such a way that gravity helps the flow down to the receiving area. A spot that would cause a minimum of construction work should be sought out. Finally, land that is too steep must not be used because of the risks of collapsing, erosion and pur off from the catchment areas (a catchment area with too steep a slope would cause a very strong and sudden increase in the flow of rainwater after a storm).





Implementation

Banking up work

The slope of the naturally watertight dikes must have an H/ L relationship of at least 1/2.5 so as to:

- limit the erosive action caused by lapping;
- facilitate regular maintenance;
- allow access to all the basins for the cleaning equipment.

In order to protect against erosion caused by lapping and possible damage caused by rodents, it is useful to turf the bank sides before adding water or to use self-locking slabs or blocks, geogrids , geotextiles or any other material to protect the sides.

Dikes must be built up by successive compactions of 15 to 20 cm layers, so as to ensure homogenous settling all the way to the "heart of the embankment" .

Compacting the invert must be carried out after that of the dikes.

Installing a watertight geomembrane is possible but has the disadvantage of increasing the investment capital cost of the structure. In this situation, the slope of the dikes can be greater (up to 1/1.5), the total surface area taken up by the structures will therefore be less.

Siphon pipe arrangements must be provided between basins so as to stop the transmission of hydrocarbons and duckweed.

It is preferable to install a stationary by-pass on each basin in order to facilitate the operations of emptying and cleaning.

The last step in the construction is to quickly fill with clean water the different basins so as to establish the permeability, while avoiding any risk of drying out of the structure, verify watertightness and to help setting up of the ecosystem (including vegetation of the banks).

Smells could appear with the change of seasons (linked to the phenomenon of anaerobiosis) if the effluent present in the first lagoon is too concentrated. It is possible to solve this situation by recirculating the water in the first basin or by diluting the effluent using a flush system in the network.

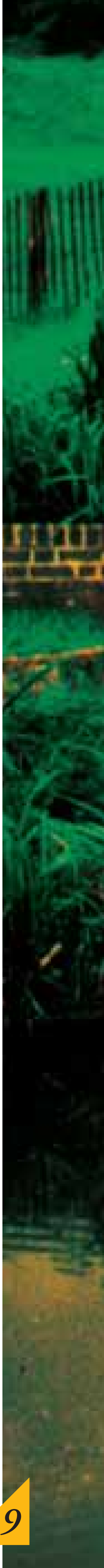
In order to avoid seepage into and between the lagoons, it is absolutely necessary that a hydrogeological and pedological study is done beforehand.

Operation

The table below provides a more detailed description of the tasks to be carried out.

Table 9: Operating lagoons

Task	Frequency	Observations
General monitoring – check list: ● presence of rodents; ● obstruction of connecting structures; ● development of duckweed; ● proper water flow; ● absence of floating debris; ● water colour; ● absence of odours; ● state of the dikes/ banks.	1 / week	This verification must be done by walking around all of the dikes. This method has the advantage of dissuading the settling in of rodents. Furthermore, methods for the **fight against duckweed** are either prevented by the settling in of ducks, or curative by the removal of plants (by floating plank for example).
Maintenance of pre-treatment structures	1 / week	It involves preventing build up of effluents in the network or by-pass and avoiding bad odours;
Cuttting on the dikes and on the sides and on the plant belt (or grazing by sheep)	2 to 4 / year	The idea is to maintain access to the bodies of water, to limit the settling in of rodents and the development of insect larva and to check the state of the sides.
Partial cleaning of the sedimentation cone (at the entrance of the first basin)	1 to 2 / year	Must be done with liquid pumping.
Cleaning of the basins	Every 5 to 10 years, according to the load actually received for the first basin, every 20 years for the following basins	Must be implemented when the volume of sludge reaches 30% of the volume of the basin. Two methods of cleaning are normally used: ● by an earthmoving machine, once the basin has been emptied. This implies the presence of a stationary by-pass on each basin; ● by pumping, without prior emptying, called "emptying under water".



Performance

The results, calculated on the flow of organic matter, achieves more than 75 % , which corresponds to a filtered COD concentration of 125 mg/l. Furthermore, the flow, and therefore the discharged flow, is often reduced in summer (-50%) by evapotranspiration.

The concentrations in total nitrogen at the discharge level are very low in the summer, but can reach several dozen mg/l (expressed in N) in the winter.

The reduction in phosphorus is noticeable over the first few years (> 60%), then dwindles down to zero after about 20 years. This drop is due to a release of phosphorus from the sediment. The initial conditions will be restored by cleaning the basins (when the area is sensitive to phosphorus, cleaning must take place every 10 years, not every 20 years).

Disinfection is important, especially in the summer (microbial reduction > 10,000). This performance is linked to the long retention time of the effluent (around 70 days for a complete treatment) with U.V. radiation effects and biological competition.

Advantages

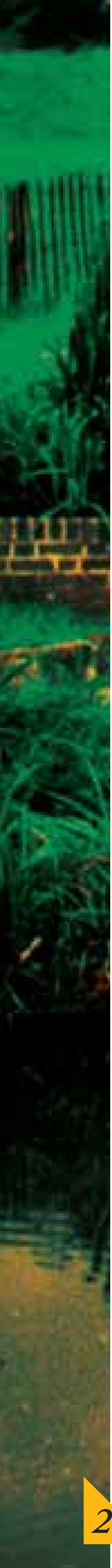
- A supply of energy is not necessary if the difference in level is favourable;
- Operation remains simple, but if overall cleaning does not take place in time, the performance of the lagoon is severely reduced;
- Eliminates a large portion of the nutrients: phosphorus and nitrogen (in summer);
- Very good elimination of pathogenic organisms in the summer (4-5 logs), good elimination in winter (3 logs);
- Adapts well to large variations in hydraulic load;
- No "hard permanent" constructions, civil engineering remains simple;
- Integrates well into the landscape;
- Absence of noise pollution;
- Pedagogic equipment for nature initiation;
- Sludge from cleaning is well stabilised (except that from at the head of the first basin) and is easy to spread on agricultural land.

Technical drawbacks

- Much ground space needed;
- Capital costs depend very heavily depending on the type of substratum. With unstable or sandy land, it is preferable not to consider this type of lagoon;
- Performance is less than in intensive processes with respect to organic matter. However, the discharge of organic matter takes place in the form of algae, which has less adverse effects than dissolved organic matter for oxygenation of the zone downstream. Moreover this discharge remains low in the summer (as a result of evapotranspiration), which is the most unfavourable period for watercourses and so the reduction of fluxes discharged is a benefit at this period;
- Quality of discharge varies according to season.

Macrophyte lagoons

Macrophyte lagoons reproduce natural wetlands with a **free water surface**, while trying to highlight the interests of natural ecosystems. They are rarely used in Europe, but are often carried out for tertiary treatment following natural lagooning, optional lagoons or aerated lagooning in the United States. This approach is generally used with the purpose of improving treatment (on the BOD_5 or SS parameters) or to refine it (nutrients, metals, etc.). **However the use of a microphyte finishing lagoon can show better results and is easier to maintain.**



Aerated lagoons

Operating principle

General description

Oxygenation is, in the case of aerated lagoons, supplied mechanically by a surface aerator or air blower. This principle differs from activated sludge only by the absence of continuous sludge extraction or sludge recycling systems. Energy consumption for the two approaches is, with equivalent capacities, comparable (1.8 to 2 kW/kg BOD_5 eliminated).

Major mechanisms that come into play

In the **aeration stage**, the water to be treated is in contact with micro-organisms that consume and assimilate the nutrients produced by the pollution that is to be removed . These micro-organisms are essentially bacteria and fungi (comparable to those present in activated sludge plants).

In the **settling stage**, suspended solids which are clusters of micro-organisms and trapped particles, settle to form sludge. This sludge is regularly pumped or removed from the basin when their volume becomes too great. This settling stage is made up of a simple settling lagoon, or preferably, two basins which can be by-passed separately for cleaning operations.

With aerated lagoons, bacterial population without recirculation leads to:

- ➔ a low density of bacteria and a long treatment time in order to obtain the required quality;
- ➔ reduced of bacteria flocculation, which requires the installation of a suitably sized settling lagoon.

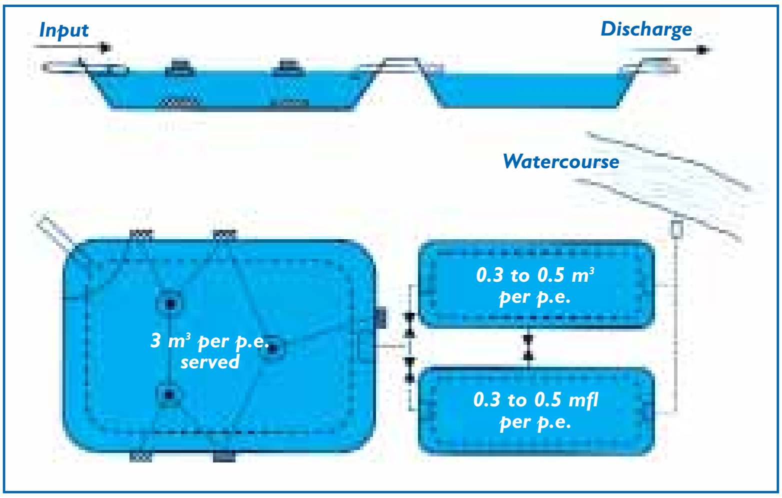


Figure 15: Drawing of the principle of aerated lagoons (according to Agences Financières de bassin, CTGREF – 1979)

Basis for design

Choice of land

A surface area between 1.5 to 3 m^2 per p.e. must be planned for.

Aeration lagoon

Table 10: Design basis for aerated lagoons

Parameter	Design basis
Retention time	20 days (retention times are reduced, in fact, to about two weeks after a few years of operation following the volume occupied by the deposit of suspended solids one must therefore not try to reduce this retention time during design).
Volume	3 m^3 per user served.
Depth	2 to 3.50 m with surface aerator (fast 4 kW turbines correspond to depths of about 2.5 m, those at 5.5 kW are used with depths between 2.5 and 3 m) > 4.00 m possible with air blower.
Shape of the basin	a square around each aerator.
Specific aeration power	Oxygen needs are around 2 Kg O_2 / kg BOD_5. In order to reduce deposits to a volume that does not affect the treatment and, furthermore, to prevent the formation of microscopic algae, it is necessary to oversize the aerators and to use a power level between 5 and 6 W / m^3. During operation, it is always possible to reduce the operating time of these reactors in relation to the operating time of the less powerful fans, which makes it possible to limit operating surcharges.

Settling lagoon

Table 11: Design basis for settling lagoons

Parameter	Dimensions
volume	0.6 to 1 m^3 per p.e.
Depth	2 to 3 m with surface fans.
Shape of the basin	rectangular with a length / width relationship equal to 2/1 or 3/1.
Depth	2 m so as to allow for one meter of water free before sludge extraction.

The use of two settling lagoons with a retention time of 4 days (0.6 m3/p.e. x 2) and operating alternately facilitates sludge extraction, which must take place every two years.

Implementation

Contrary to natural lagoons, watertightness via a geomembrane will be selected so as to limit the risks of degradation of the sides by excessive lapping of water. In the case of natural watertightness , it is advisable to install material that provides protection against water lapping on the sides (air-placed concrete, geogrids + planting of rushes). The life of the structure is dependent on this.

Whatever construction method is chosen, concrete slabs and blocks complement the protection against undermining at the level of the turbine.

Operating

The different tasks involved in operation and maintenance are listed in the following table:

Table 12: Operation of aerated lagoons

Task	Frequency	Observations
Cleaning of pre-treatment installations (grids + suction barrier)	1 / week	
General inspection of the basins	1 / week	
Extraction of sludge from the settling lagoons	Once every two years in nominal load	The 1st emptying is not necessary until after 3 or 4 years of operation.
Adjustment and programming of aeration	2 / year	This is the most complex operation which requires, several weeks after each charge, a verification of the new biological balance in the basin.
Cutting down and clearance of plants	2 to 5 / year	
Verification and reading of the counters	1 / week	
Maintain a log	1 / week	

Performance

The level of quality of the effluent is good for organic matter: a reduction of more than 80%. For nutrients, elimination remains limited to bacterial assimilation and remains around 25-30%.

This approach can easily be adapted for the addition of physico-chemical additives with a view to eliminating orthophosphates.

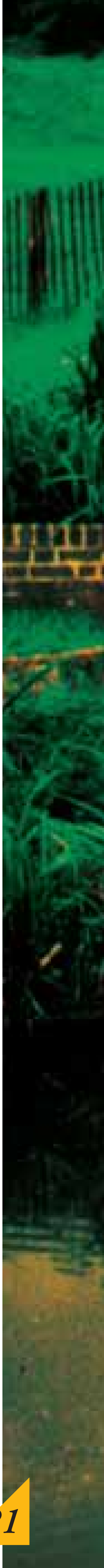
Technical advantages

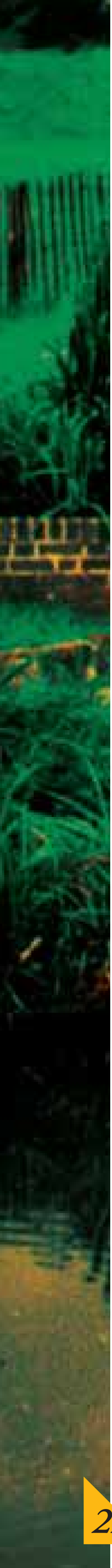
This process is particularly tolerant of very many factors which cause, in general, very serious malfunctions in traditional purification processes:

- large variation in hydraulic and/or organic loads;
- highly concentrated discharges;
- effluents with unbalanced nutrients (cause of bulking of activated sludge);
- joint treatment of industrial and domestic biodegradable discharges;
- integrates well into the landscape;
- stabilised sludge;
- removal of sludge only every two years.

Technical drawbacks

- discharge of average quality concerning all parameters;
- presence of electromechanical equipment requiring maintenance by a specialised agent;
- noise pollution linked with the presence of the aeration system;
- high energy consumption.





Combined systems [association of extensive approaches (fixed film and suspended growth cultures)]

The association of several natural systems, in free or stationary cultures, in series or in parallel, is sometimes implemented in order to adapt the treatment to a specific goal (quality of the discharge, integration of rainwater, special influent, etc.).

As a main treatment, very little experience is available, and actual performance levels are difficult to evaluate. Certain studies (Radoux M. et al , 2000) on MHEA, (Hierarchical Mosaics of Artificial Ecosystems) show some interesting potential without defining written bases for sizing.

The use of vertical and horizontal reed bed filters in series seems to be an interesting solution in order to allow a more thorough treatment of nitrogen and phosphorus according to the type of support used (Cooper, 1999). A first stage of vertical flow filters allows a good reduction in SS, in BOD5 as well as almost total nitrification. A second stage of horizontal flow reed bed filters improves the treatment on SS and BOD5, and makes possible denitrification as well as adsorption of phosphorus if the chosen support has good characteristics (Fe, Al, Ca).

More complex configurations are often used to refine secondary or tertiary treatments. After treatment of the aerated lagoon or natural lagoon types, emergent macrophyte lagoons can eliminate the risk of temporary discharges of mediocre quality.

Optional lagoon systems followed by emergent macrophyte lagoons are often used for the treatment of rainwater (Strecker et al ,1992).

When the population range reaches a value that is close to 4,000 p.e., it is useful to closely compare the capital and operational costs with processes that are more intensive. The management constraints due to the large surface area should not be ignored.

A multitude of configurations are possible according to the needs to reproduce the various natural wetland systems. One must nevertheless take into consideration the fact that the increase in the complexity of a treatment plant of this type takes place to the detriment of simplicity in management, which is however very much sought after. Furthermore, the current state of scientific knowledge on the operation of wetlands pressures us most often to try to simplify the configuration so as to better control purification.

CONCLUSIONS: ELEMENTS FOR THE TECHNICAL CHOICES

Summary of the different approaches

Purifying techniques that correspond to the terminology of the "extensive approaches" are briefly summarised in the table below, which shows that for some of them, primary treatment is needed (see glossary) upstream, and for others, they should be used exclusively as a finishing (or tertiary) treatment.

Table 13: Extensive purifying techniques

Traditional approach	**Primary treatment**	**Secondary treatment**	**Tertiary treatment**
Infiltration –percolation	Settler digester	Infiltration - percolation	
Vertical flow reed bed filters	Absolutely essential (Vertical flow filters can be used for this primary treatment)	Vertical flow filters (1st stage)	Vertical filters (2nd stage)
Horizontal flow reed bed filters	Settler / digester	Horizontal flow filters	
Natural lagoons	1st lagoon basin	2nd lagoon basin	3rd lagoon basin
Macrophyte lagoons	Not recommended	Not recommended	One or more basins
Aerated lagoons	Aerated lagoon + settling lagoon		Finishing lagoon
Hybrid system,	1st lagooning basin, 2nd lagooning basin		Infiltration - percolation
	Aerated lagoon + settling lagoon		Infiltration - percolation
for example…	Vertical flow reed bed filters +Horizontal flow reed bed filters		

Most of them ensure a positive elimination of one of the parameters that characterises tertiary treatment (nitrogen, phosphorus or bacteria that indicate faecal contamination). The levels may be variable and are shown in Table 14.

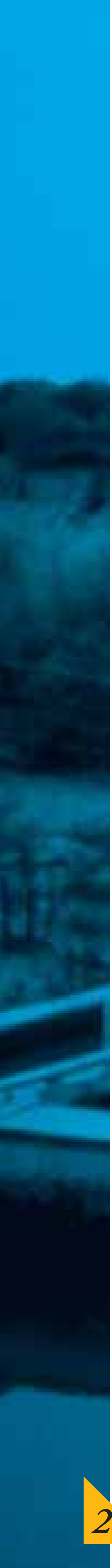
Quality of discharges

The effectiveness of extensive approaches according to parameters is shown below:

Table 14: Effectiveness of extensive approaches according to parameters

Parameters	**OM*= Organic matter**	**KjN***	**Total N***	**Total P***	**Microbial removal**
Infiltration - percolation	Yes	Yes	No	No	If special design made
Vertical flow reed bed filters	Yes	Yes	No	No	No
Horizontal flow reed bed filters	Yes	Poor nitrification	Good denitrification	No	No
Natural lagoons	Average	Yes	Yes	Yes, the first years	Yes
Macrophyte lagoons	Average	Yes	Yes	Yes, the first years	Yes
Aerated lagoons	Average	Average	No	No	No

**** see glossary***



Advantages and drawbacks: summary

The choice is therefore going to be made according to the advantages and disadvantages of the different techniques that are summarised in the table below.

Table 15: Summary of advantages and drawbacks of extensive approaches

Approach	Advantages	Drawbacks
Infiltration-percolation through sand	• Excellent results on BOD_5, COD, SS and advanced nitrification; • Surface area needed is much less than with natural lagooning; • Interesting decontamination capacity.	• Requires a primary settling structure; • Risk of clogging that must be managed; • Requires having great quantities of sand available; • Adaptation limited to hydraulic surcharges.
Vertical flow reed bed filters	• Easy to operate and low operating cost. No energy consumption if the topography makes this possible; • Processing of raw domestic sewage; • Management of organic matter retained in the 1st stage filters is reduced to a minimum; • Adapts well to seasonal variations in population.	• Regular operation, annual cutting of the exposed portion of the reeds, manual weeding before reeds are established ; • Using this approach for capacities greater than 2000 p.e. remains very delicate for reasons of controlling costs and hydraulics compared with traditional approaches; • Risk of presence of insects or rodents;
Horizontal flow reed beds filters	• Low energy consumption; • No noise pollution and integrates well into the landscape; • No highly-qualified personnel needed for maintenance; • Responds well to variations in load.	• A lot of ground space is needed, British and Danish approaches included. The latter is about 10 m^2/p.e. (equivalent to the surface of a natural lagoon). • A plant for sizes from 2,000 to 15,000 p.e. can only be considered if there is some serious thought given to the conditions of adapting the design basis and of the insurance of controlling hydraulics
Natural lagoons (stabilisation ponds)	• An energy supply is not necessary if the difference in level is favourable; • Operation remains simple, but if overall cleaning does not take place in time, the performance of the lagoon drops off very rapidly; • Eliminates a large portion of the nutrients: phosphorus and nitrogen (in summer). • Very good elimination of pathogenic bacteria in the summer; • Reduced water flows and fluxes in summer • Adapts well to large variations in hydraulic load; • No "hard permanent" constructions, civil engineering remains simple; • Integrates well into the landscape; • Pedagogic initiation to nature • Absence of noise pollution; • Sludge from cleaning is well stabilised except for that which is present at the head of the first basin.	• Much ground space needed (10 m2/p.e.); • Investment costs depend very heavily on the type of substratum. With unstable or sandy land, it is preferable not to consider this type of lagoon; • Performance is less that with intensive processes on organic matter. However, discharging organic matter takes place in the form of algae, which has less adverse effects than dissolved organic matter for oxygenation of the zone downstream; • Quality of discharge varies according to season; • Controlling the biological balance and purification processes remains limited.
Aerated lagoons	• Tolerates large variations in hydraulic and/or organic loads; • Tolerates highly concentrated discharges; • Tolerates effluents that are unbalanced in nutrients (cause of bulking in activated sludge); • Joint treatment of industrial and domestic biodegradable discharges. • Integrates well into the landscape; • Stabilised sludge • Removal of sludge every two years.	• Discharge of average quality for all parameters; • Presence of electromechanical equipment requiring maintenance by a specialised agent; • Noise pollution linked with the presence of the aeration system; • High energy consumption.

Importance of the climatic factor

Whether the different characteristics of the method are appropriate to the local context has to be the guide of the decision maker. With this in mind, the adaptability of the approaches to the climatic conditions must be studied in more detail.

Vertical flow reed bed filters can withstand periods of freezing without a great loss in the quality of treatment. However, since the feed is alternating, long periods of freezing without thermal protection such as snow, can compromise the hydraulics in the filter and therefore the treatment. Insulation with straw can avoid excessive freezing (Wallace et al, 2000, Brix, 1998). However, no difference in results can be seen between seasons on numerous sites in Denmark.

Horizontal filters can easily withstand long periods of freezing. Several factors make it possible to thermally insulate the water from outside temperatures: snow, cut reeds maintained on the surface and, for critical freezing periods, the layer of air trapped under the layer of ice that forms on the surface of the filter. There is however a risk of lower performance level than in the summertime. In extreme climates, it is useful to take into account a sabety factor with regards to sizing.

Macrophyte lagoon systems are sensitive to water temperature conditions. Degradation kinetics are reduced by a decrease in temperature. With microphyte lagoons, photosynthesis can continue to take place under one or two centimetres of ice.

In sizing of macrophyte lagoons, the degradation constant depends on the temperature. However, the variability of flows and concentrations according to season makes it difficult to interpret the impact of temperature. The nitrogen cycle is the most sensitive to the effect of temperature. Effects on BOD5 are curiously less evident and have triggered a lot of discussions (Kadlec, R.H. et al, 2000). On the other hand, SS is not affected by temperature.

Retention time in the basins varies according to climatic conditions and thus indirectly affects the expected results. High evapotranspiration found during the hot seasons can increase retention time considerably and, consequently, the results. The freezing of an upper water segment in winter, on the contrary, reduces retention time.

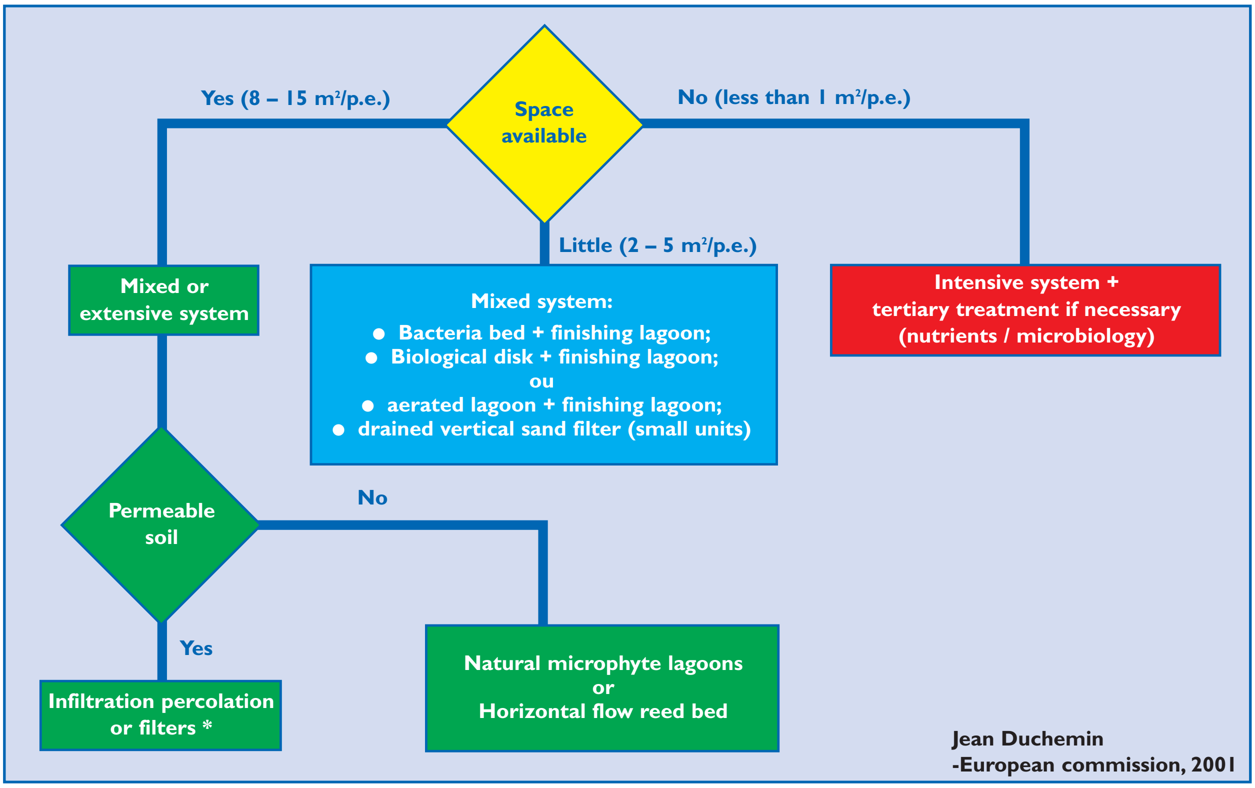
Setting up aerated lagoons in zones where the climate is extremely cold is to be avoided.

Whatever approach is chosen, in extreme climates, a safety factor should be taken into account concerning design. Supplementary work to determine these factors more precisely is yet to be done.

It is, in fact, the space available and the permeability of the soil more than the climate that are the main determining factors in choosing a technology.

Decision tree structure

The following decision tree structure can be used in the choice of an approach for waste water treatment.



Jean Duchemin
-European commission, 2001

**vertical filter if the elimination of NH4+ and bacteria (no action on NO_3-) is sought after; vertical filter + horizontal filter or horizontal filter if denitrification is desired. The risk of a high concentration of NH4+ at the discharge level is therefore higher.*

Figure 16: Decision tree structure

Cost

The data in the following table is taken from French experiments and remains, above all, valid and proven for this geographical area.

Table 16: costs (in EURO) for a plant for 1000 inhabitants (source: FNDAE technical document n°22, 1998)

	Activated sludge	Biological filters	RBCs	Aerated lagoons	Natural lagoons	Settler-digester + infiltration percolation	Settler-digester + reed bed
Investment	230.000 (± 30 %)	180.000 (± 50 %)	220.000 (± 45 %)	130.000 (± 50 %)	120.000 (± 60 %)	190.000 (± 50 %)	190.000 (± 35 %)
Operation (including energy) => Annual cost in EURO/year	11,500	7,000	7,000	6,500	4,500	6,000	5,500

Another source gives costs that are very different for intensive processes since the investment cost for activated sludge as for bacteria beds is approximately 155,000 EURO (see Agence de l'Eau Seine-Normandie, 1999). However, these latter figures stem from data sent by manufacturers, while the data from the above table comes from land surveys where the costs from 10 to 15 stations using the same approach were compared and analysed.

A third source (see Alexandre O, Grand d'Esnon , 1998), provides figures for a treatment plant of a size between 2,000 p.e. and 15,000 p.e., of the extended aeration type with a treatment of nitrogen and sometimes phosphorus. The construction of such a plant amounts to, after successful competition, 120-140 EURO HT/p.e. The entire operation which integrates project management, the different preliminary studies, the discharge authorisation procedure, enhanced value studies on sludge and discharges is close to 150 EURO HT/p.e. If the hypothesis of normal oversizing by 15 to 20 % is chosen, a treatment plant with a capacity between 2000 and 15,000 p.e. comes to 185 EURO HT/p.e. Civil engineering evaluated at 92.5 EURO /p.e. is depreciated over 20 years. The electro-mechanical equipment evaluated at 92.5 EURO /p.e. is depreciated over 12 years.

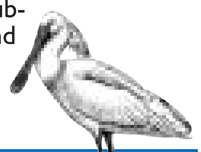
Figures, as we can see with the above examples, can vary highly according to sources although the object studied remains the same (construction of a plant in France). This confirms that carrying out cost comparisons between the different extensive techniques at the European level remains very delicate. Different studies make it possible to suggest that German purification plant costs, with the same capacity considered, are 20 to 25 % more than in France due to the cost of construction, of the material and the safety factors used (see Berland J.M., 1994). On the contrary, the cost of plants in Greece or in Portugal will be less expensive than in France, since the cost of construction is less. Furthermore, the local context could lead to different surcharges concerning capital (banking up in a granite area, permeable soil leading to the necessity of installing a geomembrane, absence of near-by sand, etc.). To give general rules in this area is risky to say the least.

On the other hand, it is possible to suggest that the operation of the different extensive approaches is simpler and, consequently, less costly than that of intensive techniques, in particular concerning energy costs and the cost incurred by the treatment and disposal of sludge. This is the big advantage with these techniques which, furthermore, do not require specialised manpower. Nevertheless, these tasks must not in any case be ignored, otherwise plant performance falls dramatically (see Table 15).

Taken as a whole, the use of extensive processes should allow, with identical capacities, to save an average of 20 to 30% on capital costs, and from 40 to 50% on operating costs, compared to intensive purification systems.

A plus for extensive processes: contribution to the landscape and pedagogic initiation to nature

Purification plants are often built in semi urban areas. They are, because of this, frequently near suburbs. In these places, the urban landscape can be criticised because of the lack of natural habitat and of its sometimes too "concrete" aspect. In these cases, opting for an extensive approach does not present any noise pollution and presents landscape qualities which can be viewed in a more positive manner than that of a traditional compact plant which could be viewed as an additional problem.



Furthermore, the wetlands (ponds, reed beds) that are recreated with these approaches often attract interesting aquatic fauna, which can be used as educational projects for school children and inhabitants in the neighbourhood.

The Rochefort Sur Mer lagoons

Infiltration percolation: a special case, the Mazagon (Spain) plant

General information

The plant treats the waste water of Mazagon, a tourist village located on the Atlantic coast in the south of Spain. The population of this village is 850 inhabitants in winter and greatly increases in summer to reach 20000 p.e. The pilot treatment plant only treats a portion of the pollution and was designed for an average capacity of 1700 p.e.

It should be noted that only partial purification is required here, which explains the under-sizing in relation to the value indicated in this guide (1.5 m^2 /p.e.) and which has been validated on a number of existing plants.

Project description

The plant is made up of a 170 m^3 sediment removal unit, a storage basin and three pairs of infiltration basins present in the dunes. Each infiltration unit has a surface area of 200 m^2. This is an undrained system. The water table is located between 5.1 meters and 6.6 meters in depth according to the basins.

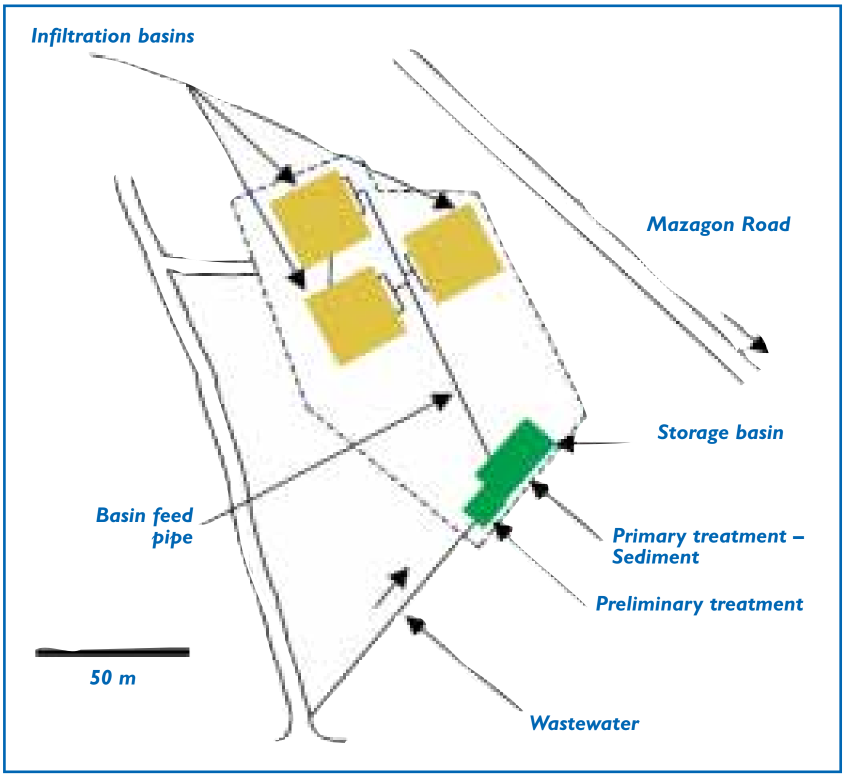


Figure 17: Plant diagram (V. Mottier, F. Brissaud, P. Nieto and Z. Alamy, 2000)

About 100 m^3 of waste water is distributed during the release of a tank. Each sequence takes place over two infiltration basins. The releases are triggered using manual valves. A wastewater feed sequence for an infiltration unit lasts between 40 and 50 minutes, which corresponds to a flow of 130 m^3/h. There is a single tank release per day per infiltration unit.

The discharges are distributed on the sand filters using a distribution system of pipes with holes.

Samples were taken at depths of 30, 60, 100, 150 and 200 centimetres using inspection chambers set up for this follow-up.

Mazagon plant (Spain)
Photo credit: F. Brissaud.

Results

Note that the effluent is not evenly distributed over the infiltration surface. Half of the surface is flooded after five minutes of distribution of the influents, 75 % after 12 minutes and 90 % after 21 minutes.

Similar heterogeneity after the end of feed can be observed. This problem is due to:

- uneven distribution by the pipes;
- a long feed with regard to the infiltration surface and of the permeability of the sand;
- unequal heights at the level of infiltration surface, despite frequent raking.

A large amount of unevenness in the load that is actually applied at the level of the surface of the infiltration plot results.

95 % of the volume of the tank exceeded two meters in depth two hours after the beginning of the feed. Percolation speed is between 1.1 and 2 m/h.

Performance

Traditional chemical parameters

The performance measured on the different traditional chemical parameters is as follows:

Table 17: Plant performance

Performance in the spring (1993) – average value over four tanks				
	COD (mgO_2/l)	NH_4 (mgN/l)	NO_2 (mgN/l)	NO_3 (mgN/l)
Influent	279	31,5	0,02	2,3
Treated water	36	0,5	0,08	28,2
Purification results	87 %	98 %		
Performance in the summer (1993) – average value over three tanks				
Influent	408	53,8	0,02	3,0
Treated water	35	0,3	0,14	32,4
Purification results	91 %	99 %		

COD was reduced by 90 % and more than 98% of the NH_4-Nwas oxidised. Performance on COD and NH_3 are therefore excellent. However, this data comes from a single survey campaign which lasted five months (from March to August 1993), which does not make it possible to verify whether performance will be maintained over the long term.

Disinfection

Performance with regards to disinfection were measured on total coliforms, faecal coliforms and faecal streptococcus. The averages were carried out using measurements that were taken over seven sequences.

The rate of reduction is expressed as follows:

$$\Delta m = \log (C_i/C_0)$$

The result is expressed log units (U log).

with C_i = number of micro-organisms in the effluent
C_0 = number of micro-organisms in the filtered water

This rate of reduction is 1.2 U log for total coliforms, 1.6 U log for faecal coliforms and 1.3 U log for faecal streptococcus.

Disinfection thus remains mediocre for an infiltration process through sand. This is mainly due to the sizing of the sand used which is relatively coarse and to the irregularity of this material. Performance for this type of parameter are even less than that attained by "traditional" compact approaches (activated sludge, biological filters, etc.).

Bibliographical references concerning infiltration percolation at Mazagon (Spain)

V. Mottier, F. Brissaud, P. Nieto and Z. Alamy - 2000 wastewater treatment by infiltration percolation : a case study, in Water Science and Technology, Vol. 41, P.P. 77-84.

Infiltration percolation: a traditional plant: the case of Souillac Paille-Basse (France - Département du Lot)

General information

The goal for this treatment process is the protection of the karstic aquifer. The population that was served at the time of the performance measurement (1993) was 900 p.e. and was essentially seasonal.

The purification network is a separate system and the daily flow is equal to 100 m^3 / d peak flow.

Project description

The plant is made up of the following:

- Pre-treatment: comminuter pump;
- Sedimentation-digester (capacity: 1200 p.e.);
- Fed to tanks of 17 or 34 m^3, according to the capacity of the reservoir in service:
  - fed by pumping at 40 m^3/h. Pumps are controlled by float controls;
  - distribution between the basins is controlled manually;
  - distribution over the basins is successively the following:
    - initial configuration: 3 feed points per basin, with equal even distribution by overflow;
    - final configuration: 2 feed points per sub-basin.
- Basins:
  - initial configuration: 2 basins each of 400 m_;

final configuration: partitioning of the basins into sub-units of 130 or 200 m^2.

- Filter pack:
  - Built-up sand (d10 = 0.21 mm; uniformity coefficient = 2.4), thickness: 0.80 m;
  - Drainage layer: 20 to 40 cm of gravel.
- Discharge: infiltrated on site to the water table.
- Operation:
  - Fed by tanks of 0.13 m or 0.26 m in the initial configuration and of 0.085 m or 0.17 m in the final configuration;
  - The length of the operating period is extremely variable, from 1 day to nearly a month. In general a single basin is in service;
  - Daily water segment on the basin that is operating: h = 50 cm / d.

Performance

Table 18: Plant performance

	Settled wastewater	Percolation effluents
SS (mg/l)	117	20 to 36
COD (mg/l)	580	201 to 282
BOD_5 (mg/l)	263	54 to 120
KjN (mg/l)	112	53 to 75
$N\text{-}NO_3$ (mg/l N)	< 1	70* to 1
Faecal coliforms / 100 ml	2.10^7	6.10^6 to 2.10^7

**** average influenced by a few exceptionally high values.***

The polluting load of the settled sewage is such that its oxidation is only possible when the daily hydraulic loads is not more than 15 cm/d. Since the loads applied are at least 3 to 5 times greater, oxidation is only partial. The solution is to change the sub-basin at each new tank; for this, more sophisticated equipment (remote-controlled motorised valves) would be required.

Large hydraulic loads or even very large ones for a thin filter bed means that it is not possible to achieve a high level of purification.

Bibliographical references concerning infiltration percolation at Souillac Paille-Basse

Brissaud F. - 1993, Epuration des eaux usées urbaines par infiltration percolation : état de l'art et études de cas, Etude Inter Agences n°9, Agences de l'Eau, Ministère de l'Environnement, Paris.

Vertical flow reed bed filters, the NEA Madytos experiment – Modi (Greece)

General information

In 1991 at the initiative of the European Community, a programme for evaluating treatment plants of the vertical flow filter type was launched in Greece in the communities of NEA MADYTOS – MODI. Design was carried out on the basis of experience from UK(Montgomery Watson, University of Portsmouth, Camphill Water) and France (Société d'Ingénierie Nature et Technique, SINT) with, as main objectives, to demonstrate:

- ➔ the effectiveness of the treatment with a minimum of electromechanical equipment;
- ➔ good integration of the process into its environment;
- ➔ the development of local responsibility and interest in treatment;
- ➔ reduction in capital and maintenance costs;
- ➔ possibility of re-using the sludge and treated discharges locally.

This plant is one of the largest plants of the vertical flow reed bed filter type in the world. It has a capacity of 3,500 population equivalents. It was put into service in June 1995 and its operation and performance was carefully monitored over 2 years, which does not allow long term consistency of the performance level to be verified.

Project description

All of the flow passes through an automatic bar screen that can be re-routed to a manual bar screen.

Primary treatment system

Two different primary treatment systems were carried out in order to tester its performance:

Approach A receives about 2/3 of the flow in a settler -digester. The sludge is distributed over sludge drying reed beds beds (vertical filters according to Liénard et al , 1995).

Approach B receives about 1/3 of the flow. It is made up of 4 vertical filters designed at 0.6 m^2/p.e. giving a surface area of 620 m^2. They operate in pairs on alternate weeks.

Secondary treatment system

Two sets of vertical filters make up this stage.

Decanted water from flow A is distributed onto a first stage of 8 vertical filters, by a siphon, of a total surface area of 1,360 m^2 dimensioned at 0.6 m^2/p.e. 6 of the 8 filters receive the water simultaneously and 2 are at rest.

The water from flow B, coming from the first stage, is distributed over 2 filters designed at 0.3 m^2/p.e. for a total surface area of 340 m^2. They operate on alternate weeks.

The second stage receives all of the water resulting from the previous steps. There are 6 vertical filters designed at 0.35 m^2/p.e. for a total surface area of 1170 m^2. 4 fed simultaneously and 2 at rest.

The following table summarises the characteristics of the filters:

Table 19: Plant performance

	Flow B First stage	**Flow B Second stage, step 1**	**Flow A Second stage, step 1**	**Flow A+B Second stage, step 2**
Design sizing (m^2/EH)	0,6	0,3	0,6	0,35
Total surface area (m^2)	620	340	1360	1170
Number of filters	4	2	8	6
Surface per filter (m^2)	(2x140) + (2x170)	170	170	195
Height of substrate				
Sand (m)	-	0,15	0,15	0,15
Fine gravel (m)	0,70	0,60	0,60	0,60
Course gravel (m)	0,10	0,10	0,10	0,10
Drainage layer (m)	0,15	0,15	0,15	0,15

Tertiary treatment system

Two lagoons located downstream from the filters reduce the number of pathogenic organisms so as to be able to recycle the water for irrigation. The two lagoons have identical characteristics: 1.5 m to 2m in depth for a total storage volume of 4500 to 7000 m^3.

Implementation

Rendering watertight

Since the soil was not impermeable, it was made watertight. The Greek situation is such that concrete is less expensive than a geomembrane for these purposes

Materials

The different lining materials (washed gravel, sands, pebbles for draining) were obtained locally.

Performance

Performance obtained over these two years of studies show a large reduction in BOD_5, COD, SS as well as active nitrification.

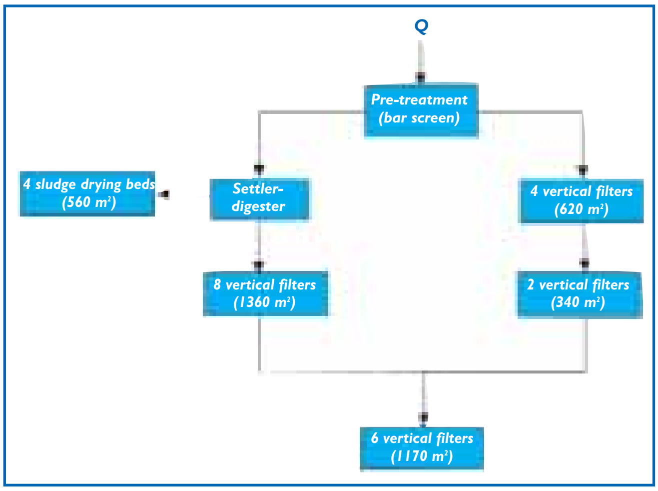


Figure 18: Drawing of the approach (Montgomery Watson, 1997)

Table 20: Average performance over the two years of study (Final report, LIFE programme)

Parameters	Input	Vertical filter output	Minimum values
BOD_5 (mg/l)	516	17	5,7
COD (mg/l)	959	58	24,9
SS (mg/l)	497	5	1,1
NH_4 (mg/l)	80	4,7	0,75
NO_3-N (mg/l)	2,6	44,9	24
PO_4-P (mg/l)	66	44	18,8
Total coliforms (cfu/100ml)	$8,8.10^7$	$6,1.10^5$ ($4,2.10^4$ in the lagoons)	689
Faecal coliforms (cfu/100ml)	$2,3.10^7$	$2,1.10^5$ ($8,6.10^3$ in the lagoons)	285

More specifically, for the different steps in the process, the following comments can be made:

Imhoff tank primary treatment (A) and vertical filters (B)

The results obtained with approaches A and B show the interest in feeding raw sewage into the vertical filters. Results are 74 to 90 % for SS, 50 to 80 % for BOD_5 and 12.5 to 37.5 % for NH_4-N on average for flows A and B respectively. Operating without a settling process makes it possible to avoid the extra costs produced by the management of sludge, and in our case, the construction of sludge drying beds. The effluent is, furthermore, well oxygenated at filter output, which is favourable for the rest of the treatment.

Secondary treatment system, Stage 1

The effectiveness of the treatment on organic matter and SS gives output concentrations of about 20 mg/l for BOD_5 and SS. The concentration of dissolved O_2 increases in the two approaches while maintaining the difference induced by the first step.

Secondary treatment system, Stage 2

The two flows are mixed together before this step. The reduction in SS and BOD_5 at levels of about 5 to 10 mg/l is accompanied by almost total nitrification (NH_4-N≈0). Concentrations of about 45 mg/l in NO_3-N are observed. Denitrification therefore remains low since it only reaches 40 %.

Conclusion

The quality of the effluent coming out of the filter stages concerning COD, BOD_5 and SS meets European recommendations (< 25 mg/l in BOD_5 and 35 mg/l in SS). The feeding of raw sewage on a first stage of filters is preferable as much for the treatment quality as for the capital cost. Filters allow very good nitrification. Variations in the quality of treatment (Montgomery Watson, 1997) are inherent to variations in load, temperatures and photosynthetic activity due to seasons. Nevertheless, filters efficiently play the role of buffering zones, and the quality of the discharge is nearly constant all year long. This type of plant responds very well to variations in load and temperature.

Bibliographical references concerning vertical flow filters at NEA Madytos – Modi (Greece)

Montgomery W., (1997), Demonstration project in the treatment of domestic wastewater with constructed wetlands. Stage II - Monitoring of Maintenance. Final report. LIFE95\UK\A13\GR\181\THE.

Liénard A., Duchène Ph., Gorini D. (1995), A study of activated sludge dewatering in experimental reed-planted or unplanted sludge drying beds. Wat. Sci. Tech., 32 (3), pp 251-261.

Hybrid system (vertical flow reed bed filters and horizontal flow reed bed filters): case study of Oaklands Park, Newnham-on-Severn, Gloucestershire (United Kingdom)

General information

The hybrid system was built in July 1989 to serve the Camphill Village Trust site in countryside near the small town of Newnham on the estuary of the Severn River (western England). The Camphill movement is an international charitable organisation which builds and manages community centres for disadvantaged people. Camphill Communities practice organic farming. Since the construction of this first system in 1989, many other installations of this type have been set up in other Camphill Communities and similar charitable organisations.

Project description

The Oaklands Park system was initially designed to serve 98 p.e. but treats, in reality, only discharges corresponding to 65 p.e. The system that can be seen in the diagram below has two stages of vertical filters, fed intermittently, of a total surface area of 63 m² followed by two stages of horizontal filters fed continuously and having a total surface area of 28m². The total surface used is only 1.4 m² / p.e. The cross-section below shows the structure of the vertical filters used in the first and second stages.

Each vertical filter is fed over 1 to 2 days then left inactive for approximately 10 days. This allows the filters to dry out between feedings and prevents clogging by the purifying biomass. Feeding is manually controlled by members of the community. The horizontal filters are continuously fed.

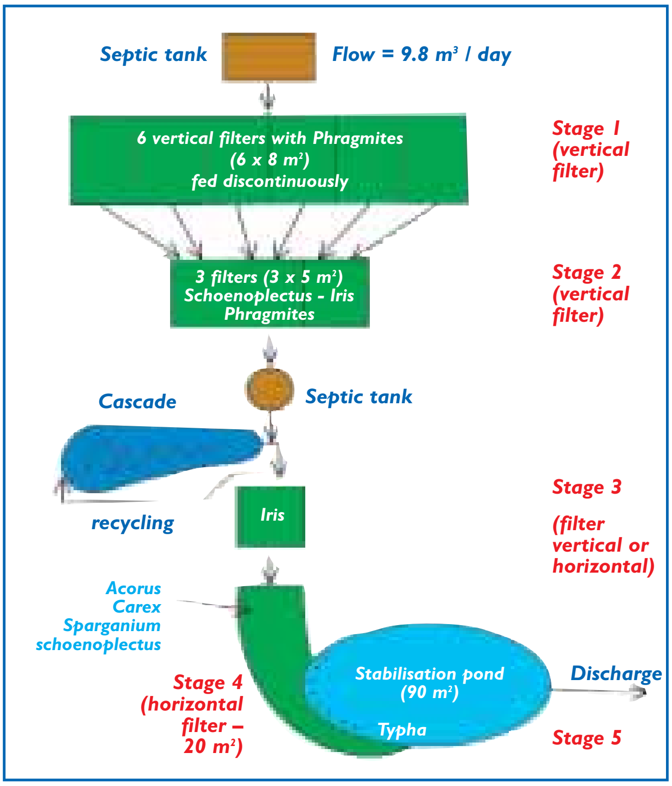


Figure 19: Oakland Park hybrid system (Cooper et al, 1996)

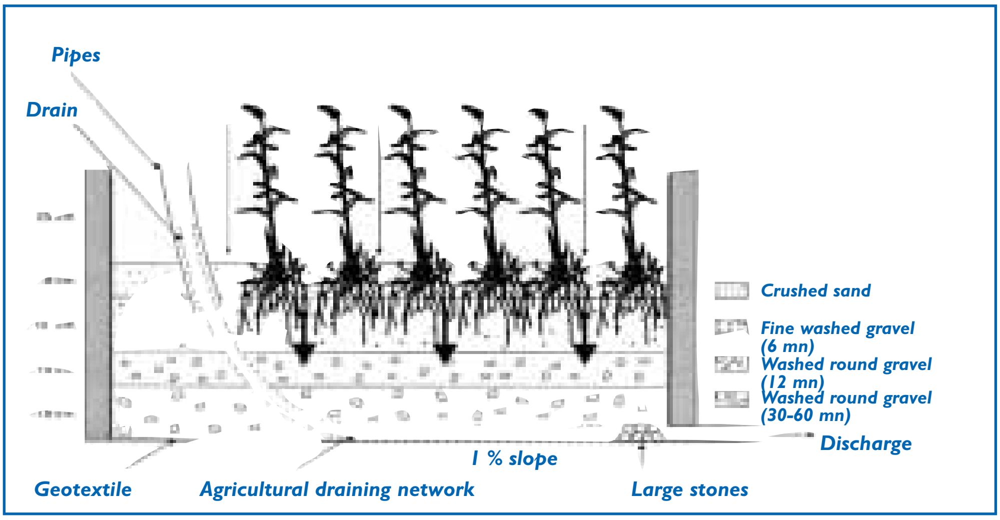


Figure 20: Cross-section of vertical filter stages

Performance

A summary of the performances from the 47 measurements taken in August 1989 and March 1990 is presented below (Bryan and Findlater / WRc, 1991, Cooper et al, 1996 and Cooper, 2001).

Table 21: performance of the Oakland Park hybrid system
(average values of 47 measurements carried out between August 1989 and March 1990)

Parameter, mg/litre	Influent	Stage I	Stage II	Stage III	Stage IV	Stage V
BOD_5	285	57	14	15	7	11
Suspended solids	169	53	17	11	9	21
NH_4N	50,5	29,2	14,0	15,4	11,1	8,1
$NO_3N + NO_2N$	1,7	10,2	22,5	10,0	7,2	2,3
Orthophosphate-P	22,7	22,7	16,9	14,5	11,9	11,2

Stage I : 6 vertical filters used intermittently (rotation => 1 in service 5 at rest)
Stage II : 3 vertical filters used intermittently (rotation => 1 in service 3 at rest)
Stage III : 1 horizontal filter
Stage IV : 1 horizontal filter
Stage V : Stabilisation pond

A second series of 17 measurements took place during the period from December 1990 to August 1991. The results of this series confirm those mentioned in the above table.

The elimination of BOD_5 and suspended solids in the stages that implement vertical filters is satisfactory and makes it possible to meet the discharge standards of the "urban waste water treatment" directive. A certain deterioration can be noted in the treated water at the level of the lagoon concerning BOD_5 and suspended solids. This is caused by the growth of algae which adds to BOD_5 and produces suspended solids. The reduction in orthophosphates and NH_4N is also very low in this stage.

Nitrification is very high in stages that implement vertical filters. This can be seen by the reduction of NH_4N and the concomitant increase in $NO_3N + NO_2N$. However, stage II does not allow complete nitrification to be achieved.

Significant increases in $NO_3N + NO_2N$ nitrogen-containing compounds in the vertical filters and then a decrease at the level of stages III and IV can be noted, despite the relatively low concentration in BOD_5. This seems to indicate that there are denitrification mechanisms at the level of the horizontal filters that are amplified by the long retention time which characterises these stages.

Denitrification also takes place at the level of the two vertical filters where the sum of the $NH_4N + NO_3N + NO_2N$ compounds is less (36.5 mg N / litre) than the NH_4N concentration coming into the system (50.5 mg N / litre). The measurement of NH_4N concentration for the effluent probably underestimates the actual nitrogen load of the discharge. In fact, waste water contains urea (which comes from urine), which can take 20 hours to be hydrolysed into NH_3 and is not detected by the analytical method which makes it possible to determine NH_4N. The actual load in nitrogen-containing pollution is around 70 – 100 mg N / litre.

This first experiment with a hybrid system was therefore clearly a success. It has demonstrated that the combined use of horizontal filters and vertical filters makes it possible to reduce BOD_5 to 20 mg / l, suspended solids to 30 mg / l and to obtain substantial nitrification.

This information was produced with the kind permission of Camphill Village Trust at Oaklands Park Gloucestershire, UK.

Bibliographical references concerning the hybrid system at Oaklands Park

Bryan D and Findlater B C, (1991), The modified Max Planck Institute Process- a review of the operation of a vertical flow Reed Bed Treatment System at Oaklands Park, WRc Report UC 1264, WRc Swindon, UK.

Burka U and Lawrence P C (1990), A new community approach to wastewater treatment with higher plants. pp 359-371 in P F Cooper and B C Findlater (Editors), Constructed Wetlands in Water Pollution Control, Pergamon Press, Oxford, UK.

Cooper P F, Job G D, Green M B and Shutes R B E (1996), Reed Beds and Constructed Wetlands for Wastewater Treatment.pp206 WRc Publications, Medmenham, Marlow, Buckinghamshire, UK.

Cooper P F (2001), Nitrification and denitrification in Hybrid Constructed Wetland systems. Chapter 12 in Transformations in Natural and Constructed Wetlands ,Vymazal, J (Editor)to be published by Backhuys Publishers, Leiden, The Netherlands in February, 2001 from paper presented at workshop of the same name held at Trebon, Czech Republic.

Seidel K (1978), Gewässerreinigung durch höhere Pflanzen, Zeitschrift Garten und Landschaft, H1, pp9-17

Natural lagoons: case of the plant in Vauciennes (France – Oise département).

General information

The Vauciennes natural lagoon system contain three basins in series. The sequence of basins is as follows:

- a microphyte lagoon;
- a macrophyte lagoon;
- a hybrid lagoon.

Performance levels in this plant were followed very closely from October 1981 to July 1991 by the SATESE of Oise and the CEMAGREF, at the request of the Agence de l'Eau Seine-Normandie (Schetrite S, 1994).

Project description

The design uses the following parameters:

- nominal capacity: 1000 population equivalents;

daily flow: 150 m³ / day;
peak flow: 24.5 m³ / h;
daily load: 54 kg BOD_5 / day.

The network that collects wastewater is part pseudo-separate (equipped with storm water outlets) and partly separate.

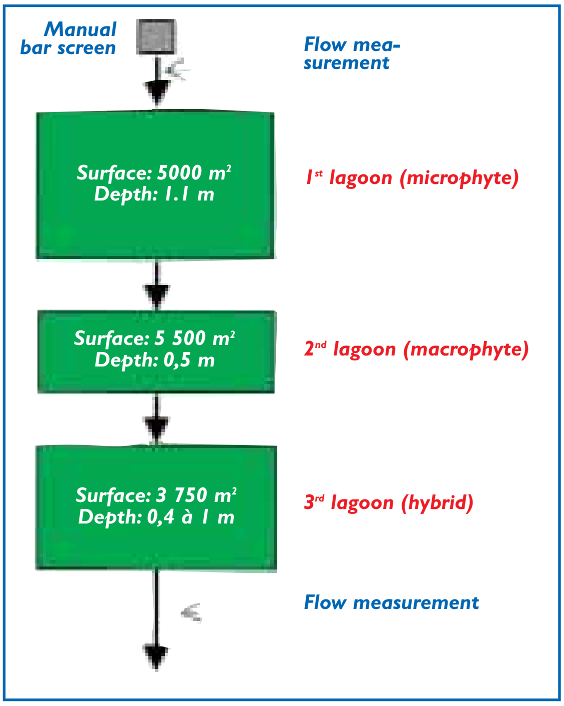


Figure 21: Vauciennes lagoons

Performance

Performance levels, calculated on average values from the 11 measurement campaigns carried out between October 1981 and July 1991, are shown below

Table 22: Performance of the plant

	BOD_5 (mg/l)	COD (mg/l)	SS (mg/l)	Kjeldahl-N (mg/l)	NH_4-N (mg/l)	Total phosphorus (mg/l)
Average concentrations of raw sewage	175	546	302	55	38	20
Average concentrations of discharge	- *	83,6	34,7	13,9	9	4,6

**** BOD was measured on samples at the output of the three basins up to the 6th measurement campaign (April 85). Taking into account the uncertainty of the value obtained (presence of algae, of Daphnia, etc.), it was no longer measured beyond that date. It is notably in order to avoid this type of incident that the "urban wastewater treatment" directive stipulates that the analysis of discharges from this type of plant have to be carried out on filtered samples.***

After start up, average results on COD and SS progressively increase and are maintained in a relatively stable range after the 3rd measurement campaign, giving reductions of between 60 and 90 % and 70 to 95 % for SS. The poor performance in the first few months can be attributed to the very low load levels of the plant (only 15 to 20 % in the 3rd campaign).

Results on Total nitrogen (Kjedhal-nitrogen + NH_4-N) that were measured in the summertime were remarkably stable whatever the load input (results = 70 %). No reduction in treatment was observed for this period, over the 10 years during which it was followed.

In winter, results on overall nitrogen decrease continuously with successive years (60 to 10 %). The output concentrations depend on the load admitted into the plants. However, the lagoons in January 1990 still only received 25 % of its nominal load. During this season, the results in eliminating overall nitrogen were on average 50 % for plants that are generally subject to higher loads. It can therefore be supposed that the treatment of the nitrogen load progressively goes down during the winter months.

Results concerning the elimination of Total phosphorus decreased regularly as from the 1st measurement campaign. They went from 75 % in 1981 to 30 % in January 1990 and this did not relate to the season. Nevertheless, during the last measurement campaign, in July 1991, results seemed to be exceptionally good (81 % in July 1991 compared to 32 % in January 1990). The most probable hypothesis to explain this sudden increase in performance is linked to the recent appearance of a cover of duckweed that would capture in the growth phase a large quantity of the phosphorus present in the water.

Concerning bacteriological aspects, the average reduction levels are all around 4 log units and do not show any significant tendency to go down when sunshine decreases

Bibliographical references concerning natural lagoons at Vauciennes

Collectif (1984), Synthèse du fonctionnement du lagunage naturel de Vauciennes (Oise), CEMAGREF, SATESE de l'Oise, Agence de l'Eau Seine Normandie, Paris.

Schetrite S. (1994), Etude synthétique du fonctionnement du lagunage naturel de Vauciennes (Oise) : Octobre 81 à juillet 91, CEMAGREF, SATESE de l'Oise, Agence de l'Eau Seine-Normandie, Paris.

Aerated lagoons: case of the Adinkerke plant (Belgium)

General information

Adinkerke is located in the Belgian Flanders. The plant in this agglomeration is an aerated lagoon. Aeration uses an air blower. If the biological principles that come into play remain the same, the design of this type of plant is very different from that shown in the technical sheets which use aerators . From an energy standpoint, the main difference with other aerated lagoons systems is the low capacity installed. Therefore we will not cover the details for designing this plant as this is not representative of most of the plants currently in use.

Project description

The plant is made up of three basins in series, the first two are aerated, the 3rd is the finishing basin (settling lagoon). The diagram below shows the different basins and their equipment.

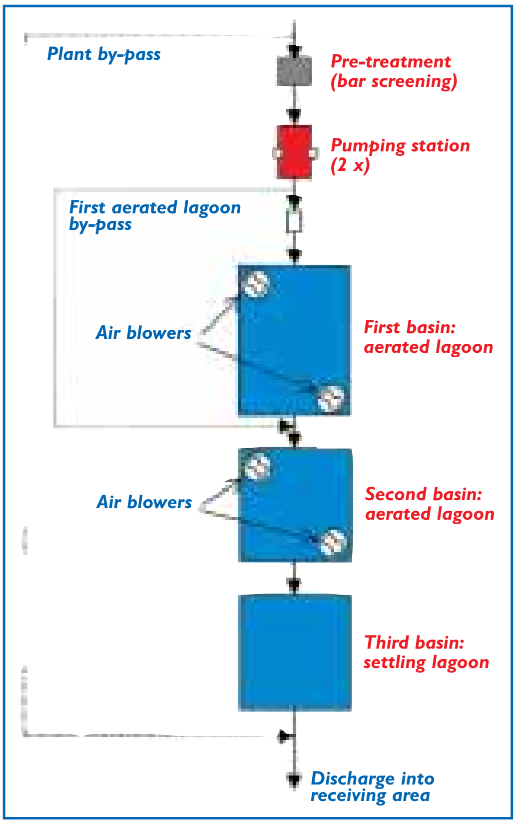


Figure 22: Aerated lagooning in Adinkerke

An aeration tank in the lagoon.

Characteristics of the equipment

Table 23: Characteristics of the equipment

	Number	Type	Dimension
Wastewater pumps	2	Submerged pumps	Flow: 2 x 40 m^3/h Flow: P1+ P2 60 m^2/h
Lagoon basins	2	Aerated lagoons	Total volume: 4000 m^3 Retention time:100 heures Total surface: 1.812 m^2
Aeration devices	4	Air blower (aero-ejector)	/
Settling lagoon	1	Rectangular	Surface: 490 m^2 Volume: 490 m^3 Depth: 1 m

Design

The design of the structures uses the following values:

→ BOD_5 load = 37 kg BOD_5 / day;
hydraulic load = 300 m^3/ day;
maximum flow = 1400 m^3/ day;

Performance

Performance levels, calculated on average values from the 18 measurements carried out in 1999, are shown below:

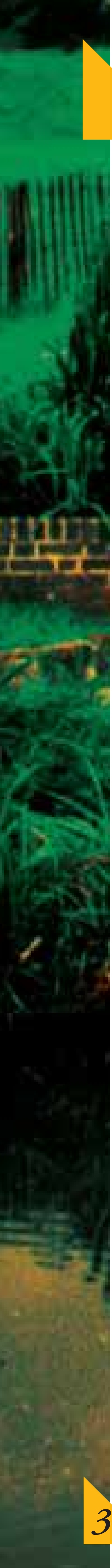
Table 24: Plant performance levels

	BOD_5	COD	Suspended solids	Total nitrogen	Total phosphorus
Waste water coming into the plant: average value over 1999 in mg / l	245,7	744,9	409,5	76,5	11,1
Discharge from the plant: average value over 1999 in mg / l	12,6	76,7	22,3	50,2	1,5
Plant results (in %)	94,9	89,7	94,6	34,4	86,5

It can be seen from these results that this technical approach using air blowers makes it possible to very easily meet the regulations of the "urban waste water treatment" directive.

Bibliographical references concerning aerated lagooning at Adinkerke

Data sent by the AQUAFIN company (Organisation in the Flemish region that designs, finances, constructs and operates the supra-communal infrastructure for the treatment of urban wastewater).



GLOSSARY

Agglomeration	area where the population and/or economic activities are sufficiently concentrated for urban wastewater to be collected and conducted to an urban waste water treatment plant or a final discharge point.
Appropriate treatment	treatment of urban waste water by any process and/or disposal system which after discharge allows the receiving waters to meet the relevant quality objectives and the relevant provisions of this and other Community Directives.
BOD_5:	The biochemical oxygen demand is a measurement of the pollution by organic matter. It is expressed in milligrams of oxygen per day and per p.e. It corresponds to the quantity of oxygen that is needed to oxidise the discharges of polluted effluents produced on average by each inhabitant in a watercourse or by a given agglomeration. This measurement is carried out according to standardised tests after five days of oxidation of the organic matter, hence the term BOD_5.
COD	Chemical Oxygen Demand or COD represents the quantity of oxygen consumed, expressed in milligrams per litre, by the chemically oxidizable matter contained in a discharge. According to the standard method, this is the oxidation by an excess of potassium dichromate (K2Cr2O7) in a fermenting and acidic medium, of the chemically oxidizable matter contained in a discharge. COD is a valuable parameter indicating the presence of pollution in wastewater. It represents the major part of the organic compounds but also oxidizable mineral salts (sulphides, chlorides, etc.). Industrial wastewater can frequently reach COD values of several grams per litre.
Collection system	system of pipes that collects and conducts urban wastewater ie the sewer network.
Denitrification	conversion of nitrates into nitrites then into N_2O or nitrogen gas. Denitrification of urban waste water takes place mainly during tertiary treatment where it takes place partially or totally by microbiological purification and relies anaerobic conditions.
Domestic waste water	waste water from residential settlements and services which originates predominately from the human metabolism and from household activities.
Eutrophication	enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned.
Hydraulic Load	weight h of a column of water with height H above a reference level, expressed in meters of water height.
Industrial wastewater	any wastewater which is discharged from premises used to carry on any trade or industry, other than domestic wastewater and run-off stormwater.
Kjeldahl-nitrogen(KjN)	Sum of organic nitrogen and ammoniacal nitrogen.
MLVSS (Mixed liquor volatile suspended solids)	The measure of sludge(biomass) concentration in the aeration tank of an activ ted sludge plant.
Permeability	capacity of the ground or rocky substrate to let water seep into deeper layers.
Population equivalents (p.e.)	organic biodegradable load that has a five-day biochemical oxygen demand (BOD_5) of 60 grams of oxygen per day.
Primary treatment	treatment of urban wastewater by a physical and/or chemical process involving settlement of suspended solids, or other processes in which the BOD_5 of the incoming waste water are reduced by at least 20 % before discharge and the total suspended solids of the incoming waste water are reduced by at least 50 %.
Secondary treatment	treatment of urban waste water by a process generally involving biological treatment with a secondary settlement or other process in which the requirements established in table 1 of annex I of the directive of 21 May1991 are respected (see table below).

Sludge	residual sludge, whether treated or untreated, from urban waste water treatment plants.
SS (Suspended Solids)	All of the mineral and (or) organic particles that are present as suspended solids in natural or polluted water.
Tertiary treatment	the expression "tertiary treatment" can refer to several types of treatments or different functions with the purpose of reaching a treatment level of higher quality than that which one could normally expect from a secondary treatment. Tertiary treatment can aim for a higher level of removal for conventional parameters such as suspended solids or also concentrate on certain parameters for which there is little removal in a secondary treatment such as phosphorus.

Table 25: Regulations concerning discharges from urban waste water treatment plants and subject to the measures of articles 4 and 5 of the EU directive. The values for concentration or for the percentage of reduction may apply.

Parameters	**Concentration**	**Minimum percentage reduction (1)**	**Reference measurement method**
Biochemical oxygen demand (BOD_5 at 20 °C) without nitrification (2)	25 mg/l O_2	70-90 40 in terms of article 4 paragraph 2	Homogenised, unfiltered, undecanted sample. Determination of dissolved oxygen before and after five-day incubation at 20°C ± 1°C, in complete darkness. Addition of a nitrification inhibitor.
Chemical oxygen demand (COD)	125 mg/l O_2	75	Homogenised, unfiltered, undecanted sample. Potassium dichromate
Total suspended solids	35 mg/l (3) 35 in terms of article 4 paragraph 2 (more than 10000 p.e.) 60 in terms of article 4 paragraph 2 (from 2000 to 10000 p.e.)	90 (3) 90 in terms of article 4 paragraph 2 (more than 10000 p.e.) 70 in terms of article 4 paragraph 2 (from 2000 to 10000 p.e.)	- Filtering of a representative sample through a 0.45 µm filter membrane, drying at 105°C and weighing. - Centrifuging of a representative sample (for at least 5 minutes, with mean acceleration of 2800 to 3200 g), drying at 105°C, and weighing.

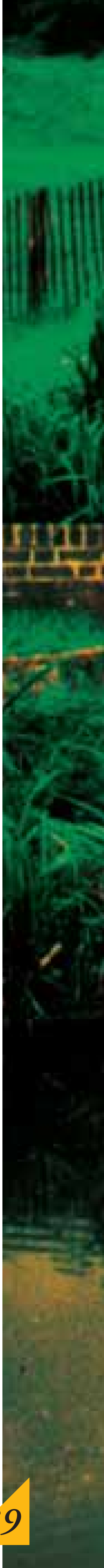
(1) Reduction in relation to incoming values.

(2) This parameter can be replaced by another parameter: total organic carbon (TOC) or total oxygen demand (TOD), if a relationship can be established between BOD5 and the substitute parameter.

(3) This requirement is optional.

Analyses concerning discharges from lagooning shall be carried out on filtered samples; however, the concentration of total suspended solids in unfiltered water samples shall not exceed 150 mgl/l.

Uniformity Coefficient (CU)	CU = d60 / d10 With: d10 = diameter on the cumulative curve for which 10 % of the sand is finer; d60 = diameter on the cumulative curve for which 60 % of the sand is finer. The UC is therefore an indicator of uniformity or, on the contrary, of the irregularity in the distribution of particle size. If UC<2, granulometry is said to be uniform. If 2<UC<5 the sand is heterogeneous but the granulometry is said to be tight since only sands are under consideration.
Urban wastewater	domestic waste water or a mixture of domestic waste water with industrial wastewater and/or run-off stormwater.



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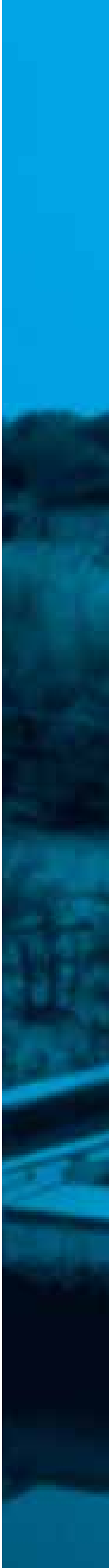

European Commission

Extensive wastewater treatment processes adapted
to small and medium sized communities

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SUMMARY

The Commission's Environment-Directorate General wants to support the distribution of less intensive purifying processes, via the development of technical exchanges and advisories. This guide and the development of aids such as structural funds and cohesion funds are examples of this.

This guide, which was developed within the framework of a group effort with France (Water Directorate of the Ministry of Ecology and of Sustainable Development, and Water Agencies), simply mentions the intensive techniques and concentrates, above all, on the extensive techniques for treating urban waste water. These techniques take up, by definition, more surface area than traditional intensive processes developed for large agglomerations. However, the investments costs for less intensive processes are generally less and the operating conditions of these less intensive processes are simpler, more flexible and allow more energy to be saved. Finally, these techniques require reduced manpower and less specialised manpower than intensive techniques.

They can be applied in the various European configurations that do not exceed a few thousand population equivalents. One must bear in mind when reading this document that the techniques that we are going to cover cannot be used for capacities greater than 5,000 p.e. except in exceptional circumstances.

After a reminder of the objectives to be met by small and medium sized agglomerations and a quick presentation of the different intensive approaches, we will describe the following techniques in more detail:

- infiltration percolation;
- vertical reed beds flow filters;
- horizontal flow reed beds filters;
- natural lagoons;
- aerated lagoons;
- association of different less intensive approaches

In order to help in the choice of an approach, a comparison of these different techniques is carried out on the following criteria:

- quality of the discharges;
- advantages and drawbacks;
- available space;
- permeability of the ground;
- adaptability of the approaches to climatic conditions;
- cost.

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