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Technical note

Wastewater treatment for small communities in Catalonia (Mediterranean region)

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Abstract

An evaluation of small wastewater treatment plants (WWTPs) treating the effluents of communities with <2000 inhabitants in Catalonia (north-east of Spain) was carried out to establish the definition of appropriate wastewater treatment (AWT) and the criteria for the selection of the alternative processes that can achieve the AWT. The implementation of an AWT in these communities before the end of the year 2005 is necessary to comply with the European Directive 91/271. The AWT is that which permits the accomplishment of quality objectives in receiving waters after the discharge of the effluents. The standards for the AWT in each particular case are set out through a contaminant loading balance. Nevertheless, the final applied standards can only be as strict as they are for larger WWTPs. These criteria are very close to those stated in the French legislation, and it is felt that they are at the same time environment-friendly and realistic for small WWTPs. Secondary treatments are generally recommended to achieve the AWT. Natural wastewater treatment systems are preferred over conventional treatments to achieve the appropriate treatment because they are simple to operate, can reach the same level of treatment efficiency and have lower operation and maintenance costs. The policy debate that has produced all these statements is described. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Appropriate waste water treatment; Small waste water treatment plants; Effluent quality requirements; Effluent standards; Water management; Water policy

1. Introduction

European Directive 91/271 (Council of the European Communities, 1991) on urban wastewater treatment states that all the member countries have to take the necessary measures to guarantee

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correct treatment of urban wastewater. The Directive also establishes the effluent standards for the communities of >2000 persons equivalent (p-e) discharging into fresh water or estuaries and that for the communities >10000 p-e discharging into open coastal waters. In the case of communities with <2000 p-e discharging into fresh waters or estuaries and those of <10000 p-e discharging into open coastal waters, the Directive states that an appropriate wastewater treatment (AWT) should be adopted. AWT is defined in the Directive itself in a general manner as a process enabling the receiving waters to maintain their quality standards after discharge.

In Spain, the autonomous regional governments are responsible for the accomplishment of the Directive 91/271. In the region of Catalonia (Fig. 1), the Water Agency developed a Sanitation Program in the mid-80s that will reach completion by the end of the year 2005. Currently, there are about 200 wastewater treatment plants (WWTPs) servicing communities of >2000 p-e (Junta de Sanejament, 1999). The specific program for all these types of communities is almost completed, and currently, the Sanitation Program is focusing on the specific program for small rural areas of <2000 p-e that will be developed in the years 2001–05. The beginning of this specific program has caused a policy debate because the AWT concept as defined in the Directive can have different interpretations. Thus, to have an objective view of the matter in accordance with the technical aspects of the wastewater treatment, the Water Agency requested that the Environmental Engineering Division of the Technical University of Catalonia compile a series of guidelines for the concrete definition of AWT and criteria for the selection of alternative processes to achieve the AWT (Mujeriego & García, 1999). The objective of this note is to present

Fig. 1. Location of the Spanish region evaluated.

both the main recommendations given to the Water Agency and how the standards for the AWT will be met. Also described is the policy debate that has produced these recommendations.

2. Situation of small WWTPs and quality of receiving waters

Table 1 shows the situation of small WWTPs according to a survey conducted in 1997 (Junta de Sanejament, 1997). Although the number of small WWTPs actually needed will probably be lower than the number shown as "under study" in Table 1, it is clear that the sanitation program for small communities will be very complex and will need major investments. Conventional biological WWTPs have been the preferred technology for some time now. Thus, 27 of the 37 WWTPs in operation in 1997 were of this type. The 13 WWTPs in the design phase were natural treatment systems, mostly reed beds and waste stabilization ponds.

The Sanitation Program sets out five different quality levels for continental surface waters in accordance with possible uses (Table 2). It also states which are the future quality objectives for bodies of water when the overall Sanitation Program will be completed. To establish the required quality level for a given body of water, first the probable uses are defined and simultaneously, water quality requirements are set for the parameters of Table 2. The future water quality objectives are mainly those corresponding to levels 1 and 2 for most water bodies. Quality level 3

Table 1
Situation of small WWTPs in Catalonia in 1997 (Junta de Sanejament, 1997)

Persons equivalent (p-e)	In operation	Under construction	Design stage	Under study[a]
<60	—	—	—	450
60–400	8	2	—	870
400	29	23	13	380
Total	37	25	13	1700

[a] Relevant data to 1999 (Junta de Sanejament, 1999).

Table 2
Continental surface water quality levels according to possible uses (Junta de Sanejament, 1996)

Quality Level	Temperature (°C)	Dissolved O_2 (mg O_2/l)	BOD_5 (mg O_2/l)	SS (mg/l)	COD (mg O_2/l)	SWQI[a] Units	Main uses
1	<20	>7	<3	<30	<20	>85	All
2	20–22	5–7	3–5	<60	20–25	60–85	Drinking water
3	22–30	3–5	5–10	<100	25–40	45–60	Irrigation
4	25–30	Present	10–25	<100	40–80	30–45	Cooling
5	>30	Not present	>25	>100	>80	<30	None

[a] Simplified water quality index. It ranges between 0 and 100 units, and it is calculated from five parameters: temperature, COD, SS, DO and electrical conductivity. For each one of these parameters, standard units are defined and this permits to sum the results obtained for the different parameters.

is only accepted for rivers near the metropolitan area of Barcelona. Quality levels 4 and 5 will not be accepted for any body of water in the future. Currently, no body of water corresponds to quality level 5 and only few small rivers belong to quality level 4. Most of the water bodies belong to quality level 1 and it is expected that when the Sanitation Program is complete, the water quality will be excellent in general.

3. AWT for small rural communities

The most important criteria recommended for the definition of AWT for small communities is that overall future quality objectives of the receiving water bodies should be meet. Thus, the AWT is that which will permit the quality objectives to be attained by the receiving waters after discharge of the effluents.

Evaluation of the pollutant mass loading with regard to the overall discharges into a basin is necessary in each case in order to establish the AWT. It is also necessary to analyze the influence of each particular discharge on the receiving waters. When the receiving waters have episodes of low water levels, even to the point of drying up, the objective of the AWT will be to promote public health and to preserve underground waters. In this specific case, the treatment plant designs will have to analyze the feasibility of eliminating discharge to surface waters, or the storage of water during the critical period. The nature of the wastewater collection system, the population served and its variation, the site of construction, the properties and the surface area available, and the financial resources for operation and maintenance (O & M) are the main particular local conditions that should be taken into account for the establishment of the AWT.

Preliminary studies at basin level are planned to help define the AWT. The present situation of the water quality in the overall basin and the WWTPs currently working will be taken into account. In addition to the usual features, the treatment plant design projects will have to include the following: (1) the present quality level of the receiving waters, (2) an evaluation of low water levels during dry periods, (3) the impact of the effluent discharge into the receiving waters in addition to the other known discharges into the basin, (4) the presence of areas of natural interest, bodies of water sensitive to eutrophication, areas with aquatic life of special interest and supply water sources, (5) an evaluation of industrial and agricultural discharges, (6) the need for conduction the effluents to other receiving waters with a higher dilution capacity, (7) the mass pollutant loading during rainy periods, (8) the presence of clean water infiltration to the wastewater collection systems and finally (9) a concrete definition of the AWT that justifies the technical solution adopted.

4. Types of treatments constituting the AWT

The studies conducted at basin level and the definition of the AWT in each particular case will allow establishment of the type (or degree) of treatment adequate for each type of community. Primary treatment as a whole complete treatment process is not recommended. Secondary treatment is recommended for all communities. It could consist of a previous treatment (pretreatment and/or primary treatment) followed by a natural treatment (land systems, waste stabilization ponds, reed beds or peat beds) or a conventional treatment (activated sludge, trickling filters and rotating biological contactors). The level of AWT needed must be carefully considered in cases where the effluent will be diverted to: (1) areas of natural interest or bodies of water sensitive to eutrophication, (2) aquatic areas of biological interest, (3) water bodies used for water supply and (4) water courses with significant shortages. In these cases, the removal of total nitrogen, faecal microorganisms and other contaminants may be necessary in addition to the usual removal of SS and BOD_5.

The main criteria recommended for the selection of the technology for the WWTPs constituting the AWT is simplicity of operation. Priority should be given to technical solutions that use a minimum of operator time and a minimum number of electromechanical facilities. The treatment process should be able to be operated by non-specialized staff. The treatment process should guarantee the effluent water quality, even during short periods of equipment failure. The technology adopted should be reliable enough to absorb high-mass loading waters during certain periods. The technologies that best adapt to these criteria are the low cost or natural treatment systems. Natural treatment systems can obtain contaminant level removals equivalent to conventional treatment systems. Furthermore, they involve lower O & M costs, although the investment required may be higher, especially considering land costs.

The following paragraphs describe a suggested protocol for the Water Agency that permits an indication of the best treatment technology (mainly with respect to natural systems) for each particular case. The results obtained with this protocol are only indicative and are opened to any change that may occur as a result of the specific characteristics of the sites.

The first criterion is the population equivalent served. This criterion allows recognition of three subjective groups of population ranges with certain optimum types of secondary treatment technologies (Table 3). For communities of <50 p-e, it is recommended, in general, that subsurface wastewater infiltration systems (decentralized) be used. Small package wastewater treatment plants can be established if soil conditions are not appropriate for infiltration systems. The population limit of 300 in Table 3 is set out according to the surface area required by slow-rate infiltration systems. For communities of >300 p-e, this technology may require a surface area of >1 ha, which is considered significant in this zone. Nevertheless, this criterion is relative because it depends on the available surface area. The population limit of 1000 is also established according to the surface area requirements of waste stabilization ponds, reed beds and rapid infiltration systems. For communities of >1000 p-e, these treatment systems may require a surface area of >1 ha.

Table 3
Recommended secondary treatment technologies as a function of the population equivalent

Secondary treatments	Range of served population (p-e)		
	50–300	300–1000	1000–2000
Natural treatments			
Slow rate infiltration	×	—	—
Stabilization ponds, reed beds and rapid infiltration	×	×	—
Conventional treatments and peat beds	×	×	×

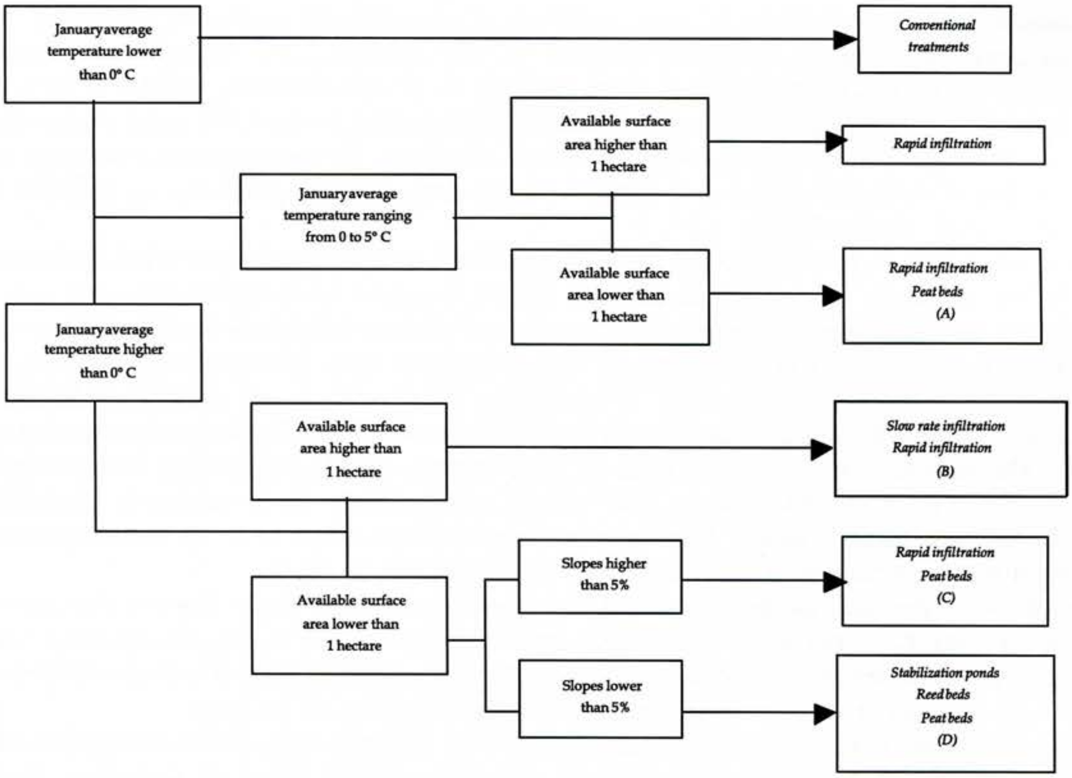

Fig. 2. Diagram for the selection of the appropriate wastewater treatment technology in communities with population ranging from 50 to 300 p-e. Capital letters in brackets correspond to comments made in the text.

For more accurate technology selection, the three ranges of population set out in Table 3 are analyzed separately in terms of the following factors: (1) climatic conditions, mainly the mean temperatures in January (the coldest month at this latitude), (2) available surface area, (3) slope of the area, (4) O & M costs and (5) investment costs. Figs. 2–4 show diagrams that allow the selection of the appropriate treatment technology according to the population range. The local circumstances allow selection of the appropriate technology listed in the right of the diagrams.

In the range of population from 50 to 300 p-e, rapid infiltration systems are preferable to peat beds because rapid infiltration systems have lower O & M costs (Fig. 2A and C). Thus, peat beds are more adequate when the available surface area is small or when soil permeability is not adequate for a rapid infiltration system. When sufficient surface area is available, slow rate infiltration systems are more appropriate than rapid infiltration (Fig. 2B). If the available surface area is <1 ha and the slope is $<5\%$, waste stabilization ponds and reed beds are preferred to peat beds because they have lower O & M costs (Fig. 2D). Waste stabilization ponds have lower investment costs than reed beds.

In the range of population from 300 to 1000 p-e, peat beds are preferable to conventional systems because their associated O & M costs are usually lower (Fig. 3E–G). However, major restrictions in available surface area could only allow implementation of a conventional system.

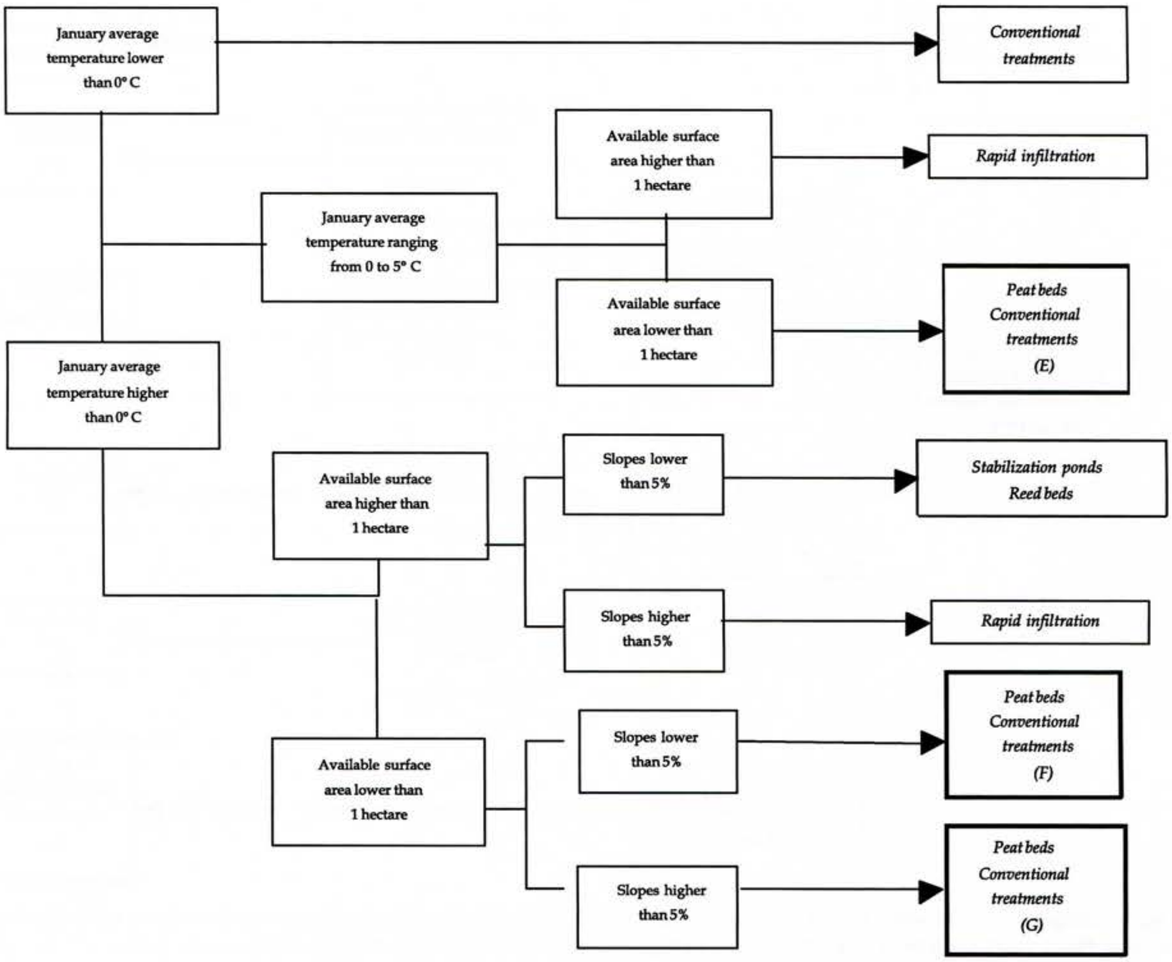

Fig. 3. Diagram for the selection of the appropriate wastewater treatment technology in communities with population ranging from 300 to 1000 p-e. Capital letters in brackets correspond to comments made in the text.

In the range of population from 1000 to 2000 p-e, when the available surface area is > 1 ha, the implementation of a peat bed is always possible, although the alternative of using a rapid infiltration system can be verified (Fig. 4H and K). Peat beds are also preferable to conventional systems according to the surface availability (Fig. 4I and L). When the available surface area is > 1 ha and the slope is $< 5\%$, the construction of waste stabilization ponds may be possible (Fig. 4J).

5. Comparison to other countries and policy debate

The definition of AWT varies among different European countries and in each case is based to the relative importance given to: (1) the characteristics of the effluents in relation to their contaminant load and (2) the future objective quality of the receiving waters. In Italy, the AWT is based in uniform effluent standards independent of the receiving waters. Only more restrictive

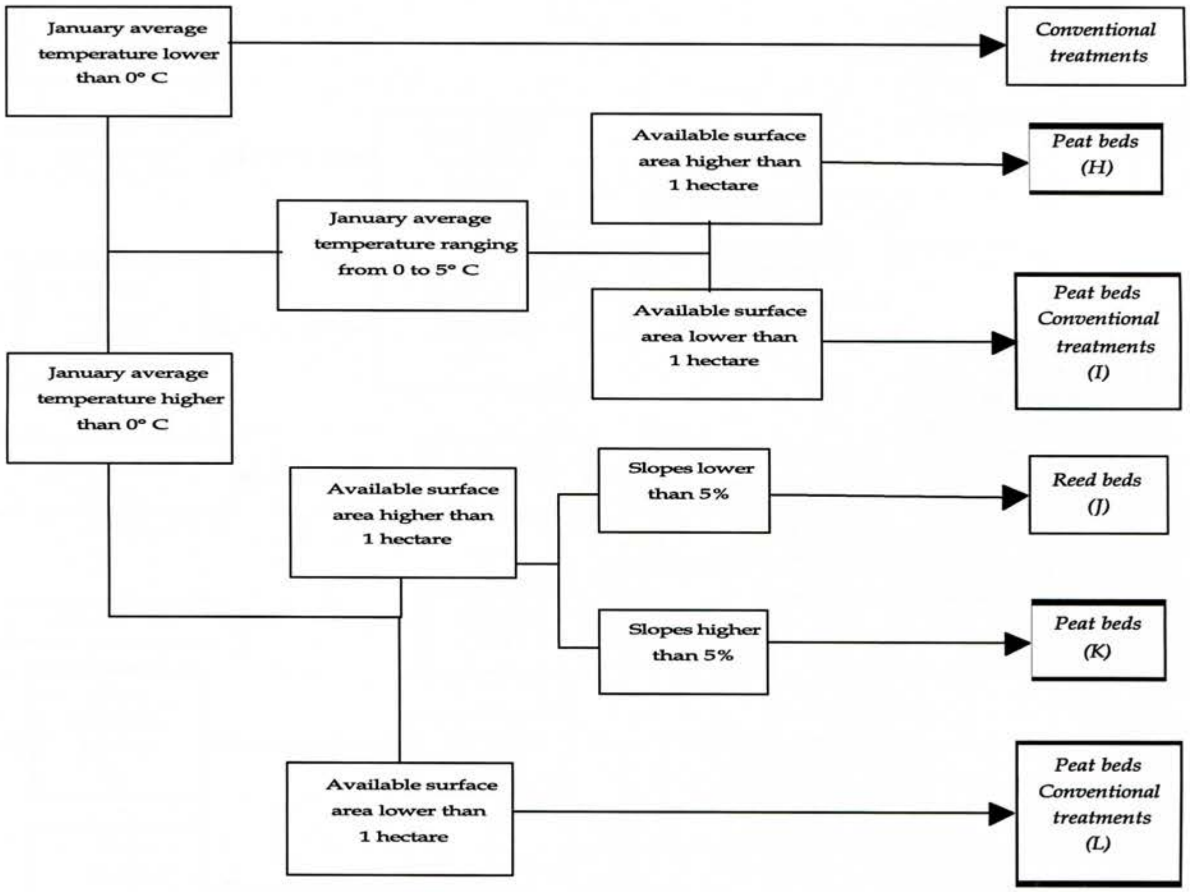

Fig. 4. Diagram for the selection of the appropriate wastewater treatment technology in communities with population ranging from 1000 to 2000 p-e. Capital letters in brackets correspond to comments made in the text.

requirements are set up for lakes sensitive to eutrophication (Chabrier, Brunetti, & Canziani, 1993). In other countries, as in Germany, the AWT standards are established in relation to the contaminant load of the effluents (Bundesgesetzblatt, 1997). In northern countries, such as Denmark and Norway, the definition of the AWT is set up according to the quality objectives of the receiving waters; moreover, the standards vary for the different wastewater technologies (Jansen, Pedersen, & Moldt, 1993; Rusten, Kolkim, & Ødegaard, 1995). There are countries such as France where the AWT definition is based on both the contaminant load of the effluents and the quality objectives of the receiving waters (AESN, 1997). The recommendations given to the Catalonian Water Agency are very similar to those stated in the French legislation. It is considered that this AWT definition is, at the same time, environment-friendly and realistic considering the capabilities of small towns. In most of the European countries, natural wastewater treatments are recommended to achieve the AWT, mainly due to their reliability.

The policy debate that has led to the recommendations given to the Water Agency has focused on three aspects. First, primary treatments alone are discouraged in the recommendations because they are considered as only a partial treatment that does not guarantee public health. However, based on a contaminant loading balance, they could attain the AWT when the effluent is discharged into water bodies with high dilution and high self-purification capacity, and without significant low water levels. Those who consider the primary treatment as a possible alternative argue that if it is not obligatory to reach a secondary treatment level, the application of primary treatments can ease the financing of the Sanitation Program because they need lower investments. Second, in bodies of water with low water levels, the necessary AWT based on a contaminant loading balance could require effluents with more strict limits than those stated in the Directive 91/271 for WWTPs treating waters from communities >2000 p-e. This does not make sense because it is not logical to request a greater effort to the small WWTPs than that of the larger WWTPs. For this reason, in the recommendations, it is stated that the standards of the small WWTPs can only be as strict as the standards for larger plants. This situation is realistic for the small towns, although it is not the most environment-friendly option. Finally, the debate has focused on the choice of appropriate technologies: natural versus conventional treatments. The recommendations given to the Water Agency encourage the construction of natural treatments, if possible, in detriment of the conventional treatments. Nevertheless, some technicians doubt of the efficiency of natural treatments mainly because there is not much experience in Catalonia with this type of systems. The authors feel that the experience of more than 30 years of operating natural systems in other countries of Europe and around the world is enough to guarantee the reliability and successful operation of these systems. Natural treatment systems are a realistic option for small towns. Conventional mechanic treatments require highly trained operators, complex equipment and expertise practice that can be difficult to meet in small towns.

6. Conclusions and summary

The AWT in Catalonia permits the quality objectives to be met in receiving waters after the discharge of the effluents, and it is based on contaminant loading balances. Nevertheless, the standards for AWT can only be as strict as they are for larger plants. These criteria are very close to those stated in the French legislation, and it is felt that they at the same time environment-friendly and realistic considering the capabilities of small WWTPs.

The main criteria for the selection of the technology constituting the AWT are: simplicity of operation of the WWTP, reliability of the effluent quality and O & M costs. Natural treatment systems best meet these requirements. However, although there is much successful experience in Europe with these systems, some technicians still doubt of their efficiency.

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