Constructed Wetlands and Waste Stabilization Ponds for municipal wastewater treatment in France: comparison of performance and maintenance operations in terms of durability and reliability

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Abstract
In France, vertical flow constructed wetlands and waste stabilisation ponds are both extensive treatment processes well adapted to small rural communities mainly because they are easy to operate and their performance is reliable. Most of the time, the effluent has a better quality than required by legislation; even if WSP performance can be affected by seasonal variations, especially as regards nutrients. For VFCWs, nitrate concentrations remain high due to the fully aerobic conditions prevailing in the 2nd stage filters. In the 1st stage filters only a little denitrification can occur in the drainage layer when water is temporarily stored to batch feed the 2nd stage filters. For both processes the removal of sludge accumulated in the first pond/filters is only necessary every 10 years or more at nominal load. Dry matter content of the sludge removed from VFCWs is obviously higher than that from ponds. For both processes annual routine maintenance operations for a plant designed for 400 p.e. requires approximately 100 hours of presence at the plant by a member of the municipal staff. For a 1000 p.e. WSP plant, less time is needed than for a VFCW plant, because of the annual harvesting of the aerial part of the reeds. Once sludge is removed, these plants are ready to perform a new cycle of operation without having to change any electro-mechanical equipment. This contributes greatly to the reliability of performance.

Keywords
Vertical Flow Constructed Wetlands, Waste Stabilization Ponds, operation and maintenance, sludge management.

INTRODUCTION

Waste Stabilization Ponds [WSPs] and Vertical Flow Constructed Wetlands [VFCWs] are not equally developed in France at the moment (the total number of WSP plants can be estimated at 2500 to 3000, which means approximately 10 times more than CW plants) due to the relative youth of the latter technique which is however growing fast. Nevertheless, they are both considered as well adapted for wastewater treatment for most small communities in France mainly due to their simplicity of operation and maintenance. It is particularly the case when topography allows gravity feeding which can be carried out by a willing member of the municipal staff without any particular electromechanical engineering skills. Comparison of maintenance operations will be considered in this paper.

Table 1. Main characteristics (differences and similarities) of VFCWs and WSPs in France

	VFCWs	WSPs
Energy consumption	No	No
Type of treatment	Attached growth cultures on fine media	Suspended growth cultures
Brief description and usual dimensioning	1st stage: 3 VF filters in parallel (total: 1.2-1.5 m^2/p.e.) 2nd stage: 2 or 3 filters in parallel (total: 0.8-1.0 m^2/p.e.)	1st pond: facultative (6 m^2/p.e.) 2nd and 3rd: maturation (2.5+2.5 m^2/p.e.)
Footprint for 400 p.e.	2600 m2	6000 m2
Type of sewerage network	Separated or partially combined	Combined or very partially separated
Treatment objectives ("French circulaire", 1997)	25 mg/L BOD_5 and 125 mg/L COD	60 % COD and 60% KN
Design and building	Relatively complex	Relatively simple
Difference in height for gravity feeding	minimum 4m (depends on size)	1m
Range of use in people equivalent (p.e.)	50 p.e. to 2000 p.e. (a few larger, 3500 p.e. maximum)	200 p.e. to 2000 p.e. (some much larger in summer tourist areas)
Aesthetic aspects	Good	Good

This paper will examine both processes and explain in what way regular and episodic maintenance operations are important in order to achieve optimal performance.

COMPARISON OF PERFORMANCE AND PROCESSES

From Tables 2 and 3, one can see that performance of both processes comply with and most of the time exceed specified discharge limits mentioned as "treatment objectives" in the Table 1.

WSPs

Table 2 shows results that are well within the limits even if the standard deviation [SD] is considerable, mainly due to seasonal influences. The variations are particularly noticeable for nutrients whose removal is very dependent on phytoplankton growth that is obviously more effective in summer. From Figure 1, one can see that summer favours all these processes when water temperature is sufficiently high and pH increases to about 9 when light allows algal photosynthesis. Nevertheless, biomass assimilation is not the only process which ensures nutrient removal, even if it is probably the most important for both nitrogen and phosphorus.

Table 2. Removal by WSPs: Assessment of plants fed from non separated sewerage systems. (Cemagref *et al.*, 1997)

	COD		CODf		SS		TKN		TP	
	% Removal	Outlet $mg.L^{-1}$	% Removal	Outlet $mg.L^{-1}$	% Removal	Outlet $mg.L^{-1}$	% Removal	Outlet $mg.L^{-1}$	% Removal	Outlet $mg.L^{-1}$
Mean	78	141	86	85	79	54	72	19	66	7.5
SD	*16*	*69*	*9*	*37*	*20*	*41*	*23*	*11*	*24*	*6.0*

Removal in flux [(load inlet – load outlet)/ load inlet]; SD: Standard Deviation

Stripping of gaseous ammonia, nitrification and almost simultaneous denitrification play a significant role (Middlebrooks *et al.*, 1982). However, it must be noted that for WSPs, TKN concentrations represents total nitrogen concentration due to the fact that there is almost no

occurrence of nitrate in WSPs basins. Denitrification starts almost simultaneously in the depths of the water column where the number of algae and oxygen levels decrease.
Only retention of organic nitrogen, which is part of the suspended solids that settle near the inlet point, is little dependent on seasonal variations.

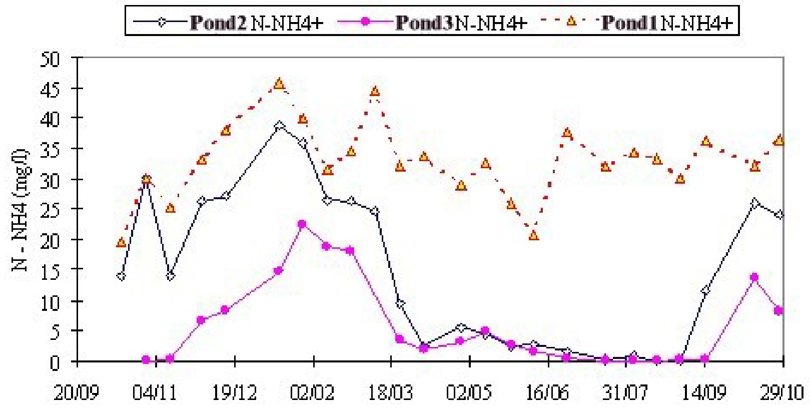

Figure 1: Seasonal changes in the ammonia concentrations at Saint Pierre d'Aurillac WSP treatment plant (Racault *et al.*, 1996)

Additionally, a national survey, showed that organic load has little influence in summer when concentrations in N-NH_4^+ very often remain under 15 mg/L. This can be seen as opportune considering that receiving waters are more sensitive to this parameter in summer (April to September).
Figure 1 showing concentrations of ammonia measured in each basin of a WSP plant at regular intervals for one year confirms a clear difference in seasonal behaviour: ammonia reduction is less in winter. This monitoring of concentration was done for a study related to pond malfunction (Racault, 1993).
Due to anoxic/anaerobic conditions prevailing in the first basin at that time, oxidation of nitrogen compounds was not as effective as expected and this partly explains why the ammonia concentration in this basin remains stable. The following ponds ameliorate this malfunction and one can see that the quality of the effluent is good. Additionally, Racault *et al.*, (1995), report a noticeable effect of organic load on ammonia concentrations in winter.

VFCWs
Table 3 shows the results of a recent survey on VFCWs (Molle *et al.*, 2004). Except for phosphorus, which is not retained by the granular siliceous media of the filters, all the average concentrations reported are lower than those for the WSP plants which are presented in Table 2.

Table 3. Performances of VFCWs (48 plants between 0.2 and 7.2 years of operation)

	COD		BOD		SS		TKN		TP	
	% yields	Outlet $mg.L^{-1}$	% yields	Outlet $mg.L^{-1}$	% yields	Outlet $mg.L^{-1}$	% yields	Outlet $mg.L^{-1}$	% yields	Outlet $mg.L^{-1}$
Mean	88	88	94	17	94	16	82	13	30	7.9
SD	16	50	8.3	25.5	9.3	27	20.5	17	89.3	6.9
(N)	(108)	(122)	(106)	(119)	(109)	(122)	(108)	(120)	(109)	(118)

Mean hydraulic loads of 0.37 $m.d^{-1}$ (SD: 0.46; min :0.09; max 2.91) and a mean COD load of 200 $g.m^{-2}.d^{-1}$ (SD: 234; min: 17.3; max: 1677) on the first stage in operation.

Ammonia and organic nitrogen are very well oxidised in VFCWs which means that high concentrations of nitrate salts remain in the discharged effluent, especially after passing through the 2nd stage filters that complete the nitrification which began in the 1st stage filters. This is because 2nd stage filters are in fully aerobic conditions.

Denitrification only occurs at the bottom of the 1st stage filters where effluent is temporarily stored for the self-priming of the siphon that batch feeds the distribution network on the surface of the 2nd stage filter in operation. Denitrification is initiated by residual biodegradable carbon compounds which remain in the drainage layer of the 1st stage filters. However denitrification is not complete as can be seen from the remaining nitrate concentrations in Table 4 which presents data from the Colomieu VFCW plant given by Molle (2003). This shows the behaviour of nitrogen compounds related to nitrification and denitrification at each stage. 24h composite samples were taken after 7 days of operation of the same filters at the 1st and 2nd stages (day 7: hydraulic load: 95% organic load 110%). Results from the outlet of 2nd stage filters highlight the good level of nitrification which always tends to minimize the remaining concentrations of reduced nitrogen compounds at the outlet.

Another day 7 reading (marked 7th*) from another week with high hydraulic load (up to 350%) emphasises the reduction of nitrification on the 1st stage filters which have a height of organic deposits on the surface (about 8cm) which slightly diminishes the infiltration rate. So, the conjunction of both a higher hydraulic load and a lower infiltration rate limits the oxygen diffusion from the atmosphere. Nitrification is reduced and the removal rate of denitrification is obviously limited by lack of nitrates comparable to previously published data from the Montromand plant (Boutin *et al.*, 1996). Even with such high hydraulic loads the remaining TKN and ammonia concentrations in the discharged effluent remain low due to the nitrification which continues in the 2nd stage filters.

Table 4. Follow-up of nitrogen compounds at Colomieu VFCWs plant (concentrations in $mg.L^{-1}$, plus % removal)

	Influent		Outlet 1st stage filters		Outlet 2ndt stage filters	
Day	7th	7th*	7th	7th*	7th	7th*
TKN	75.60	29.10	17.90 (76 %)	19.90 (32%)	0.72 (96%)	3.5 (82%)
$N\text{-}NH_4^+$	51.60	13.00	14.00	10.70	0.06	2.7
$N\text{-}NO_2^-$	0.07	0.02	0.81	0.13	0.05	0.13
$N\text{-}NO_3^-$	0.00	0.00	8.05	0.97	25.30	16.3
TN	75.67	29.12	26.76 (65%)	21.00 (28%)	26.07 (2.5%)	19.93 (5.1%)

Despite the Standard Deviation values reported in Tables 2 and 3 from a relatively statistically large sample, the reliability of performance for both processes should be noted.

For WSPs, this is mainly the result of a very long hydraulic retention time that allows the growth of a complex food chain whose development increases from one pond to another and allows the purification effect to become more and more efficient at the same time.

For VFCWs, when the plant is properly designed and the water is able to cross the filter media, the quality of the effluent is relatively good. In addition as illustrated by the related tables above, biological activity is very active and probably stimulated by a symbiosis which takes place in the root zone of the reeds.

SLUDGE ACCUMULATION AND HANDLING

This section will only focus on a comparison of the estimated sludge volumes produced by each process, based on the example of sludge removal from a VFCW at Gensac la Pallue (Molle *et al.*, 2004) and a dozen case studies concerning the removal of sludge accumulated the first pond for WSPs (Racault *et al.,* 2004).

The most important value appears to be the dry matter content which results from the accumulation and mineralization processes after an almost equal operation time, estimated to be 8.5% for WSP and 25% for VFCW.

On the other hand, even though the quality and loads of influent per capita of the two processes are very similar, the quantity of dry matter remaining in the first pond is approximately double that of a VFCW.

Table 5. Comparison of sludge accumulated in VFCWs and WSPs

	VFCWs	WSPs
Height of sludge when removed	22.5 cm	25.5 cm
Total time of operation	14 years	Approximately 13 years
Dry matter content	2 samples: 21.7% and 28.4% Average: 25%	12 samples: 0.8 % to 14.2% Average: 8.5%
Height of sludge accumulated	Approximately 1.5cm/ year	Approximately 2.0cm/year
Volume taking in account the design criteria	Approximately 20L/p.e./year	Approximately 110L/p.e./year
Kg of dry matter	Approximately 6 kg/p.e./year	Approximately 12 kg/p.e./year

The following hypotheses could explain such a difference:
- on VFCWs, as already explained by Molle et al. (2004), the thin layer of sludge accumulated each week is almost all the time in direct contact with the atmosphere and thus aerobic mineralization can quickly take place in relatively dry matter (once in rest period, the accumulated deposits loose a part of their water content by gravity). The mineralization rate achieved is approximately 60%. In the bottom of WSPs, the redox potential obviously tends to favour anaerobic processes of mineralization. However, the microbial activity must take place in a water-saturated environment that does not favour the mineralization process (enzymes and other microbial excreta are diluted). For the same load as applied to a VFCW, the mineralisation in a WSP would account for approximately 20%.
- the rhizosphere effect is not well documented but it can have a positive influence on the mineralisation processes. In the 20 cm of organic deposits, multiple recycling of organic matter occurs in the living biomass during the ten or more years of accumulation. Additionally, one must consider that the aerial part of the reeds is produced from these organic deposits in constant transformation. This vegetation is harvested each year and removed, this surely contributes to the limitation of the increase of sludge deposits. It would be interesting to take measurements from non-harvested filters to determine the increase of the height of the sludge deposits (and their principal chemical composition) compared to those observed up to now on plants in operation.

OPERATIONAL CONSTRAINTS

Tables 6 and 7 present the entire set of operations that are necessary to achieve the best performances for each type of treatment.
3 different colours of cell are displayed:
In light grey: routine tasks that are common to both processes.
In white: tasks that are necessary for VFCWs.
In grey: tasks that are necessary for WSPs.

The maintenance operations reported below are thought to be necessary in order to achieve optimal treatment and attain the expected durable and reliable performances. In other words, these tasks may have a direct effect on the process if they are not done properly. Of course, each task does not carry the same weight but one must consider that in general lack of attention must surely affect the functioning of the plant in the long term.
For sludge management, for both processes, it should be noted that in addition to a difference in frequency, this task requires appreciably more material means (tractor, loader-backhoe, liquid manure vacuum tank, etc.) and at least 2 people at the same time if it is to be done correctly. In addition, the time for spreading the sludge on agricultural land is not included in the figures in the following tables.
All the duration times in the related tables are expressed as actual presence at the plants independently of travel and rest breaks.

Routine tasks common to both processes

Cleaning of the bar screen: Upstream of the plant a bar screen must be installed to retain large solids which may have an aesthetically detrimental effect (if they remain on the surface of the first WSP) or block the feeding system (siphon for CW). When the bar screen is correctly sized weekly maintenance is sufficient. In hot weather, however, frequent inspection of the bar screen will prevent the release of odours particularly when the quantity of waste increases due to tourists, for example. Screening debris must be evacuated with municipal solid waste.
Vegetation cutting on the dykes and surroundings: For WSPs it is recommended that the crest of dykes is at least 4 metres wide so as to be approachable by a tractor and different equipment such as liquid manure vacuum tanks and clearing machines. Cutting the grassed areas 3 to 5 times a year represents a considerable amount of work, especially when you take the area between the dyke and the water, and the slope, which is usually 1:2.5, into account. For large WSPs, it is better to use agricultural machines that have larger cutting widths than gardening tools such as lawnmowers and strimmers.
On the other hand the latter are more suited to the maintenance of the immediate surroundings of VFCWs for which the dykes are narrower or even non-existent when a simple partition isolates 2 adjoining filters at each stage.
General inspection of the basins/filters and on-going operational records: A logbook where observations such as the date, time, weather conditions and maintenance of pre-treatment work is of great importance in order to monitor plant function over time. This document also allows a yearly assessment of the time required for maintenance to be made and thus budgeting and is of great help if technical assistance is necessary.
Specific items for each process should be recorded:

For WSP:
- Correct flow of water (lowering water levels) should be noted and the communication devices between the basins inspected and cleared when necessary,
- State of the embankments (erosion, rodent damage, …) and repair,
- Colour of water, which should normally be green (a change in colour may be an indication that a particular species of microorganism is developing),
- Offensive smells that indicate possible overloading,
- Presence of ducks or geese, which can be an efficient biological control of the development of duckweed.

For VFCW:
- Functioning of the self-priming siphons and valves, some parts such as flexible tubes must be regularly changed and/or spare parts immediately available,
- Correct distribution of the water over the filter in operation at each stage must be considered in relation to the equality of distribution and cleaning of the system,
- Height of the deposit on the first stage filters, a significant difference may indicate an inappropriate distribution of the influent,
- Development of the reeds, infestation by weeds: one year after planting the development of reeds is generally homogeneous and dense. Any significant difference may also indicate an inappropriate distribution of the influent, especially on the second stage filters where there is generally little water in the sand layer at the top of the filters if the granulometry is correct,
- Nitrate and ammonia tests at the end of a feeding period. Optimal functioning of a VFCW produces nitrate and any lowering of the concentration of nitrate or increase in ammonia reflects a lack of oxygen, which may indicate an overload or a problem which may become more important in the near future. This check can easily be carried out using test papers.

Specific task for VFCWs

Grease accumulation: Grease is generally retained in the 1st stage temporary storage tank where the siphon is installed. Regular cleaning with a nozzle is generally sufficient to avoid accumulation of big deposits of fat that might block the siphon tubes. As a result of expertise, designers have progressively increased the diameter of the siphons to obtain reliable functioning without frequent cleaning of the storage tank. In this way, fat mixed with organic deposits can mineralise on the first stage filters.

Gate operation: This task is absolutely fundamental in order to create alternate periods of feeding and rest which are necessary:

i) to control the growth of the attached biomass on the filter media (pea gravel for 1st stage, sand + pea gravel for 2nd stage filters) and rhizomes and roots of the reeds,

ii) to mineralise the organic deposits resulting from the total suspended solids contained in the raw sewage retained at the surface of the 1st stage filters,

iii) to maintain aerobic conditions within the filter bed.

Checking and cleaning of the distribution system on 1st and 2nd stage filters: A good distribution of the wastewater to be treated is necessary to prevent clogging of overloaded zones and inefficient short-circuiting due to lack of biomass and reeds in under-loaded areas. The design of siphon and distribution network must allow good distribution over the whole area and a sufficient delivery rate at any one inlet point to prevent too rapid a sedimentation of suspended solids. Episodic cleaning is sometimes necessary and particularly after the annual cutting of the reeds when unwanted vegetation can limit the flow of some holes of the distribution network.

Table 6. Normal operation of VFCWs

Task	Frequency	400 p.e.		1 000 p.e.	
		Duration of each operation	Total per year (hours)	Duration of each operation	Total per year (hours)
Gate operation, control of the siphons	2/week	5 min.	9	5 min.	9
Preliminary treatment: bar screen	1/week	10 min.	9	10 min.	9
General inspection of the filters, weed control	1/week	10 min.	9	15 min.	13
On-going operational records (number of batches, NO_3^- and NH_4^+ tests, …)	1/week	15 min.	13	20 min.	18
Vegetation cutting on the dykes and surroundings	6/year	4 hours	24	8 hours	48
Check-up and cleaning of the distribution system 1st and 2nd stages	2/year	2 hours	4	3 hours	6
Cleaning of the manholes	2/year	1 hour	2	1.5 hour	3
Cutting and disposal of the reeds	1/year	30 hours	30	80 hours	80
Extraction of sludge on the first stage filters*	1/10 years	30 hours	3	60 hours	6
Total annual amount (hours)			**103**		**192**

* These relatively short times are given from the experience of sludge withdrawal in Gensac la Pallue where the topography is flat and the space between filters allows easy use of tractors which can also land spread the sludge close by. It would take longer for plants which are less accessible because of the slope for example. Such aspects should be taken into account at the design stage. For up-to-date plants it is also necessary to dismantle the distribution device to facilitate the use of the backhoe.

Cleaning of the manholes: The drainage layer of the filters is made up of pebbles in which a network of plastic drains (minimum diameter 100 mm) is placed. These drains are connected to manholes that may be common to adjoining filters. At the outlet of 1st stage filters, the siphon that will ensure the batch functioning of 2nd stage filters is placed in manholes. A little sediment will accumulate (partly from biomass degradation but mostly from vegetation when caps are opened) and must be flushed at the same time as the distribution network is cleaned.

Cutting and disposal of the reeds: Every year at the beginning of winter the faded aerial part of the reeds is cut and removed from the filters of both stages. This operation is more important for the 1st stage filters where it limits the increase of the deposits (about 15 mm height per year) that are mainly due to TSS from wastewater. On the 2nd stage filters, it is an opportunity to verify that the holes in the distribution network are not blocked and to clean it. In cold regions, even if cutting takes place when vegetation is still standing, the cut vegetation can be left in place to ensure a kind of insulation of the surface of the filters. The remainder will be taken away the next spring early enough to avoid damage to new shoots which will arise from the sludge. As opposed to cutting of macrophytes in ponds, this task is fairly easy to do because of the possibility of standing dry foot on the filters.

- *Sludge removal of the 1st stage filters*: Based on the experience at the Gensac la Pallue plant (Molle *et al.,* 2004), it has been estimated that the sludge height increases at about 15 mm per year for the conditions prevailing in this plant. If the design of the filters is correct in relation to expected hydraulic loads, the removal of sludge is not necessary more than every 10 years at nominal load. There should be enough height between the infiltration surface and the distribution inlet points to accommodate both build-up of sludge over ten to a dozen years and temporary excess water during peak hydraulic loads.

The sludge removal can be done easily with a loader-backhoe equipped with an excavating bucket sharp enough to cut the roots and rhizomes without disturbing the layers of the filtration media of the filters. Particular attention must be paid to access for this equipment from outside the filters to prevent compaction of the granular media colonised by biomass.

Specific task for WSPs

Cleaning of the grease trap: At the beginning of the first pond, a simple grease trap with a scum board has often been installed to hold back floating material such as grease or debris. These days this grease trap is often installed above the deeper area at the head of the 1st pond (see below).

Sludge removal from the deeper area: The correct up-to date design of WSPs in France should include a deeper area (extra depth) at the beginning of the 1st pond. It is to facilitate the extraction of primary sludge that accumulates as a sedimentation cone near the inlet point. This zone can occupy some dozens of m^2 for small sized ponds and approximately 0.5 % of the surface of big ponds. Ideally, it should be reachable with a liquid manure vacuum tank for easy withdrawal each year. The maximum recommended depth is 2 meters.

Rodent prevention: if water rats and/or coypus proliferate deterioration of the embankments will quickly follow. The presence of burrows is a sign. The solution is to perform regular maintenance and, if necessary to set traps or employ hunters.

Sludge removal from the whole first basin: After about thirteen years of operation under French organic loading conditions the complete cleaning of this pond may become necessary. The decision to clean out the pond requires a diagnosis of the state of sludge accumulation. Such bathymetry of the deposits is generally made by local surveillance organisations (SATESE). After short-circuiting the flow of wastewater to the following basins, the removal of the sludge can start. Based on a questionnaire sent to some skilled SATESE operators (Racault et al., 2004) it appears that the 2 preferred methods are:

- pumping the supernatant water into the other basins and pushing the sludge with a wetlands bulldozer to a place where it can be easily pumped out with vacuum equipment
- a floating platform is used to guide a pump which evacuates the sludge directly into a liquid manure vacuum tanker.

The sludge extracted can be spread on agricultural land if its quality complies with threshold values required by the regulations.

Table 7. Operation of WSPs

Task	Frequency	400 pe: Duration of each operation	400 pe: Total per year (hours)	1000 pe: Duration of each operation	1000 pe: Total per year (hours)
Preliminary treatment: bar screen + grease trap	1/week	20 min.	17	25 min.	22
General inspection of the basins	1/week	15 min.	13	20 min.	17
On-going operational records	1/week	10 min.	9	10 min.	9
Vegetation cutting on the dykes and on the edges of the ponds	3 to 5/year	8 to 13 hours	40	11 to 18 hours	55
Rodent prevention	All year round	4 hours	4	6 hours	6
Extraction of sludge in the sedimentation cone (at the entrance of the first basin)	1/year	8 hours	8	13 hours	13
Extraction of sludge in the whole first basin	1/13 years	12 days	7	20 days	12
Total annual amount (hours)			98		134

Note: Time needed for possible duckweed harvesting is not included.

From comparison of Tables 6 and 7, it can be seen that the total time of operation in one year for small sized plants is roughly the same for both processes. On the other hand the difference tends to increase in favour of WSPs as the size of the plant increases. This is mainly due to the recommended harvest of the aerial part of the reeds which has to be cut every year and which accounts for approximately 40% of the annual time needed for a plant designed for 1000 p.e. instead of 30% for the 400 p.e. size. The time for this task cannot be easily reduced because the type of equipment necessary is the same and this operation has to be done manually.
On the other hand, the cutting of the vegetation on the dykes of WSPs, which also accounts for a large part of the total annual amount, can be done with agricultural equipment which tends to minimise extra time needed by higher productivity.

CONCLUSION

Even if they are not capable of achieving the same performance as activated sludge plants, many studies report quite acceptable levels of effluent quality of both WSPs and VFCWs. These good performances are also confirmed by the data presented in this paper. However, what the operators are most interested in is the reliability of performance. This is not as dependent on complex and rigid operational constraints as are many other conventional/intensive processes. Once they are properly designed and built, the probability of malfunctioning is low.
If concentrated wastewaters do not enter WSPs and exceed the oxygenation capacity of the system, there is little to be done at frequent and regular intervals which can have a direct effect on performance, except cleaning the bar screen. Nevertheless, annual removal of the sludge from the extra depth must surely contribute to the reliability of functioning.
This observation can be explained by the complex purification mechanisms involved in the different basins where equilibrium between bacteria, algae and zooplankton constitutes a biocenose with an important buffer effect favoured by a long hydraulic retention time (more than 70 days on average) dependent only on climatic conditions.
Once in operation functioning of such WSPs cannot be altered and the dimensioning, design and building must be well adapted to the project for which they are set up (particularly non concentrated wastewaters to ensure that aerobic conditions will dominate all the time).

In contrast, due to the compulsory alternate feeding of VFCWs, very brief but regular and frequent operation of the gates of each filter of the 1st stage, and to a lesser extent of the 2nd stage must be done. At the same time correct functioning of the siphons has to be checked to ensure the batch feeding necessary to achieve a good distribution.
The recommended alternate feeding regime of the 1st stage filters is to change twice a week taking into account that in most cases the rest period is double the feeding one. However the person in charge of the operation has, to a certain extent, the choice in adapting this rhythm according to local constraints.
This alternate feeding is of utmost importance to avoid clogging which depends directly on the correct aeration of the filters. Additionally, the batch feeding provided by the self-priming siphon also increases the aeration of the media of the filter in operation. One also needs to understand that the mechanical action of the reeds, which creates a ring around each shoot where water can infiltrate, is considered to be very important in allowing a constant relatively high infiltration rate. Such action to stimulate infiltration is considered to be much more important than their direct contribution by the oxygen released by their roots in the global aeration process.
Compared to mechanical intensive processes, the real possibilities of malfunctioning are slight and cannot give a worse result than loss of sludge from the clarifier that could occur in an activated sludge plant, for example. Even if only physical processes occurred, they would be sufficient to provide a better quality effluent.
Another positive aspect of both these systems is that once sludge is properly removed from the ponds/filters, they are ready to perform a new cycle of operation. No electro-mechanical devices have to be changed. This must surely mean lower operation costs as well as a reliability of performance which is not negatively affected by episodic non-functioning of such equipment.

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Filtres plantés de roseaux à flux vertical et lagunage naturel en traitement d'eaux usées domestiques en France : comparaison des performances et des contraintes d'exploitation en terme de pérennité et fiabilité

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Résumé

En France, les filtres plantés de roseaux à flux vertical et les lagunages naturels sont tous deux des systèmes de traitement extensifs bien adaptés aux petites communes rurales essentiellement parce qu'ils sont faciles à exploiter et que leurs performances sont fiables. La plupart du temps, l'effluent rejeté est de meilleure qualité que les niveaux minimums requis par la réglementation [respectivement D4 et D3 de la circulaire du 17 février 1997], même si la qualité de rejet d'un lagunage peut être affectée par des variations saisonnières, particulièrement les concentrations en nutriments. En sortie des filtres plantés, les concentrations de nitrates sont élevées en raison des conditions fortement aérobies qui prévalent dans les filtres du 2ème étage. Dans ceux du 1er étage, une légère dénitrification peut intervenir à la base des filtres quand l'eau est temporairement stockée pour alimenter le siphon qui réalise les bâchées sur les filtre du 2ème étage. Pour les 2 procédés, l'extraction des boues accumulée dans la 1ère lagune ou sur les filtres du 1er étage est seulement nécessaire à échéance d'une dizaine d'années à charge nominale. Le teneur en matière sèche de la boue extraite des filtres plantés est d'évidence plus importante que celle des lagunes. Pour les 2 procédés, les tâches routinières d'exploitation pour une station de 400 équivalents-habitants représentent environ 100 heures de présence annuelle du préposé. Pour un lagunage naturel de 1 000 EH, il faut consacrer moins de temps que pour des filtres plantés de roseaux de taille équivalente à cause du faucardage annuel des roseaux qui n'est guère réductible. Quand les boues ont été extraites des zones adéquates, ces stations sont prêtes pour un nouveau cycle de fonctionnement sans avoir à changer un équipement électromécanique et cela contribue fortement à la fiabilité des performances épuratoires.

Mots-clés

Filtres plantés de roseaux à flux vertical, lagunage naturel, fonctionnement et exploitation, gestion des boues.