Wat. Sci. Tech. Vol. 27, No. 9, pp. 97–104, 1993.

0273–1223/93 $24·00

WASTEWATER TREATMENT BY INFILTRATION BASINS. CASE STUDY: SAINT SYMPHORIEN DE LAY, FRANCE

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ABSTRACT

Domestic wastewater treatment by infiltration basins is a process that is becoming common in France. In the absence of accurate operating data, we felt it would be useful to conduct a case study at an existing plant. The Saint Symphorien de Lay plant, serving a population-equivalent of 500, was chosen because the basins are watertight and drained.
The study revealed 85% TSS, COD and Total Phosphorus removal. Nitrogen yields varied over the flooding period, with a high production of nitrates at the beginning of the period. The rate of decontamination (1 to 2 Log unit) was lower than expected.
The infiltration surface should increase from 1 to 1.5 m^2/p.e. and spread over three basins. Research is now focusing on finding the biologically active depth of an infiltration basin.

KEYWORDS

Wastewater, Small treatment plant, Infiltration-percolation, Sand filtration, Batch feeding, On-site study.

INTRODUCTION

One of the oldest methods of wastewater treatment is for effluent to be poured over the soil and the pollution broken down by the biological processes occurring during infiltration. This method, known as infiltration-percolation, was first used 2,000 years ago in the city of Athens, where the Ancient Greeks used to spread their wastewater over the fields (LEFEVRE, 1988). Closer to modern times, Sir Edward Franklin (1870), followed by Sedgwick (1902) laid the foundations of infiltration-percolation by demonstrating that the process produces a remarkably purified effluent (PINCICE and Mc KEE, 1969), but it wasn't until the 30s that the Americans re-discovered the technique.
At the time it was essentially used for groundwater recharge by the infiltration-percolation of secondary effluent. Many sites were built,

such as Flushing-Meadows and Phoenix (Arizona), Hollister (California) and Lake-George (New-York), producing excellent results both from the organic purification and bacteriological decontamination viewpoints. It thus became apparent that infiltration-percolation could not only be applied for the recycling of wastewater (groundwater recharge, irrigation), but also in the treatment of primary effluent.

Infiltration-percolation allows compliance with stringent treatment standards whilst limiting the plant's operating constraints. It is thus one of the many treatment processes specially suited to the needs of small communities, notably as an alternative to stabilization ponds, where the required surface area (10 m^2/p.e.) may be a limiting factor. There are now some fifty plants in France, and the process seems to be gaining favour. We felt it would be useful to study the operation of one of these plants to assess the efficiency of the technique.

GENERAL FEATURES OF INFILTRATION-PERCOLATION

Infiltration-percolation consists in the sequential filtration of wastewater, having already undergone fairly intensive treatment, through generally sandy soil (in-situ or brought-in soil); the medium is kept unsaturated to allow aerobic biological purification to take place (Figure 1).

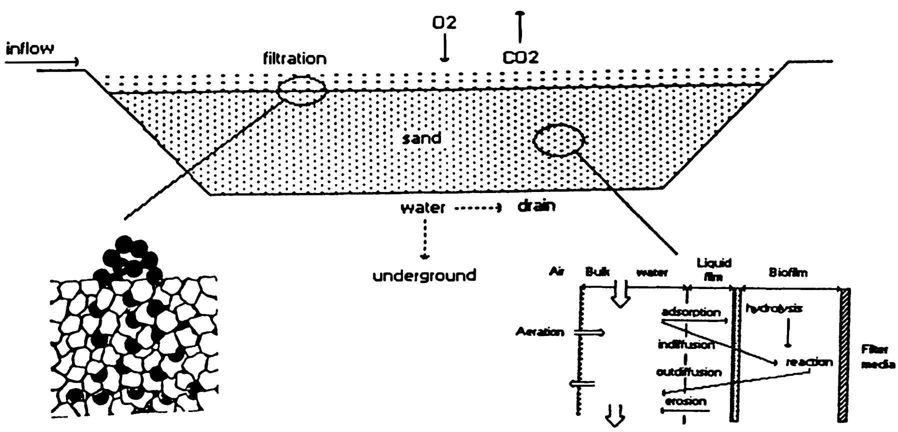

Fig. 1. Operating principle of an infiltration basin (mixed from LESAVRE and CHERIER, 1991; ARVIN and HARREMOES, 1989).

Most of the soil-types used for infiltration-percolation are sand or sandy-loam (DE VRIES, 1972; AULENBACH, 1979; BOUWER et al, 1980; LELAND and DAMEWOOD, 1990). The soil must be quite finely-graded to ensure the retention of suspended solids, but should not be so fine as to prevent the effluent from percolating through the medium and entering the second treatment phase in which pollutants are broken down by the fixed biomass. Grading size is often 0.1 to 1 mm with a uniformity coefficient of 2 to 5.

The cation exchange capacity (CEC) may be taken into account since it represents the measurement of the ammonium ion adsorption capacity and therefore the nitrification capacity. A CEC of 1-3 meq/100 g sand appears to give good treatment results (URADNISHECK and CORCORAN, 1979; KRISTIANSEN, 1981; MATHEW et al, 1984).

As far as the size of the basin is concerned, most infiltration plants in the USA (for groundwater recharge) or in France have been built on the basis of 1-3 m^2/p.e.
The optimum depth of the infiltration medium appears to be the most complex parameter to define. Many authors appear to agree that the biological phenomena occur in the first forty centimetres (CHRISTIAN et al, 1975; FEDERLE et al, 1986; PELL et al, 1990).
The total depth often depends on the required objectives. The basins at existing sites, specially built for carbon removal, nitrification-denitrification, and phosphorus retention, often have 2 to 3 metres of sand; this seems excessive. However, where decontamination objectives are concerned, it is the retention time that is important, and a higher depth would seem more appropriate (with 10 cm batch feeding).
An important factor in the efficiency of infiltration basins is the sequencing of the flooding periods. In order to preserve conditions of aerobiosis, rest periods must be provided between wastewater inputs to allow oxygen renewal, which can only take place via the surface. Moreover, after a certain flooding time, yields drop and filtration problems (clogging) arise requiring the implementation of a drying period.
An operating cycle (Figure 2) therefore involves a succession of batches (input of a 10-cm layer of water to wet the surface) followed by a drying period.

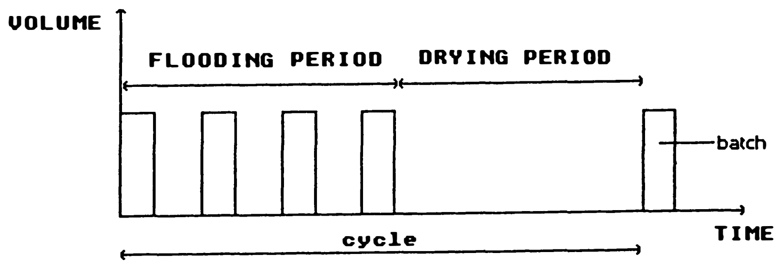

Fig. 2. Operating cycle of an infiltration basin.

Measurements taken at plants using basins with several metres of sand and those taken on laboratory columns using 75 cm of sand (DE VRIES, 1972; VIGNESWARAN and SUAZO, 1987) have shown that the filtration of wastewater through sandy soil effectively breaks down carbonaceous pollution (TSS, COD and BOD_5) with yields close to 90%.
Nitrogen compounds are removed through successive processes (Figure 3) occurring in the soil during the flooding and drying periods that characterise the operating cycle of infiltration basins. The overall results for nitrogen removal vary, but in all cases the process leads to the production of nitrates, above all at the beginning of the flooding period (leaching).
The mechanisms by which phosphorus is removed are less clear since they involve complex phenomena. Some authors point to hydraulic loading (BOUWER et al, 1980) and others to the maximum retention capacity of the sand after several years of operation (NAGPAL, 1986). Among these, the most satisfactory explanation appears to be the presence of compounds that adsorb phosphorus (clay, iron and aluminium hydroxide, $CaCO_3$, ...) linked to the favourable electrochemical conditions of the medium (AULENBACH and MEISHENG, 1988).

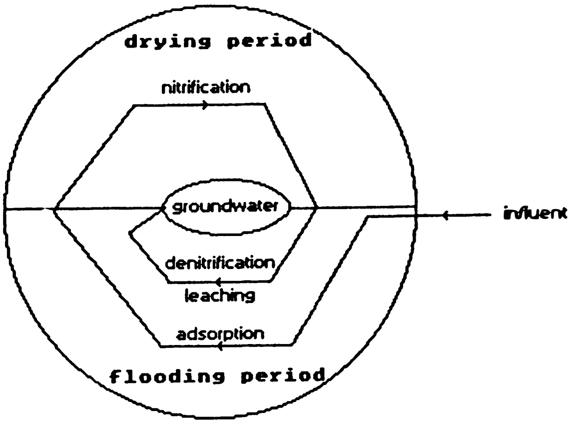

Fig. 3. Process involved in the removal of nitrogen compounds during flooding and drying period (Mathew et al, 1984).

SAINT SYMPHORIEN DE LAY CASE STUDY

The site

This combined treatment plant, commissioned in mid-1987, consists of two settling tanks with alternate six-month feeding cycles, followed by two watertight infiltration basins with drains (Figure 4). Each settling tank is fitted with a self-priming siphon that delivers 20 m^3 of effluent to the basin in operation. This represents a level of around 10 cm. A central overflow gutter on top of the basins ensures distribution of the influent over the whole surface area. See also Table 1.

TABLE 1 Main Characteristics of the Plant

	P1	P2	B1	B2
Surface area (m^2)	120	170	240	210
Volume (m^3)	200	250	-	-
Retention time (h)	64	80	20	20
Sand depth (m)	-	-	1.7	1.7

The frequency of the batches is directly dependent on the flow-rate of the incoming wastewater. The plant serves a population equivalent of around 500 and the dry weather flow-rate is 70 to 80 m^3/day. The operating cycle of each basin consists of seven days' flooding followed by seven days' drying.

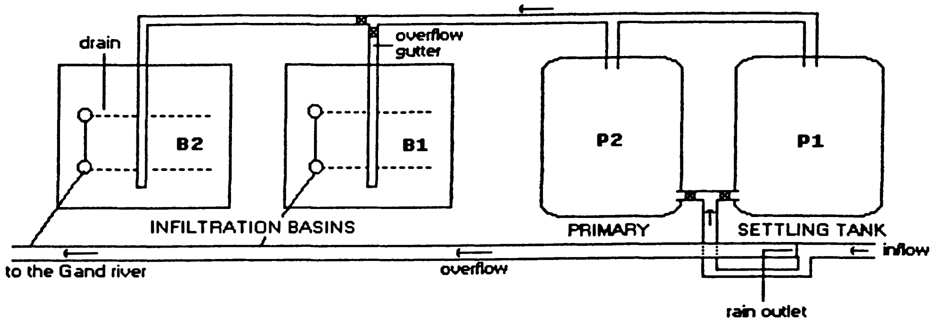

Fig. 4. Saint Symphorien de Lay wastewater treatment plant.

Results

From March 1989 to April 1990, the plant underwent regular follow-up. The results under discussion in this paper were obtained during the flooding period (from 12/06/89 to 18/06/89). This period is representative of operation under stable operating conditions with a constant influent flow-rate of 70 to 75 m^3/day.

Primary treatment. Table 2 details the performance of the settling tanks. Although the reduction of carbonaceous pollution is satisfactory - with 48% TSS and 26% COD reduction - nitrogen remains low with approximately 10% reduction. No phosphorus reduction was noted.

TABLE 2 Quality Range of Wastewater in Primary Treatment during a Flooding Cycle (mg/l)

	Day	TSS	COD	N-NTK	$N-NH_4$	$P-PO_4$	P-PT
	1st	102	412	60.2	46.0	-	-
Raw	2nd	120	461	62.3	47.6	11.7	14.5
wastewater	4th	139	540	64.4	49.0	12.0	15.0
	6th	190	620	67.9	51.1	14.5	17.4
	1st	99	323	51.8	37.8	-	-
Primary	2nd	63	360	52.5	40.1	12.5	15.3
effluent	4th	75	315	55.3	43.7	11.3	15.2
	6th	102	470	59.5	46.2	13.0	16.7

Whilst the quality range of the settling tank is quite standard, some operating problems were apparent. In the summer, sludge rising to the surface of the settling tank due to fermentation at the bottom may be deposited on the filtration surface and cause clogging.

Infiltration basins. The first change we effected at the beginning of our on-site study was the system of batch feeding. We replaced the continuous flooding, which only utilised 50% of the available surface area, with the infiltration of a 10 cm layer of water (4 times a day) evenly spread over the filtration surface area. Yields instantly improved: from 55% to 82% for TSS, from 62% to 85% for COD and from 10% to 85% for Total Phosphorus.

The calculation of the yield for nitrogenous compounds over a week's flooding reveals a more complex reality. Figure 5 shows wide variations in nitrate contents over the 7-day flooding cycle.

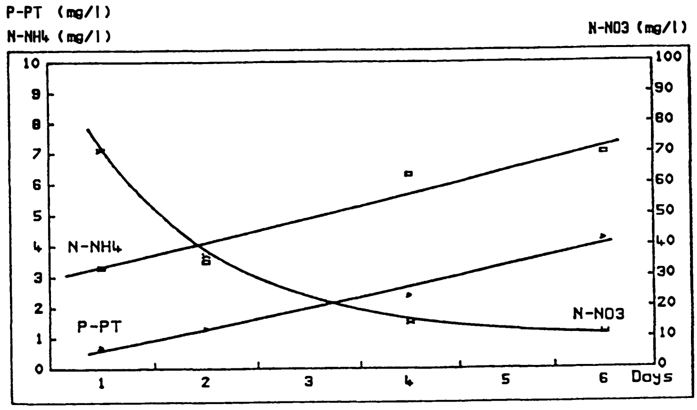

Fig. 5. Concentrations (mg/l) of $N\text{-}NO_3$, $N\text{-}NH_4$ and P-PT at the bottom of the sand filter during the flooding period.

A steady increase in ammonium and phosphorus concentration may also be noted (in the form of ortho-phosphate); this reveals the system's lower capacity for ammonium oxidation and ortho-phosphate adsorption. The high concentration of nitrates discharged with the initial batches of a flooding cycle correspond to the release of nitrates formed during the past drying period. The evolution of the Redox potential measured at the sand filter inflow and outflow is shown in Figure 6. The peak corresponding to the large-scale release of nitrates with batch 2 is plain to see. The resulting drop in potential is caused by dilution at the point where the percolation rate is at its highest. The system's nitrification capacity steadily renews as the filtration rate falls.
However, the following was observed for batches 11 and 17 :

- the absence of a nitrate peak as in batch 2, due to the leaching of the nitrates that accumulated during the drying period,
- the nitrification capacity between two batches decreases, due to insufficient oxygen renewal in the filter medium.

A drying period is needed to allow interstitial water to drain off, and air to enter the medium, thereby renewing the oxygen.

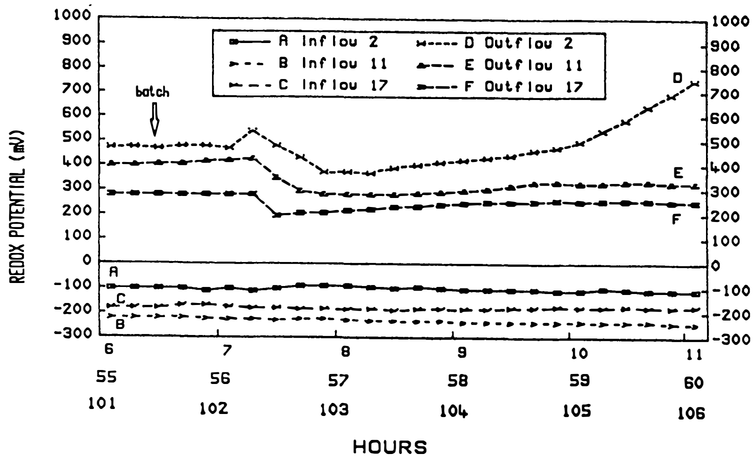

Fig. 6. Evolution of Redox potential in the sand filter during batches n°2, 11 and 17 of the flooding period (times = 0 when the first batch begin).

CONCLUSION

An on-site study was conducted on the infiltration basins at the Saint Symphorien de Lay domestic wastewater treatment plant (France). Primary treatment, consisting of two settling tanks operating alternately on a six-month basis, does not appear to be the optimum process. Despite the release of sludge from the settling tank, the two infiltration basins have proved effective. Over the course of seven measuring campaigns spread over one year, the following average yields were obtained :

TABLE 3 Efficiency of the Saint Symphorien de Lay Plant

Parameters (mg/l)	TSS	COD	$N-NH_4$	$N-NO_3$	N-NTK	$P-PO_4$	P-PT
Raw wastewater	150	433	39.4	-	53.4	10.5	12.6
Primary effluent	78	320	38.4	-	49.0	10.5	12.6
Sand filter	12	55	*	**	**	2.2	2.9

* Between 3-8 mg/l from the 1st day to the 7th day
** Between 70-10 mg/l from the 1st day to the 7th day

Although the infiltration basin has shown its potential as a treatment process in its own right, it should still be stressed that such plants cannot and must not function unattended. The alternation of the basins according to a fixed frequency pattern needs to be monitored, and simple maintenance operations (scraping of the surface) carried out. We recommend increasing the number of basins from two to three in order to forestall any type of problem (sludge release, heavy rainfall). Spread over three basins, a surface area of 1 m^2/p.e. for separate system or 1.5 m^2/p.e. for combined system, would be enough to guarantee the same yields with increased safety.

Research is now focusing on finding the biologically active depth of an infiltration basin. Studies are being conducted on columns (75 cm) with the plant's sand, and will concentrate on purification yields, biomass (estimated by ATP dosing) and oxygen renewal. For the first two of these parameters, the phenomena appear to occur in the first 30 centimetres.

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