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TREATMENT OF SLUDGE FROM SEPTIC TANKS IN A REED-BED FILTERS PILOT PLANT.

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ABSTRACT

Since 1992, French legislation requires the creation of master plans for evacuation and treatment of wastewater. Zones of collective and individual (on-site) treatment have to be defined. Local authorities may take responsibility for controlling and operating private on-site treatment systems. This will result in a considerable increase in the amount of sludge from septic tanks (faecal sludge : FS) that needs to be treated. Large wastewater treatment plants are able to treat such FS transported and removed with vacuum trucks. Nevertheless, in some rural areas, there are fewer of these plants. Cemagref has been asked to study the feasibility of treatment plants specially designed for treating FS.

The pilot plant is made up of 2 stages :

- the 1st stage is designed mainly to achieve filtration of the high concentrations of suspended solids in the FS. It also appears that an important aerobic biological treatment process occurs in the drainage gravel layer connected to the atmosphere. Removal rates of 70 % for soluble COD, 79 % for KN and 66 % for ammonia concentrations have been obtained.

- the 2nd stage consists of 4 PVC columns ($0.1m^2$), each filled with 15 cm of sand on top of 0, 20, 40 and 60 cm of gravel. COD concentrations around 150 mg 1⁻¹ and low ammonia concentrations (< 1 mg 1⁻¹) can be achieved with columns filled with 60 cm of gravel. The extent to which the reeds improve the biological treatment has not been established and from a hydraulic point of view, their effectiveness is debatable over a period of less than one year after being planted.

KEYWORDS

Faecal sludge, on-site wastewater treatment, pilot plant, reeds, sand filtration, small treatment plants

INTRODUCTION

Since 1992, French legislation obliges « communes » (districts) or groups of districts to define zones of collective wastewater treatment and zones where individual on-site wastewater treatment would be more appropriate (Décret N°94469, 1994). Part or all of a district may be classified as an individual treatment zone if installing a sewerage network is of no interest to the environment and/or if its cost is excessive. In addition, districts must make sure that the installations are technically in conformity, in terms of both the design and the construction. Even if the treatment capacities of the individual treatment zones cannot be directly checked, districts must ensure that they are operating correctly by checking certain indicators and in particular :

i) by checking that the elements are in good working order, that the ventilation works properly and that they are easily accessed, ii) by checking that the influents flow correctly until they reach the treatment system, iii) by checking that the sludge accumulates normally inside the septic tank and that its contents are periodically emptied.

It is also planned that districts will be able to take direct charge of maintaining the installations and be responsible for all related expenses. The application of these measures should gradually result in an increase in the quantity of sludge extracted from septic tanks, with an average frequency of emptying that could be of around 3 years.

In order to manage this flow of sludge in the best possible way, the « département » of Indre et Loire has drawn up a blueprint for removing FS (Viguie *et al.*, 1992). It appears that when considering the number of wastewater treatment plants in a given geographic area capable of receiving and treating the sludge without being damaged, there are insufficient of them to optimise collection and transport costs. The Departmental Office for Health and Welfare in Indre et Loire (Direction Départementale de l'Action Sanitaire et Sociale d'Indre et Loire) therefore asked Cemagref to study the technical feasibility of treatment plants specially designed to treat FS. On the basis of the experience acquired by Cemagref concerning treatment using biofilms fixed on fine media either planted or unplanted with reeds, the decision was taken to begin a pilot plant scale research phase. Some of the results are presented in this article.

MATERIALS AND METHODS

Quality of the influent sludge to the 1st stage

The raw FS used to feed the 1st stage filters was ordered from a septic tank emptying firm from the Lyon area who was asked to deliver sludge coming solely from septic tanks. Table 1 summarises the quality of the products received in 3 deliveries between January 1995 and March 1996.

		January 19	995	July 199	5	December 1995
Parameters		Average of	Coeff.	Average of	Coeff.	1 value
<u></u>		3 values	var.(%)	4 values	var.(%)	
pН		7.18	5	7.66	5	7.5
Cond.	μS cm ⁻¹	2330	8	2830	6	3200
CODr*	mg l-1	19920	30	29020	18	71100
CODd**	mg l-1	2090	14	5275	41	19390
BODr	mg l-1	-	-	2625	l value	4260
TSS	mg 1-1	17260	9	19130	25	60200
VSS	%	68.4	2	71.80	3	54.7
N-KNr*	mg - 1	1030	11	1272	9	3920
N-KNd**	mg l-1			435	6	1190
N-NH4 ⁺	mg l-1	360	21	332	2	566
TN	mg l-1	1032	11	1305	9	3920
ТР	mg l-1	160	96	325	27	786
P-PO4 ³⁻	mg 1-1	33	6	32	36	76
GOD	mg 1-1	24562	27	34734		88700

Table 1: Physico-chemical characteristics of the raw FS.

CODr* = raw COD for the product as a whole (ditto for BODr and N-KNr*).

CODd** = COD of a fraction dissolved or soluble after centrifuging and/or filtering. (ditto for N-KNd*).

Coeff. var. = Coefficient of variation in %.

For most of the parameters, the variability of the standard deviation illustrates how difficult it is, with this type of non-uniform and concentrated product, to obtain a sample of constant and representative quality that is in conformity with the values found in the bibliography (Flanagan *et al.*, 1979; Leroy, 1992).

Considering the relatively high nitrogen content in the FS, especially organic nitrogen, and knowing that the sludge was likely to be stored in filters over a long period of time, during which it will be partially 5th International Conference on

Wetland Systems for Water Pollution Control, Vienna 1996

Imineralised, it seemed wise to define a parameter that took into account the oxygen requirements as a whole. The GOD (Global Oxygen Demand) includes the break down of the carbon containing fraction of ϵ the organic matter and the oxidation process of the Kjeldhal nitrogen into nitrates. According to literature, the quantity of oxygen necessary in order to transform 1 mg of ammonia nitrogen into nitrates varies between 4.18 and 4.57 mg of O₂. A value of 4.5 was kept as the oxidation coefficient with KN, which gives :

GOD = CODr + 4.5 N-KNr

The BODr measurement is considered to be of little significance since the biodegradability is far superior to that suggested by the CODr/BODr ratios, also reported by Flanagan and Ott (1979).

Stage one of the treatment

- Using the results obtained with reed-planted sludge drying beds (Lienard *et al.*, 1995), 2 filters were installed in PVC containers with a unit surface area equal to 0.6 m². The filter beds comprise from bottom to top :

- a 10 cm drainage layer made up of 20/60 mm pebbles, in the middle of which is placed a 75 mm diameter plastic drain pipe with 5 mm long slits every 15 cm in its lower part. At the opposite end to the outlet, the drain pipe is fitted with a ventilating shaft that ensures the natural aeration of the filter-bed,

- a plastic geoscreen with a 4 to 6 mm mesh,

- 5 cm of 5/12 mm gravel,

- 10 cm of 3/8 mm gravel.

Before any sludge was fed in, the clearance height was around 70 cm above the gravel. At the end of October 1994 around fifteen reed seedlings (*Phragmites australis*) potted in small plastic pots filled with compost, purchased from a specialist horticulturist, were planted directly into the gravel in each of the beds. At the time of being planted and for the next three weeks, the reeds were fed with sludge from a wastewater treatment plant.

The filters were placed indoors under artificial light (2 x 2 horticultural, 30 W neon lamps) to avoid the reeds withering and to accelerate the growth once the filters are placed outside from April 1995 onwards.

Both filters were fed, jointly, once a week in parallel with the raw FS stored in two vats, each measuring 1.5 m³, and mixed using an immersed pump before each feed. The rainfall level was measured.

During hot summer periods, (of around 35°C in the shade), the number of feeds was doubled in order to attenuate the phenomenon of sludge shrinkage along the sides of the containers where thermal insulation is difficult.

Stage two of the treatment

The second stage of the treatment consists of four transparent PVC columns, fed in parallel, with a unit surface area equal to 0.1 m^2 . The filter-bed rests on a plate punched with holes and this is placed in contact with the atmosphere. The lower part of each column is equipped with 4 punched sleeves that may serve as air inlets at different heights in the bed, but in particular they allow sensors to be installed (O₂, T°C, redox, conductivity, etc.). Independent clock and timer controlled peristaltic pumps are used to feed the columns at the rate of one batch a day, for 4 days. A baffle device that consists of a PVC pipe stuck on a splash pad with a diameter of around 10 cm improves influent distribution and limits problems linked to erosion.

The experiment was carried out over two periods :

<u>Period 1</u>: between January and May 1995, in order to establish the height of gravel that was needed under a layer of sand. Of course, whilst the sand's main role is to act as a purifier, it also plays an important role in reducing the infiltration rate and improving the distribution of the influent. The four columns, fed with effluent from the first stage, were placed inside a building where they were subjected to temperatures of between 15 and 20 °C. In column A, the filter-bed was simply made up of a layer of sand resting on a geoscreen with a mesh of around 2 mm. <u>Period 2</u>: between June 1995 and April 1996, Here, the aim was to show the effect of the reeds (*Phragmites australis*) on the treatment capacities and from a hydraulic point of view to seek a possible improvement in the infiltration rates. Various tests were carried out at the same time in order to try and optimise the removal of nitrogen. They led to the columns being fed at certain periods with influents other than those from the first stage.

	PERIOI	D 1 (January - May Sand Gravel (cm) (cm) 15 0 15 20 15 40	y 1995)	PERIOD 2 (Ju	PERIOD 2 (June 1995 - April 19			
Column	Reeds	Sand	Gravel	Locatio n	Reeds	Sand	Gravel	Location
		(cm)	(cm)		(nb. of stems m^{-2})	(cm)	(cm)	
A	0	15	0	in.	200	20	60	out.
В	0	15	20	in.	200	20	60	out.
С	0	15	40	in.	0	20	60	out.
D	0	15	60	in.	0	20	60	in.

Table 2. Structure and location of the columns

sand : d10 = 0.23 mm, C.U. (Coefficient of Uniformity) = 4.04 ; gravel : d10 = 2.5 mm, C.U. = 2.6 in. = inside ; out. = outside.

Table 2 sums up the main characteristics of the experimental system.

In contrast with the first stage filters, the compost from around the roots of the reed seedlings embedded in the sand in columns A and B was removed. They were planted with a high density of stalks per column in order to simulate abundant growth in a short space of time.

Measuring the infiltration rate and permeability

Darcy's law makes it possible to calculate the permeability coefficient for a saturated area of ground (Hillel, 1984). For a non saturated area, hydraulic conductivity depends on many parameters (degree of saturation, surface tension, presence of biofilm, etc.). Unfortunately, in our case, when the purpose of the experiment is the observation of the treatment capacity and the prevention of clogging, it is impossible to measure them without modifying the characteristics of the system itself and therefore, it is not possible to determine the intrinsic hydraulic characteristics of the filter-bed. Nevertheless, measuring the infiltration rate remains the most direct means of gaining an insight into the hydraulic behaviour of the experimental columns. The results obtained at different periods are therefore presented.

RESULTS

Influent load and the increase in sludge height on the first stage

On average, over the 440 days of observation, the influent loading is near to 7.10 1 m⁻² d⁻¹ of raw FS, representing 190 g of TSS m⁻² d⁻¹ or in other words close to 300 g of GOD m⁻² d⁻¹. Initially, one may conclude that these influent loads are greater than those observed in the dewatering of sludge in activated sludge treatment plants : around 160 g of TSS m⁻² d⁻¹ (Lienard *et al.*, 1995).

The change in sludge heights was similar in both filters (North and South) until the beginning of the Summer 1995.

Then, on the Southern filter, exposed to intensive sunlight, there was sludge shrinkage along the sides. This kind of problem is inherent to experiments of this type in low volume reactors. The phenomenon appears during stage 2 on Fig 1. Despite more regular feeding, it was very difficult to return to a normal situation before the end of the Winter 95-96 (cumulated load close to 70 kg of TSS m⁻²). We were able to estimate that short circuits caused losses of TSS and GOD representing up to 10 and 17 % respectively of the influent loads. This phenomenon is probably due to the fact that the TSS from the FS, broken down anaerobically in septic tanks, are only slightly flocculent.

5th International Conference on Wetland Systems for Water Pollution Control, Vienna 1996





Figure 1. Increase in the sludge height in the first stage as a function of the cumulated influent load.

Quality of the effluent and yields in the first stage

Compared with the results obtained for activated sludge, when feeding with FS, the quality of the percolation flow is relatively poor. The yields obtained from January to May 1995 are however high and can be considered as reliable, considering the number of measurements taken and their relatively low variability. From June onwards, they were adversely affected by shrinkages along the sides that were large enough to short circuit part of the treatment process and greatly reduce the performance of this first stage.

		January - May 1995					June - September 1995			
Param	eters	Nb.val.	Average	(min-max)	Av.removal	(%) Nb _: val.	Average	(min-max)	Av.removal (%)	
CODr	mg -1	13	2345	(1425-3270)	88	8	6245	(3430-9157)	78	
CODd	mg l-1	12	625	(389-875)	70	6	1742	(916-2590)	67	
BOD	mg l-1	-		-		1	1095	-	58	
TSS	mg 1-1	13	1240	(716-1775)	<i>93</i>	8	3056	(1780-4635)	84	
VSS	%	13	80	(75-84)	-	8	80.10	(76-83)	-	
N-KNr	mg -1	13	217	(151-287)	79	8	372	(277-498)	71	
N-KNd	mg 1-1	-		-	-	6	163	(113-300)	62	
N-NH4 ⁺	mg I-l	13	123	(82-175)	66	8	135	(82-222)	59	
N-NO2 ⁻	mg -1	13	22	(5-46)	-	7	8	(0-40)	-	
N-NO3 ⁻	mg -1	13	34	(0-58)	-	6	10	(0-40)	-	
TN	mg -1	13	273	(156-391)	73	6	426	(277-831)	67	
ТР	mg 1-1	2	21	(17.4-24.5)	87	8	49	(36-58)	85	
P-PO4 ³⁻	mg 1-1	2	63	(3.80-8.75)	82	6	5	(0-11)	84	
GOD	mg I-1	13	3323	(2104-4561)	86	8	7919	(4676-11398)	77	

Table 3. Quality of the effluent and yields in the first stage.

These yields may be attributed to two distinct mechanisms : i) physical filtration, by sludge depositing on the surface of the filter which makes it possible to retain a lot of the TSS that have a direct impact on the CODr and the particulate organic nitrogen content ; ii) biological treatment, highlighted by the yields observed on soluble concentrations, particularly ammonia. This activity results from the biomass that is fixed on the aerated gravel of the drainage layer, providing the contact time is long enough. A similar observation had already been made (Lienard *et al.*, 1995). One also notes that the TSS at the filter outlets

have a higher organic content than those in the influent sludge, probably mostly due to the dislodging of biomass.

Impact of the gravel height on the efficiency of the second stage columns

The following table, based on the results obtained with a low surface loading of 36 g of GOD $m^{-2} d^{-1}$, shows that the surface sand is certainly the site of considerable treatment activity with yields of around 85 % for COD and the oxidation of ammonia salts. Nevertheless, the thicker the gravel layer, the greater its observed impact.

Avera 36 g GO	nge load DD m ⁻² d ⁻¹	CODr mg 1-1	TSS mg l ⁻¹	N-KN mg I ⁻¹	N-NH₄ mg l ⁻¹	N-NO ₃ mg l ⁻¹	TN mg 1 -1
	Average	279	47	12	8.53	156	165
Column A	Coeff. var.%	27	19	43	0.26/27*	25	23
0 gravel	Nb. val.	19	7	9	19	19	9
	Average	185	32	4.11	1	202	188
Column B	Coeff. var.%	25	24	59	0.1/3.2*	18	19
20 cm	Nb. val.	19	7	8	19	19	8
	Average	154	27	1.81	0.48	222	216
Column C	Coeff. var.%	27	31	0.64/3.9*	0.1/1.8*	16	21
40 cm	Nb. val.	20	7	9	20	20	9
	Average	114	19	1.11	0.23	228	223
Column D	Coeff. var.%	21	54	42	45	15	19
60 cm	Nb. val.	20	7	10	20	20	10

Table 4. The effect of gravel height on effluent quality.

Coeff. var. = Coefficient of variation in %; * min. / max.

Without contradicting previous observations (Guilloteau *et al.*,1993), one sees that for effluents that are considerably more concentrated than domestic wastewater, the gravel is also the site of a significant amount of biological activity. If the extremes are compared (columns A and D), the gain obtained in concentration by using the additional 60 cm of gravel may be quantified:

	CODr	TSS	N-NH4 ⁺	N-NO ₃
(col. A - col. D) / col. A	60 %	60 %	85 %	45 %

The intrinsic permeability of the gravel is very high and makes it possible to maintain sufficient aeration since the base of the filter is in contact with the atmosphere. The percolation rate that is determined by the sand, which is considerably less permeable and sensitive to clogging, allows sufficient contact time between the effluent and the biofilm fixed on the gravel.

Effect of the reeds on the treatment capacity of the second stage columns

Between June and September 1995, no significant effect was observed in the quality of the effluents leaving the 4 columns. This could be explained by the fact that, despite the high density of planting, the roots of the seedlings were only small. Two and a half months after planting, the number of stalks in each of the two columns were counted.

Table 5. Count of the number of stalks at the end of August 1995.

	Number of living stalks	Number of dead stalks	Total number of stalks
column A	105	35	140
column B	85	30	115

XIII/4 - 6

Wetland Systems for Water Pollution Control, Vienna 1996

•For unexplained reasons, one may note that the growth rate is different in the 2 columns. It is planned to resume these tests during the summer of 1996 when the plants will be more developed, one year after being planted.

Effect of the reeds on the hydraulics of the second stage

A first set of observations was made during the summer of 1995, by measuring the infiltration rates in the 4 columns on three occasions, on Monday morning during the 1st feed of a cycle and then, on Thursday morning when the last batch was fed in. Without giving full details of the results, it was noted that :

- the initial infiltration rates were between 6.03 10^{-4} m s⁻¹ (column D) and 9.04 10^{-4} m s⁻¹ (column B). These variations may be explained by the difficulty experienced in installing the sand in exactly the same way in the 4 columns, in particular with the reeds in place,

- between the beginning and the end of August, the infiltration rate for the 3 columns placed outside, although their behaviour was relatively identical, decreased by one log unit,

- the infiltration rate for column D fell quite quickly to around 10^{-6} m s⁻¹ and it resulted a clogging. This may be explained by the fact that the summer weather conditions, with rainfall that did not exceed 65 mm during the month of August 1995, were favourable to the columns placed outside,

- whatever the variations in load, the infiltration rate of all the columns decreased on average by one log unit during a 4 day feed cycle and did not totally recover once there was a surface loading of around 60 g of GOD m⁻² d⁻¹. It would therefore seem that this loading is a maximum value under these experimental conditions (around 3 g 1⁻¹ of TSS and 20 cm of sand).

At the end of the summer, the 4 columns were near to clogging due to the high concentrations of influent TSS (resulting from the sludge shrinkage phenomenon along the sides of the first stage filters, as mentioned earlier). At the end of October 1995 the decision was taken to replace the sand in columns C and D that were not planted.

A new set of infiltration rate measurements was carried out after this operation. The results were as follows : Col. A 5.77 10^{-4} m s⁻¹, col. B 3.06 10^{-4} m s⁻¹, col. C 3.21 10^{-4} m s⁻¹, col. D 2.00 10^{-4} m s⁻¹.

The 4 columns were then fed with a reconstituted influent containing less TSS (300 to 500 mg 1^{-1}). During the winter, it was noted that the non planted columns were relatively stable, whereas column B had to be left to rest twice for 3 to 4 weeks. Relative to column A however, significantly less vegetative development could be observed (See table 5).



Figure 2. Comparison of the change in the infiltration rates of the outside columns.

During the winter, the infiltration rates of the planted columns were almost systematically lower than those of column C.

Wetland Systems for Water Pollution Control, Vienna 1996

From April onwards, they all had infiltration rates of around 2 10⁻⁴ m s⁻¹, probably linked to the spring growth of the reeds which had developed to at least 1000 stalks per m² uniformly distributed so that the infiltration, that is the organic load is well spread over the filter-bed.

DISCUSSION - CONCLUSION

The observations made on the 1st treatment stage of the pilot plant confirm that the reeds help to avoid clogging of gravel beds fed with liquids that are very rich in total suspended solids (> 17 g 1^{-1}) at relatively low hydraulic loads (around 7 mm d⁻¹ in the present case, 30 to 50 mm d⁻¹ for the dewatering of activated sludge). These filter-beds can act both as an excellent physical filter, capable of retaining a major part of 'the particulate load (85 % of the TSS), and as a biological reactor able to achieve yields of around 60 % for ammonia salts and 70 % for the dissolved fraction of the COD, providing the drainage layer is correctly . aerated. The situation is more complex however on the second stage, using sand and influents that are far less concentrated but in which the TSS content can reach 1 to 3 g 1^{-1} .

Treatment plants comprising biological systems fixed on fine media are systems that function with very low organic loads and which do not require any final clarifying process. For this reason, they are of interest to small pollution centres that do not want to have to manage sophisticated installations. The aim is, however, to optimise the filter-bed surface, mainly in order to reduce investment costs and to find the right balance to combine efficiency and reliability of treatment in all seasons. It is therefore important to ensure that biomass production is not excessive and to control clogging. Nevertheless, the biological activity of the biofilm is only fully effective if the organic load of the influent is well distributed, if the contact time is sufficiently long and if the porous media is well aerated.

It has been demonstrated that a 60 cm gravel height can improve the yields in COD and the oxidation of the ammonia salts within a 60 to 85 % range. But these results are linked to the presence of a 20 cm layer of sand, which, besides its own efficiency, is essential for distributing and reducing the infiltration rate of the influent. Even with a TSS concentration of 0.3 to 0.5 g 1^{-1} , it is not certain that a reed bed can guarantee that there will be no clogging, in particular in winter. Possibly a layer of plain sand (unplanted), that may be broken up, or even partially replaced if necessary, would be more appropriate ? From a hydraulic point of view, the results presented here do not permit any conclusion to be drawn as to whether one choice is better than another, but it is also true that the effectiveness of the reeds can most probably only be truly judged after at least one year of growth. These results are however not in contradiction with feeding the 1st stage of reed-bed filters solely made up of gravel, with raw domestic wastewater.

The synthesis of all the data collected from these pilot plants should make it possible to perform the necessary calculations and design a treatment plant able to accept a weekly volume of 50 m³ of sludge, which represent the quantity that is generated by a sludge collecting area of 12 to 15 000 people equipped with individual sanitation systems. If the experience with this future full size experimental plant proves to be positive from a technical and economic point of view, other similar plants could be established in France.

REFERENCES

Décret N°94 469 du 3 juin 1994, published in the J.O. du 8 juin 1994, 8275-8278.

- Flanagan, J.D., Ott, C.R. (1979). Chemical oxidation of septage. J. Wat. Pollut. Control Fed., 51 (7), 1976-1985.
- Guilloteau, J.A., Lesavre, J., Liénard, A. and Genty P. (1993). Wastewater treatment over sand columns. Treatment yields, localisation of the biomass and gaz renewal. *Wat. Sci. Tech.*, **28** (10), 251-261.

Hillel, D. (1984). L'eau et le sol. Principes et processus physiques. Ed. KB, 288 p.

- Leroy, F. (1992). Les gadoues de fosses septiques. Vidange et schémas de traitement et d'élimination. Tribune de l'Eau, (560), 81-84.
- Liénard, A., Duchène, Ph. and Gorini, D. (1995). A study of activated sludge dewatering in experimental reed-planted or unplanted sludge drying beds. *Wat. Sci. Tech.*, **32** (3), 251-261.

.5th International Conference on .<u>Wetland Systems for Water Pollution Control, Vienna 1996</u>_______XIII/4 - 9 .Viguié, F. and Caudrelier, F. (1992). Le schéma d'élimination des matières de vidange en Indre et Loire. Courants, (16), 32-37.