Seine Centre, the new flexible Colombes sewage treatment plant – from theory to practice

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Abstract Upon the filling of the Seine Centre sewage plant in May 1998, the SIAAP commissioned its first wastewater treatment plant adapted for handling part of the large amounts of rain period surplus water: its flow rate ranges from 2.8 m^3/s during dry weather to 12 m^3/s in wet weather conditions.

Four operational configurations for treating 240,000 m^3/day during dry weather, with different quality objectives, and three configurations for treating the rain period surplus water were designed. Immediately upon filling of the plant, however, the operators had to devise innovative configurations for meeting new discharge standards. This paper will aim at demonstrating (considering a major achievement the various aspects of which will be explained) the SIAAP's will to conform in real time, through a dynamic management of its facilities, to the variation of the priorities in the environmental demands, while preserving the quality of the adjacent owners' immediate environment.

Keywords Biofilters; clari-flocculation; denitrification; nitrification; rain period surplus water

Introduction

The Seine Centre plant is built right on the densely built-up fringe of Paris. Because of the immediate proximity of the inhabited areas, the design engineers have to contrive a totally enclosed plant, in order to reduce as much as possible the risk of nuisance in the neighbourhood. The odor annoyance was primarily prevented by confining the works within a twin-envelope system.

Since the works had to be covered, which involved an additional expenditure, compact processes became of interest. That approach was all the more appropriate because the site was particularly exiguous – 4 hectares.

The Seine Centre plant can receive water from two sewers that convey waters of quite different quality. As regards dry weather, the plant was dimensioned in relation to water from the main interceptor in order to meet the highest requirements. The rated flow rate was set to 240,000 m^3/day (mean rate: 2.8 m^3/s), the carbon-, nitrogen- and phosphorus-bearing pollutants being removed.

After an initial step of settling and phosphorus removal taking place in lamellar clarifiers through the use of chemical reactants, the biological treatment involves three stages of biological filters that are series-operated in the basic treatment procedure. Thus, the removal of carbon pollution, the nitrification and the denitrification are successively carried out. Other intermediate configurations may be adopted. A specific treatment quality corresponds to each configuration. Such a flexibility is of the utmost interest for the SIAAP on account of its multiple transport systems that are being networked as well as the number of its sewage treatment plants.

As regards wet weather, the peak rate was set to 12 m^3/s, with an extensive removal of carbon pollution. The physicochemical treatment remains unchanged, since the equipment is liable to work at high velocities. Several configurations can be arranged for the biological treatment, according to the flow rates; the maximum amount of water being treated is obtained with the three series-operated stages of biofilters.

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The results of plant operation achieved using two dry weather configurations and one wet weather configuration are set out in this paper. First, the basic dry weather configuration, providing for the most thorough effluent treatment (carbon pollution, nitrification, denitrification); second, an innovative dry weather configuration that illustrates an example of flow management between two SIAAP sewage treatment plants, namely Seine Aval and Seine Centre. During the first winter after the Seine Centre plant filling the SIAAP had to run a large part of the Seine Aval facilities idle, whereas they have a treatment capacity of 2,100,000 m^3/day. That idle run was justified by the preparation of hydraulic links made necessary for feeding the clari-flocculation unit that was being built at the Seine Aval site. That unit will soon treat 22.5 m^3/s excess water in rainy weather. Water that was not treated at Seine Aval was partly by-passed to Seine Centre, the daily rate of which was then brought up to 360,000 m^3/day (denitrification was not required), whereas the basic configuration was designed to handle 240,000 m^3/day with denitrification. This operating mode did not correspond to any initially anticipated dry weather configuration.

Lastly, we shall report on the first test results as regards the wet weather configuration, which accommodates a 8.5 m^3/s peak rate at the plant for 8 hours.

Methods

Treatment systems

The single basic dry weather configuration, with a 2.8 m^3/s nominal flow rate will be described in detail. It makes it possible to achieve the maximum efficiency with all the various pollutants. This gives an opportunity to specify the procedures being used. We shall then set out the treatment system as designed by the operators for treating 4.2 m^3/s, i.e. 360,000 m^3/day, as well as the wet weather configuration that has a 8.5 m^3/s nominal flow rate. All the systems to be described in this paper involve the injection of reactants ($FeCl_3$ and a polymer) in primary settling conditions.

Dry weather system – basic configuration: 2.8 m^3/s

This treatment system corresponds to Figure 1. It is the most efficient version and achieved the costliest performance.

Pre-treatment. It has no specific feature apart from the fact that because of the downstream processes, it is pushed to a 6 mm screening for protecting the physicochemical treatment, and is carried out with a 1.5 mm screening to ensure the operation of the biological stages.

Physicochemical treatment. Since the abatement of phosphorus pollution is required, the chemical precipitation of phosphates was adopted. Because of that necessity, along with the lack of room and the variation in hydraulic capacities, it was decided to use the lamellar set-

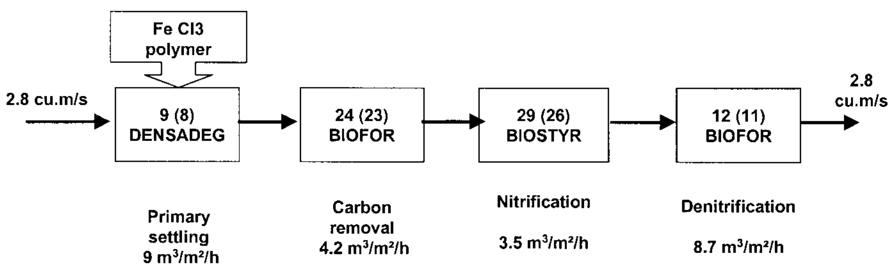

Figure 1 Dry weather with reactants: 2.8 m^3/s

tling after a coagulation-flocculation. These functions are fulfilled through an array of 9 Densadeg sludge recirculation lamellar clarifiers, manufactured by Degrémont, each with a 140 m^2 area, which makes it possible to increase the flow of flocculated sludge in the various portions of the work, which is advantageous in that it favours flocculation in dry periods. With a 2.8 m^3/s rate and 8 units in operation, the rising velocity is very low, about 9 m/hr.

Biological treatment

Removal of carbon pollution. Carbon removal is performed over an array of 24 BIOFOR-type biofilters (built by Degrémont) that are distributed on either side of a central gallery. The upflow filters have an individual area of 104 m^2 and are filled with a 2.9 m thick body of granular expanded clay. One daily backwash is performed in order to dislodge the retained solids and the resulting sludge.

Nitrification. This step is conducted over an array of 29 BIOSTYR-type biofilters (built by OTV), each with a 330 m^3 working capacity. They are upflow biofilters that are filled with a floating support material, consisting of expanded polystyrene beads that are retained in the filter by a ceiling provided with strainers. One daily backwash is performed in order to dislodge the resulting sludge and restore the filter permeability.

Denitrification. This step is conducted over the third array of biofilters consisting of 12 BIOFOR filters. The carbon is supplied in the form of methanol. Though this stage is specifically provided for denitrification in the basic configuration, it is fitted, like the first stage of BIOFOR filters, with air injection equipment. It is therefore quite able to fulfil the same functions as the other two biological stages. Depending on the requirements to be strictly met, other operating modes have been contemplated, particularly without any injection of reactants in primary settling; these are not dealt with herein.

Optimised dry weather system: 4.2 m^3/s

Water that was not treated at Seine Aval, because of the partial plant shutdown in winter, was partly by-passed to Seine Centre. Priority was given to a maximum abatement of carbon pollution. The third, denitrification-dedicated stage of the above-mentioned configuration is directly supplied with clarified water. Two thirds of the flow (2.8 m^3/s) are treated up to complete nitrification, whereas the other third (1.4 m^3/s) is only treated as regards carbon pollution. Nitrification is primed at this stage but remains incomplete because of low temperatures and high carbon loads. This configuration is derived from the wet weather configuration to be described hereinafter.

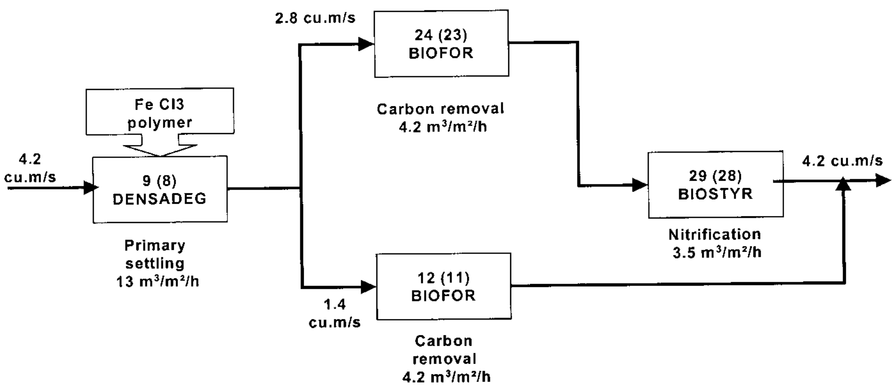

Figure 2 Optimized dry weather: 4.2 m3/s

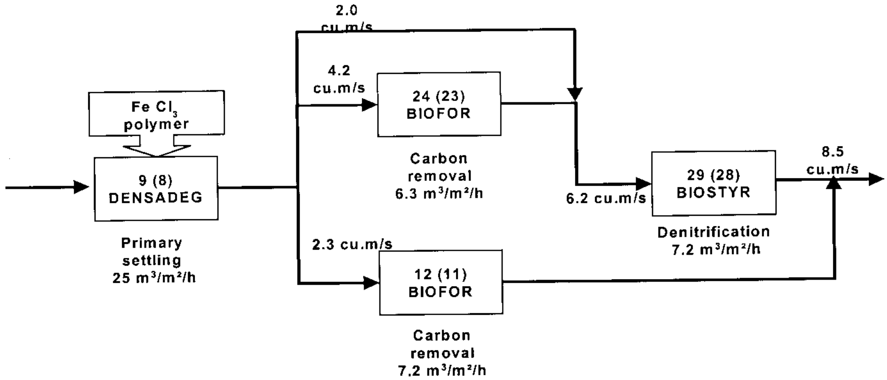

Figure 3 Rainy weather: 8.5 m^3/s for eight hours

Rainy weather system: 8.5 m^3/s for 8 hours

The transition from the basic configuration treating 2.8 m^3/s to this basic wet weather configuration takes place in a short period of time: half an hour. The plant can then handle 8.5 m^3/s for 8 hours. The velocity in the lamellar clarifiers switches from 9 m/hr to 25 m/hr. The water velocity over the first biological stage (BIOFOR) rises by 50%.

The water velocity over the second nitrifying stage rises by 100%. It is fed at the rate of 68% water from the first biological stage and 32% clarified water.

The third biological stage, which denitrifies in the previously mentioned weather configuration, is now aerated and supplied with clarified water at the rate of 27% of the total amount of water accommodated by the plant.

Results

Dry weather system – basic configuration: 2.8 m^3/s

This system was tested by the end of the 1998–1999 winter, the main purpose consisting in testing nitrification at the lowest temperatures, below 16°C (80°F). The mean flow rate through the biological system, namely BIOFOR filters in the 1st stage and BIOSTYR filters in the 2nd stage, was 266,000 m^3/day and the raw water concentrations were similar with those that were used for dimensioning.

Table 1 Raw water quality

	S.S (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	$NH_4^{\equiv}$ (mg/l)	TotalP-P (mg/l)	$PO_4^{\equiv}$-P (mg/l)
Raw water	302	559	256	50.2	30.5	10.9	5.6

Primary settling. With four clarifiers in operation, the surface loading is 21 m^3/m^2/hr. The reactants were added at the rate of 35 mg/l pure $FeCl_3$ and 0.4 mg/l polymer. Due to a $FeCl_3$ deficiency, not all the orthophosphates could be precipitated; additional tests, however, showed that the facilities are quite able to deliver residual water meeting the standard, provided that an additional amount of $FeCl_3$ is supplied.

Table 2 Primary setting

	S.S (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	NH_4^+ (mg/l)	totalP-P (mg/l)	$PO_4^{\equiv}$-P (mg/l)
Clarified water	51	254	135	43.1	31	4.4	2.3
Efficiency	83%	55%	47%	14%	/	60%	59%

Table 3 First stage (BIOFOR)

	S.S (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	NH_4^+ (mg/l)
Oulet 1st stage	20	114	29	33.7	27.6
Efficiency	61%	55%	79%	22%	11%

Table 4 Second stage (BIOSTYR)

	S.S (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	NH_4^+ (mg/l)
Outlet 2nd stage	5	43	8	3.8	2.4
Efficiency	75%	63%	72%	89%	91%

BIOFOR – 1st stage: abatement of carbon pollution. The applied loads are 1.9 kg/m^3/day SS and 9.3 kg/m^3 COD. In spite of these heavy loads, nitrification is primed. (See Table 3)

BIOSTYR – 2nd stage: nitrification. The applied loads are 1.25 kg/m^3/day BOD_5 and 1.05 kg/m^3/day NTK. (See Table 4)

BIOFOR – 3rd stage: denitrification. Denitrification was not required in winter. It was successfully implemented immediately in the early spring: water discharged into the river Seine contained less than 3 mg/l N-NO_3 and less than 7 mg/l total nitrogen. (See Table 5)

Table 5 Breakdown of treatment results

	S.S mg/l	COD mg/l	$_{soluble}$COD mg/l	BOD_5 mg/l	TKNl Mg/l	NH_4^+ mg/l	Total P-P mg/l	$PO_4^{\equiv}$-P mg/l
Raw water	302	559	213	256	50.2	30.5	10.9	5.6
Purified water	5	43	39	8	3.8	2.4	2.6	2.1
Efficiency	98%	93%	82%	97%	92%	92%	76%	62%
Removed amounts, tons/day	79	137.2	46.3	66	12.3	8	2.2	0.9

Primary settling alone provides for the abatement of 83% SS, nearly 50% BOD_5 and for the removal of phosphorus. Upon discharge, the various pollutions are abated with an efficiency of 98% for SS, 97% for BOD5, 92% for NTK and 76% for total phosphorus.

These results could be achieved with waters that rank among the most heavily loaded ones that are liable to come to Seine Centre. A great efficiency persists with BOD_5 even beyond the guaranteed treatment capacity, as evidenced by Figure 4 in the applied loads area. These remarks are also applicable to both nitrification and denitrification: the peak loads are readily accommodated by the system, provided, of course, that they do not last too long a time.

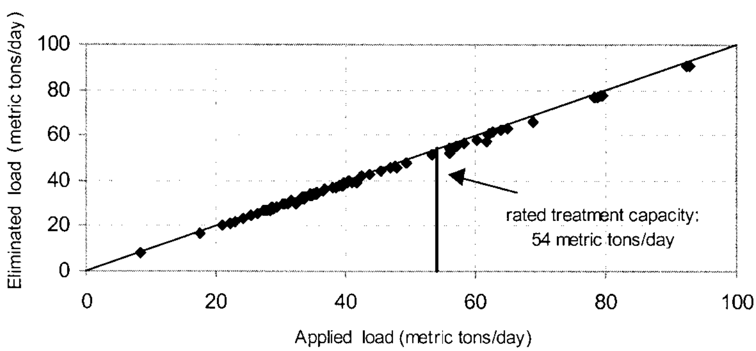

Figure 4 Daily BOD_5 loads applied and removed at Seine Centre under basic configuration

Water, however, is often less heavily loaded by 20–40%, so that the plant is operated below its rated capacity as regards both carbon pollution abatement and nitrification, but ensuring a good denitrification.

Optimized dry weather system: 4.2 m^3/s

When the Seine Aval treatment plant was run partly idle, it was decided, in order to prevent any discharge of raw water into the river, to increase the flow rate from 240, 000 m^3/day up to 360,000 m^3/day, the maximum abatement of carbon pollution being aimed at. That could only be achieved to the detriment of the complete effluent nitrification and denitrification. Under that configuration, it even happened that the amounts of carbon-bearing pollutants that could be removed were higher than with the previous configuration, though globally less loaded waters arrived at Seine Centre. (See Table 6)

Table 6 Optional dry weather performance

	Treated amount m^3/day	S.S mg/l	COD mg/l	BOD_5 mg/l	TKN mg/l	NH_4^+ mg/l	NO_3-N^- mg/l	total P-P mg/l	$PO_4^{\equiv}$-P mg/l
Raw water	365 000	255	443	190	39.6	24.7	0.6	7.2	2.9
Clarified water	365 000	32	174	90	33.2	24.0	0.6	1.9	0.6
Outlet Biofor 1st +3rd	365 000	10	47	11	22.8	21.5	5.5	0.7	0.4
Outlet Biostyr	267 000	5	34	5	3.4	0.7	23.5	0.7	0.3
Discharge to Seine	365 000	6	37	6	8.9	7.7	18.3	0.7	0.4
Global efficiency		98%	92%	97%	77%	69%		90%	86%
		Removed amounts tons/day							
		91	148	67	11.2	5.9		2.4	0.9

Figure 5 compares the BOD_5 loads that are removed under that configuration with the loads that could have been removed under the basic configuration that could have been arranged if, for instance, activated sludge had been involved.

Through the modular design of the Seine Centre plant, the optimal configuration can be chosen in accordance with water loading and treatment goals for making the best use of its maximum treatment capacities.

Wet weather system: 8.5 m^3/s for 8 hours

During the five days before the rainwater treatment test, the plant was fed at the rate of 306,000 m^3/day. Its performance was as follows (see Table 7).

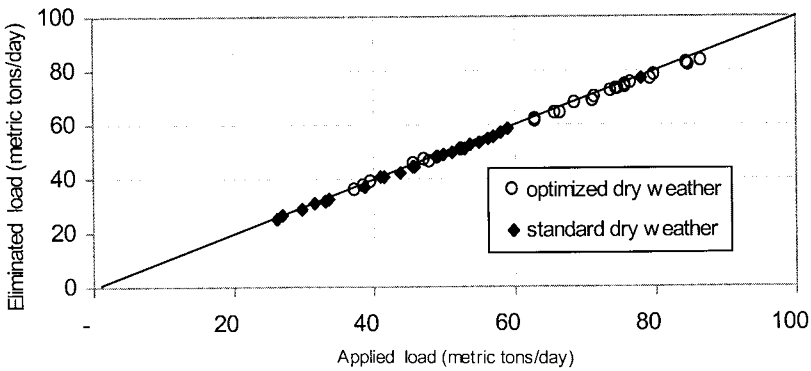

Figure 5 Daily BOD_5 loads applied and removed at Seine Centre under basic configuration and optimised configuration

Table 7 Pre-test water quality

	S.S mg/l	COD mg/l	BOD_5 mg/l	TKN mg/l	NH_4^+ mg/l	NO_3-N^- mg/l	total P-P mg/l	$PO_4^{\equiv}$-P mg/l
Raw water	223	357	143	30	17	0.4	5	2.1
Purified water	3	22	5	1.4	0.5	3.4	0.2	0.2

255,000 m^3 water were treated at a constant flow rate during that period of time, i.e. about thrice as much as the nominal flow rate. The outlet water quality with respect to SS, COD and BOD_5 is only slightly degraded. The reactants were added at the rate of 29 mg/l pure $FeCl_3$ and 0.4 mg/l polymer.

Table 8 Test performance

	S.S mg/l	COD mg/l	BOD_5 mg/l	TKN mg/l	NH_4^+ mg/l	NO_3-N^- mg/l	total P-P mg/l	$PO_4^{\equiv}$-P mg/l
Raw water	231	369	165	33.4	20.8	0.3	5.6	2.3
Clarified water	37	130	63	22.3	19.3	0.3	1.2	0.5
Purified water	10	42	11	8.5	6.2	16.4	0.8	0.5
Amounts removed settling over 8 peak hours								
	49.5	61.1	26	2.8				0.46
Total removed amount over 8 peak hours								
	56.5	83.5	39.3	6.4	3.8		1.2	0.46
Mean total amount removed over 24 hrs including 8 peak hours								
	101	151	67	12	7.2		2.2	

Settling alone provides for the removal of 88% SS, 73% COD and 66% BOD_5. Considering the whole system, the amounts of carbon-bearing pollutants that are removed in 8 hours are nearly the same as those being removed in 24 hours, without any significant quality degradation of the water discharged into the river. Phosphate removal is fully preserved; of course, the global nitrification efficiency decreases, since only a part of water is nitrified. The quality of water treated in the nitrification stage, however, was not altered in spite of the instantaneous increase of the applied nitrogen loads by 50%. The return to dry weather configuration is immediate in nitrification.

The "third stage" behavior which, during the previous hour, provides for effluent denitrification (in anoxia) and presently abates the carbon pollution in the presence of oxygen is noteworthy: the third stage receives 27% of clarified water and reduces its BOD_5 from 62 mg/l down to 23 mg/l. Thus, it takes part in the 6% reduction of total BOD_5.

Table 9 Mean daily quality, 6 hours after the 8.5 m^3/s test

	S.S mg/l	COD mg/l	BOD_5 mg/l	TKN mg/l	NH_4^+ mg/l	NO_3-N^- mg/l	total P-P mg/l	$PO_4^{\equiv}$–P mg/l
Raw water	153	293	126	28.5	19	0.5	4.5	2.2
Purified water	4	24	4	1.4	0.4	4.3	0.3	0.2

A few hours after the nominal flow rate was restored, the plant recovered its initial performance, inclusive of the original denitrification.

Conclusions

Whereas Seine Centre is still in the acceptance phase, configurations different from those mentioned in the specifications had to be implemented for achieving the best possible protection of the discharge environment, thus evidencing the design advantages offered by that plant.

The major reasons for such a flexible and quick start are the choice of biological filters that can intermittently accommodate great variations of hydraulic loading, the over-dimensioned and efficient clari-flocculation and, of course, a sludge treatment that can quickly conform to a rapid increase of sludge production.

The results obtained by the SIAAP over years of experimentation with the BIOFOR and BIOSTYR pilot plants had clearly established the Seine Centre dimensioning parameters. The first year of operation confirmed the expectations about the outstanding quality of purification as regards water treated both during dry weather and wet weather. Whereas the flow rate was multiplied by 3 in relation to the nominal plant flow rate, the purified water still has an exceptional quality (10 mg/l SS, 42 mg/l COD, 11 mg/l BOD_5 and 8.7 mg/l NTK).

Since the biofilter can handle high peaks of hydraulic loading (thrice as much as the nominal flow rate), the over-dimensioning of clari-flocculation is over 12 m^3/s and the plant is modular, hydraulics is no longer a hindrance, whereas it was often a limiting factor in many treatment plants.

Such significant and quick variations of the treatment capacity, however, are only made possible through an over-dimensioning of sludge treatment involving three sludge storage tanks, ten centrifuges and four incinerators.