ORP as a control parameter in a single sludge biological nitrogen and phosphorus removal activated sludge system

M de la Ménardiére[1], J Charpentier[2], A Vachon[3] and G Martin[1]*
[1]Laboratoire de Chimie des nuisances et génie de l'environnement, Ecole Nationale Superieure de Chimie de Rennes, avenue du général Leclerc 35000 Rennes, France
[2]Compagnie Générale des eaux (C.R. Bretagne) 11 rue Kleber 35000 Rennes
[3]Agence de Bassin Loire-Bretagne BP 6339 avenue de Buffon 45039 Orléans cedex

Abstract

This study was carried out at full scale on the St Mars la Jaille activated sludge system (Western France), which is one of the first successful biological excess phosphorus removal systems in Europe. The aim of the study was to show how the parameter oxidation reduction potential (ORP) can be used to optimise biological nitrogen and phosphorus removal in a two-series reactor system, by controlling air supply to the second aeration tank (for nitrification and denitrification) and monitoring anaerobiosis in the first non-aerated tank. It would appear that setting ORP regulation limits in the aeration tank is of utmost importance in control of the system. High levels of carbon, nitrogen and phosphorus removal were obtained for lower and upper ORP limits in the aeration tank of +200 and +400 mV respectively and +300 and +500 mV respectively (COD and SS removal > 95%; TKN removal > 90% and P removal > 80%). Furthermore, ORP recordings enabled the aerobic, anoxic and anaerobic phases of a cycle in the aeration tank, and the degree of anaerobiosis in the non-aerated tank, to be monitored.

Introduction

Many studies have been published about biological phosphorus removal in waste-water treatment plants (Barnard, 1975). The processes implemented (Phoredox, Bardenpho, UCT...), generally incorporate in the system an anaerobic zone which is fed the influent waste water and some recycle of sludge or mixed liquor.

A number of waste-water plants throughout France, operating at low sludge loading, are designed for nitrogen removal only and include two tanks: in the first tank, anoxic conditions are maintained to denitrify nitrates of recycled sludge; in the second tank ammonia removal is obtained by nitrification induced through aerobic conditions. This was the case of Saint Mars la Jaille waste-water plant. In 1984 Florentz showed that it was possible to create anaerobic conditions in the first tank of this plant in order to stimulate biological excess phosphorus removal. The requirement of anaerobic conditions in the first tank for biological phosphorus removal implied that nitrogen removal (NH_4^+ and NO_3^-) should be provided in the second tank. This was achieved by alternating aeration and non-aeration periods in the second tank, to obtain nitrification and denitrification respectively, and so limit the NO_3^- recycled to the first tank to maintain the anaerobic conditions (David and Charpentier, 1984).

This scheme proved very economical, because the result was obtained with a low extra financial cost, the only additional construction costs being to add an air-pressurised floating tank to thicken excess sludge without any phosphorus release.

The need to provide nitrification and denitrification periods in the single second tank meant that some control method for the aeration cycle was required. Once such control method is to use oxidation reduction potential (ORP) to regulate switching aeration on and off.

Roberts and Rudd (1963) achieved ORP regulation with lower and upper values evolving at +140 and +450 mV respectively. Mosey (1985) set up a theoretical graph, associating dissolved forms of nitrogen and ORP, which gave a minimal concentration of ammonia and nitrate at +350 mV. David and Charpentier (1984) and Charpentier (1988) proved the reliability of an ORP regulation system and developed it in many full-scale plants. They found that nitrogen removal was obtained with ORP values evolving between +200 and +400 mV.

Redox probes were installed in the second aerobic tank of Saint Mars la Jaille, to control aeration, and in the first anaerobic tank, to monitor the degree of anaerobiosis. Different limits of the ORP regulation in the aeration tank were tested. Our purpose is to show how ORP can be used to optimise nitrogen removal by controlling aeration in the second aeration tank and hence to limit the recycling of NO_3^- to the first non-aeration tank. Also, ORP was to be used to monitor the state of anaerobiosis in the non-aeration tank.

List of symbols

Symbol		Description
ORP	–	oxidation reduction potential
COD	–	chemical oxygen demand
SS	–	suspended solids
TKN	–	total Kjeldahl nitrogen
BOD	–	biological oxygen demand
SVI	–	sludge volume index
VSS	–	volatile suspended solids
DO	–	dissolved oxygen
Tot.P	–	total phosphate

Materials and methods

Plant description

Characteristics of the plant

The plant consists of two tanks in series, a non-aerated followed by an aerated tank. Sludge recycle is from the settler to the non-aerated tank. Primary treatment comprises grit and grease removal, but no screening and no primary settling. The influent is fed into the non-aerated tank (580 m³) (Fig. 1) which is stirred 15 h a day, then passes to the aeration tank (1 970 m³) which is equipped with 2 surface aerator turbines. Two ORP probes were installed in the system; one (S1) in the first zone and the other (S2) in the second zone. The ORP probe S2 was used to regulate aeration; the turbines were switched on at the lower ORP limit and switched off at the upper ORP limit. An oxygen sensor, located

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*To whom all correspondence should be addressed.

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near S2, was used to compare ORP regulation and oxygen measurements. An ir-pressurised floating tank gives a rapid thickening of excess sludge, coming directly from the bottom of the sedimentation tank.

The plant was operating below its design capacity (12 000 population equivalent). Influent was a mixture of urban origin (15% of BOD_5) and of industrial origin as well (85% of BOD_5, mainly from salting plant and poultry abattoirs). The influent pH was neutral (7,0 to 7,3), and $COD/BOD_5 = 1,9$. Readily biodegradable COD was not determined according to methods by Ekama *et al.* (1986) i.e. by the flow-through activated sludge system method, aerobic batch reactor method or anoxic batch reactor method. But BOD_5 soluble may estimate this biodegradable pollution (Treteault *et al.*, 1986). During a characteristic period, this value was 325 mgO_2/ℓ and BOD_5tot/BOD_5sol equal to 1,83. These values correspond to the type of industrial effluent. Sludge age was 35 d on average, given by the flow, concentration and functioning time of the air-pressurised floating tank. Mean working conditions of the plant are summarised in Table 1.

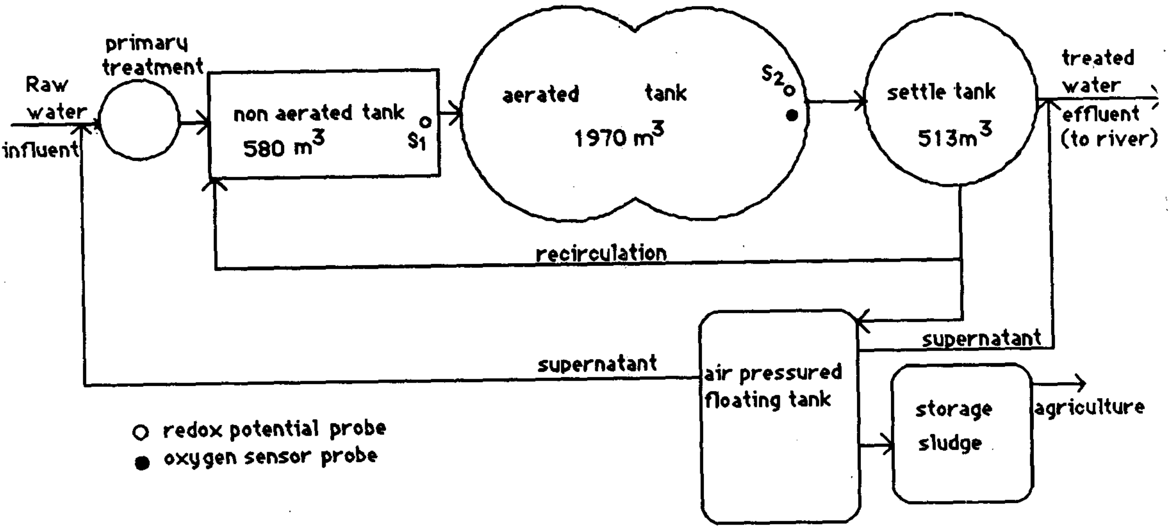


Figure 1
Diagram of Saint Mars la Jaille sewage treatment plant

TABLE 1
OPERATING PARAMETERS OF THE PLANT

	Non-aerated tank	Aeration tank	Settling tank		
Volume (m^3)	580	1970	513	mean mass load $kgBOD_5/kg$ VSS.d	0,04 39% of the design value
Mean hydraulic retention time (h)	28	96	14	mean volume load $kgBOD_5/m^3.d$	0,12 39% of the design value
Mixed liquor concentration (g/ℓ)	4,2	4		recirculation rate (% of influent rate)	98

Influent characteristics

	Flow rate	COD	BOD_5	SS	TKN	Tot.P	pH
Influent	491 (m^3/d)	850 (mgO_2/ℓ)	470 (mgO_2/ℓ)	345 (mg/ℓ)	80 (mgN/ℓ)	18 (mgP/ℓ)	7,2

TABLE 2
CLIMATIC CONDITIONS AND REDOX CONTROL

Period		I	II	III	IV	V	VI
Dates		29/6 to 19/7/87	20/7 to 17/8/87	18/8 to 12/9/87	28/9 to 7/10/87	30/11/87 to 3/1/88	4/1 to 24/1/88
Temperature (°C)		21	18	19	14	6	8
Daily influent flow rate (m^3/d)		526	472	505	463	825	1 522
ORP limits (mV)	lower	+ 150	+ 200	+ 300	+ 350	+ 150	+ 250
	upper	+ 350	+ 400	+ 500	+ 550	+ 450	+ 350

Experimental phases

Six experimental periods were monitored. The results of each period (Table 2) represent the average of the values over one month (except for period IV which lasted 8 d). ORP values refer to a conventional hydrogen electrode. During the six periods all operating parameters were kept unchanged except the lower and upper limits of the ORP regulation in the aerated tank.

However, during the last two periods temperature values were lower and very high influent flow-rate values were observed, especially during the last period, which had consequences on influent characteristics (low BOD_5 concentration) and on the hydraulic retention time in the non-aerated zone. Furthermore, a shutdown of the aerators was programmed during the winter peak hours when hourly flow rates were very high (last two periods).

With regard to ORP regulation in the aeration tank, the first four periods are characterised by a constant gap (200 mV) between lower and upper limits of ORP (Fig. 2), but with a variation in the median point. In the first period the ORP values were + 150 and + 350 mV respectively; in the second period + 200 and + 400 mV; and in the third period + 300 and + 500 mV respectively. The fourth period is a test with high ORP values (+ 350 and + 550 mV).

In the last two periods, the same median ORP value (+300mV) was kept, but with a large and short amplitude (period V: +150 and +450 and period VI: +250 and +350mV). These periods were compared with period II (+200 and +400 mV), where the median ORP value was also +300mV).

Analytical methods

COD, BOD_5, pH and total phosphorus were measured on influent and effluent before filtration, and phosphates, nitrates, nitrites and ammonia after filtration. Analyses were conducted in accordance with French standard methods (AFNOR, 1986). The sensors used to measure redox potential were Polymetron sensors fitted out with Ingold electrodes. Electrodes were cleaned and calibrated periodically.

Inlet samples were collected after the preliminary treatment by the composite sampling method and maintained in a refrigerator; outlet samples were grab samples out of the settler and there was not much variation in the parameters during the day.

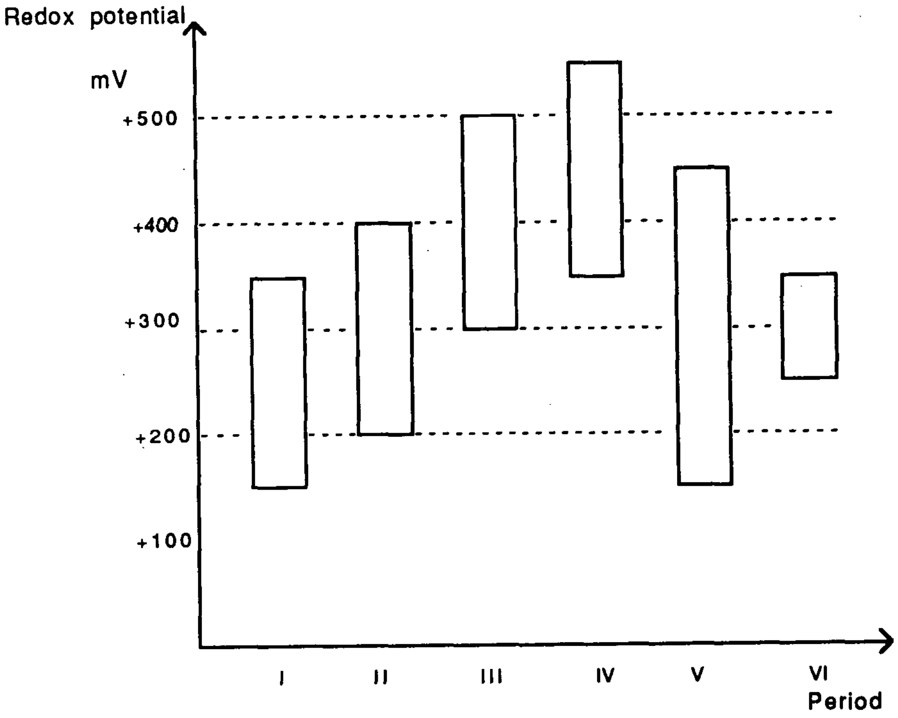


Figure 2

Upper and lower values of ORP for different periods

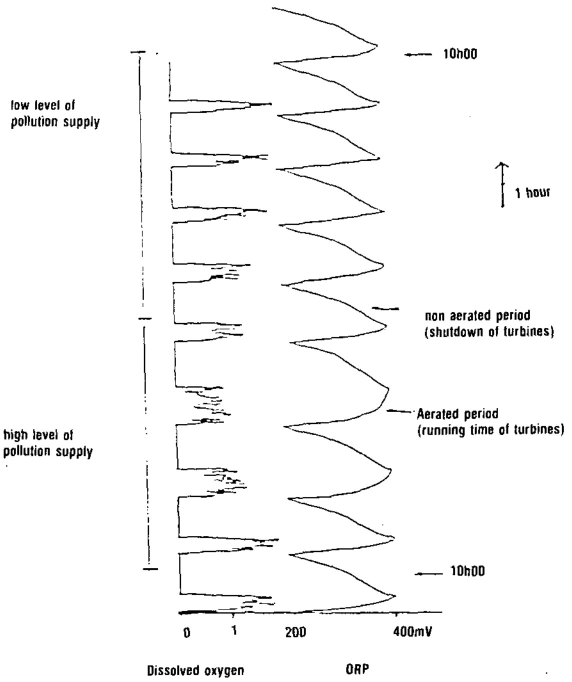


Figure 3
Twenty hours of ORP and DO recordings during a normal day (period 11)

Results and discussion

Observations on ORP recordings

In the aeration tank

During an aeration cycle, 2 phases can be identified on ORP recordings (Fig. 3): the ascending portion on the chart corresponds to the running of the aerators, while the descending portion corresponds to the shutdown of the aerators.

The ascending portion is shorter during weekends and at nights when the system has lower loading, and longer during days when pollution supply is at its highest level because of industrial activity.

The ORP recordings can be used for good monitoring of dissolved forms of nitrogen, as described by Charpentier (1988). Along the ascending portion of the ORP plot, a point of inflexion can be observed during period III, corresponding to the disappearance of ammonia in the medium (Fig. 4); along the descending part, another variation of the slope (point of inflexion) can be seen during the first two periods (I and II) — this corresponds to the disappearance of nitrates.

Comparing ORP to oxygen recordings, ORP recordings are large and regular while dissolved oxygen recordings are jagged and jerky. This makes ORP regulation more reliable than dissolved oxygen regulation. Furthermore, ORP recordings allow the anoxic and anaerobic phases in the aeration tank to be monitored when oxygen concentration is zero and hence cannot be used for monitoring purposes.

TABLE 3
AVERAGE REDOX AND PHOSPHATE VALUES IN THE NON-AERATED TANK

Period	I	II	III	IV
ORP limits in the aeration tank (mV)	+150/ +350	+200/ +400	+300/ +500	+350/ +550
Average ORP values in the non-aerated tank (mV)	- 218	- 200	- 184	- 108
PO$_4$-P in the interstitial water (non-aerated zone) (mgP/ℓ)	67	56	62	57
NO$_3$ (mgNO$_3^-$ /ℓ)	0,5	0,6	0,6	1,0

In the non-aerated tank

As shown in Table 3, the higher the ORP regulation limits are in the aeration tank, the higher the ORP values are in the non-aerated tank. However, anaerobiosis is maintained even during the fourth period (ORP value always less than -100 mV); this is confirmed by a high level of phosphorus released to the interstitial water (up to 73 mgP/ℓ) (Fig. 5) and a very low residual nitrate value.

Maintaining anaerobic conditions facilitated good phosphorus removal. In the absence of an electron accepter (O$_2$ and NO$_3$), fermentative metabolism is induced (producing volatile fatty acids) which favours polyP microorganisms such as *Acinetobacter*. Gerber and Winter (1984) advocated long hydraulic retention times (20 to 24 h) to improve P removal. In this study the hydraulic retention time in the non-aerated zone was about 20 h.

The long hydraulic retention time in the non-aerated zone (about 20 h) and cessation of stirring at night for 9 h, avoided any disturbances due for example to the presence of nitrates (Hascoet and Florentz, 1985).

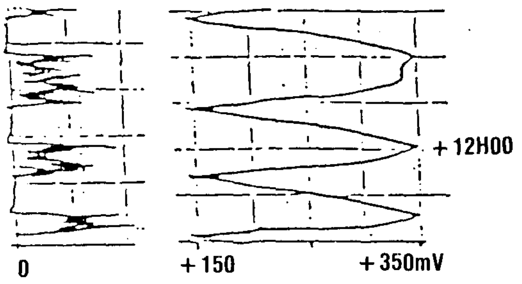
Carbon, nitrogen and phosphorus removal

The data corresponding to the different periods are presented in Table 4.

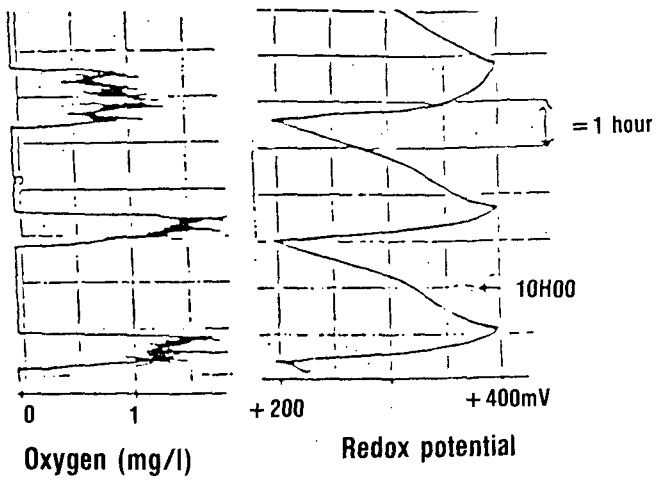
Carbon removal (COD, SS)

The influent, fed into the plant, had nearly the same characteristics during the first three periods while higher values were observed during the fourth period, probably due to increased industrial activities. COD and SS effluent quality improved from the first to the third period, while slightly higher values were observed during the fourth period. For this observation, there may be two explanations:

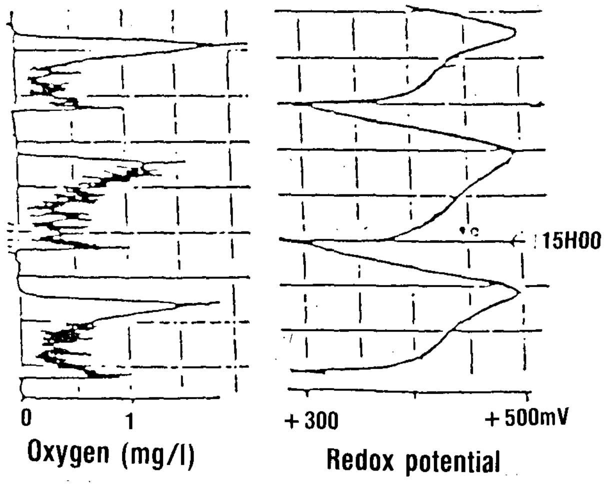
- Firstly, during this period the influent COD is significantly higher than for the other periods, an increase in influent COD will result in increase in effluent COD due to the increase in soluble unbiodegradable COD (Henze *et al.*, 1987); or
- alternatively, during this period denitrification occurred in the settling tank due to the high ORP limits leading to rising sludge and overflow in the effluent.



Period I



Period II



Period III

Figure 4
Records of redox potential and oxygen

TABLE 4
INFLUENT AND EFFLUENT CHARACTERISTICS DURING PERIODS I, II, III, IV

		Flow rate m³/d	COD mgO$_2$/ℓ	SS mg/ℓ	TKN mgN/ℓ	Tot.P mgP/ℓ	NH$_4^+$ mgN/ℓ	NO$_3^-$ mgNO$_3$/ℓ	PO$_4^{3-}$ mgP/ℓ
I	influent	526	827	306	91	22,0	51		17,7
+150/+350	effluent		84	19	21,7	9,3	21	0,5	8,9
removal	(%)		90	94	76	58	59		49
II	influent	472	862	366	85	17,4	51		16,1
+200/+400	effluent		68	15	15,8	4,2	8,0	3,3	4,0
removal	(%)		92	96	81	76	84		77
III	influent	505	940	441	93	20,2	55		16,2
+300/+500	effluent		47	8	4,1	2,4	1,0	5,7	2,2
removal	(%)		95	98	95	88	98		86
IV	influent	463	1244	775	164	36,7	63		29,4
+350/+550	effluent		54	10	6,9	6,0	1,1	17,7	5,8
removal	(%)		96	98	96	84	98		80

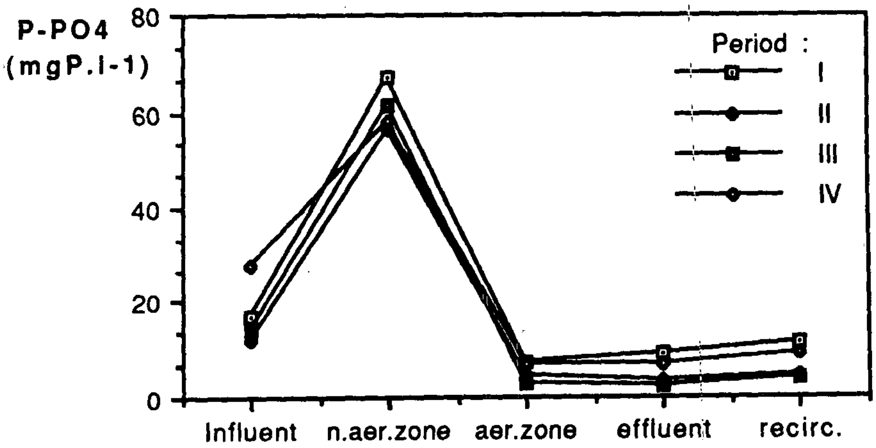


Figure 5
Phosphate concentration in different zones

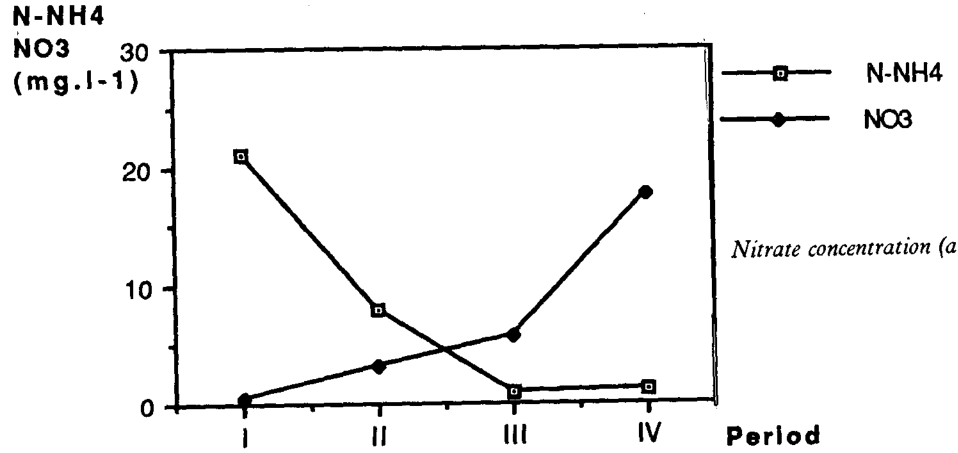


Figure 6
Nitrate concentration (ammonia and nitrates) in the effluent for different periods

Operation under limited oxygen supply conditions favoured high sludge volume indices (309 mℓ/g, period 1) while high oxygen supply gave lower SVI (151 mℓ/g, period IV).

Nitrogen removal

Fig. 6 shows the effluent ammonia and nitrate values during the different periods.

A high effluent ammonia value was obtained during the first period, because the low ORP limits (+150 and +350 mV) caused an insufficient air supply from the turbines and a correspondingly low dissolved oxygen concentration in the aeration tank (0 to 1 mgO_2/ℓ) resulting in a low nitrification rate.

A high nitrogen removal (ammonia plus nitrate) is observed during period III; high N removal was achieved when lower and upper ORP limits were between +300 and +500mV respectively. The last period (+350 and +550mV) was characterised by high nitrate concentration in the effluent due to inadequate turbine shutdown resulting in insufficient denitrification time in the aeration tank. Also during this period the influent TKN/COD ratio was at its highest, resulting in higher NO_3^- generation.

Phosphorus removal

During the first three periods, the percentage of phosphorus removal increased from 56 to 88%, and dropped to 84% during the fourth period (Table 5).

In the case of Saint Mars la Jaille, high percentage P removals (> 80%) were reached when lower and upper ORP limits were +200 and +400 mV respectively and +300 and +500 mV respectively (as for N removal); below these ORP values, the percentage of phosphorus removal was less than 80%.

However, although the percentage removal parameter has significance in evaluating effluent quality, it bears no relation to the phosphorus removal capacity of the system; the parameter $\Delta P/\Delta COD$ is superior in this regard. If the ratio $\Delta P/\Delta COD$ is considered (Table 5), the same value was obtained for periods I and II (0,017 mgP/mgCOD), a slightly higher value for period III (0,020 mgP/mgCOD) and the highest value for period IV (0,026 mgP/mgCOD). The higher $\Delta P/\Delta COD$ values were obtained for periods III and IV despite the high effluent NO_3^- concentrations measured during these periods. During periods III and IV, the influent COD concentrations increased significantly over those in periods I and II due to increased industrial activity. These results would tend to indicate that the industrial component of the influent waste water stimulates biological phosphorus removal, probably due to a large readily biodegradable COD fraction. However, these indications can be regarded as tentative only; period IV lasted only for eight days.

A value of 4,9 mgP/100mgVSS in the sludge was obtained; this is more than the metabolic requirements of the biomass and confirms biological excess phosphorus uptake by polyP microorganisms.

TABLE 5
PHOSPHORUS REMOVAL DURING THE DIFFERENT PERIODS

Periods	I + 150/ + 350 mV	II + 200/ + 400 mV	III + 300/ + 500 mV	IV + 350/ + 550 mV
P_{inf}/COD_{inf}	0,0266	0,0202	0,0214	0,0295
COD_{inf}/P_{inf}	37,6	49,5	46,5	33,9
$Tot.Phosphorus_{effluent}$ (mgP/ℓ)	9,3	4,2	2,4	6,0
ΔP/ΔCOD	0,017	0,017	0,020	0,026
Phosphorus (%) removal	58	76	88	84

TABLE 6
RUNNING OF TURBINES

Period		I	II	III	IV
Mean turbine running time for an aeration cycle (hours)	During days with industrial activities	1,5	2	2-3	4
	During nights and weekends	0,4-0,5	0,5-0,7	0,5-0,7	1,5

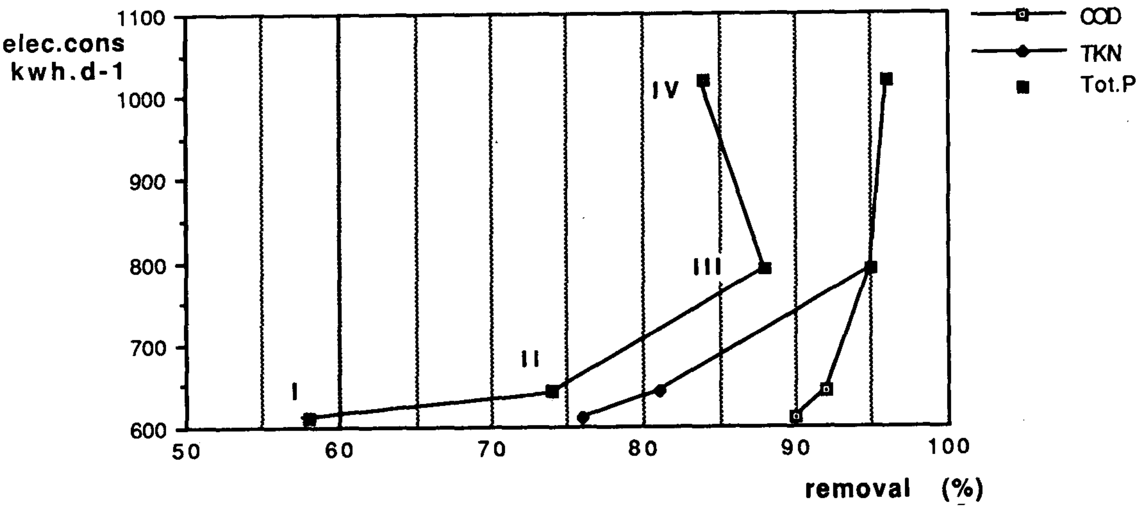


Figure 7
Consumption of electricity by turbines for removal of COD, TKN and Tot.P

The experiment demonstrates that simultaneous N and P removal is possible in a two-series reactor system, and the operating conditions in such a system can be controlled by setting ORP limits for aeration.

Turbine electricity consumption

The results of pollution removal were related to an economic criterion i.e. the consumption of electricity by turbines. For high ORP limits (periods III, IV), the daily running time of the turbines was much higher (Table 6). The higher the ORP regulation limits, the longer the turbines operate. From Fig. 7 it can be concluded that for period I, removal of C, N and P was inadequate, i.e. the system was oxygen limited. A small increase in aeration was enough to optimise removal (period II and period III); during period IV over-aeration caused higher energy cost with only slight improvement in percentage removals.

TABLE 7
INFLUENT AND EFFLUENT CHARACTERISTICS DURING PERIODS II, V, VI

		ΔEH	Temp. (°C)	Flow rate m^3/d	COD mgO_2/ℓ	SS mg/ℓ	TKN mgN/ℓ	Tot.P mgP/ℓ	NH_4^+ mgN/ℓ	NO_3^- $mgNO3/\ell$	PO_4^{3-} mgP/ℓ
II	inf.	200	18	472	862	366	85	17,4	51		16,1
+200/+400mV	eff.				68	15	15,8	4,2	8,0	3,3	4,0
removal	(%)				92	96	81	76	84		77
V	inf.	300	6,4	825	716	336	90	17,6	28		14,1
+150/+450mV	eff.				79	13	16,9	5,1	8,2	2,0	4,8
removal	(%)				89	96	81	71	71		66
VI	inf.	100	8,3	1 522	390	169	42	8,1	17		6,5
+250/+350mV	eff.				47	17	13,1	2,7	9,6	2,0	2,6
removal	(%)				88	90	69	67	43		60

Other factors affecting operating conditions and C, N, and P removal

Two additional tests were carried out in order to study the influence of the magnitude of the gap between the two ORP limits (lower and upper) in the aeration tank on system performance; ΔORP = 300mV during period V and ΔORP = 100mV during period VI. The median ORP value is the same, +300mV and equals the value during period II; accordingly, we will compare periods II, V and VI. The two periods, V and VI were disturbed by heavy rains (especially period VI); rain water entered the sewer, diluting the influent and introducing oxygen into it (Table 7).

C, N and P removal

The influent and effluent qualities during the three periods are shown in Table 9. If the percentage of C, N and P removal is considered the process efficiency appears to have deteriorated slightly during period V and VI, probably due to dilution of influent.

During all three periods significant effluent TKN and ammonia concentrations were measured. This would imply incomplete nitrification and indicates that the upper ORP limits were too low, resulting in inadequate aeration.

With regard to phosphorus removal, although phosphorus removal was maintained during all three periods, a low ΔP/ΔCOD was measured during period VI (0,016 mgP/mgCOD). During this period the daily flow rates were significantly higher and the influent concentrations lower due to rain-water infiltration in the sewer. Thus, it would appear that rain-water infiltration has a negative effect on the phosphorus removal capacity of the system.

Low temperatures (up to 6°C) seemed to have no measureable effects on C, N, and P removal, confirming the conclusion of Venter *et al.* (1978) and Barnard (1984).

The phosphorus release decreases from period II, to period V, to period VI (Table 8 and Eq. 1) from:

$$P_{release} = P_{an} - \frac{(P_{inf.} \times Q_{inf.}) + (Q_r \times P_{eff.})}{Q_{inf} + Q_r} \qquad (1)$$

$$P_{release} \text{ per influent COD} = \frac{P_{an}(1+r) - (P_{inf.} + rP_{eff.})}{COD_{inf.}} \qquad (2)$$

where:

P_{inf} — Phosphorus influent
Q_{inf} — Influent flow rate
Qr — Recirculation flow rate
P_{eff} — Phosphorus effluent
P_{an} — Phosphorus in non-aerated tank
r — Recirculation rate
COD_{inf} — Influent COD
COD_{eff} — Effluent COD

However, this result is to be expected as the influent COD concentrations also decrease; the magnitude of phosphorus release is related to the influent COD, or more precisely to the magnitude of the readily biodegradable COD fraction of the influent COD. If the mass of phosphorus release per influent COD is calculated (Table 8 and Eq. 2), then the calculated results are also expected viz. the phosphorus release efficiency decreases as the influent COD decreases.

TABLE 8
REDOX AND P VALUES OF THE NON-AERATED TANK

Period		II	V	VI
ORP limits in the aeration tank	(mV)	+200/ +400	+150/ +450	+250/ +350
Mean ORP values in the non-aerated tank	(mV)	- 200	- 88	- 30
PO_4-P in the non-aerated tank	(mgP/ℓ)	56	47	22
$P_{release}$	(mgP/ℓ)	44,9	32,9	15,3
$P_{release}$/influent COD	mgP/ mgCOD	0,105	0,099	0,085
Mean hydraulic retention time	(h)	29	17	9

TABLE 9
PHOSPHORUS REMOVAL DURING PERIODS II, V AND VI

Periods	II	V	VI
P_{inf}/COD_{inf}	0,0202	0,024	0,0207
$\Delta P/\Delta COD$	0,0166	0,0196	0,0157
P effluent (mgP/ℓ)	4,2	5,1	2,7
Phosphorus (%) removal	76	71	67

Operating conditions

The larger the gap between the two ORP limits, the longer the aeration cycle, as shown in Table 10.

A ΔORP of 300mV leads to very long aeration cycle time (more than 5 h) and difficulties in reaching the upper ORP limit. A short gap (100 mV) leads to short aeration cycle time, especially during nights and weekends, which may cause mechanical disturbances for turbine operation. Turbine shutdown during the winter peak hours appears to have no incidence on the ORP regulation. Thus with this type of influent, a variation in ORP of 200 mV provided the best balance between mechanical and good quality constraints.

Conclusions

In the non aerated tank ORP measurements brought a better understanding of the operating conditions. During dry weather ORP values evolved between -230 to -100 mV, P release was maintained at a high level (60 mgP/ℓ) while an absence of nitrates was observed. Anaerobic conditions were disturbed by infiltration of rain water in the sewer (- 30 mV during rainy periods) and excessive air supply in the aeration tank (-100 mV).

In the aeration tank ORP regulation has been confirmed as a very useful tool for many reasons:

- Large and regular recordings make it very reliable. ORP measurements maintain significance when dissolved oxygen concentrations are zero; DO value cannot be used at all for control purposes during the non-aerated period.
- On the ORP recordings points of inflection can be observed on the ascending part, probably corresponding to NH_4^+ disappearance, and on the descending part, probably corresponding to NO_3^- disappearance. Thus, the ORP recording provides a visual monitoring of the aerobic, anoxic and anaerobic phases in the aeration tank.
- Correct setting of ORP regulation limits has proved an essential operating parameter to ensure good simultaneous C, N and P removal. In St Mars la Jaille, high levels of C, N and P removal were obtained for lower and upper ORP limits of +200 and +400 mV respectively and +300 and +500 mV respectively (effluent TKN < 5 mg N.l-1, P removal > 80%). A gap of 200 mV between lower and upper ORP limits provided the best balance between mechanical and quality constraints.
- ORP regulation contributes successfully to the stability of effluent quality, in spite of large variability of the influent characteristics, flow rates and concentrations in C, N and P compounds.

At Saint Mars la Jaille using a large size non-aerated tank, high P removal level was obtained even when excessive air supply was provided in the aeration tank or when a large amount of rainwater entered the sewer, although negative effects were observed.

This study has confirmed that simultaneous N and P removal is possible in a two-series rector system. In this system, ORP serves a useful function as a control parameter: It helps to monitor anaerobic conditions in the non-aerated zone; it is a reliable tool to control air supply in the aeration tank; it contributes to a high and stable effluent quality; it minimises electricity consumption. The system operation and ORP control method can be applied to many activated sludge systems designed for N removal only, to incorporate P removal with low investment cost. However, particularities of the Saint Mars la Jaille plant will have to be taken into account for transfer of results reported here to other plants. In particular, due cognisance must be taken of the influent waste-water characteristics. Of importance in this regard is the readily biodegradable COD fraction of the influent.

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TABLE 10
MEAN AERATION CYCLE TIME DURING NIGHT AND DAY FOR PERIODS II, V, VI

Period		II	V	VI
ΔEH(mV)		**200**	**300**	**100**
Mean aeration cycle time (running+shutdown)(hours)	During days with industrial activities	4	5,5	1,5
	During nights and weekend	2,5	3	1

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