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REAL-TIME CONTROL OF NITROGEN REMOVAL USING THREE ORP BENDING-POINTS: SIGNIFICATION, CONTROL STRATEGY AND RESULTS

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ABSTRACT

The necessity to achieve nitrogen and phosphorus removal in wastewater, according to the European Directive (EEC 1991), leads to the conception of new methods to control the aeration of low-loaded activated sludge plants. The behaviour of N.NOx concentrations and of ORP during a complete nitrification-denitrification cycle is described by a typical profile with 3 bending-points: α, β and χ. The goal of this study is to get more insights into the biological and chemical signification of the bending-points. This leads to the conception of new real-time control systems able to be adaptative to the influent load variations and free from ORP drift problems. The results obtained on pilot-scale plant using a three bending-points based control strategy show a real advantage through a decrease of the global aeration duration. Copyright © 1996 IAWQ. Published by Elsevier Science Ltd.

KEYWORDS

Activated sludge; bending-points; denitrification; nitrification; Oxidation Reduction Potential; real-time control; sulfides.

INTRODUCTION

The necessity to achieve nitrogen and phosphorus removal in wastewater, according to the European Directive (EEC 1991), leads to the conception of new methods to control the aeration of low-loaded activated sludge plants. These new systems must secure and optimize the aeration periods so that their length is adjusted to the influent load variations. The incapacity of Dissolved Oxygen (DO) monitoring to give information during anoxic, and obviously anaerobic periods created a new interest for the Oxidation Reduction Potential (ORP) measurement. Several researchers have studied the potential use of ORP measurement for the control of the aeration. Some authors described methods based on the use of ORP absolute values (Héduit, 1989; Charpentier *et al.*, 1989). When a fixed low level is reached (denitrification) aeration is switched on, and stopped when a fixed high level is obtained (nitrification). Due to operational problems: wear of the electrode, drift of the signal, and so on, high and low levels must be continuously adjusted making the system unreliable. Recently, technologies using relative ORP changes with time (Sasaki *et al.*, 1993; Lefevre *et al.* 1993) have appeared. They seem to give better control results but, again require intensive maintenance of the electrodes. Some authors (Wareham *et al*, 1993; Wouters-Wasiak *et al.*, 1994) discussed the use of bending-points on the ORP curves, which are difficult to explain theoretically. The meaning of the absolute value of ORP in activated sludge is still undefined and its use badly mastered. The goal of this study is to get more insights into the biological and chemical signification of the bending-points. This should lead to the conception of new real-time control systems able to be adaptative to the influent load variations and free from ORP drift problems. This regulation will enable us to optimize aeration in order to avoid lengthy nitrification periods and incomplete denitrification stages.

MATERIAL AND METHODS

All experiments have been achieved on a 30 litre pilot-scale plant working very like a low-load activated sludge wastewater treatment plant (fig. 1). This pilot was fed with domestic wastewater of the Town of Toulouse (France).

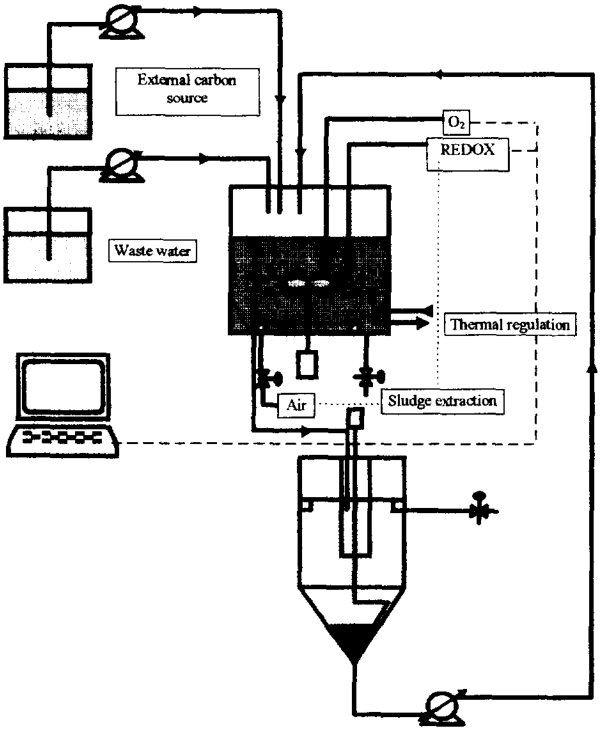

Figure 1. Pilot-scale plant.

All analysis methods were issued of the French Standard Methods (AFNOR, 1994). The measuring out of the dose of sulfides was made using the Methylene Blue Method (Standard Methods, 1975)

RESULTS AND DISCUSSION

Biological and chemical signification of bending-points.

A lot of wastewater treatment plants using low-load activated sludge processes are fit out with a sequencing aeration system. This enables performing nitrification and denitrification stages in the same tank. It is then difficult to find a regulation way of this sequencing system that avoid NH_4^+ or NO_x (NO_3^- + NO_2^-) accumulations. The behaviour of N.NOx concentrations and ORP during a complete nitrification-denitrification cycle (observed on a continuous pilot-scale plant fed with domestic wastewater) (fig. 2), is described by a typical profile with 3 bending-points: α, β and χ. They correspond respectively to the end of the consumption of NH_4^+ accumulated during the previous denitrification period, to the beginning of the anoxic stage, and to the beginning of the anaerobic phase.

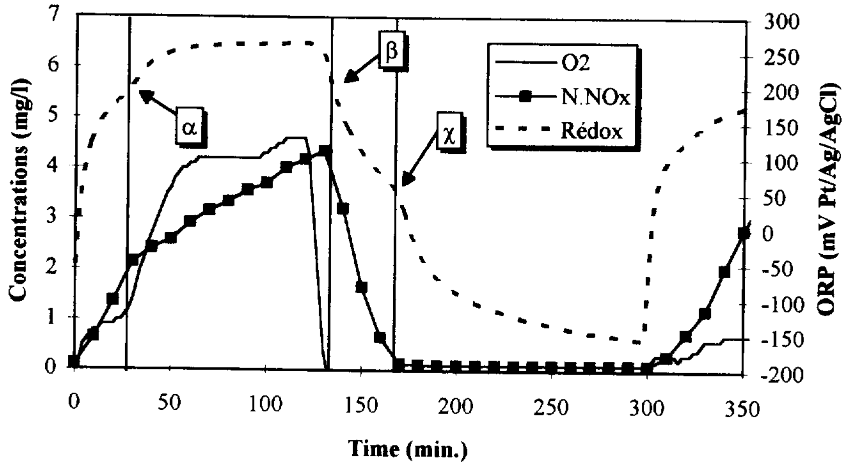

Figure 2. Typical ORP profile of nitrification-denitrification cycle.

The bend corresponding to a seems to be due to a DO increase caused by NH_{4+} disappearance (value near 0). Experiments in pure water confirmed in wastewater show that a strong concentration variation of NOx (0-30 mg N/l) produces only a limited ORP increase (30 mV) while the electroactivity of DO is much more important (200 mV for an increase from 0 to 2 mg O2/l). In the same way ammonia seems to have no influence on the ORP value. The α point, observed at the end of NH_4^+ consumption, is thus well correlated to the DO increase and constitutes then a good indication that nitrification is over.

The bend called β always corresponds to DO disappearance. We can consider that the ORP fall is bending because the only electroactive species left are those issued of NOx. Their slow decrease linked to the denitrification reaction is responsible for the appearance of an asymptotical decrease of the ORP value. The value of the step thus obtained seems not to have a biological signification, but depends among other things on the surface state of the platinum probe. The β point enables us to detect exactly the beginning of the denitrification phase.

Finally, the χ point is linked to the disappearance of nitrates. In fact our experiments on several RedOx couples have shown that this sudden decrease of ORP is due to the beginning of a sulfato-reductive activity that produces sulfides. Sulfides have a great impact on ORP value so that a 0.07 mg S-Sulfides/l concentration increase, in absence of oxygen, leads to a 100 mV fall of the ORP value, (fig. 3).

We can remark that (fig. 3) the profile obtained by injection of sulfides in pure water is identical to the one of figure 2. Furthermore, the measuring out of the dose of sulfides before and after the χ point during a denitrification phase shows an increase of their concentration. This seems to be responsible for the appearance of the χ point. (fig.4).

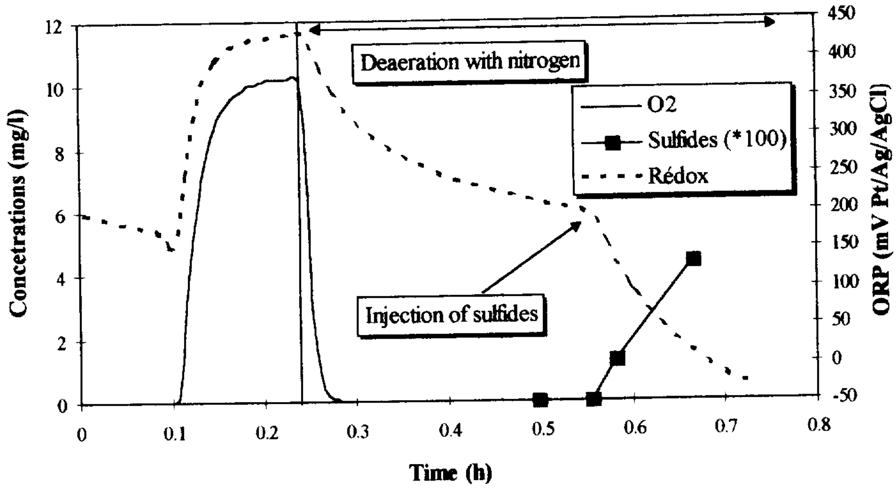

Figure 3. Influence of sulfides on ORP in "pure water".

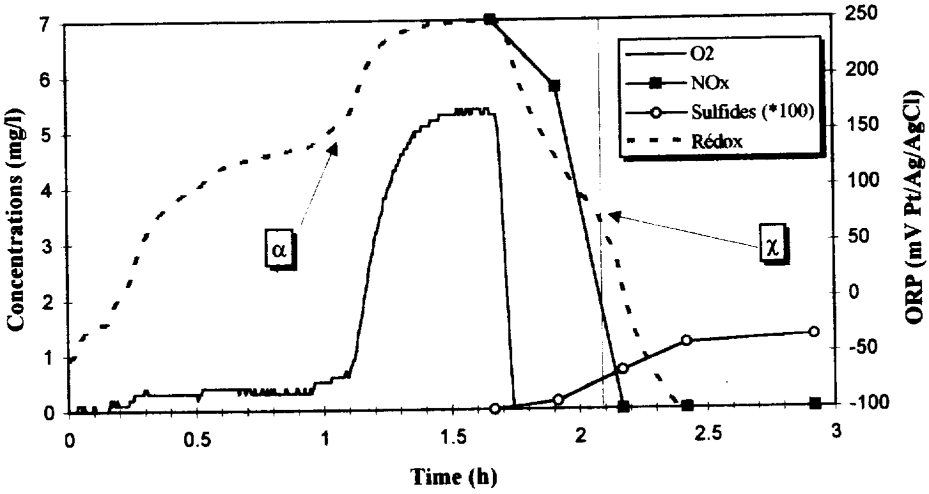

Figure 4. Evolution of Sulfides during a denitrification stage.

The sulfato-reductive activity can not appear before the complete disappearance of nitrates which are inhibitors of this activity. So the bending-point at the end of the denitrification period, observed by several researchers (Al-Ghusain *et al.* 1993, Sasaki *et al.* 1993, Wouters-Wasiak *et al.* 1994) is not caused by the beginning of a fermentative activity but is due to the production of a very ORP active chemical species (fig. 2) by a respiratory biological activity which uses sulfates as electron acceptor (HS^-/SO_4^-).

The mechanisms responsible for the appearance of the 3 bending-points are thus linked to the several major biological activities playing a role in a nitrification-denitrification cycle: the α point enables a good detection of the end of the optimal aeration period (end of nitrification). The detection of β point indicates the beginning of the anoxic phase. Finally the appearance of the χ point is linked to the production of sulfides. This last point is reached only if the carbonaceous substrate is not limiting and if there is no inhibitor of sulfato-reductive activity such as, for example, nitrates. The χ point is thus always present at the end of the denitrification stage and constitutes then a good indication that denitrification is over.

Control strategy

These results allowed us to design a new real-time control of the aeration based on the detection of the 3 bending-points (double linearized derivation). This regulation system has been tested on a continuous low-loaded activated sludge pilot-scale plant since June 1994. The maintenance of the ORP electrode is very simple as the system is not disturbed by the wear of the surface of platinum. Therefore it is no longer necessary to clean it or to burnish it.

Results

As far as we consider the control efficiency of this system, the results show that the detection of the a point is systematic and allows to stop the aeration at the moment where the accumulated NH_4^+ has been nitrified. The aeration "turn on", controlled by the χ point, is accomplished whatever the absolute values of the ORP are (fig. 5), but always after the complete disappearance of nitrates. The control system is thus completely free from having to specify absolute values and from ORP drift as only the shape of the curves is important.

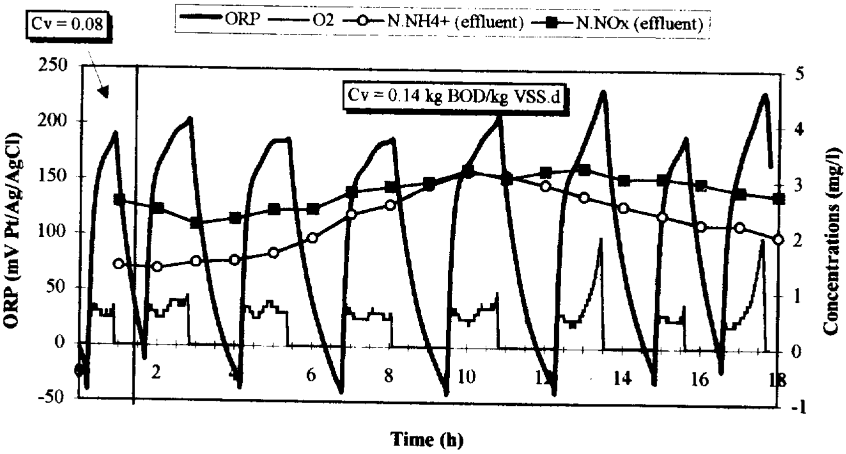

Figure 5. Cycle by bending-points control.

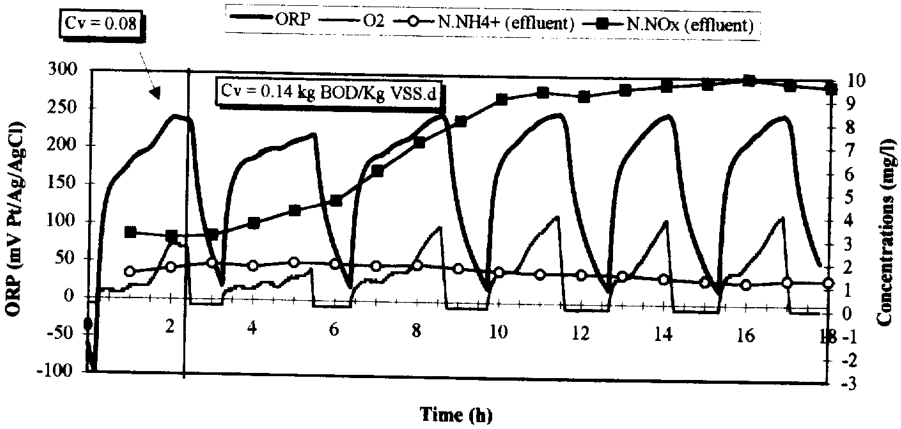

Figure 6. Cycle by classical ORP control (levels).

This real-time control system enables in the same way a good elimination of carbonaceous pollution and removal of nitrogen under 10 mg N/l for an influent concentration of 90 mg NTK/l (removal > 89 %). Moreover, the detection of the three bending-points enables to measure, in real-time, the length of each phase and so to regulate an external carbon source adjunction. This should avoid lengthy denitrification stages. The complete removal of nitrates during the well controlled denitrification phases (NOx < 0.1 mg/l) prevents denitrification problems in the secondary clarifiers and gives an effluent quality of NNOx < 4 mg N/l (av. in two hours). Finally, the comparison of these results with the ones obtained with a classical regulation system using levels (fig. 6), shows a real advantage for our system through a decrease of the global aeration duration (Table 1).

We can see in figure 6 and in Table 1 that, under high load conditions, the classical control system is not adaptative and provokes over-aeration periods and incomplete denitrification stages, so that effluent quality no longer correspond to the European Directive. We have to notice that figure 5 and figure 6 show experiments worked strictly in the same conditions, only the aeration regulation systems are different.

Table 1. Comparison between two control methods

	Classical ORP control	three bending-points control
NH_4^+ (effluent in mg N/l)	1.5	2.8
NO_X (effluent in mg N/l)	7.8	2.3
Global nitrogen (effluent in mg N/l)	15.7	8.7
Aeration wear (per day)	14.37	11.24
Aeration wear on anoxic wear	1.52	0.92

So the real-time control that we used allows a real decrease of global aeration duration with an effluent quality compatible with the European Directive.

The reliability of our real-time control system should soon be tested on a large scale domestic wastewater plant.

ACKNOWLEDGEMENT

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REFERENCES

AFNOR (1994). Recueil de normes françaises 1994: Qualité de l'eau (environnement). AFNOR (Ed.), Paris.

Al-Ghusain, I. A., Huang, J., Hao, J. O. and Lim, B. S. (1994). Using pH a real-time control parameter for wastewater treatment and sludge digestion processes. *Wat. Sci. Tech.*, **30**(4), 159-168.

Charpentier, J., Godart, H., Martin, G. and Mogno, Y. (1989). Oxidation-reduction potential (ORP) regulation as a way to optimize aeration and C,N,P removal: experimental basis and various full-scale examples. *Wat. Sci. Tech.*, **21**(10/11), 1209-1223.

Héduit, A. (1989). Potentiel d'électrode de platine en épuration biologique des eaux. *Etudes ressources en eau CEMAGREF*, **1**.

Lefevre, F., Audic, J. M. and Bujon, B. (1993). Automatic regulation of activated sludge aeration-single-tank nitrification-denitrification. *Wat. Sci. Tech.*, **28**(10), 289-298.

Sasaki, K., Yamamoto, Y., Tsumura, K., Hatsumata, S. and Tatewaki, M. (1993). Simultaneous removal of nitrogen and phosphorus in intermittently aerated 2-tank Act. Slu. process using DO and ORP bending point control. *Wat. Sci. Tech.*, **28**(11-12), 513-521.

Standard Methods (1975). APHA-AWWA-WPCF (Ed.), 14th edition, Washington.

Wareham, D. G., Hall, K. J. and Mavinic, D. S. (1993). Real-time control of wastewater treatment systems using ORP. *Wat. Sci. Tech.*, **28**(11-12), 273-282.

Wouters-Wasiak, K., Héduit, A., Audic, J. M. and Lefevre, F. (1994). Real-time control of nitrogen removal at full scale using oxidation reduction potential. *Wat. Sci. Tech.*, **30**(4), 207-210.