Available at www.sciencedirect.com

SCIENCE DIRECT®

journal homepage: www.elsevier.com/locate/watres

Towards a "crippled-mode" operation of an industrial wastewater treatment plant

*Konrad Szafnicki**, *Cécile Narce*

Ecole Nationale Supérieure des Mines de Saint-Etienne, 158, cours Fauriel, F-42023 SAINT-ETIENNE Cedex 2 France

A R T I C L E   I N F O

Article history:
Received 13 May 2005
Received in revised form
28 October 2005
Accepted 4 November 2005
Available online 6 January 2006

Keywords:
Supervision
Industrial wastewater treatment
Fault management

A B S T R A C T

In house treatment of metal plating wastewater mainly involves chemical treatments performed in continuous flow stirred tank reactors (CFSTR). The inflow of these tanks is directly produced by the plating shops activity, and the storage capacity never exceeds a few hours of incoming flow. Thus, any fault on one of the CFSTR may impose a complete stop of the whole manufacturing process, which is unacceptable for the manufacturer. Another solution would be having "spare" CFSTRs ready to be used as alternative in case of any CFSTR fault or maintenance. The latter solution however implies additional costs in equipment, storage space and maintenance so as to keep this equipment fit and ready for operation.

The paper presents the study of a "crippled-mode" wastewater treatment (WWT) operation which enables a sufficiently efficient working of the WWT plant during maintenance phases and failure repairing on any of the CFSTR, without any extra equipment needed. This survey has been performed on real industrial WWT plants, with a continuous influent and under industrial operation constraints. The performances of the detoxication have been analysed when a CFSTR is short-circuited and the corresponding chemical treatment is shunt in the upstream or downstream CSFTR.

This work shows the possibility of satisfying the environmental regulations with a WWT plant functioning under subnormal conditions.

1. Introduction

Industrial activities, and particularly metal-processing activities (e.g. electroplating) use significant quantities of water during their manufacturing cycles. They thus generate significant amounts of wastewater, which usually do not satisfy environmental regulations so as to be discharged directly to the receiving water.

According to the regulations, these industrial activities have to be equipped with dedicated detoxication plants, so as to meet the admissible quantities of rejected pollutants (metal ions, cyanide etc.), as specified by the law, e.g. in Journal Officiel (1985) as far as French electroplating workshops are concerned.

The detoxication plants are usually designed in an "optimal" way, i.e. as economically as possible, since these installations do not generate added value. As a consequence, industrial wastewater treatment plants (WWTP) often have to operate under "tight" constraints; particularly if the pollutant flow is continuous and/or in small and medium-size enterprises (SMEs), which are tight on budget.

A continuous pollutant flow, 24 h a day, can generate a critical situation if one of the WWTP's components breaks down (e.g. one of the CFSTR) and if the wastewater

*Corresponding author. Tel. +33 477 42 02 24; fax: +33 4 77 42 66 33.
E-mail address: konrad@emse.fr (K. Szafnicki).
0043-1354/$ - see front matter
doi:10.1016/j.watres.2005.11.009

storage capacities are not sufficient vs. the time to fix the failure.

Indeed, any fault can become critical because of the propagation risk and any interruption of the wastewater treatment (WWT) operation can imply the interruption of the whole production process in the plating shops upstream. Many investigations have been dedicated to the development and in situ validation of solutions (tools, methodologies, knowledge-bases, etc.) for efficient, real-time diagnosis and management of WWTP; Baeza et al. (2002), Baeza et al. (2000), Szafnicki et al.(2005), Szafnicki et al. (1998), Sànchez-Marrè et al. (1994), Serra et al. (1993).

The aim of this paper is to propose a flexible, cheaper and simpler approach of operating a WWTP in case of some CFSTR's malfunction and/or stop for maintenance or repair. The approach would consist of a "crippled-mode" WWT operation, thus enabling efficient wastewater detoxication during any unavoidable maintenances or repairs, and saving extra costs caused by putting in significant wastewater stocking equipments (e.g. CFSTRs). This alternative, flexible solution can be set up with a somewhat shrewd design of the WWTP.

2. Process description

A classical, widely used flow diagram of the WWT in plating shops consists of several CFSTRs, each one having a dedicated role, Figs. 1 and 2, as may be found, e.g. in Olsson and Newell (1999), SITS (1998), Degrémont (1991), Westerterp et al. (1987), Meinck et al. (1968). Particularly:

- chromium VI reduction ($Cr^{VI} \rightarrow Cr^{III}$),
- cyanide oxidation ($CN^- \rightarrow CNO^-$),
- pH control for metal hydroxydes precipitation ($Me^{n+} + nOH^- \rightarrow Me(OH)_n$),
- metal hydroxydes flocculation, sedimentation, sludge thickening, filtration (press filters, sand filters) and sludge removal; to be landfilled or utilized for metals recovery.

Metal plating wastewater (MPWW) is collected in a separated sewer through the plating shops, and directed by gravity into two storage reservoirs: one stocking alkaline-cyanide wastewater (AKR) and another stocking acidic (and chromic) wastewater (ACR). The wastewater is usually pumped to the chemical treatment reactors (respectively D and C), from where it flows by gravity through P and F to the lamellar sedimentation tank (LS), etc.

A few of the most delicate detoxication stages have been outlined in Fig. 1. They involve mainly chemical treatments, consisting of redox reactions in continuous flow under, possibly, optimal conditions (pH, reagents and catalysers concentrations, etc.). The latter have to be regulated in real-time, given the variations of wastewater characteristics and inflow (pollutants concentrations, pH, flow, etc.). For example, the decyanidation stage, implying oxidation of cyanides, has to occur under an optimal value of pH_D, which depends on the oxidant used, Table 1. In this application, the decyanidation reaction is performed using H_2O_2, Zumbrunn (1969). It is optimal by pH ~9.5 and catalysed by the presence of Cu^{2+}.

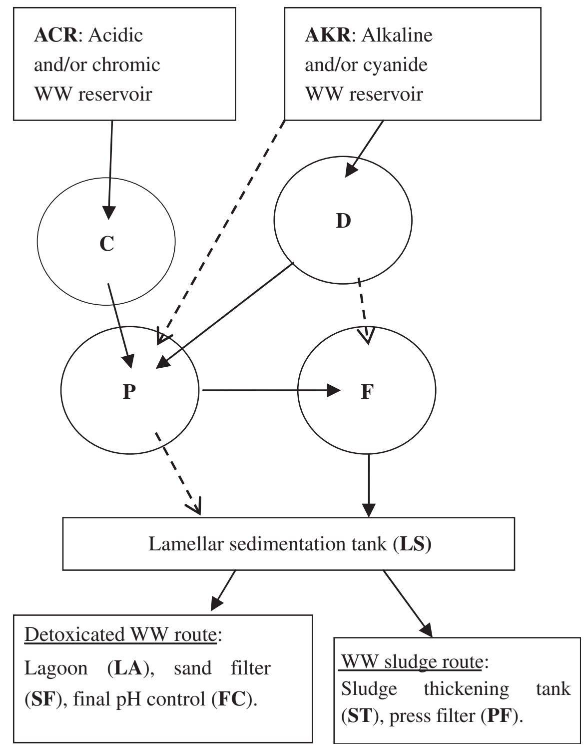

Fig. 1 – Main stages in a "classical" WWTP. [D]–decyanidation, [C]–chromium VI reduction (if Cr^{VI} is present in the wastewater), [P]–precipitation, [F]–flocculation. Dotted arrows indicate "crippled-mode" operation possibilities.

The pH_D therefore has to be controlled so as to remain as stable and close to the optimal value as possible, filtering the "perturbations" due to the variations of the inflow Q_B and/or of pH_B, Fig. 2. Consequently, dedicated control procedures have to be set up, involving sensors (pH meters, potential meters, concentration meters, etc.), controllers and actuators—dosing pumps and reagents tanks. For example, the pH_D is then controlled by injection of an acidic reagent ($Q_{ra|D}$ if pH_D is too high) or an alkaline reagent ($Q_{rb|D}$ if pH_D is too low). The reagents generally used are strong bases (NaOH) and acids (HCl, H_2SO_4, HNO_3, etc.). Nevertheless, when precise and stable pH control is required, weak(er) bases or acids are preferred because of their buffer properties in the vicinity of their ionization constants *Ka*, Chemieonline (2005), Table 2.

The precipitation stage also has its optimal reaction conditions depending on the pH value. In this application, the solubilities (σ, in mg/L) of the main metalhydroxydes to be precipitated during the treatment ($Ni(OH)_2$, $Cu(OH)_2$, $Zn(OH)_2$) have a *common* minimum for pH $\in$ [9,10], Degrémont (1991). The precipitation stage thus requires a precise pH control.

The evolution of the pH in the decyanidation and precipitation CFSTRs is presented on Fig. 6. It shows that under normal work, as presented diagrammatically in Fig. 2, the separated flows of MPWW are pumped into decyanidation and precipitation CFSTRs respectively. In each tank a pH control is performed so as to fit to the preset values.