Przykłady kursów

TOWARDS AN INTERACTIVE PEDAGOGICAL CSFTR-REACTORS SIMULATION TOOL APPLIED TO INDUSTRIAL WASTEWATER DETOXICATION

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Abstract:

An interactive pedagogical methodology, applied to industrial wastewater detoxication process (WWDP) is presented. It is based on a dedicated real- or accelerated-time simulator, which can represent and simulate up to five interconnected Continuous Flow Stirred Tank Reactors (CFSTR), commonly used in continuous-flow detoxication processes of industrial sewage effluents. Various aspects of the WWDP, such as: environmental engineering, process modelling and control, real-time supervision, fault management, process optimization (efficiency, safety, operation costs), can be dealt with, either separately or within the same pedagogical module. The simulator has been developed in a freeware environment (Java) and can be used in cyber education *via* usual internet browsers.

I. Introduction

Industrial activities, paticularly surface treatment (electroplating) activities, generate significant volumes of wastewater (WW) which require specific and complex detoxication before being rejected to the urban sewage network or to the environment.
Environmental standards require that the concentrations of free cyanides (CN^-) and heavy metal ions (*e.g.* Cr^{6+}, Pb^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+},...), at the outfall sewer, is less than the maximal admissible values, Table 1.
The challenge depends on optimization of industrial wastewater detoxication, *i.e.* so that their detoxication efficiency and operating costs are both optimal.
This paper presents a project concerning the development of an interactive pedagogical methodology, based on a simulation tool, dedicated to different audiences; such as: engineering students, continuing education or continuous professional training as well as vocational training.

Element	France, 1985	France/EU, **2006**
Al	5,0	5,0
Cd	0,2	0,2
Cr^{VI}	0,1	0,1
Cr^{III}	3,0	2,0
Cr total	3,0	-
Cu	2,0	2,0
Fe	5,0	5,0
Ni	5,0	2,0
Pb	1,0	0,5
Sn	2,0	2,0
Zn	5,0	3,0
CN^-	0,1	0,1

Table 1. *Excerpt of the newest french environmental standard concerning – among others – the electroplating industry (Decree, 2006). Max. concentrations in mg/L.*

II. WWDP: a complex, hazardous process

Industrial WWDP involves several complex stages, which goal is to destroy or to modify toxic compounds into less toxic or extractable ones. For example:

- oxidation of cyanides into cyanates (Eq. 1.1 to 1.3),
- reduction of hexavalent chromium into trivalent chromium (Eq. 2.1 & 2.2),
- precipitation and flocculation of heavy metals in order to settle them, for example, under their hydroxide form ($Me(OH)_n$), so as to generate sludges which may be disposed in a dedicated landfill or utilized for colored metals recovery.

Cyanide oxydation using sodium hypochlorite (NaClO, Javel) writes:

$$NaCN + NaClO + H_2O \rightarrow CNCl + 2NaOH \tag{1.1}$$

If pH > 10,5 then almost instantaneously:

$$CNCl + 2NaOH \rightarrow NaCl + NaCNO + H_2O$$

Caution ! Gaseous CNCl is lethal !! Therefore, for safety, usually pH >> 11,5.

Using hydrogen peroxide (H_2O_2):

$$NaCN + H_2O_2 \rightarrow NaCNO + H_2O \tag{1.2}$$

($pH_{optimal} \sim 9{,}5$, reaction is catalyzed by copper ions).

Cyanide oxydation using persulfuric acid (H_2SO_5, Caro's acid):

$$NaCN + H_2SO_5 \rightarrow NaCNO + H_2SO_4 \tag{1.3}$$

($pH_{optimal} > 9{,}5$).

Hexavalent chromium reduction using sodium bisulphite ($NaHSO_3$):
$H_2Cr_2O_7 + 3NaHSO_3 + 3H_2SO_4 \rightarrow Cr_2(SO_4)_3 + 3NaHSO_4 + 4H_2O$ (2.1)

If pH < 2,5 then reaction is instantaneous. Critical threshold: pH > 3,5.

Hexavalent chromium reduction using ferrous sulphate ($FeSO_4$):

$$H_2Cr_2O_7 + 6FeSO_4 + 6H_2SO_4 \rightarrow Cr_2(SO_4)_3 + 3Fe_2(SO_4)_3 + 7H_2O \quad (2.2)$$

($pH_{optimal} < 6$).
Usually generates significant amount of sludge (3-4 times more than Eq. 2.1).

An industrial WWDP usually includes a set of continuous flow stirred tank reactors (CFSTR); in each CFSTR a particular detoxication stage is carried out, *e.g.* decyanidation, dechromation, neutralization, flocculation, etc. Fig. 1 (Degrémont 1991, Meinck *et al*. 1968-1977, Olsson & Newell 2001, SITS 2002, ...). Every mentioned stage is rather uneasy to operate, particularly as far as continuous flow wastewater detoxication is concerned. Moreover, the oxidation and reduction stages can be hazardous, depending on the reactant used. The managers as well as the operators of WWDPs are therefore very much interested in a safe, efficient and economical operation of their processes.

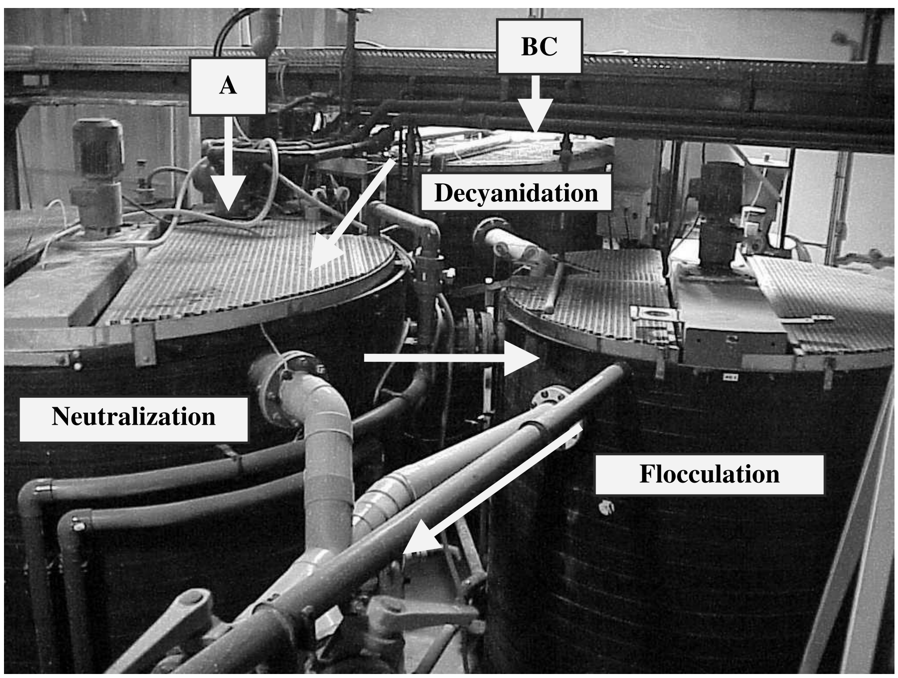

Figure 1*. Picture of a part of an industrial WWDP. Arrows show effluents flow directions. [A] – acidic WW inflow. [BC] – alkaline – cyanidated WW inflow.*

III. Computer-aided WWDP simulation and optimization

The ENSM.SE has been developing an integrated computer-based methodology, including a dedicated simulator of the detoxication process (Szafnicki & Narce 2006, Szafnicki *et al*. 2005, Szafnicki *et al*. 1998). The latter enables real- or accelerated-time simulations of a set of CFSTRs, within a simulation tool as close as possible to the real, industrial detoxication process, Fig. 2.

The user can, for example, choose among different reactants (e.g. strong acids: HCl, H_2SO_4, or weak acids: CO_2, ...) and modify the operation and/or control parametres (*e.g.* volumes of CFSTRs, settings of pH-controllers, etc.).

The whole plant is simulated under real industrial constraints, for example by integrating real industrial data recorded *in situ*, on an operating WWDP (WW flow, pH, redox potential, temperatures, ...).

Dedicated reactants-intake and consumption indicators provide information about the detoxication costs and therefore the WWDP efficiency (e.g. volumes of detoxicated WW, used reactants – volumes and prices, real-time control efficiency, etc.).

IV. Applications in education

The methodology – and the simulator – have already been successfully used in student education (Licence and Master levels) as well as continuing education. Professional trainings (*e.g*. safety consciousness raising courses for galvanisation plants operators) on international level are being planned. Thanks to the dedicated implementation language: Java (www.java.com), which is available as freeware, the simulator can easily be used also for cyber education *via* any internet browser (IE, Nsc, Mozilla, Opera...).

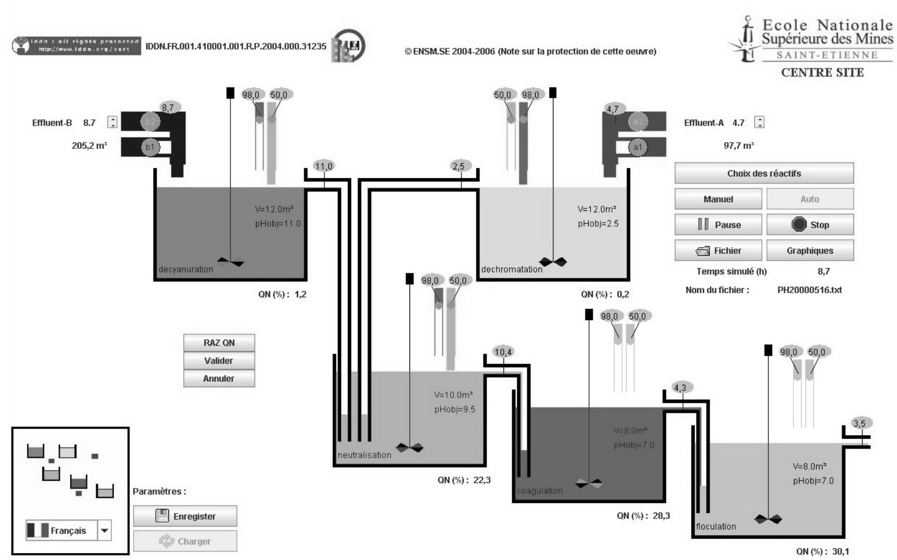

Figure 2. *Multiple-CFSTR simulator main screen. The user interface is here in French; but it can be adapted and translated in real-time into other languages (English, German, Polish, Portuguese, Chinese...).*

Different aspects can be dealt with using this simulator; either separately or within the same course module, for example:

- environmental engineering: industrial WW detoxication,
- WW detoxication process (physical-chemical, continuous flow,...),
- real-time process control applied to strongly non-linear dynamic process,
- WW detoxication plant monitoring, supervision and optimization.

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