EOLI
Efficient Operation of Urban Wastewater Treatment Plants

UNAM contribution to
Deliverable D2.4
Values of indicators of removal efficiency

By
Germán Buitrón and Iván Moreno-Andrade

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I. INTRODUCTION

This deliverable provides the values of indicators of removal efficiency, during the improvement of the application of the optimal control law for the case of toxic compounds removal (4-cholophenol biodegradation, 4CP) at the UNAM. The long-term stability of system under the standard conditions was also evaluated for the degradation of 4CP. In this case the removal efficiencies results from the process controlled by the Event-driven Time Optimal Control strategy (described in deliverable D5.1) in the long-term stability experiments were evaluated.

II. METHODOLOGY

II. 1. Description of the pilot reactor

A pilot reactor of 10L (7L of working volume) was used. The reactor has a conical form to favor the settling of the sludge. The system of control was implemented using a personal computer and a data acquisition card (National instruments 6025E data acquisition card and the Labview package). An automatic temperature controller based on a recycle water pump was used to maintain a constant temperature of 20°C inside the reactor. The input and output water flows were controlled by the computed system using two peristaltic pumps (Cole-Parmer model 7523, Masterflex series), respectively. The computer controls a mixer and a gas mass flow controller (Cole-Parmer E-33116-20) that turned on the aerator from the bottom of the reactor, in addition there are a Temperature and Dissolved Oxygen Sensor (Endress + Hauser, COS4). The aeration flow was 1.5 L/min.

The synthetic wastewater containing 4CP as sole carbon source and complemented with nutrients as is described by AFNOR (1985). The results for each one of the experiments report the data on line (Temperature, DO, and the Influent_FR) and the data off line (Conc of 4CP, CODs, DOCs, MET, DO, VOLreact, InfluentFR, TSS, VSS, SVI, SV, 4CP_in, CODt_inf, CODs_in f, pH_inf, pH (in the reactor at the end of the reaction phase), AirFR_in, CODT_ef, CODS_ef, TSSef, Kla, SOUR (End,To 4CP, To acetate), rpm (mixer), Temp (in the reactor), InfluentFR_in, the phases duration (AWOF, FWA, Aeration, Settling, Draw and the Total time). Two different control strategies were used: Fixed Time Control (FTC) and Event Driven Time Optimal Control (ED-TOC) as is described in the deliverable D1.1.

II. 2.Efficience in the long-term stability of the system

In order to test the removal efficiency, the efficiency values in the long-term stability of SBR system operated by the ED-TOC strategy were obtained. The bioreactor was operated during more than 400 cycles (100 days) by the ED-TOC strategy. The reactor was operated under the standard conditions as is described in the methodology of D1.2, i.e., the wastewater degraded in this periods were synthetic wastewater containing 4CP (350 mg/L) and nutrients as a sole carbon source.

The reactor operates in two sets of experiments:

Set 1:

- **Acclimation**: cycle 1 to 40

  During this period the reactor was acclimated to the degradation of 4CP as is described in the D.1.1

- **Operation with the ED-TOC strategy**: cycle 41 to 188

  The reactor operated during all the period with efficiencies higher than 99% for the 4CP degradation, and 97% as a COD.
- **Experiments with variation of pH.** From the cycle 101 to the cycle 110 the pH of the reactor was adjusted to 3.5 (±0.5). In the cycle 111 the pH was neutralized to 7.0 and the reactor continued operating under the standard conditions. With this experiment the robustness of the reactor to variations on the pH values was tested. In the figures 15 it is possible to observe that this stress periods not affect the efficiency of the reactor (degradation of the 4CP and the COD), but the specific degradation rate (q) decreases in 35% mgCOD/mgVSS/h and 40% mg4CP/mgVSS/h for the qCOD and q4CP respectively. When the reactor operated again at pH of 7, the biomass was recovered in 6 cycles (from cycle 111 to 117) After this period the specific degradation rate was recovered to 50.8 mg4CP/mgVSS/h.

At the end of the cycle 194, the biomass was discharged and a second set of experiments was started.

Set 2:

- **Acclimation:** cycle 195 to 218
- **Operation with the ED-TOC strategy:** cycle 223 to 450

The reactor operated of the reactor during all the period with efficiencies higher than 99% for the 4CP degradation, and 97% as a COD.

- **Experiments with high biomass concentration.**

From the cycle 356 to the cycle 404 the biomass was not purged, with this, the VSS increases 135% (from 2000 to 4700 mg/L). At this point the ED-TOC strategy was robust and the degradation was effectively achieved. The degradation efficiencies were conserved (higher than 99% for the 4CP degradation and 97% as a COD). However the ED-TOC strategy took more time than the usual degradation time (75% more), and the specific degradation rate decreased 80%, due to the microorganisms stress of deficiency of oxygen, thus the strategy was not optimal. The ED-TOC strategy maintained an efficient degradation but if the limitation of oxygen continues, the ED-TOC strategy will present problems related to the control strategy since it is based in the measurement of the dissolved oxygen in the reactor.

III. RESULTS

Figure 1 show the operation data, corresponding to the total and volatile suspended solids. It is possible observed that the operation of the reactor was stable. In general, the efficiencies were higher than 99% for the 4CP degradation, and 97% as a COD degradation. The specific degradation rate was 95.3±8.2 mgCOD/mgVSS/h for the COD and 50.8±4.7 mg4CP/mgVSS/h for the 4CP during the operation with the ED-TOC strategy. The sludge volumetric index was 80 ± 6.8 mL/gVSS.

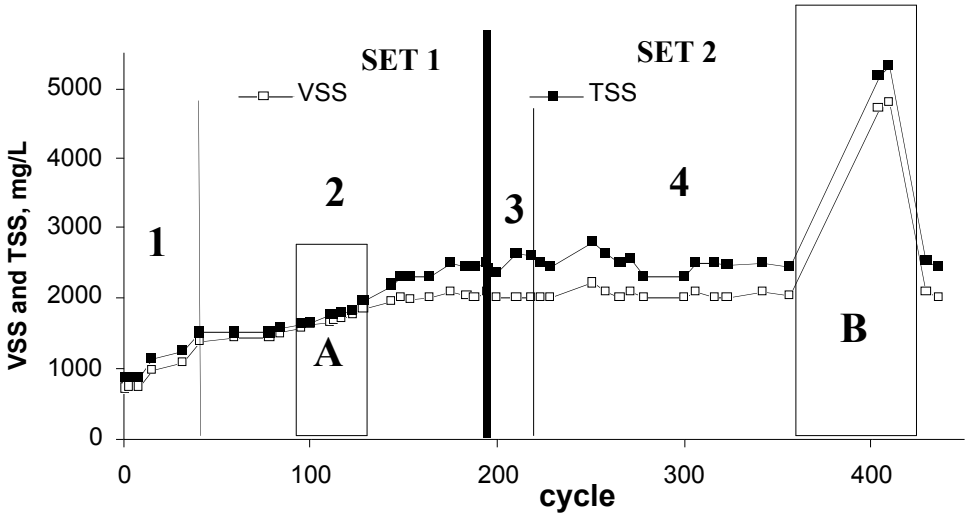

Figure 1. Experimental data of the VSS and TSS during the long term degradation by the ED-TOC strategy. In the figure is showed the sets of experiments: **1)** Acclimation, set1, **2)** ED-TOC, set 1, **3)** Acclimation, set2, **4)** ED-TOC, set 2.
A) Low pH, **B)** Increase of biomass.

The 4CP removal efficiencies during the long-term stability experiments were 99.97±0.08 mg/L as 4CP and 96.9±1.7 mg/L as COD (figure 2).

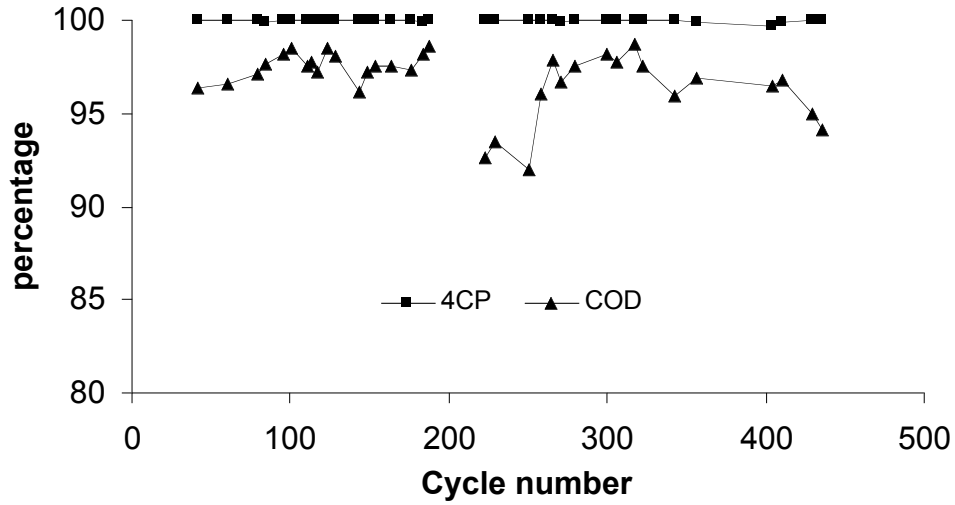

Figure 2. COD and 4CP removal efficiencies during the long-term stability experiments

The results of the parameters of the effluent were analyzed statistically by means of a normal distribution (STATGRAFICS 5,0), this analysis is descriptive for a single variable to study. The analysis of normal distribution showed that the quality of the effluent derived from the process was excellent, since in 95% of the samples the residual COD in the effluent was smaller than 29 mg/L (figure 3) and the TSS in effluent were smaller than 26 mg/L (figure 4). This demonstrates the feasibility to use strategy ED-TOC in the efficient

residual water degradation that contains inhibiting compounds and can be implemented in an industry

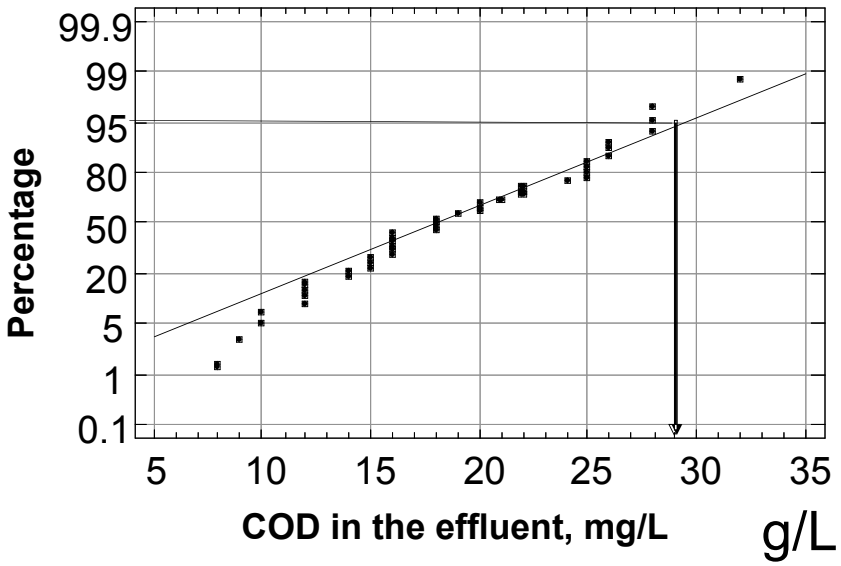

Figure 3. Normal distribution analysis of the COD removal efficiency during the long-term stability experiments

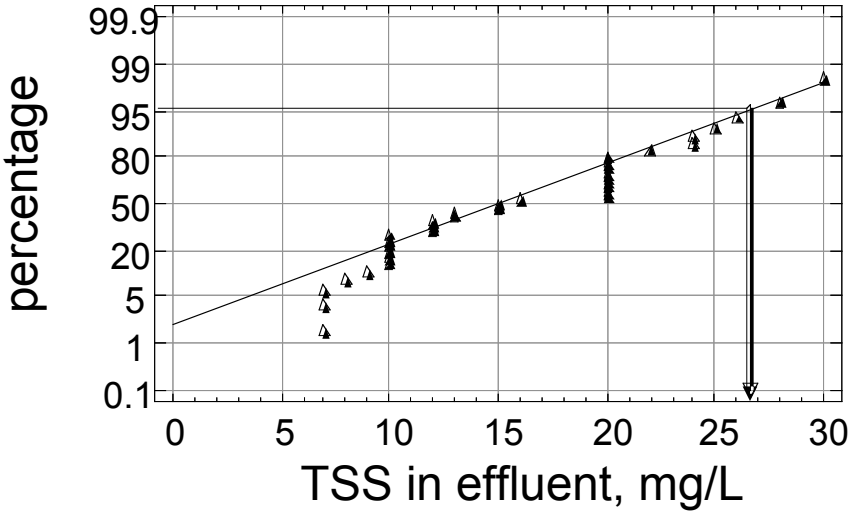

Figure 4. Normal distribution analysis of the TSS removal efficiency during the long-term stability experiments

IV. CONCLUSIONS

The reactor operated by ED-TOC strategy showed that is robust and stable in large periods of operation (100 days), with efficiencies of plus than 99% for the 4CP degradation, and 97% as COD degradation.