How wastewater processes can be optimized using LOQO

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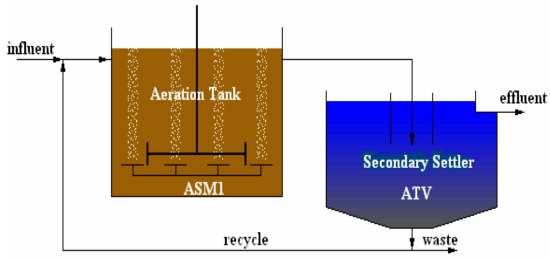
The high costs associated with wastewater treatment, threatening the very survival of many industries, require a wise optimization of the Activated Sludge Process (Aeration Tank and Secondary Settler).
The resulting optimization problem has 57 parameters, 82 variables and 65 constraints, was coded in AMPL and solved with the software package LOQO (primal-dual interior point method).



Activated Sludge System

The model

Constraints

1. **Mass balances around the Aeration Tank**

$$\frac{Q}{V_a}(\xi_{in}-\xi)+r_i(\xi)=0$$

ξ is the concentration of each compound – S_S, S_O, S_{NO}, S_{ND}, S_{NH}, S_{alk}, X_I, X_{BH}, X_{BA}, X_S, X_P, X_{ND}.
r_i is the conversion rate of each compound (ASM1 model).

2. **Composite variables**

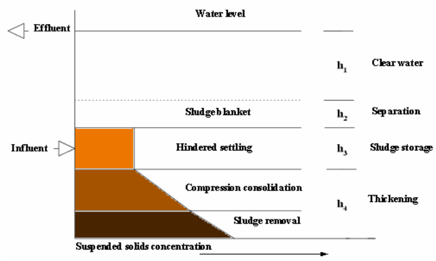
In real systems, some of the previous variables are not available and readily measured composite variables are used instead – *X, S, COD, VSS, TSS, BOD, TKN, N*.

3. **Quality constraints**

These are imposed by law in the variables *COD*, *TSS* and *N* at the effluent.

4. **Constraints of the Secondary Settler**

$$\frac{Q_P}{A_S}=2400\left(\frac{0.7\,TSS}{1000\,SVI}\right)^{-1.34} \qquad h_3=\frac{0.3\,TSS\,V_a\,SVI}{1000(480A_S)} \qquad h_4=\frac{0.7\,TSS}{1000}\frac{SVI}{1000}$$



Secondary Settler

5. **Flow and mass balances around the system**

The model still requires balances to the suspended matter, to the dissolved matter and flows.

6. **Simple bounds**

All the variables are nonnegative and some have operational bounds (*TSS, HRT*, K_La, S_{alk}).

Objective function

The objective is to minimize a cost function obtained from real data:

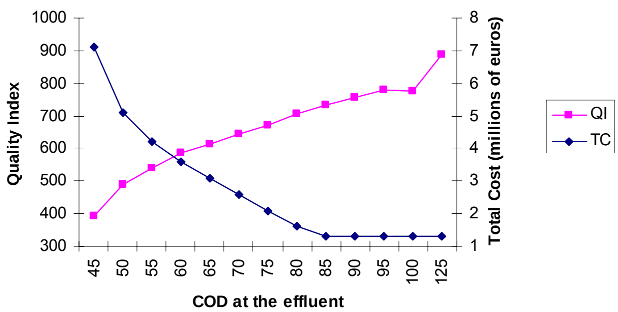
$$174.2\,V_a^{1.1}+12487\,G_S^{0.62}+114.8\,G_S+955.5\,A_S^{0.96}+41.3\left[A_S\left(1+h_3+h_4\right)\right]^{1.1}$$

Results

The quality of the effluent influences directly the cost of the treatment plant project, especially in terms of carbonaceous matter (COD). As higher quality to the effluent is demanded, the total cost increases. However, from a COD value of 85 the cost no longer decreases.

COD (g/m³)	TSS (g/m³)	V_a (m³)	G_S (m³/d NPT)	A_S (m²)	h_S (m)	r	Q_{ef} (m3/d)	Total Cost (millions)	LOQO Iterations (*)
50	33.2	1026	8733	338	3.0	1.8	1514	5.1	103
60	33.2	1302	4796	255	3.4	1.1	1520	3.6	96
70	33.4	1186	2639	286	3.3	1.3	1502	2.6	105
80	33.2	1099	933	310	3.1	1.5	1500	1.6	82
90	35.0	1067	503	309	3.1	1.5	1502	1.3	66
100	34.9	1019	504	314	3.0	1.6	1502	1.2	52

(*) primal and dual infeasibilies $\leq 10^{-5}$ and 2 digits of agreement between primal and dual functions.



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