ECONOMIC OPTIMISATION OF WASTEWATER TREATMENT PLANT DESIGN AND OPERATION THROUGH MODELLING

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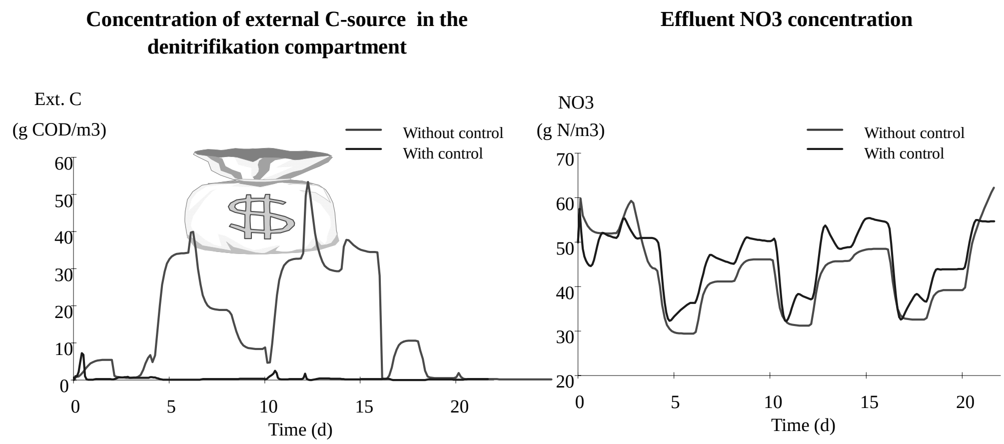
Objective methods for evaluating the overall design and operation of wastewater treatment plants (WWTP) are of importance, both for economical and environmental reasons. An overall decision support index based on economical cost functions for different aspects of treatment plant construction, maintenance and operation, and including internalisation of the value of a river's quality is introduced. Work is underway to include more elaborate aspects of WWT such as plant flexibility and robustness against failure. The latter aspects especially play a role as the time horizon over which the cost evaluation is made increases towards the life span of a treatment works. It is also felt as an omission in many previous optimisation studies that little attention is paid to the potential cost reductions of real-time control as exposed by dynamic simulation. Special focus is therefore put on this aspect of cost optimisation.

This comprehensive cost index allows to evaluate the combined effects of both design and (advanced) operation (i) during the planning phase of new WWTP's, and (ii) for the evaluation of new operational strategies versus traditional expansions of plants already in operation. It is not the intention of the authors to provide an exhaustive list of objective criterion functions, but rather to give the reader some examples illustrating the approach built on a particular choice of cost functions (see table). Examples that will be presented in some detail include:

1. A denitrification control strategy where methanol dosing is manipulated and compared with a fixed dosing approach (see figure). Return of investment is in the range of months;
2. An extension of a municipal treatment facility with nitrogen removal within the current -reactor volumes using control, reducing the expected investment cost for traditional volume expansion 7-fold;
3. Inclusion of an advanced control strategy for a final clarifier giving separation performance equivalent to 100 m^2 settling area;
4. A controlled sludge storage tank that showed beneficial for effluent quality, but resulted in increased sludge disposal costs, leading to a compromise solution.



Process Unit	Capital Cost	Fixed Operating Costs	Variable Operating Costs
Activated Sludge	$461 \times I \times V^{0.71} + 6530 \times I \times 1.05 \times (Gs)^{0.71}$	$53.9 \times W_{ma} \times (Gs)^{0.6}$	$121 \times W_{op} \times (Gs)^{0.55} + 65 \times Pc \times HP(t)$
Final Settler	$824 \times I \times (A)^{0.77}$	$9.23 \times W_{ma} \times A^{0.6} + 8.62 \times I \times A^{0.76}$	$17.1 \times W_{op} \times (A)^{0.6}$
Sludge Pump	$9870 \times I \times (Q_{slu})^{0.53}$	$112 \times W_{ma} \times (Q_{slu})^{0.43} + 214 \times I \times (Q_{slu})^{0.64}$	$257 \times W_{op} \times (Q_{slu})^{0.41} + 65 \times Pc \times W(t)$
Water Pump	$1710 \times I \times (Q_{wat})^{0.53}$	$0.951 \times I \times Q_{wat} + 6.11 \times I \times (Q_{wat})^{0.8}$	$0.133 \times W_{op} \times Q_{wat} + 65 \times Pc \times W(t)$
Overall Costs			$SC \times Q_{waste}(t) \times X_{slu}(t)$ *Levies(t)*

A: Surface area of settler (m^2)
Gs : Air flow rate ($m^3.h^{-1}$)
HP : Power of air blowers (kw)
I : Engineering News Record Construction Cost Index
Pc : Energy cost ($cents.kwh^{-1}$)
Q_{slu} : Flow rate of recycle sludge ($m^3.d^{-1}$)
Q_{waste}: Flow rate of waste sludge ($m^3.d^{-1}$)
Q_{wat} : Flow rate of lifted or recycled water ($m^3.d^{-1}$)
r : Discount rate
SC : Cost of sludge treatment and disposal ($\$.kg^{-1}$)
V : Volume of activated sludge basins (m^3)
W : Pumping power (kw)
W_{ma}: Wages for maintenance ($\$.h^{-1}$)
W_{op}: Wages for operation ($\$.h^{-1}$)
X_{slu}: Concentration of disposal sludge ($kg\ SS.m^{-3}$)

For the Fixed and Variable Operational Costs a discount rate is applied and it is assumed that the annual costs are constant during the life span of 20 years.

For the Levies the Flemish legislation is rigorously applied, i.e. a number of pollution units is calculated and multiplied with a Unitfine of approx. 30 \$/Pollution Unit:

$$Fine = Unitfine \cdot \left(k_{organic} \cdot N_{organic} + k_{metals} \cdot N_{metals} + k_{nutrients} \cdot N_{Nutrients} + N_{heat}\right)$$

Values of the different components of the *Pollution Units* N_i are calculated from flows Q_{year}, Q^{cool} (m^3/yr) and Q_{day} (l/d) and concentrations of different pollutants expressed in (mg/l). Weighing factors *k* are set to one for most treatment plants.

$$N_{organic} = \frac{Q_{day}}{180} \cdot \left(\frac{0.35 \cdot SS}{500} + 0.45 \cdot \frac{2 \cdot BOD_5 + COD}{1350}\right) \cdot (0.4 + 0.6 \cdot d) \qquad N_{nutrients} = \frac{Q_{year}}{10000}(N + P) \qquad N_{heat} = \frac{Q^{cool}}{10000}$$

$$N_{metals} = \frac{Q_{year}}{1000}\left(40 \cdot Hg + 10 \cdot (Ag + Cd) + 5 \cdot (Cu + Zn) + 2 \cdot Ni + As + Cr + Pb\right)$$