Optimisation of aeration energy costs of an intermittently aerated decentralized wastewater treatment plant

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Introduction

The use of decentralized wastewater treatment plants (dWWTP) is an accepted practice, especially in rural areas. Their small dimension and dispersion across the territory have led to a largely unattended operation of many of these plants.

In Portugal, several small dWWTP use the activated sludge process. This technical solution presents as major drawback the continuously increasing costs associated with to mechanical aeration.

The use of online data obtained with robust instruments and dynamic simulation of treatment performance can provide comprehensive process information, serving as a basis for optimised operation.

Aim

The aim of this study was to assess the potential associated to dynamic simulation for the improved supervision and control of dWWTP, promoting aeration optimisation.

Activated sludge process

Main steps (Fig. 1):

- aeration tank: wastewater aeration in the presence of a flocculent microbial suspension (biomass),
- settler: flocculent biomass separation by sedimentation,
- discharge of clarified effluent,
- return of sedimented biomass to the aeration tank,
- waste of excess biomass.

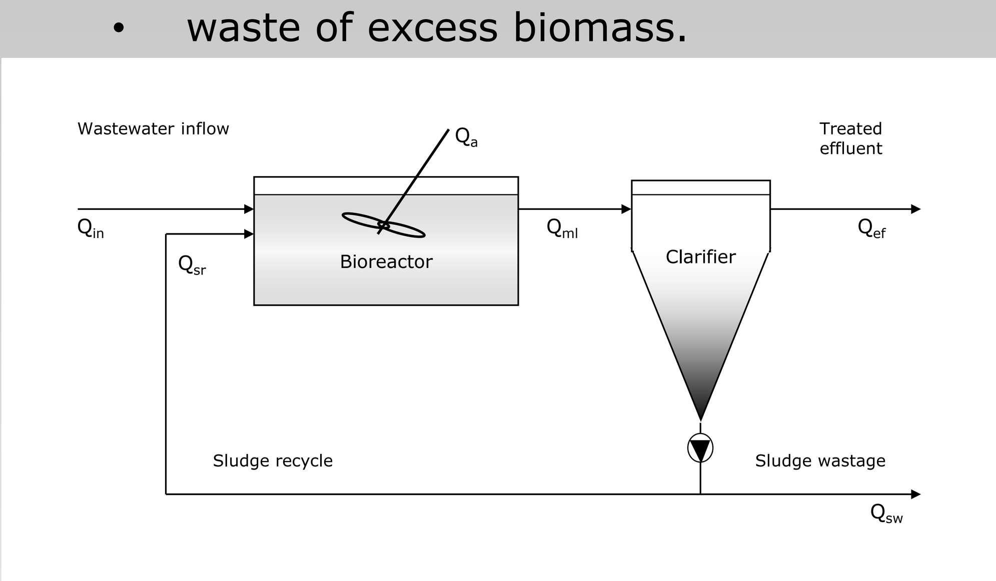

Fig. 1 – process layout

Qin	wastewater inlet flow
Qml	outlet flow from the bioreactor
Qef	treated effluent flow
Qa	air flow
Qsr	sludge recycle flow
Qsw	sludge waste flow

Case study

An extensive monitoring study (one year) was carried out at a dWWTP (Fig. 2) treating the domestic wastewater from a 850-inhabitant village located in the north of Portugal. The treatment used is extended aeration activated sludge designed for carbonaceous substrate removal.

Fig. 2 – case study plant

Process model

The nonlinear dynamic model developed in *gProms ModelBuilder* comprises three modules (Ribeiro, 2011).

Hydrodynamic module:

- based on continuity principle,
- flow characteristics of the dischargers.

Biological treatment module:

- based on the ASM1, nonlinear model developed by IWA (Henze et al., 2000),
- carbonaceous substrate removal processes only.

Solids separation module:

- comprises a function which reflects the efficiency of particulate material removal,
- considers complete mix in the clarified efluente compartment.

Optimisation process/goals

A non-linear dynamic model was developed and implemented in gPROMS ModelBuilder, to evaluate the possibility of reducing operational energy costs associated with the mechanical aeration. Air is intermittently supplied by a surface aerator operated on a timer (intermittent aeration). Air needs depend on the input COD load, which was measured by combining information from a flowmeter and submersible probe (Fig. 3). The aeration cycles consist in alternating on/off periods. In this real dWWTP daily routine, both periods are kept constant: 12 minutes on, 36 minutes off (Fig. 4). To the purpose of this optimisation it was considered that a variable speed motor was connected to the mechanical aerator, allowing a more efficient adjustment of air supply to the needs of this dWWTP. At the same time, it was imposed that the effluent total chemical oxygen demand (COD) discharge standards must be respected. In Portugal, a dWWTP's discharge must not exceed 150 mgO_2/L. Thus the tested optimisation limits were set at 40, 50 and 75 mgO_2/L. Since this plant is oversized for the actual incoming load a reduction of the aeration tank volume to half its actual size was also simulated keeping constant the aeration power per volume.

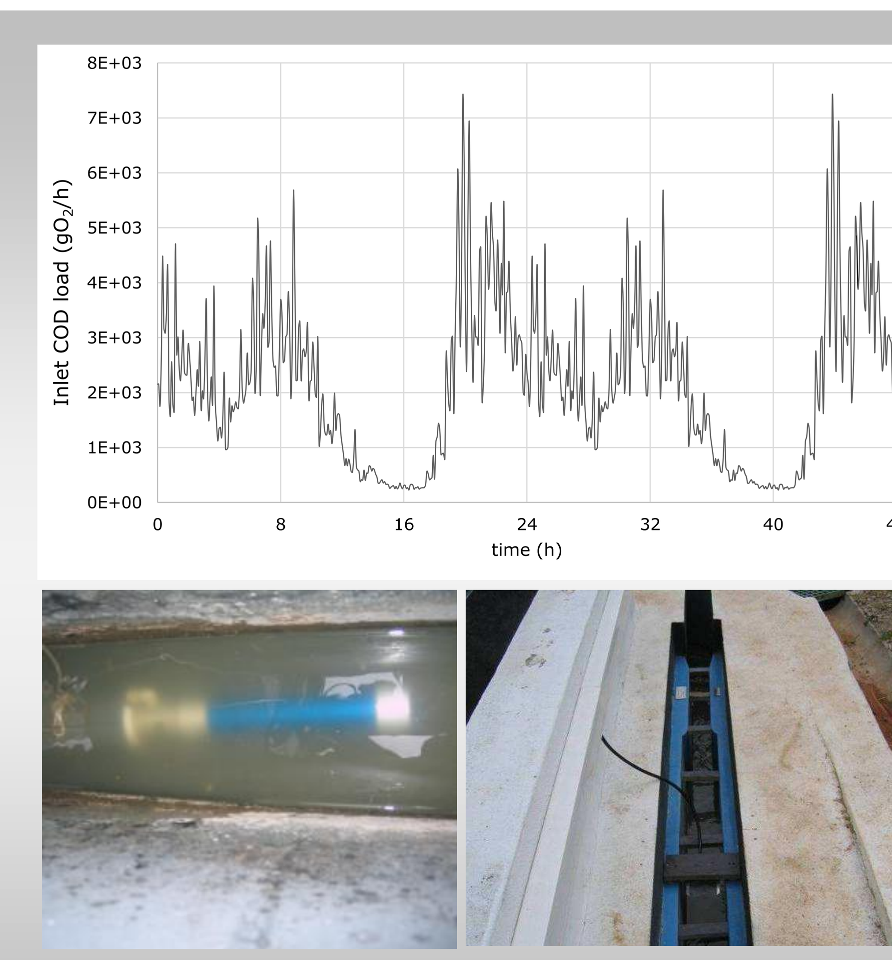

Fig. 3 – Inlet COD load; submersible COD probe (left) and Parshall flume (right) at the dWWTP inlet

Results and conclusions

Aeration Rate Profiles

Effluent COD Profiles

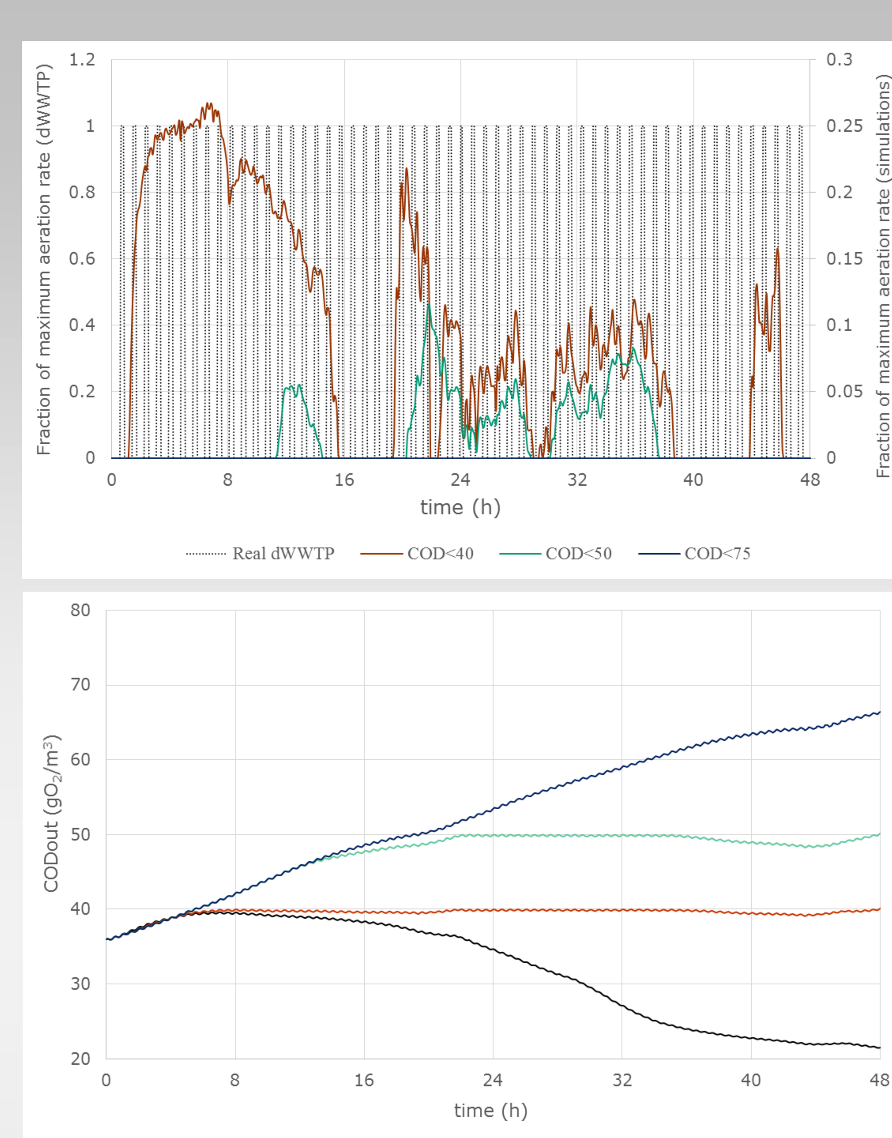

Fig. 4 – Optimisation results for V=252 m³

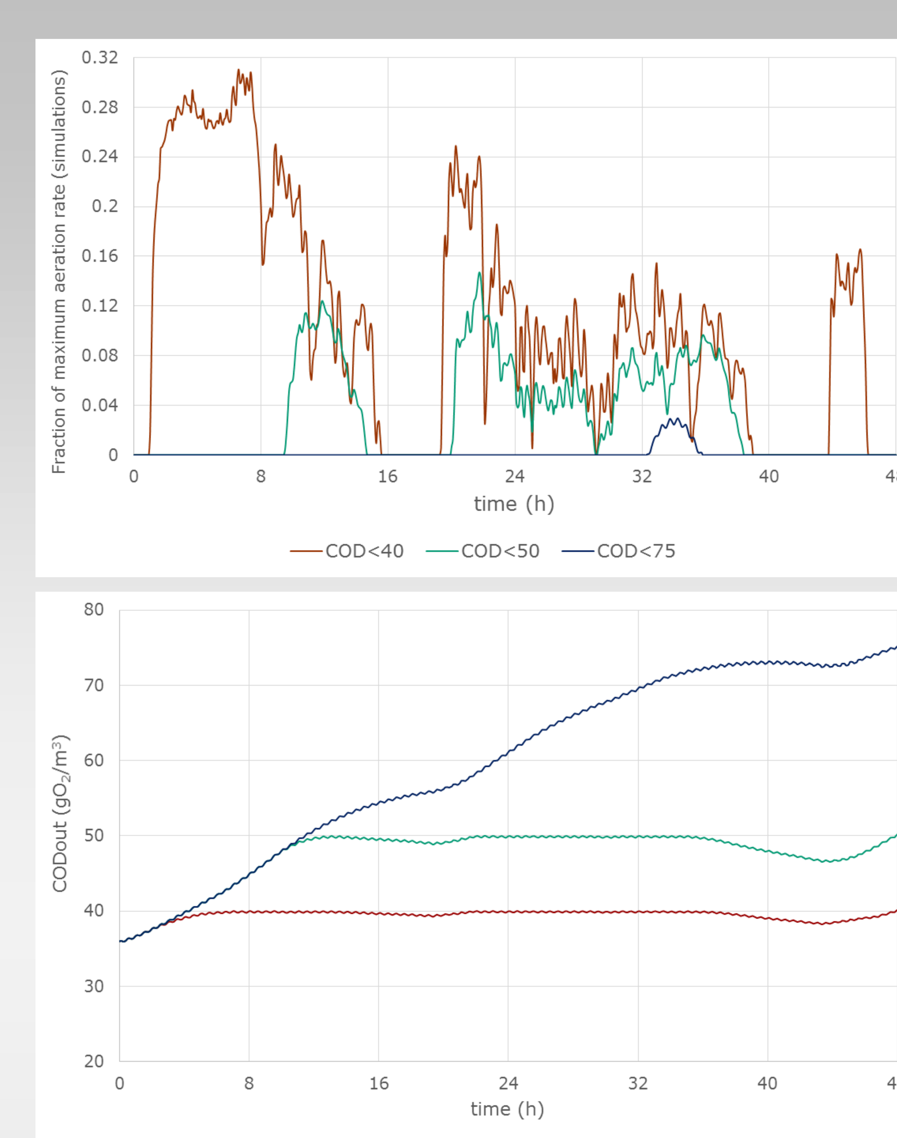

Fig. 5 – Oprimisation results for V=126 m³

Table 1 – Total power consumption and estimated anual savings

Volume (m³)	Situation	Total Power Consumption (kWh/day)	Anual Savings (k€)
V =252	Real dWWTP	53.1	-
	COD<40	17.1	1.5
	COD<50	3.24	2.2
	COD<75	0	2.3
V = 126	COD<40	9.78	1.9
	COD<50	2.94	2.2
	COD<75	0.11	2.3

Dynamic simulation of the treatment performance served as a basis for the process optimisation. The present work shows the usefulness of a model based approach for the operation of a dWWTP, for the simple case of energy saving through aeration optimisation. The results proved that the real system operates presently with an excess of oxygen. Optimisation of the air supply to the this aerated process with fluctuations of affluent carbon load, leads to a substantial reduction of aeration energy costs without violating the legal discharge limits (Fig. 4, Table 1). It also indicates that the plant could operate under these limits with half its aeration tank size (Fig. 5, Table 1).

Acknowledgements

The authors gratefully acknowledge the contractor company (Águas da Serra) of the case study WWTP for the data and information provided. This work was financed by Portuguese national funds through FCT - Fundação para a Ciência e a Tecnologia in the framework of project PTDC/AAG-TEC/4124/2012.

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