ENERGY SAVINGS IN BIOLOGICAL PROCESS AERATION SYSTEMS: COUPLING MODELLING WITH OFF-GAS TESTS.

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Abstract: *Continuous off-gas measurements coupled with activated sludge process modelling in a WWTP provided useful information on the state of the existing aeration system. Different working conditions have been analysed and results gave indications about optimal maintenance frequency or replacement of fine pore diffusers and blowers. In addition, process modelling coupled with off-gas monitoring can provide data for a reliable and accurate estimation of aeration efficiency. Scenario analyses can help in defining realistic goals of energy reduction for planned activities or investments in new equipment.*

1. Introduction

Dynamic simulation of WWTPs based on mathematical models and the use of appropriate instrumentation, control and automation (ICA) tools may improve energy and depurative efficiency up to 30% in biological process in wastewater treatment plants (WWTP) (Olsson, 2006).

A continuous-flow conventional activated sludge (CAS) plant in Northern Italy has been studied and modelled. ~~Performance and energy consumption of the existing aeration system has been evaluated under different operating conditions and the extent of potential energy saving have been evaluated.~~ The wastewater treatment plant was originally designed to serve over 200 000 PE. Over the last decade, the decline of industrial activities reduced flowrate and loadings. Today the plants treats an average dry weather flow of about 45000 m^3/d and serves about 160000 PE. The existing blowers are overdesigned for the present reduced load, and this causes problems in adjusting and controlling the aeration flowrate, which often exceeds the actual oxygenation needs of the biological process. However, the inlet daily flow pattern is still strongly influenced by the existing industrial activities, mostly textile finishing, that produce pronounced load variations between day and night and between working days and weekends and make aeration control even more difficult. This prompted the plant operators to evaluate possible solutions to reduce air flowrates and the related energy consumptions and costs. In this study, performance and energy consumption of the existing aeration system has been evaluated under different operating conditions and the extent of potential energy saving with appropriate interventions have been evaluated.

2. Material and Methods

The wastewater treatment plant treats an average dry weather flow of about 45000 m^3/d and serves about 160000 AE. The inlet flow is strongly influenced by industrial activities, mostly textile finishing, that increase the daily load variation between day and night and working days and weekends.

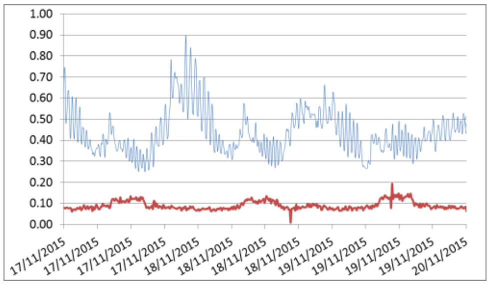
Two different software tools have been used to model the biological process: ASM1 (Henze et al., 1987) implemented in WEST® by DHI and ASDM or Biowin General Model (Jones and Takács, 2004) implemented in Biowin by Envirosim.

Influent and biomass characterization has been carried out by respirometric tests to determine COD fractions, heterotrophic and autotrophic biomass specific rates. Characterization of the wastewater follows the procedure described by Petersen et al. (2002). COD entering the biological section ranges between 170 and 350 mg/l, of which about 50% is biodegradable (bCOD), about 3% is readily biodegradable (rbCOD) and 40% is organic inert particulate. TKN ranges from 25 to 40 mg/l. Off-gas released from the aeration tanks has been sampled by two in-situ hoods (figure 1) and analysed through a specific commercial instrument according to ASCE (1997).

Figure 1. Off- gas measuring hoods. The aeration tank is U-shaped and the two hoods are placed near the inlet (left) and the outlet (right) of the aeration tank.

3. Results and conclusions

Figure 2 shows the trend of estimated αF in two different locations of the aeration tank. The extremely low value near the inlet shows that the efficiency of the installed diffusers has decreased more than that of the diffuser located close to the outlet of the aeration tank.



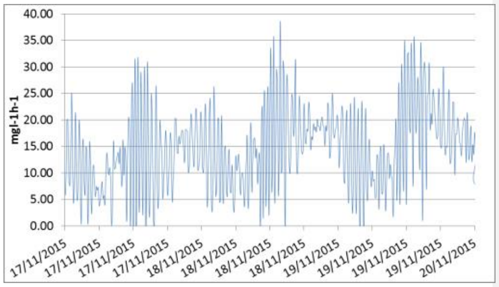


Figure 2. AlphaF trends as measured near the inlet (left – lower line), and the outlet (left – upper line) of the aeration tank and calculated OUR near the outlet (right) of the aeration tank.

The procedure allowed to compare the required air flowrate (calculated) with the actual flowrate measured by flowmeters (figure 3).

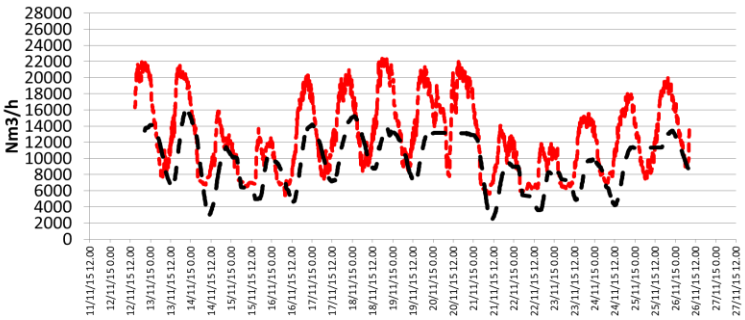


Figure 3. Actual airflow (in red) VS required airflow elaborated by Alphameter (in black)

In situ off-gas measurement and respirometric measurement of COD fraction and biomass activity rates allowed to obtain a reliable estimate of the aeration specific parameters. The results of the elaboration have been used:

(1) to give indications on how to ~~on how to~~ upgradee the existing aeration system with adequately sized diffusers and blowers,

(2) to quantify the energy savings compared with the present system,

(3) to plan maintenance interventions to keep a high energy efficiency,

(4) to quantify the energy savings that can be achieved by optimizing the aeration system.

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Steady state results are reported in table 1. The required airflow using new diffusers (αF=0.55) is reduced by 32%.

Table 1. *Steady state results*

Parameters	**Dry weather**				
	Project	**Actual diffusers**		**New diffusers**	
		Working day	**Weekend**	**Working day**	**Weekend**
AOTR (kgO2/d)	18’272	11’282	7’748	11’282	7’748

αF	0.650	0.400	0.400	0.55	0.55
OTE	-	0.073	0.073	0.110	0.110
Qair (Nm3/h)	37'659	22'894	16'067	15'464	10'965
Required Wire to air power (kW)	700	579	406	391	277

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Thanks to Off-gas analysis instrumentation the real αF factor spatial trend has been carried out. The spatial αF values are reported in figure 4.

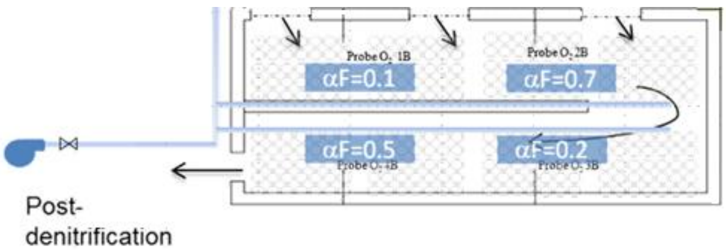

Figure 4. αF spatial trend in nitrification tank

Some Cost analysis have been reported in table 2. All the evaluation have been carried out considering 100 non-working days + 8 night hours. E.g. about 750'000 kWh/y could be saveable considering the installation of a new centrifuge blower (IGVs-VDVs controlled) coupled with cleaned diffusers (αF=0.55).

Table 2. *Estimated energy consumption with cleaned diffusers and different blowers*

	Actual Blower (centrifugal single-stage 700 kW)	New blower (centrifugal single-stage 450 kW IGVs - VDVs control)		New blowers (2x320 kW centrifugal single-stage IGVs - VFD control)	
	MAX AIRFLOW: 25000 Nm3/h	MAX AIRFLOW: 15000 Nm3/h		MAX AIRFLOW: 12000 Nm3/h each	
	Old diff	Old diff	Cleaned diff	Old diff	Cleaned diff
100 non-working days + 8 night hours kWh/year	1'642'085	1'236'915	854'727	1'453'996	883'812
€/year SPENT	246'313	185'537	128'209	218'099	132'572
€/year SAVEABLE	-	60'776	118'104	28'213	113'741
Estimated investment costs blower + diffuser membrane			300 k€		2x180 k€

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maintenance (after 4 years)				
investment return period (years)		4.23		4.92
NPV		942’284		835’805

The investment return period in this situation is approximately 4.23 years considering also the membrane maintenance of the diffusers after 4 years.

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