Evaluation and follow-up of coarse and fine bubble diffused aeration systems

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The basis for the evaluation and monitoring of a diffused aeration system is the ratio of the actual oxygen requirement demand and the oxygen flow

The consistent way to evaluate diffuser aeration systems globally is to relate the oxygen requirement of the influent load (AOR) to the oxygen flow rate supplied to the process (Q_{O2}). In this way, the oxygen demand of the incoming load is set against the oxygen supplied for its treatment, resulting in the process oxygen transfer efficiency parameter (OTE_f)

$$\mathbf{OTE_f\ (\%) = 100 * AOR / Q_{O2}}$$

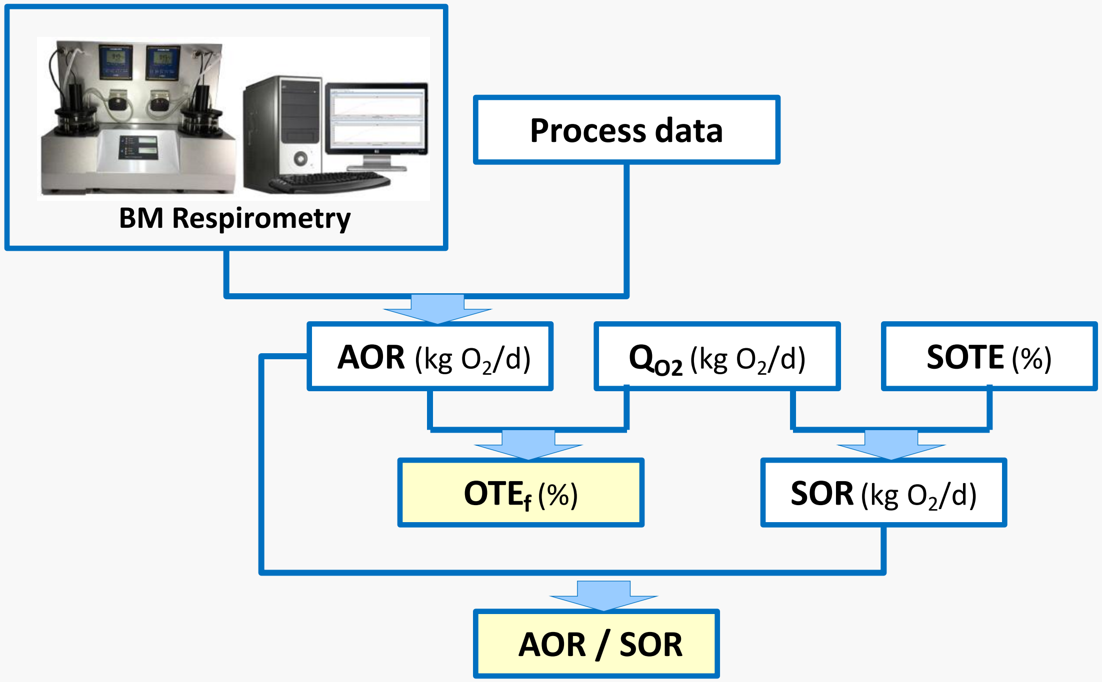
The complement of the OTE_f is the ration between AOR and the standar oxygen requirement (SOR) giving way to the AOR/SOR:

$$\mathbf{AOR/SOR = AOR / (SOTE * Q_{O2})}$$

OTE_f, AOR/SOR and derived parameters can be used as an effective tool for the evaluation and follow-up of diffused aeration systems for the following alerts:

- **insufficient aeration**
- **over-aeration**
- **lack of maintenance (cleaning)**
- **membranes replacement**
- **possibility of energy optimisation**
- **...**

Basic diagram to obtain the key parameters for evaluating and follow up a diffused aeration system



BM Respirometry: To obtain the biodegradable COD (mg/L) and sludge production (P_X)
Process data: Influent flow rate (m^3/d), NTK to be removed (mg N/L), Nitrate to be removed (mg NO_3-N/L)
AOR: Actual oxygen requirement of the influent load (kg O_2/d)
Q_{O2}: Oxygen flow rate supplied by the aeration system (kg O_2/d)
SOTE: Standard oxygen transfer efficiency (%) - calculated from the curve provided by the manufacturer -
SOR: Standard oxygen requirement (kg O_2/d)
OTE_f: Oxygen transfer efficiency in the process (%)
AOR/SOR: Ratio of actual oxygen requirement to standard oxygen requirement

Parameters

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AOR (kg O_2/d) (I)

Actual oxygen requirement from influent

AOR is the actual average of the total oxygen required in the biological process from the current influent load.

This total oxygen requirement includes three partial requirements:

- Requirement for the carbonaceous organic matter: $AOR_C = Q * bCOD_e / 1000 - 1,42 * P_X$

- Requirement for nitrification: $AOR_N = 4,57 * Q * N_n / 1000$

- Requirement for denitrification: $AOR_{DN} = 2,28 * Q * N\text{-}NO_3 / 1000$

(Metcalf & Eddy - 2003, Henze, et al 2008)

Where:
Q: Influent flow (m^3/d)
$bCOD_e$: Eliminated biodegradable COD (mg/L)
P_X: Sludge production (kg MLVSS/d) = $Y_{obs} * Q * bCOD_e / 1000$
N_n : Ninitrogen for nitrification (mg N/L) ≈ NTK eliminated (mg N/L)
$N\text{-}NO_3$: Nitrate for denitrification (mg $N\text{-}NO_3$/L)

The denitrification requirement, carried out under anoxic conditions, is presented as a credit against the total oxygen requirement.

$$\mathbf{AOR = AOR_C + AOR_N - AOR_N}$$

AOR (kg O_2/d) (II)

To be taken into account when determining the AOR_C

It is particularly important to calculate the organic matter requirement (AOR_C) from the biodegradable COD (bCOD) removed (*) and also the sludge production from the determination of the yield coefficient (Y_H) and the specific oxygen consumption rate in the endogenous phase.

The biodegradable COD, the Y_H coefficient and the specific oxygen uptake rate in the endogenous phase are obtained from tests by a BM respirometer.

BM-EVO2 respirometer from Surcis

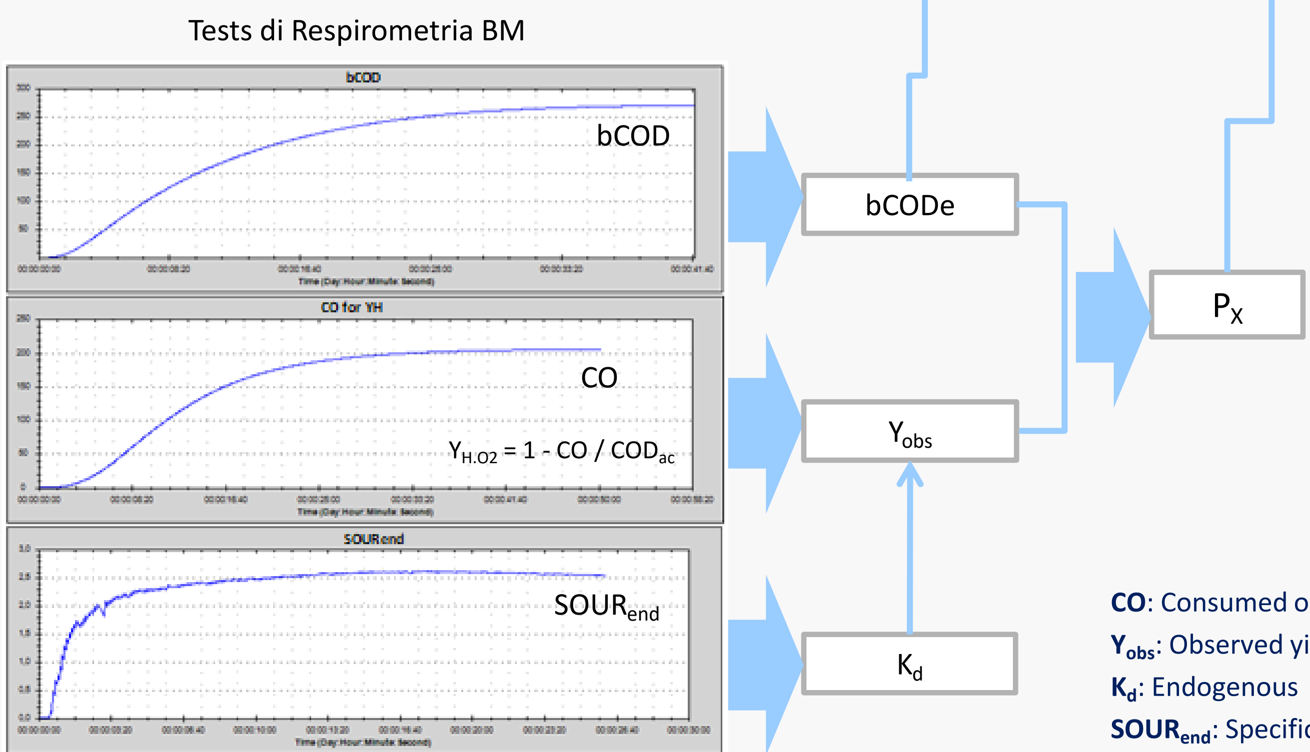
(*) The reason to use the biodegradable COD (bCOD) is based on the fact that, when a significant proportion of the slowly biodegradable fraction of COD (lbCOD) of very low activity is present in the wastewater, BOD5 may not be able to detect this oxygen demand. Therefore, even if estimated values of oxygen demand per unit load of BOD5 are applied, they may not be representative of the overall oxygen demand of organic matter and there is a risk that a lower oxygen requirement is calculated than is actually required for the process.

AOR (kg O_2/d) (III)

BM Respirometry in the AOR_C determination

BM Respirometry is crucial for the determination of AOR_C as it can provide an accurate result on the biodegradable COD (bCOD) value for organic matter, as well as the Y_H coefficient and endogenous SOUR for the determination of sludge production (P_X)

$$AOR_C = Q * bCOD_e / 1000 - 1,42 * P_X$$



CO: Consumed oxygen (mg/L)

Y_{obs}: Observed yield coefficient (VSS/COD)

K_d: Endogenous decay coefficient (d^{-1})

$SOUR_{end}$: Specific endogenous oxygen uptake rate (kg O_2/kg SSV/d)

SOR (kg O_2/d)

Oxygen requirement on standar conditions

SOR is the parameter indicating the average oxygen currently supplied on standard conditions (1 atmosphere, 20 ºC and 0 mg/L oxygen)

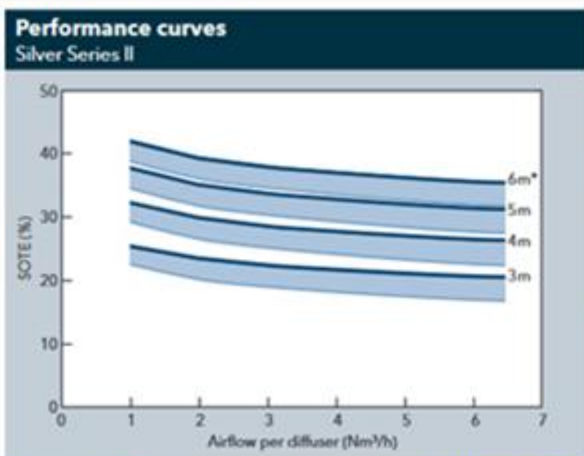
$$SOR = Q_{O2} * SOTE$$

Where:

Q_{O2}: Oxygen flow (kg O_2/d) = 0,285 * Q_{air} (m^3/d)

0,285: Factor to pass m^3 air/d to kg O_2/d

SOTE: Standard oxygen transfer efficiency (%) - calculated from data and performance curves supplied by the manufaturer -



Technical data	
Disc material	Specially blended high-grade EPDM
Diameter	178 or 229 mm (7 or 9 in)
Airflow range per disc	0.8-7 Nm^3/h (0.5-4.5 scfm)
Standard oxygen transfer efficiency (SOTE)	Approx. 6.5% per m submergence (2% per ft)
Standard aeration efficiency (SAE)	2.5-6 kg O_2 /kWh (4-10 lb O_2 /hph)

Source: Xylem

*Submergence

AOR/SOR ratio

The AOR/SOR ratio is a primary assessment of the aeration system and the main starting parameter of the procedure.

Standard reference values for bubble diffures

$(AOR/SOR)_{ref}$	Value
FINE BUBBLE	**0,33**
COARSE BUBBLE	**0,5**

"Sanitaire - Diffused aeration design guide", University of Idaho, Civil Engineering, 2003

"Design Manual Fine Pore Aeration Systems", US EPA, EPA/625/1 89/023

The standar AOR/SOR values will be used as calculation base for other reference values and assessments.

OTE_f (%)
Oxygen Transfer Efficiency

The oxygen transfer efficiency in the process is one of the most important parameters in aeration systems. The higher the OTE_f, the less air has to be supplied to the reactor to guarantee the required oxygen.

$$OTE_f = 100 * AOR / Q_{O2}$$

Ferrell, P.E., BCEE, CEM, LEED Green Assoc.- 2010; Viktor Larsson – 2011

The determination of OTE_f allows plants to assess the long-term operating costs of their aeration systems and to confirm that sufficient capacity is available to meet the oxygen requirements of the load entering the process. It is therefore a parameter that can be considered crucial for monitoring the aeration system.

$Q_{O2.ref}$ (kg O_2/d)

The reference flow rate would correspond to the estimated flow that would be required, for the same AOR requirement, after effective maintenance of the diffusers (cleaning or replacement)

From standard reference values of $(AOR/SOR)_{ref}$

= **0,33** (fine bubble)

= **0,5** (coarse bubble)

Fine bubble diffusers $Q_{O2.ref} = 100 * AOR / (0,33 * SOTE)$

Coarse bubble diffusers $Q_{O2.ref} = 100 * AOR / (0,5 * SOTE)$

F

(fouling factor)

This is the factor that assesses the current condition of the diffusers in terms of fouling /dirtiness or ageing.

It is actually the deviation of the current oxygen flow rate from the optimal reference flow rate.

$$\mathbf{F = Q_{O2.ref} / Q_{O2}}$$

The normal range of F factor is in between 0,7 and 0,9

The F-factor, specially in fine-pore diffusers, decreases over time due to ageing, fouling, inorganic fouling or changes due to wastewater quality, sludge characteristics and operating conditions.

OE (%)

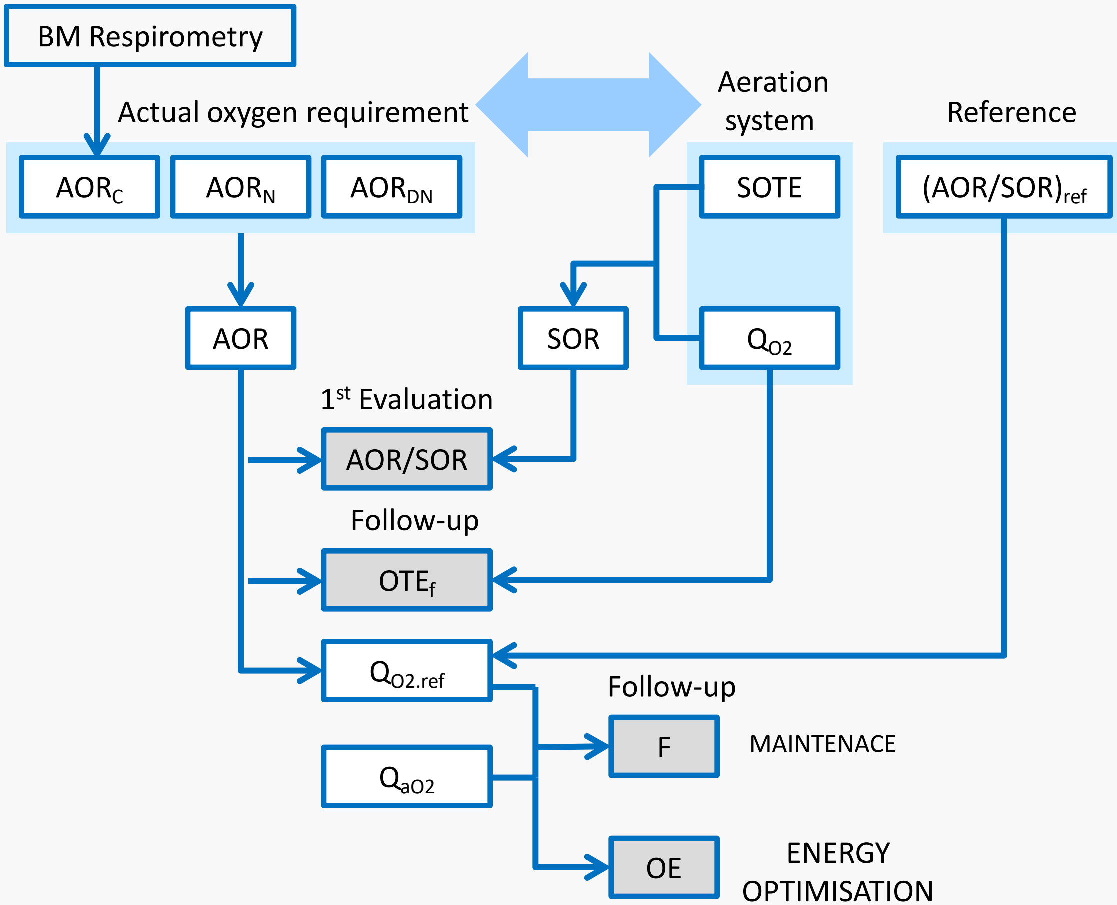
This parameter represents the estimated potential energy optimisation in any bubble aeration system that the effective maintenance by cleaning or replacing the membrane (if the diffusers are old enough to be replaced) can bring about.

For this purpose, the theoretical optimisation percentage is calculated from the difference between the current oxygen flow rate and the reference flow rate with respect to the current flow rate.

$$OE = (Q_{O2} - Q_{O2.ref}) / Q_{O2}$$

Procedure

Diagram of the procedure



Emilio Serrano

SURCIS, S.L.

Phone: +34 932 194 595 / +34 652 803 255

E-mail: surcis@surcis.com / eserrano@surcis.com

Internet: www.surcis.com