New practical procedure for the evaluation and follow-up of diffused aeration systems

SURCIS

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 the way of the standard oxygen requirement (SOR).

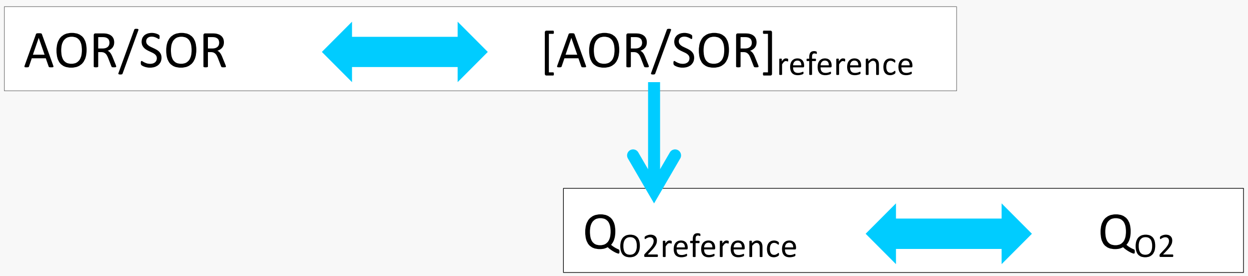
AOR/SOR

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

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

Principle of the procedure to evaluate the diffused aeration sytem

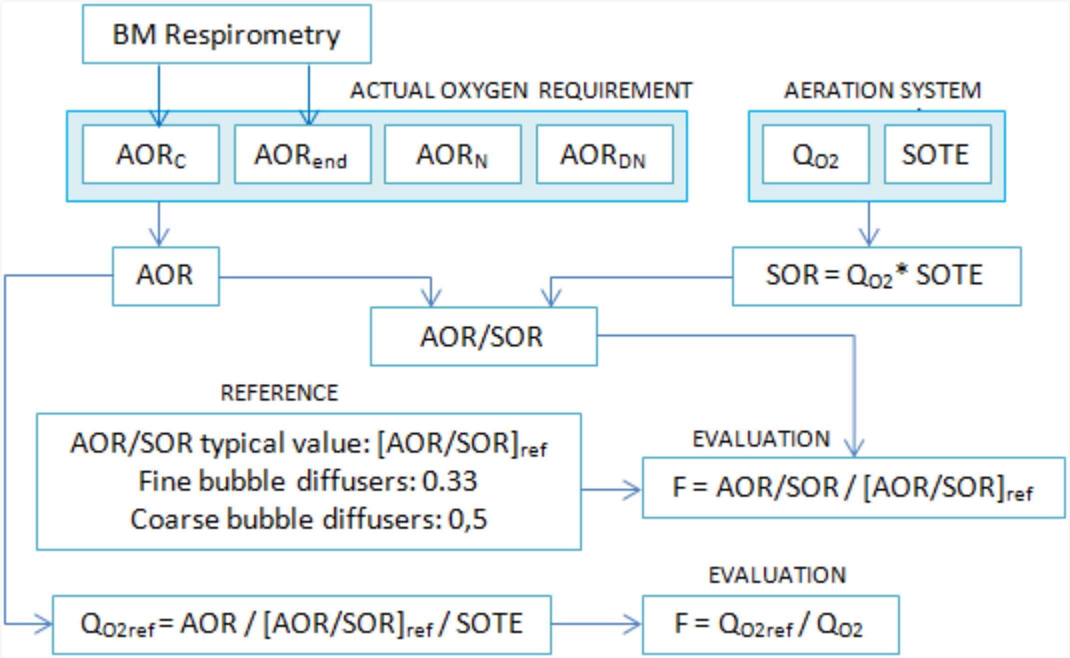
The procedure is based on the relationship between the actual oxygen requirement (AOR) with the oxygen flow rate corrected by the efficiency of oxygen transfer under standard conditions (SOR) and, from here, proceed directly to the evaluation of the system by comparing it with a range and typical reference values.



$$F = (AOR/SOR) / [AOR/SOR]_{reference} = Q_{O2reference} / Q_{O2}$$

Q_{O2}: Oxygen flow in the aeration system (kg O_2/d)

Diagram of the procedure to evaluate a diffused aeration system



AOR	Actual oxygen requirement (kg O_2/d)
Q_{O2}	Oxygen flow rate supplied by the aeration system (kg O_2/d) = 6.84 * Q_{air} (Nm^3/h)
SOTE	Standard oxygen transfer efficiency (%) - calculated from the curve provided by the manufacturer.
SOR	Standard oxygen requirement (kg O_2/d) for new diffusers
AOR/SOR	Relationship between AOR and SOR
$[AOR/SOR]_{ref}$	AOR/SOR reference & typical values for evaluation
F	Fouling factor

Parameters

$[AOR/SOR]_{ref}$	Reference value of the ratio between the actual oxygen requirement (AOR)and standard oxygen requirement (SOR), corresponding to normal / optimal condition.
AOR (kg O_2/d)	Actual Oxygen Requirement = AOR_C + AOR_{end} + AOR_N – AOR_{DN}
AOR_C	Actual oxygen requirement of carbonaceous organic matter
AOR_{end}	Actual Oxygen Requirement from the endogenous oxygen uptake rate of the sludge
AOR_N	Actual Oxygen Requirement for nitrification
AOR_{DN}	Actual Oxygen Requirement for denitrification
Q_{O2} (kg O_2/d)	Oxygen flow of the aeration system (average)
$Q_{O2 \cdot ref}$(kg O_2/d)	Oxygen flow reference , corresponding to normal / optimal condition.
SOTE (%)	Standard Oxygen Transfer Efficiency in clean water on stantadard conditions
SOR (kg O_2/d)	Oxygen Requirement on Standard conditions
AOR/SOR	Actual relationship between AOR and SOR
F	Fouling factor

AOR (kg O_2/d) **(I)**

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

This total oxygen requirement includes four partial requirements:

-Requirement for the carbonaceous organic matter (kg O_2/d): $AOR_C = Q * CO / 1000$

-Requirement for endogenus respiration (kg O_2/d): $AOR_{end} = 24 * V * OUR_{end} / 1000$

-Requirement for nitrification (kg O_2/d): $AOR_N = 4.57 * Q * N_n / 1000$

-Requirement for denitrification (kg O_2/d): AOR_{DN} (kg O_2/d) $= 2.28 * Q * N\text{-}NO_3 / 1000$

Where:

Q: Influent flow (m^3/d)

CO: Consumed oxygen for the eliminated organic matter (m^3/d)

V: Aerobic reactor (m^3)

OUR_{end}: Oxygen uptake rate of the sludge under endogenous phase (mg O_2(L.h)

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)

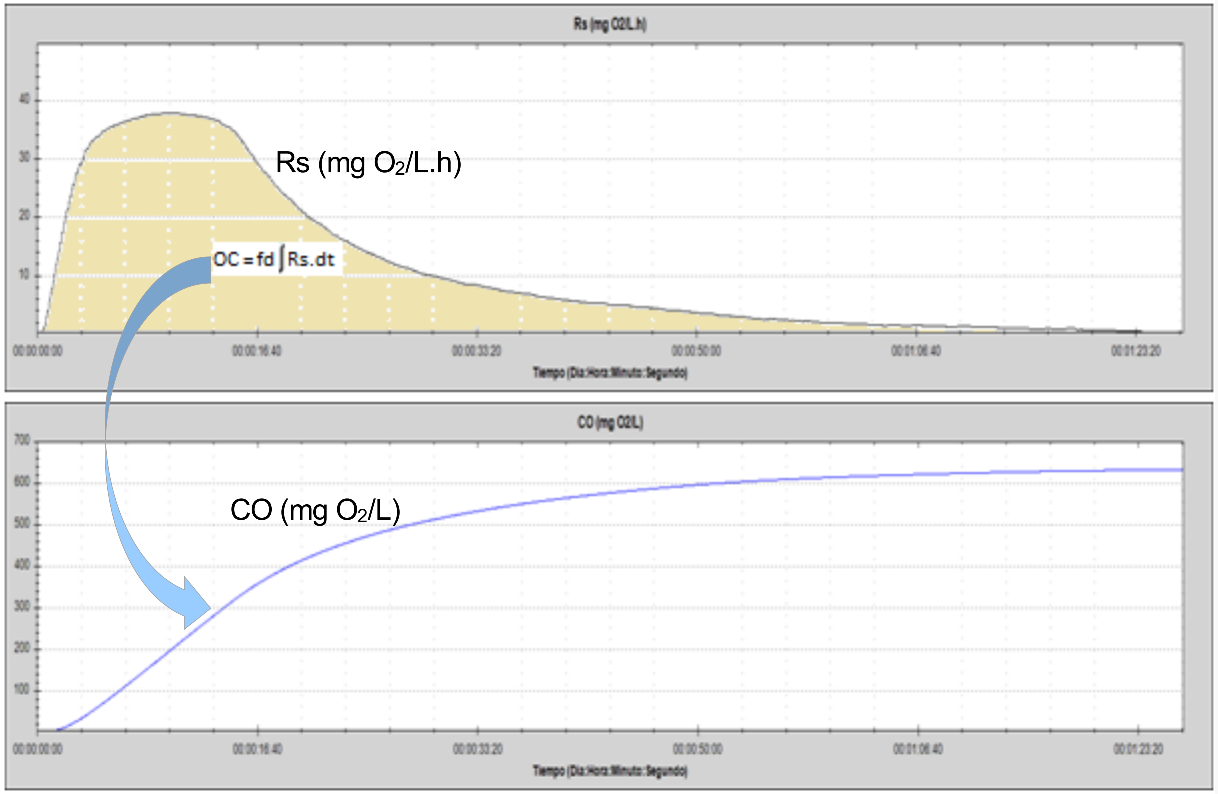
The oxygen requirement by denitrification (AOR_{DN}), performed under anoxic conditions, is presented as a credit against the total oxygen requirement.

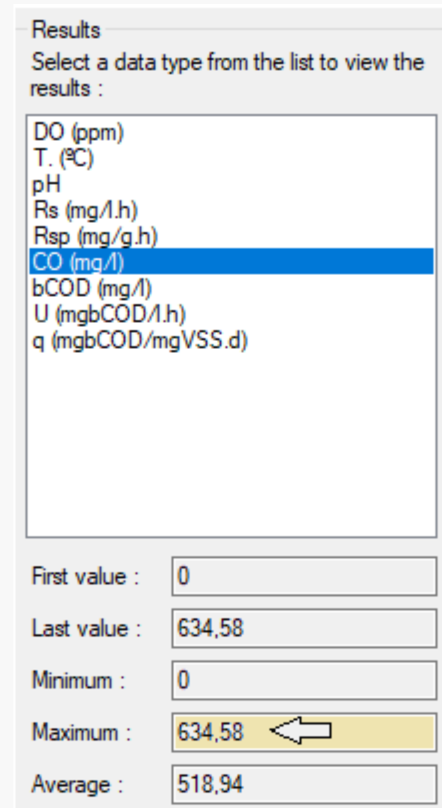
$$\mathbf{AOR = AOR_C + AOR_{end} + AOR_N - AOR_N}$$

AOR$_C$ by BM Respirometry test

$AOR_C = Q * CO / 1000$

In this case, the AOR$_C$ is directly calculated from the consumed oxygen (CO) of the biodegradable COD as a result of the integration of exogenous oxygen consumption rates specifically related to carbonaceous organic matter by means a single test with a BM respirometer.

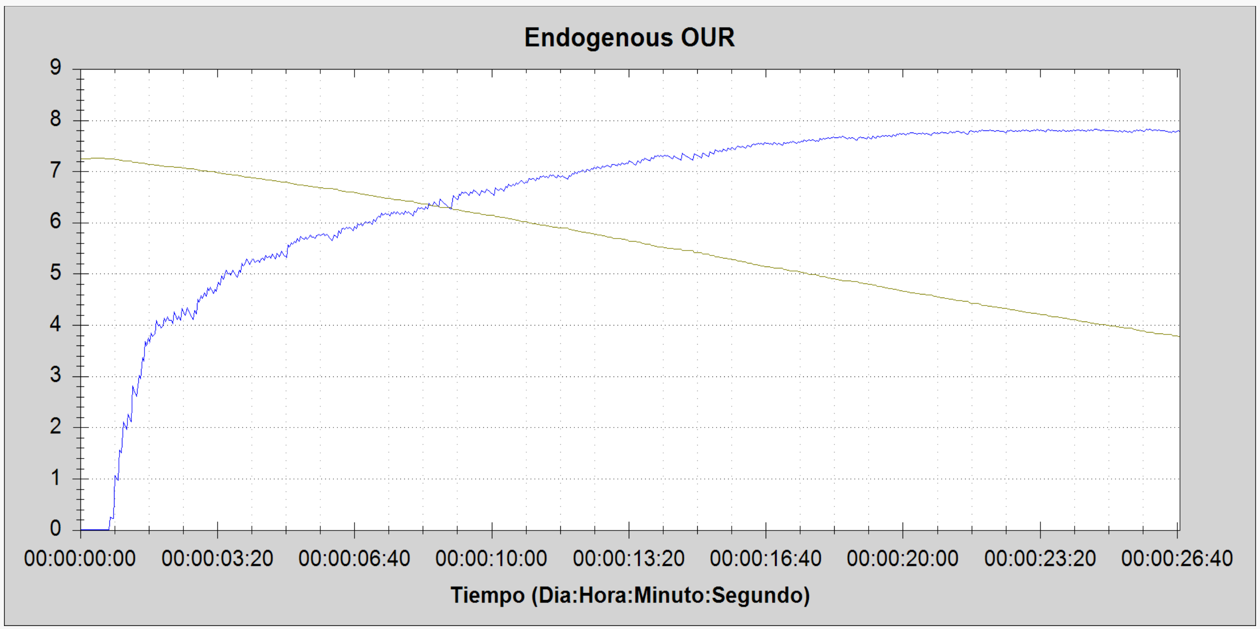


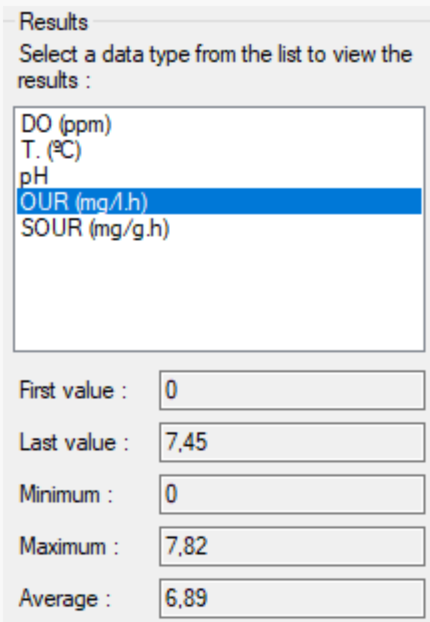


AOR_{end} by BM respirometry test

$$AOR_{end} = V * OUR_{end} / 1000$$

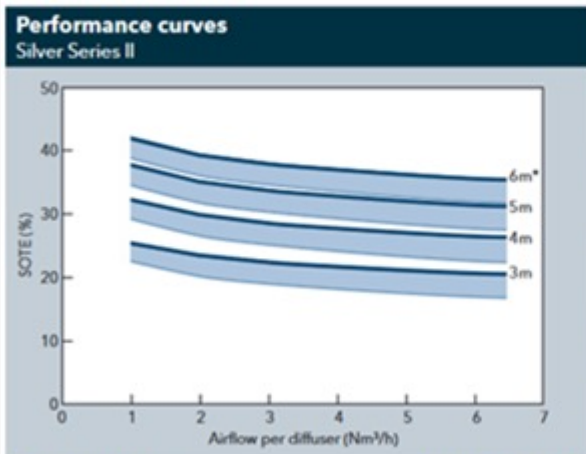
AOR_{end} is calculated from oxygen uptake rate test (OUR_{end}) of the sludge under endogenous phase (without any substrate)





SOTE (%)

SOTE is the oxygen transfer efficiency to the process under standard conditions (20 ºC, 1 atmosphere and 0 mg/L of oxygen)



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

In any case, the SOTE, for practical purposes, will apply the following calculation criterion:

For fine bubble diffusers: 6.5% per m diffuser depth.

For coarse bubble diffusers: 2.46% per m of diffuser depth.

(Harlan H. Bengtson-2017)

SOR (kg O_2/d)

Oxygen requirement on standard conditions

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

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

(Simon Bengtsson, Bengt Carlsson, David Gustavsson, 2019 - Sweden Water Research; James A. Mueller, William C. Boyle, H. Johannes Pöpel « Aeration Principles and Practices », 2002)

Where:

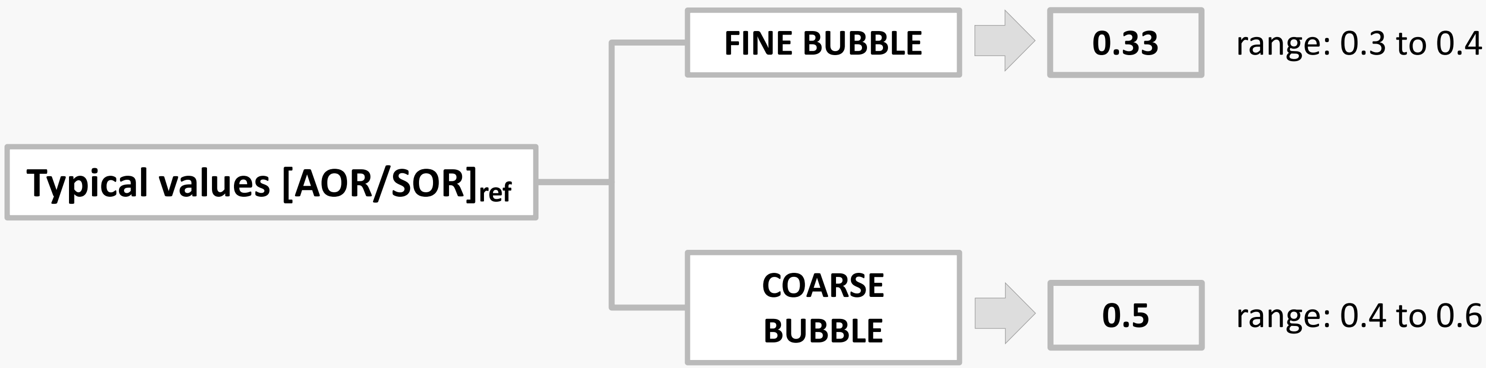
Q_{O2}: Oxygen flow (kg O_2/d) = 0.285 * Q_{air} (m^3/d)

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

SOTE: Standard oxygen transfer efficiency (%)

$[AOR/SOR]_{ref}$

The $[AOR/SOR]_{ref}$ is the reference value against which we will compare the actual value of the AOR/SOR in the process.



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

Bengtson, Harlan H – 2017

Phil Korth - 2013

AOR/SOR

The AOR/SOR ratio is the key parameter of the procedure to carry out the aeration system evaluation and follow up.

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

Once the AOR/SOR is calculated, then it wll be compared with the the $\mathbf{[AOR/SOR]_{ref}}$

Evaluation and follow-up

F

(fouling factor)

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

Since the SOR is directly depending of the oxygen flow, the fouling factor is actually the deviation of the current oxygen flow rate from the optimal reference flow rate.

$$\mathbf{F = (AOR/SOR) / [AOR/SOR]_{ref}}$$

$$\mathbf{F = Q_{O2ref} / Q_{O2}}$$

$Q_{O2ref} = AOR / ([AOR/SOR]_{ref} * SOTE)$

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 aging, fouling, inorganic fouling or changes due to wastewater quality, sludge characteristics and operating conditions.

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