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

SURCIS

BM Multipurpose Respirometry System from SURCIS

1. Automatic control of pH pH
2. pH sensor
3. Free maintenance dissolved oxygen sensor
4. Stirring motor
5. Peristaltic pump for homogenization purpose
6. Double chamber reactor assembly
7. Automatic temperature control system
8. LEDs for controlling devices
9. Oxygen and temperature controller
10. pH controller
11. BM Software in PC

BM- Advance model

BM Respirometry operation modes and automatic parameters

BM Respirometry Operation Modes

OUR & Cyclic OUR modes

OUR: **Oxygen Uptake Rate** (mg O_2/l.h)

It measures the oxygen uptake rate for only one measurement or serial o measurements.

SOUR: **Specific OUR** (mg O_2/g VSS.h)

Specific OUR related to MLVSS. SOUR = OUR / MLVSS

R mode

Rs: **Dynamic Exogenous Respiration Rate** (mg O_2/l.h)

It measures the oxygen uptake rate from the mixture of the activated sludge and certain amount of wastewater sample or compound within a continuous chain of measurements.

Rsp: **Dynamic Exogenous Specific Respiration Rate** (mg O_2/g VSS.h)

Specific Rs referred to MLVSS. Rsp = Rs / MLVSS

CO: Consumed oxygen (mg O_2/L)

bCOD: **Biodegradable COD** (mg/l)

Biodegradable or soluble readily biodegradable COD fraction, based on Rs measurements integration from a mixture of activated sludge and biodegradable sample.

U: **COD removal rate** (mg COD/l,h)

Speed at which the COD is being removed.

q: **Specific COD removal rate** (mg COD/ mg VSS.d)

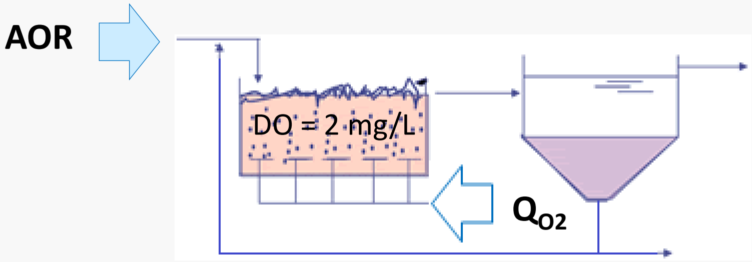
Specific U referred to MLVSS concentration.

Principle of a practical procedure for the evaluation and follow up of a diffused aeration system

The principle of this practical procedure is based on the relationship between the actual oxygen requirement (**AOR**) and the oxygen flow rate (**Q_{O2}**) required to maintain a given level of dissolved oxygen (DO) in the biological reactor. The relationship between both parameters generates the oxygen transfer efficiency in process (**OTE_f**) to monitor the aeration system.

On the other hand, with the participation of the specific standard oxygen transfer efficiency of the diffused system (**SOTE**), the oxygen flow is converted to standard oxygen requirement (**SOR**). Then the actual **AOR/SOR** ratio, when compared to a reference value, becomes the effective tool for system evaluation by generating the estimated value of the fouling factor parameter (**F**)

- Insufficient aeration.
- Over-aeration.
- Lack of maintenance (cleaning).
- Membranes replacement.
- Possible energy optimization.



$$OTE_f = 100 \cdot AOR / Q_{O2}$$

$$F = [AOR / SOR] / [AOR / SOR]_{reference}$$

Where;

AOR (kg O_2/d): Actual Oxygen Requirement from influent loading

Q_{O2} (kg O_2/d): Oxygen flow supplied by the aeration sytem

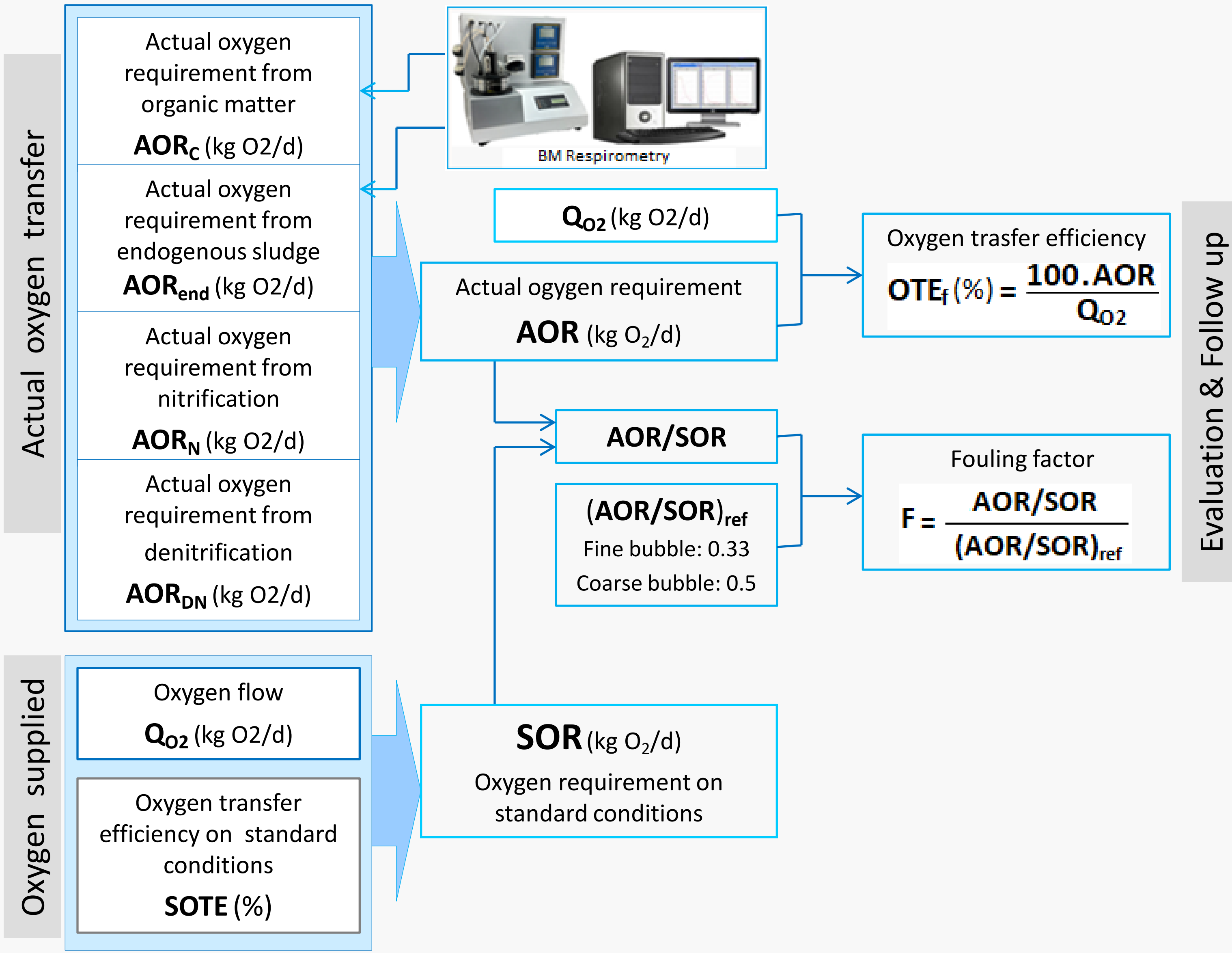
SOR (Kg O2/d): Standard Oxygen Requirement = **Q_{O2} . SOTE**

SOTE (%): Oxygen Transfer Efficiency in clean water on stantadard conditions (specific of the aeration system)

OTE_f (%): Oxygen Tranfer Efficiency in process

F (%): Fouling factor

Diagram of a practical procedure to evaluate a diffused aeration system



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 (%)	Oxygen Transfer Efficiency in clean water on stantadard conditions
SOR (kg O_2/d)	Oxygen Requirement on Standard conditions
AOR/SOR	Acual relationship between AOR and SOR
F	Fouling factor
OTE_f (%)	Oxygen transfer efficiency in process (field)

AOR (kg O_2/d)

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 (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-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-NO_3: Nitrate for denitrification (mg N-NO_3/L)

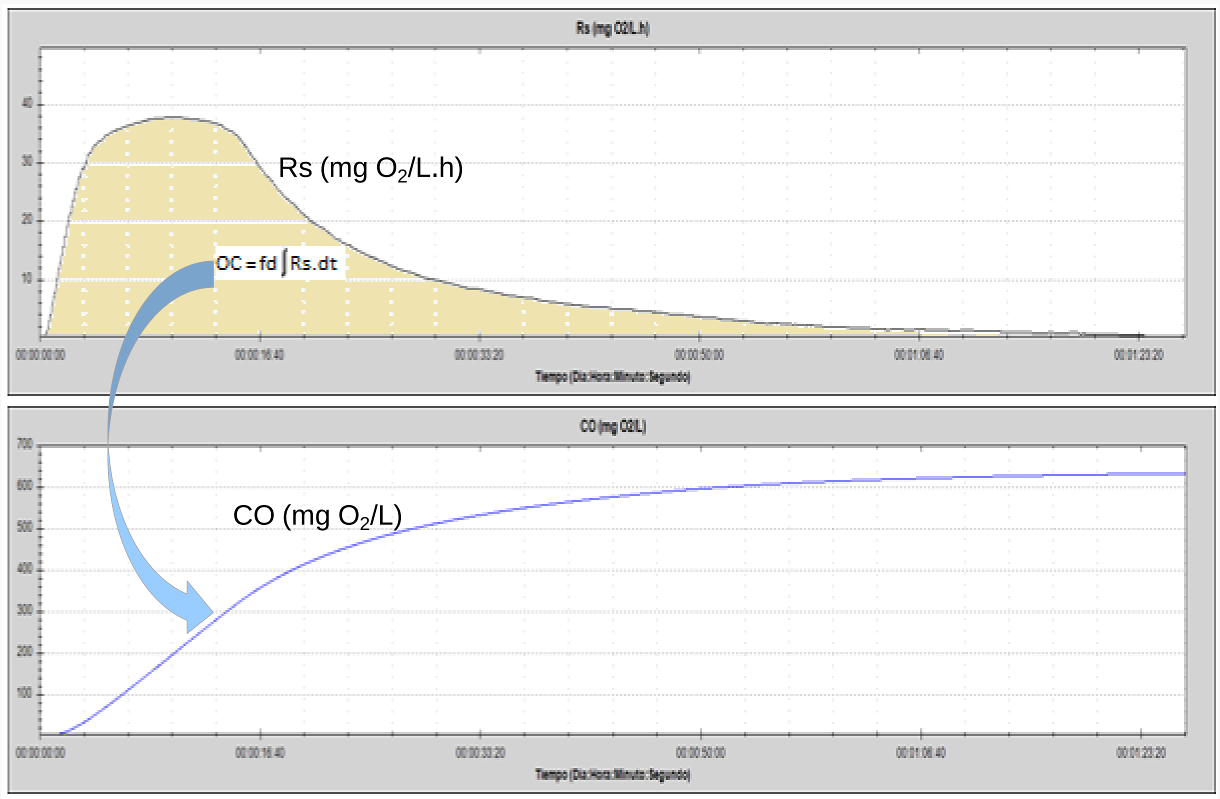
The oxygen requirement by denitrification (AOR_{DN}), performed under anoxic conditions, is presented as a credit against the total oxygen requirement.

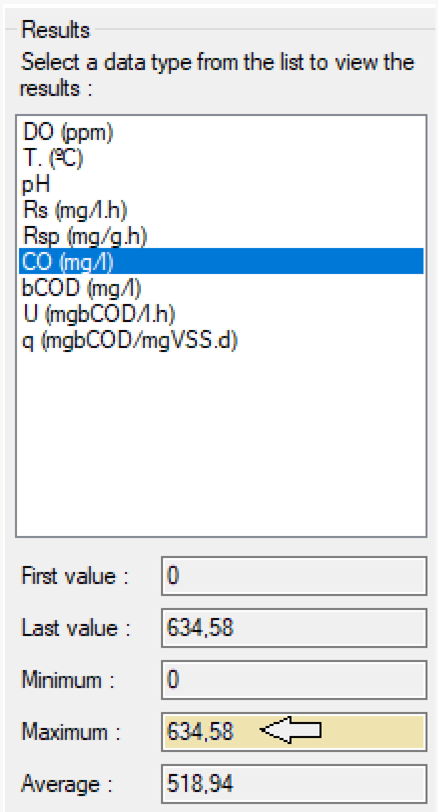
$$\mathbf{AOR = AOR_C + AOR_{end} + AOR_N - AOR_N}$$

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.

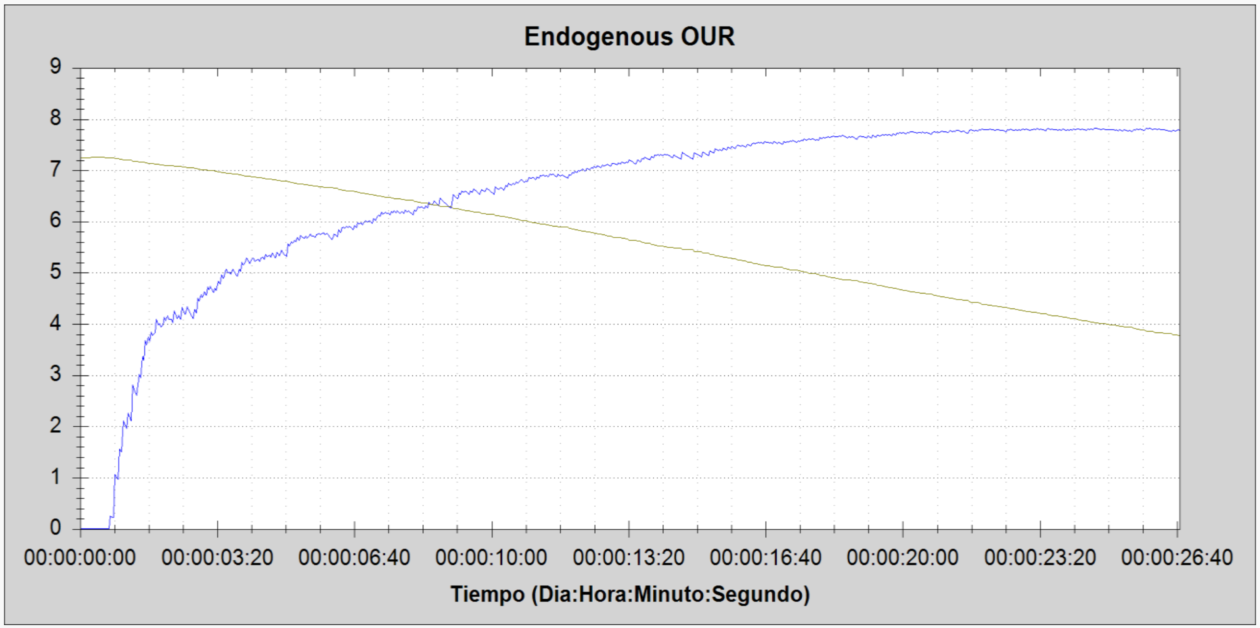


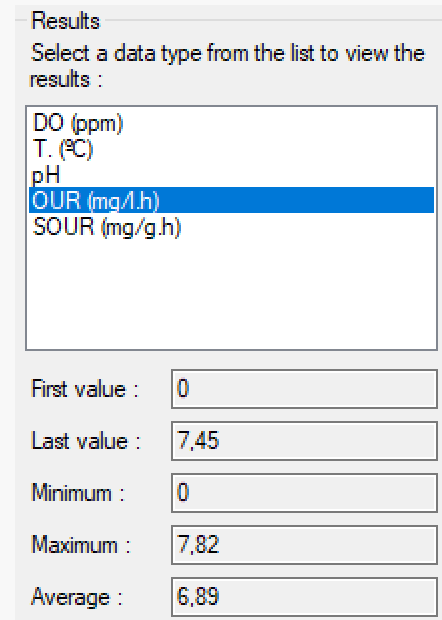


AOR_{end} by BM respirometry test

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

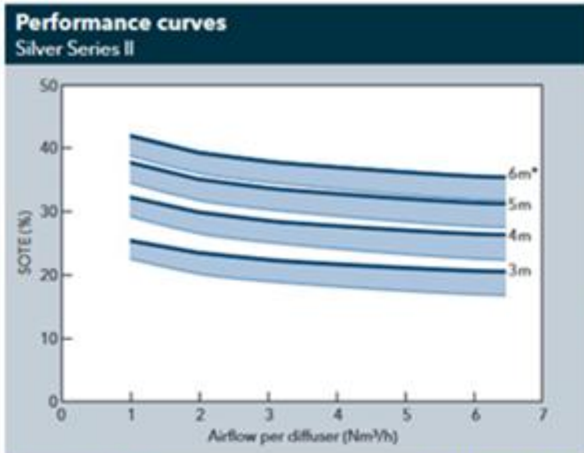
AOR_{end} is calculated from oxygen uptake rate test (OUR_{end}) of the sludge under endogenous phase (without any substrate)





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 standar 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:

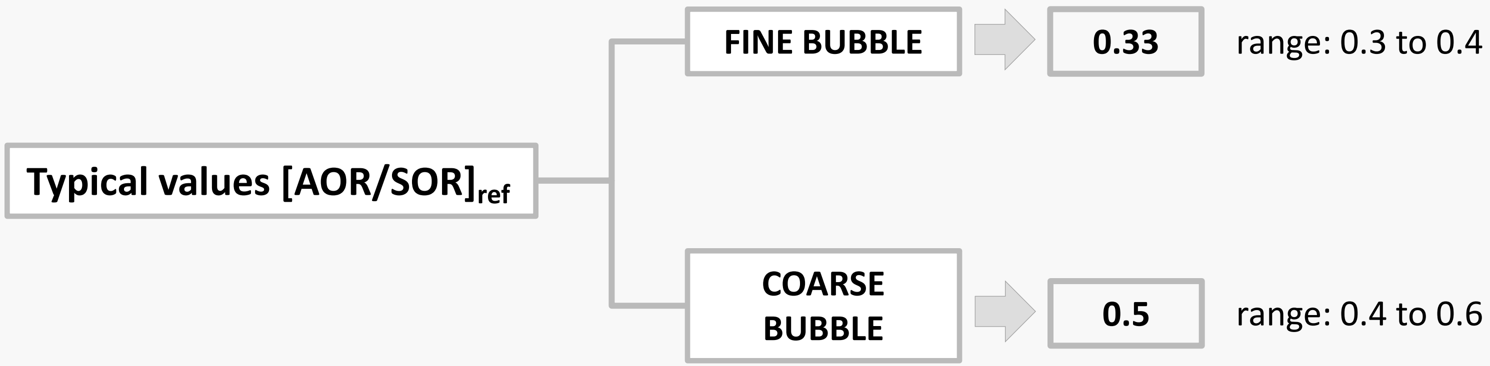
Q_{O2}: Oxygen flow (kg O_2/d) = 0.285 * Q_{air} (m^3/d)

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.

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

Once the AOR/SOR is calculated, then it wll be compared with the the **[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.

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

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.

OTE_f (%)

Oxygen transfer efficiency in process

The oxygen transfer efficiency of the process is one of the most important parameters in aeration systems. The higher the OTE_f, the less air needs to be supplied to the reactor to ensure the oxygenation currently required by the treatment process.

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

The determination of OTE_f allows operators to assess the long-term operating costs of their aeration systems and to ensure that sufficient capacity is available to meet the demand of the influent load. It is therefore a parameter that can be considered essential for aeration system evaluation and monitoring.

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