BM Respirometry

https://www.youtube.com/watch?v=UeMvk7U5ZMo

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What is BM Respirometry?

It is a technology designed by SURCIS that combines the traditional Respirometry with a state of the art method that permits to carry out different types of tests on a fast and simple way to measure the oxygen uptake and derived parameters from the microorganisms of the activated sludgein any biological wastewater treatment plant.

BM - Respirometry can work on different combinations:

- Activated sludge
- Activated sludge + wastewater sample
- Activated sludge + any sample
- Activated sludge + standard compound
- ...

Some applications in BM Respirometry

- Oxygen requirement and energy optimization
- Bioaugmentation control and tracking
- COD fractions: Automatic rbCOD, bCOD, Calculation of nbCOD and sbCOD
- BOD5 estimation
- Analysis of the Influence of different conditions (pH, Temp., Oxygen, ...) in the process
- Operative parameter optimization: SRT, F/M
- Nitrification rate – Nitrification capacity
- Denitrification rate - soluble bCOD necessary for denitrification
- Anoxic - Anaerobic process (in BM-Advance Pro)
- Global Toxicity referred to one specific biomass
- Specific Toxicity to nitrification
- Kinetic parameters
- Support for simulation programs
- Many others

BM respirometers are open systems support all kinds of combinations
to step into an endless number of applications.

BM respirometry systems

Multi-purpose Respirometers BM™ Series

BM-Respirometers are laboratory analyzers specially developed for practical and efficient biological wastewater treatment management, design and research

Comparative table of BM respirometers

Comparative items	BM-T+	BM EVO	BM EVO2	BM Advance	BM Advance2	BM Advance Pro	Comments
Automatic measurements: **OUR** (mg/l.h) **SOUR** (mg/g.h) **OUR & SOUR cíclico** **Rs dinámica** (mg/l.h) **Rsp** (mg/g.h) **CO** (mg/l) **bCOD** (mg/l) **rbCOD** (mg/l) **U** (mg DQO/l.h) **q** (mg DQO/mgSS.d)	✓	✓	2 x ✓	✓	2 x ✓	✓	From the automatic measurements we can go to the applications.
Thermo system in the analyzer		✓	2 x ✓	✓	2 x ✓	✓	Cooling (Peltier) + Heating system included
External thermo unit	✓						External unit (separated unit) formed by Cooling (Peltier) + Heating system.
Easy transportable system	✓						Analyzer + case → 20 kg D-40 + case → 5 kg
Padded aluminium cases for easy transportation	✓						1 case for analyser + 1 case for the thermo-unit. D-40
pH measurement and control				✓	2 x ✓	✓	Especially important in all nitrification tests.
ORP measurement						✓	Redox
Possibility to set conditions and be able to modify them during the test	✓	✓	2 x ✓	✓	✓	✓	Important to carry out studies to analyze the influence of the conditions (pH, OD, Temp.)
BM software update from Internet	✓	✓	2 x ✓	✓	✓	✓	BM software is automatically updated.
Capability for biomass-carrier reactor	✓	✓	2 x ✓	✓	2 x ✓	✓	For MBBR and granular biomass

BM
operation modes

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

bCOD: **Biodegradable COD** (mg O_2/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.

BM Advance Respirometry system

Key points of the components and control systems included in the BM - Respirometers

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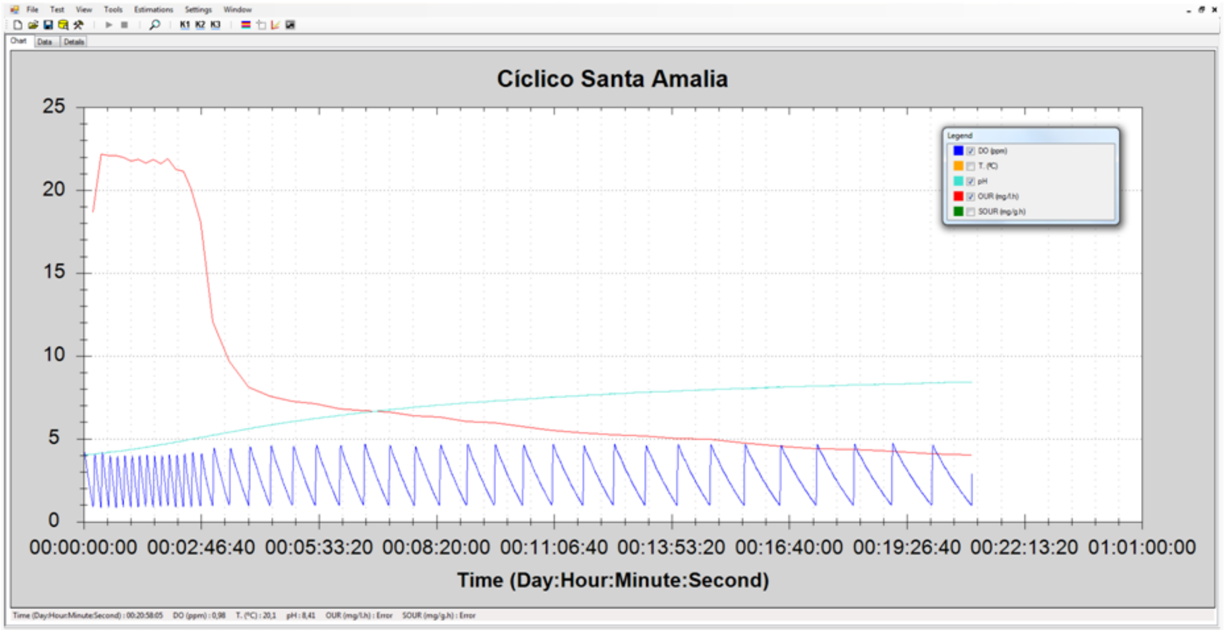
List of some key points concerning the components and systems included in the BM respirometers that make the difference

- Direct oxygen measurements from a maintenance-free oxygen sensor
- No oxygenation restriction during test performance
- pH control system in the BM-Advance system
- pH control and ORP measurements in the BM-Advance Pro system
- Automatic solid-state device for heating & cooling
- Option for a special reactor assembly to simulate a Moving Bed Biofilm Reactor (MBBR)
- Double reactor in model in BM-Advance2

No oxygenation restriction during test performance

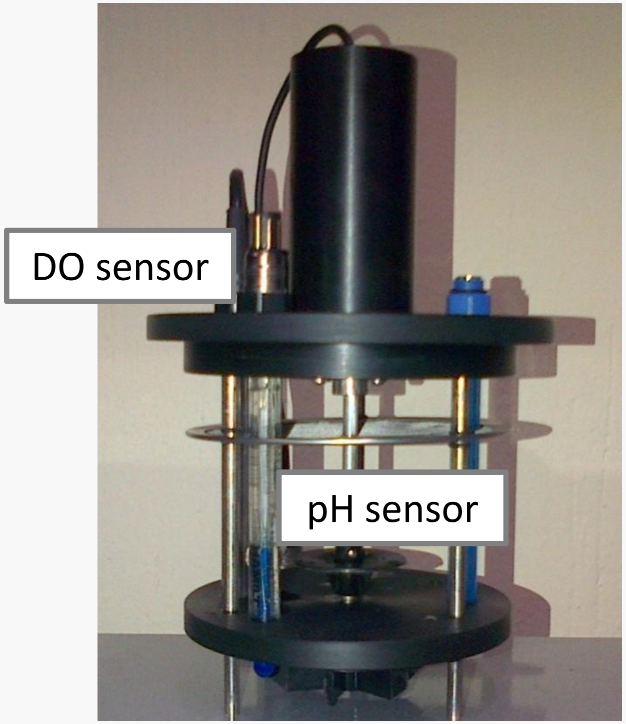
The air supplied to the reaction vessel comes from a small compressor which can be controlled in the settings board by fixing the percentage of the total air-flow.

Reactor assembly



Respirometry Cyclic OUR test of more than 20 h

High reliability Sensors



DO sensor – All models

40 ppb to saturation

0 – 60 ºC

Electrochemical oxygen sensor

Patented **OPTIFLOW** membrane – specially dsigned for harsh ambient -

100% maintenance-free sensor: membrane and electrolyte don't need to be replaced.

Response time is fast and independent of flow.

Very stable under harsh ambient conditions.

pH sensor – Advance and Advance Pro models

pH 0 to 14

0 – 135 ºC

Almost drift-free measurement.

Reference electrolyte factory prepressurized for a clog-free diaphragm potentials.

Everef-F Reference cartridge for silver-free electrolytes.

Poison resistant "PHI" pH glass.

ORP sensor – Advance Pro model

Set to -1000 mV to + 1000 mV

0 – 130 ºC

ORP element: Pt wire

Maintenance-free sensor.

High-performance ceramic diaphragms to reduce the effect of flow potentials.

pH control in the BM-Advance models

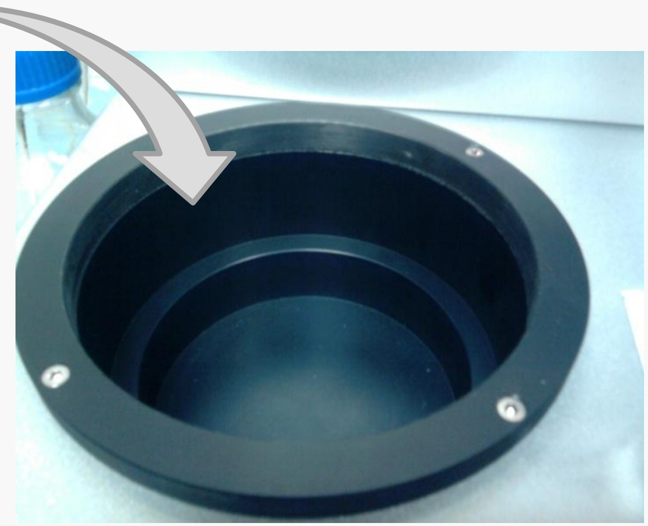
pH control system

Automatic pH buffers dosage in the reactor

Automatic heating-cooling system

Solid-state system based on peltier technology for temperature control (heating & cooling). This heating and cooling system is built into the same analyzer console without the need of using any water bath.

Reactor is carried to the heating-cooling site



Heating-cooling assembly

Optional reactor for MBBR

BM respirometers are the only respirometers on the market that can offer the possibility of making use of one special bio-reactor assembly (designed by Surcis) for respirometric tests simulating moving bed bio-film reactors (MBBR type) or granular biomass.

Biomass-carriersot granular loading
in the reactor-cage

Biomass-carriers + mixed-liquor
loaded in the reactor vessel

Reactor installed in the system
and ready for the test performance

BM Respirometry Applications

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Primary assessment of the activated sludge process

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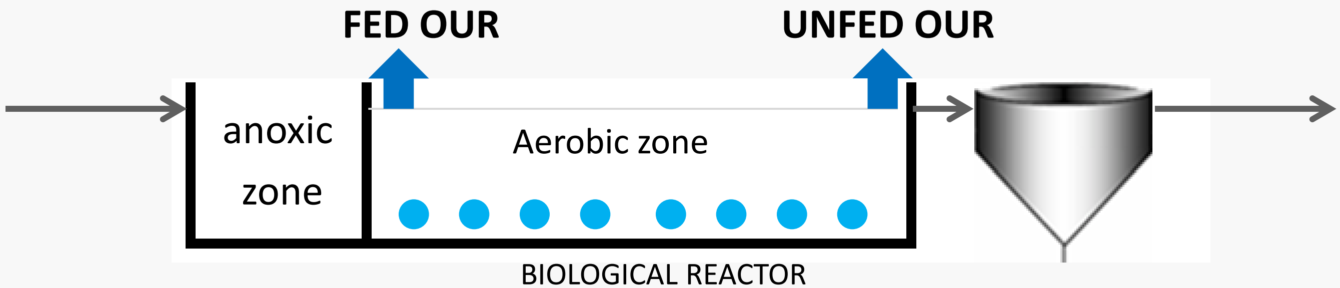
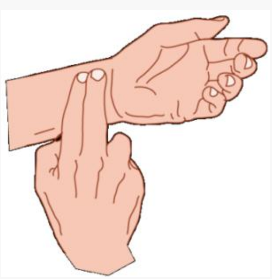
Taking the pulse of the process by the Loading Factor

The ASP can be assessed by means the relationship betrween the values of two OUR tests: one from the influent sludge (FED OUR) and another form the effluent sludge (UNFED OUR)



Loading factor (LF)

LF = FED OUR / UNFED OUR



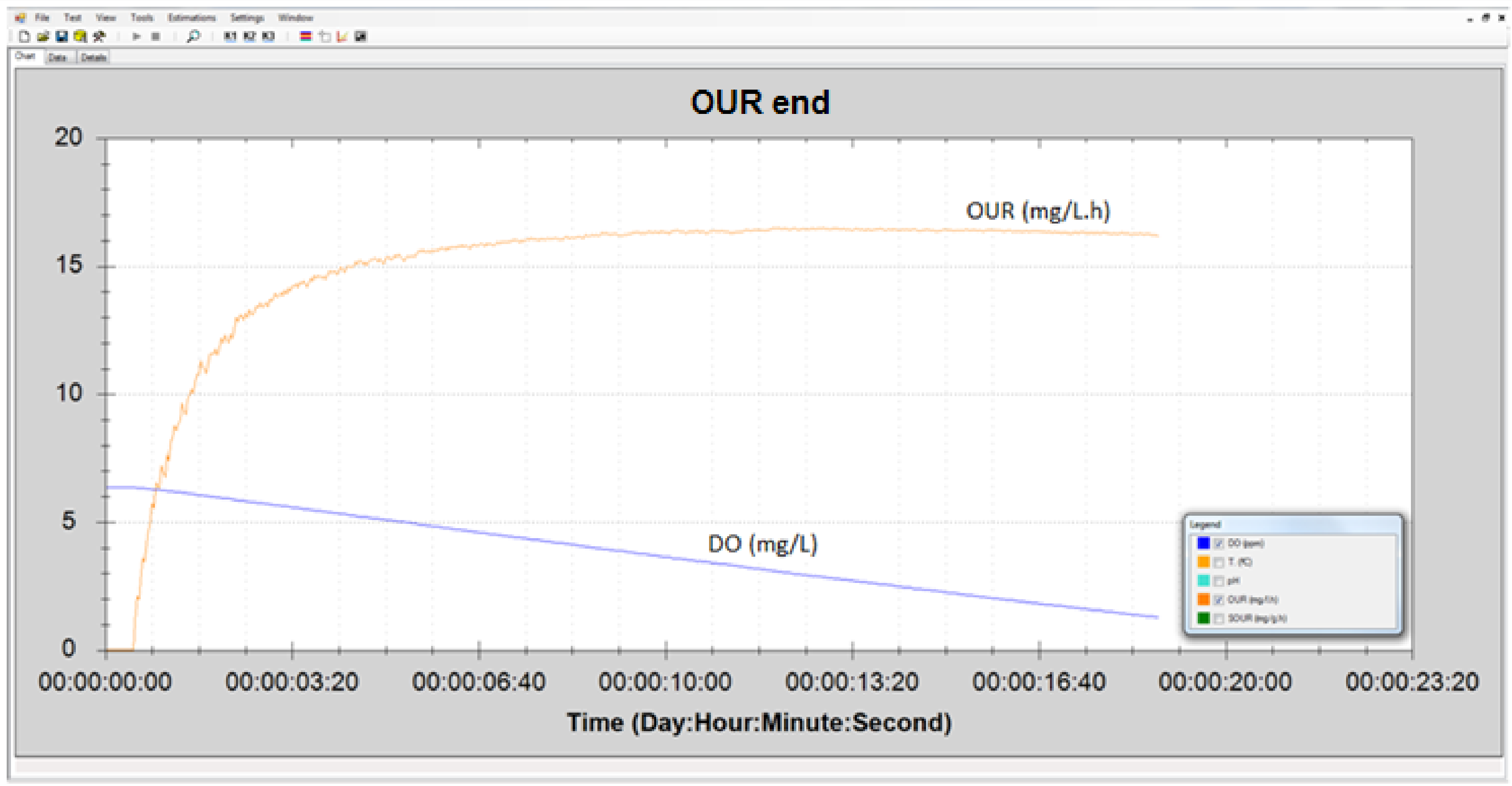
LF	Assessment
FC ≤ 1	Inhibition / Toxicity
1 < CF < 2	Low efficiency or very low loading rate
2 < FC < 5	Good performance & Normal loading rate
FC ≥ 5	Abnormal high loading rate

Endogenous respiration

Endogenous respiration rate

It is about the endogenous oxygen uptake rate test (OUR end) of the activated sludge after being aerated for a sufficient time to eliminate any kind of degradable subtrate.

Normally the endogenous respiration state can be recognized when the oxygen readings are stable within its oxygen saturation level.



DO and OUR respirogram for OUR end

OUR_{end} assessment

Table guide of usual OUR_{end} values

MLVSS (mg/l)	OUR_{end} (mg/l.h)
1000	2 – 3.5
1500	3 - 5
2000	4 - 7
2500	5 – 8.5
3000	6 - 10
3500	7 - 12
4000	8 – 13.5
4500	9 – 15.5

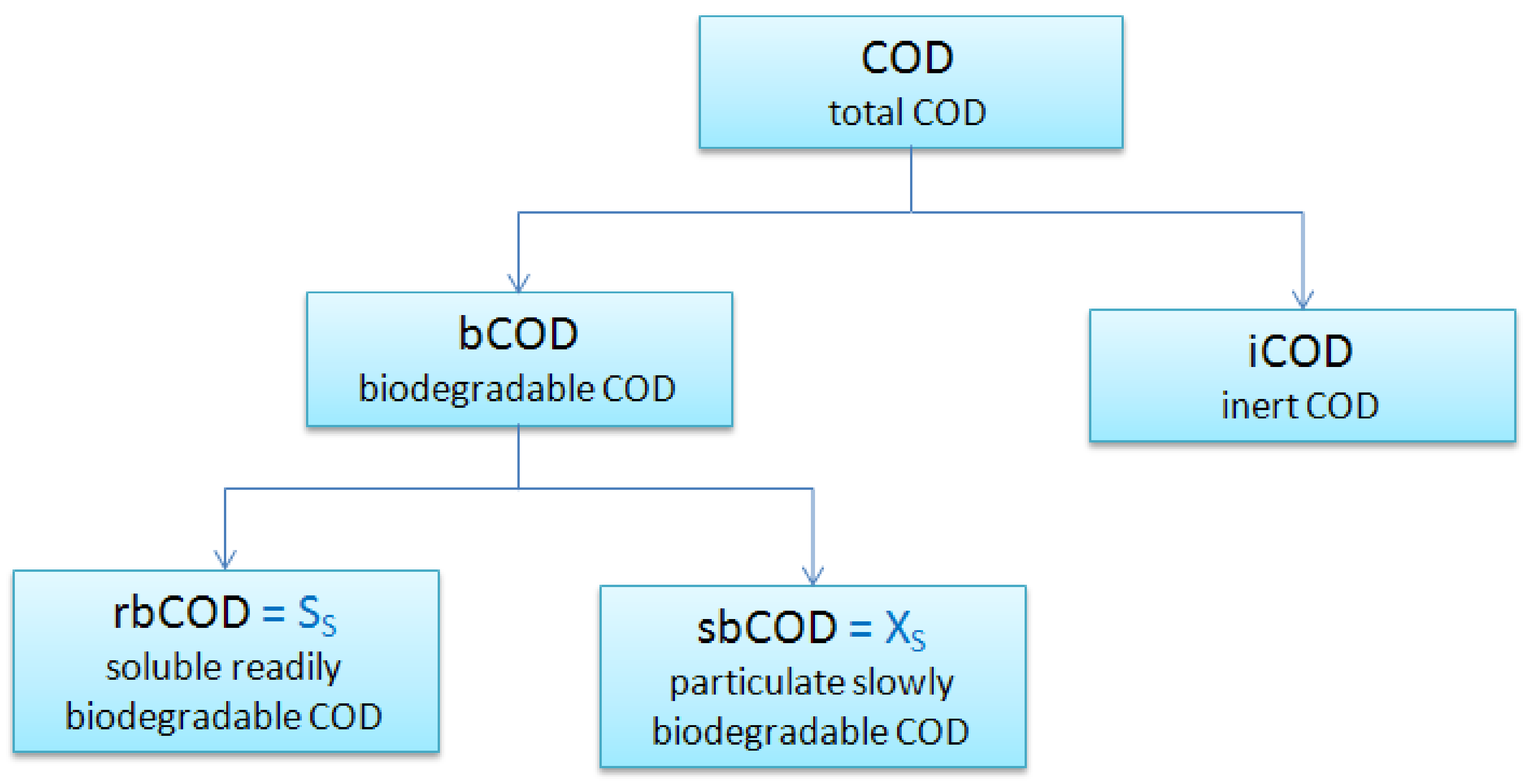
Some reasons for which the OUR end value could be below its normal range

- **Low active biomass concentration**
  1. Any of the current process conditions (or several) is out of the normal range: Temperature, Oxygen, pH, Nutrients,…
  2. Too high % of slowly biodegradable COD (sbCOD) in total COD → Biomass starvation

- **Toxicity already present in the biological reactor**

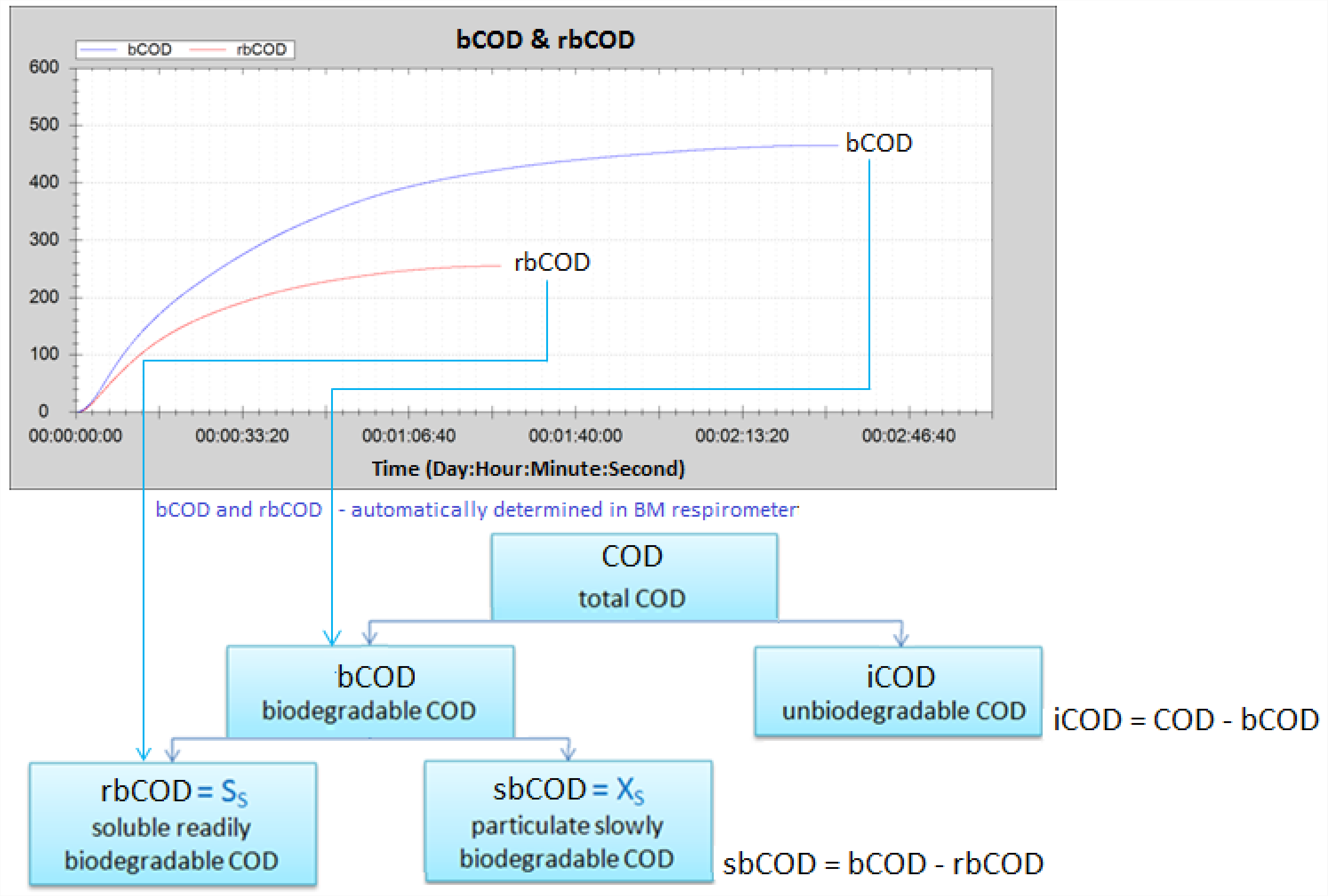
COD fractions

Main COD fractions (1)



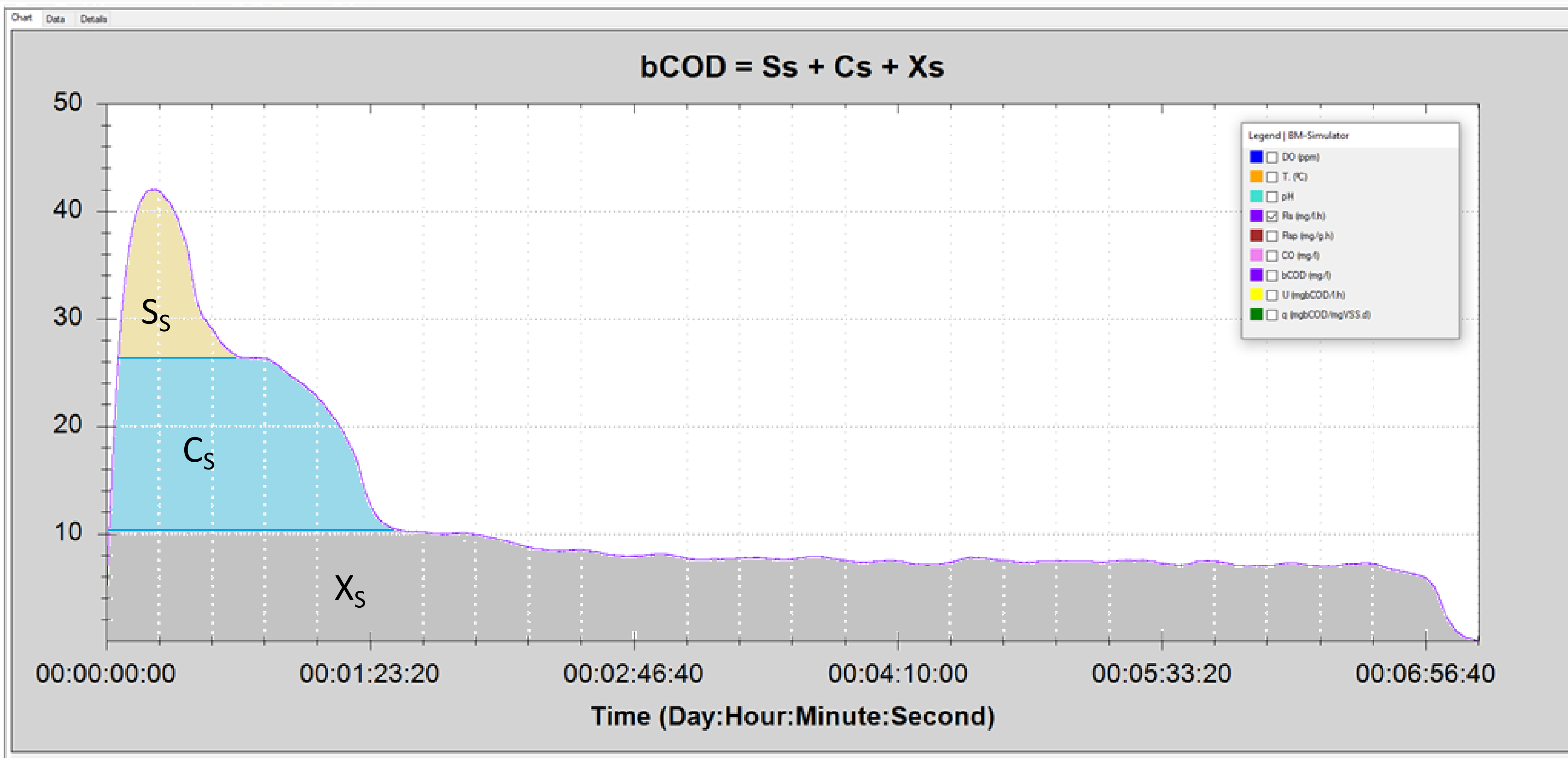
Main COD fractions (2)

Normally with only two R tests - for bCOD and rbCOD (soluble sample) – , together with the total COD value, we can determine the main COD fractions



COD fractions in one single R test

Where that is the case, within a single R test and by making use of one of the software options, it is possible to determine the bCOD fractions by breaking down the different corresponding areas.



S_S : Readily biodegradable COD (mg/l)

C_S : Colloidal slowly biodegradable COD (mg/l)

X_S : Particulate biodegradable COD (mg/l)

Toxicity

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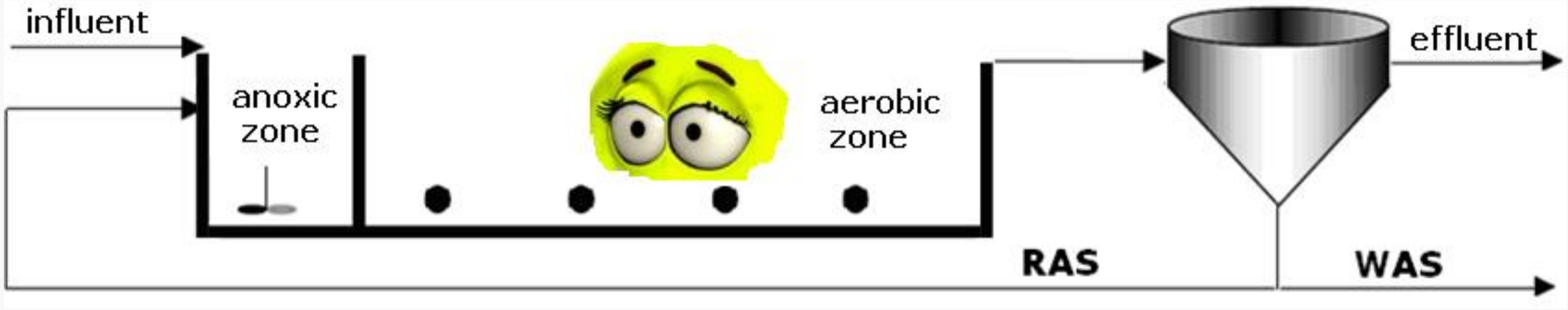
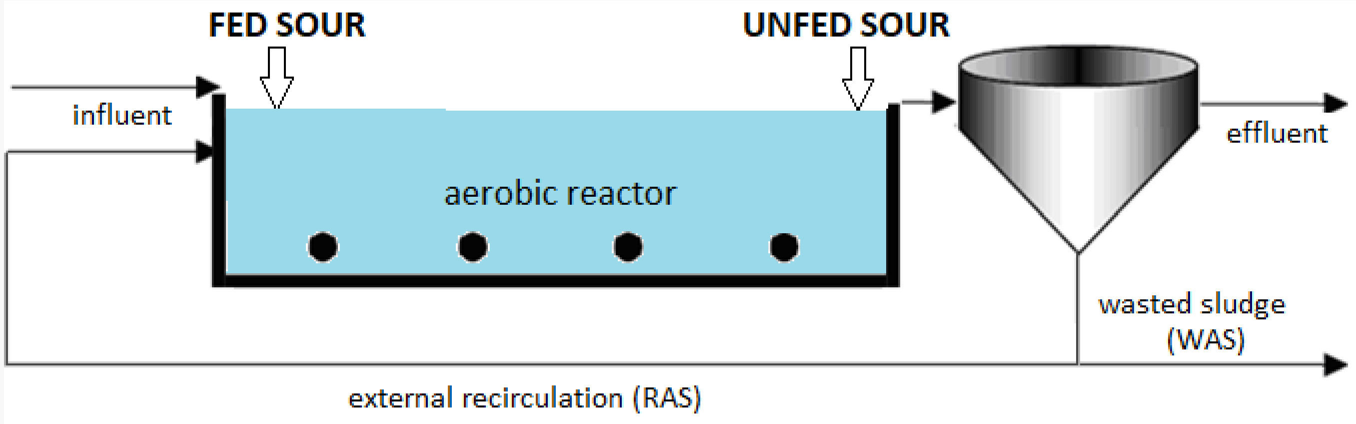
Basically we can see two cases of toxicity

1. **Toxicity already present in the ASP**



2. **Potential toxicity in the wastewater or compound that should be analyzed before entering in the ASP**

Symptoms for a toxicity already present in the activated sludge process



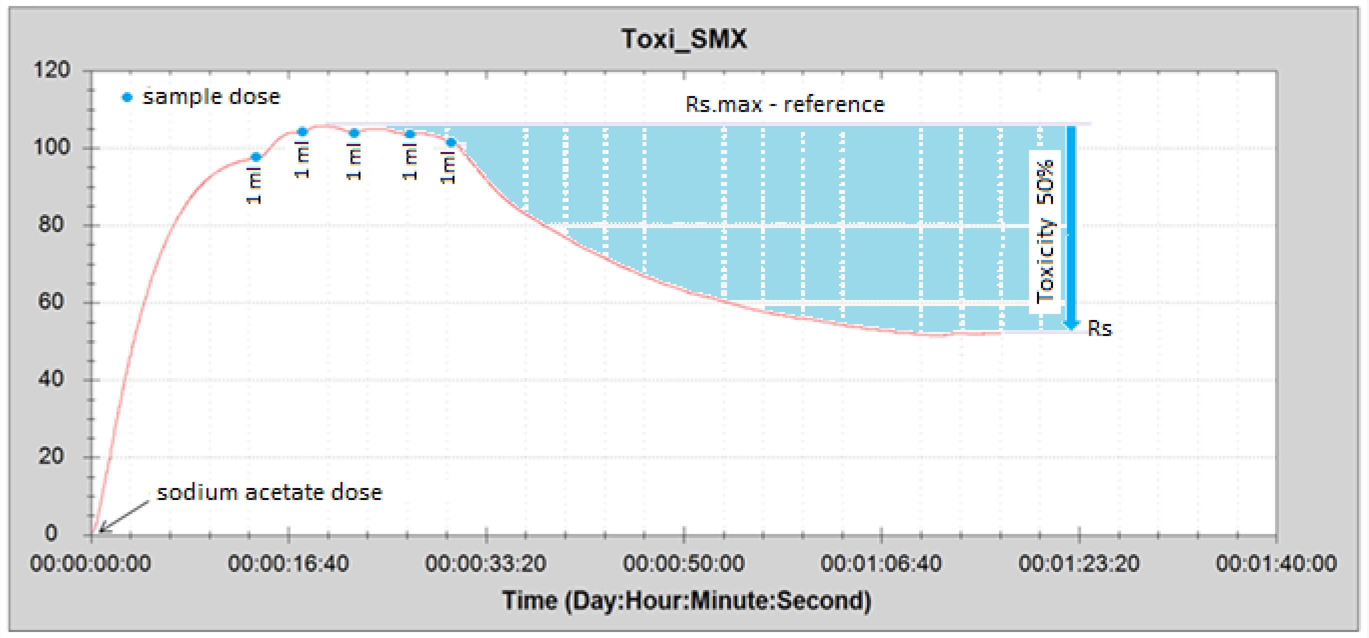
FED SOUR: SOUR in mixed-liquor from the process start

UNFED SOUR: SOUR in mixed-liquor from process end (effluent sludge)

Parameter	Condition
FED SOUR / UNFED SOUR	**< 1.3**
OUR_{end}	**<< Reference values** in Table OURend vs MLVSS

Short term toxicity

The method is based on one R test (using endogenous RAS sludge) where its added a readily biodegradable standard substrate (e.g. sodium acetate) with sufficient concentration to get its maximum respiration and, once this has been achieved, adding sucessive doses of sample to compare the respiration rate in progress with the maximum respiration rate reached in the test (reference)



Rs respirogram for short term toxicity

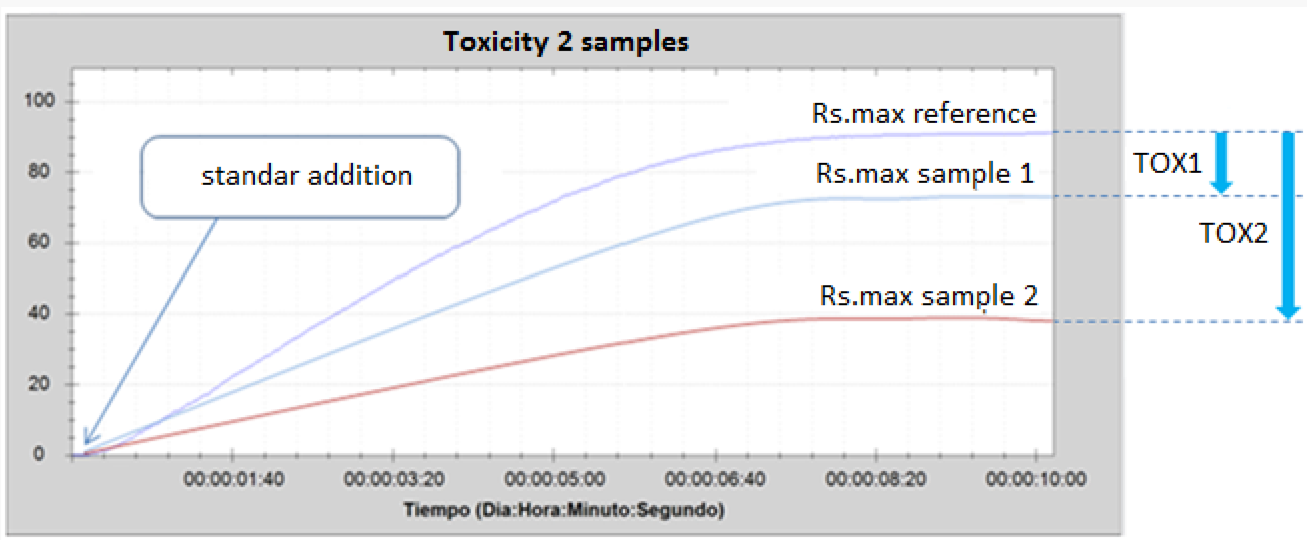
Toxicity (%) = 100 * (Rs.max – Rs) / Rs.max

Toxicity for global biomass or specific nitrifier

This method is based on the preparation of one mixed-liquor with RAS sludge + distilled water (reference) and one o several more mixed-liquor with RAS sludge + sample/s to be analyzed.

Mixed-liquors preparation → Endogenous respiration sludge → R test with estándar addition (*) → Rs.max comparison vs Rs.max reference

(*) The method is valid both to analyze a global toxicity (by adding the standar of sodium acetate) or a specific toxicity for nitrification (by adding the standar of ammonium chloride)



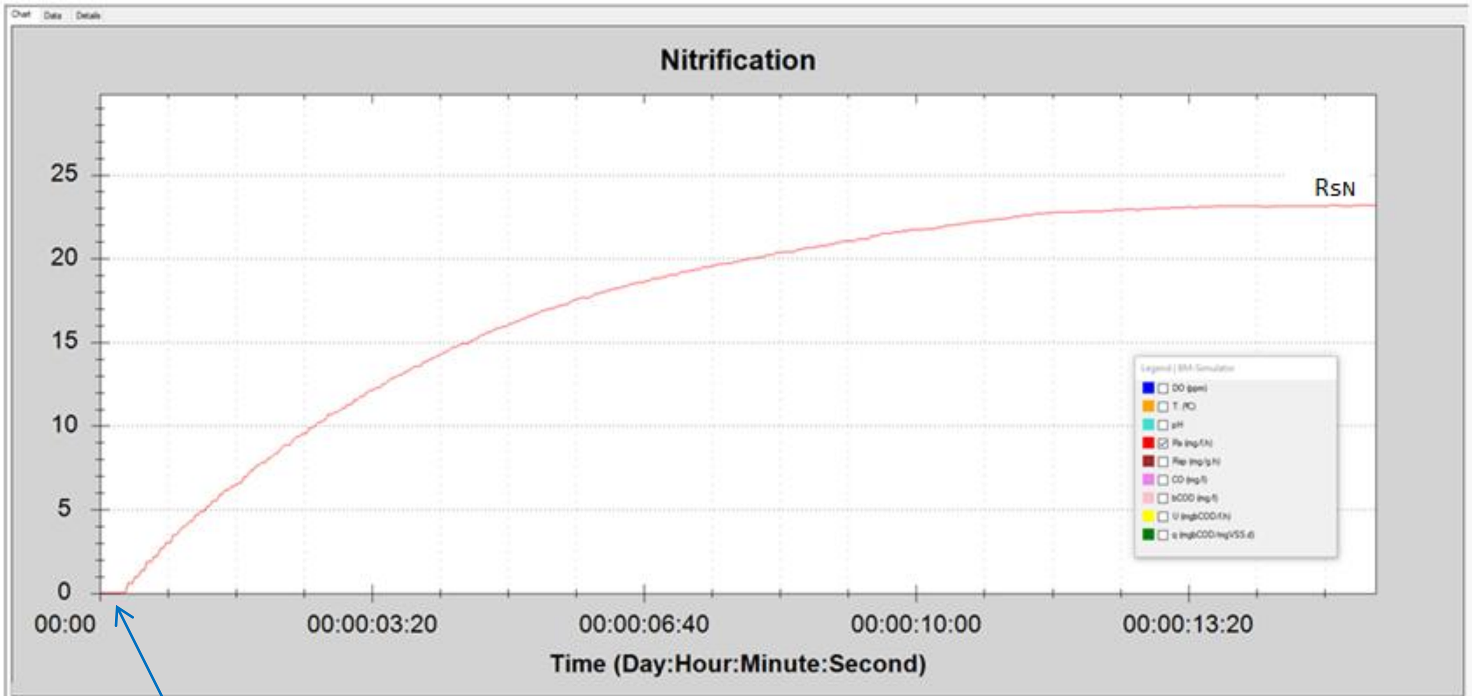
Combined Rs respirograms to asses 2 samples toxicity

Toxicity (%) = 100 * (Rs.max ref. – Rs sample) / Rs.max ref.

Nitrification

Nitrification rate

We carry out a R test with ammonium chloride on equivalent ammonium concentration, until we reach the representative Rs (Rs_N)



Rs respirogram

Ammonium chloride addition

Nitrification rate (mg N/l.h): **AUR** = (Rs_N / 4,57) * DO / (K_{OA} + DO)

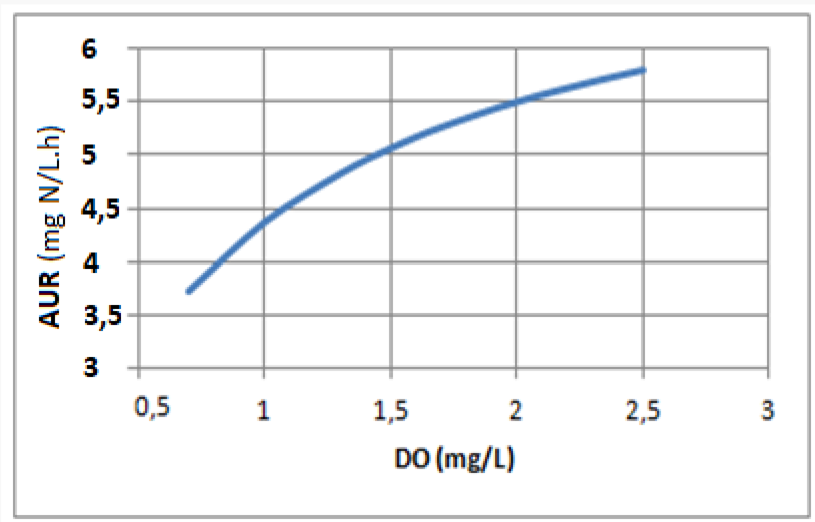
Rs_N: Respiration rate due to nitrification (mg O_2/l.h)

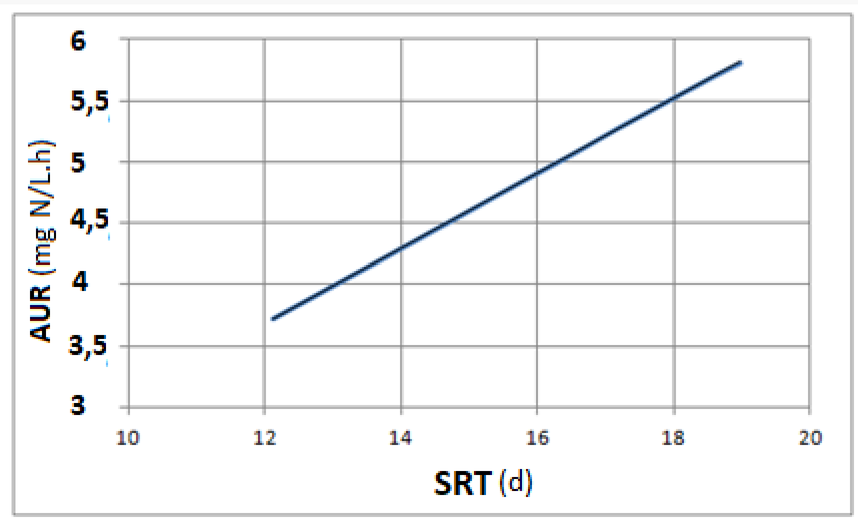
4,57: mg O_2 / mg Ammonium oxidized

DO: Actual dissolved oxygen in the biological ractor

K_{OA}: Nitrification coefficient ≈ 0,5 (habitual default value)

Dissolved Oxygen (DO) and Sludge Age (SRT) for Nitrification





AUR = [Rs_N / 4.57] * OD / (K_{OD} + OD)

SRT = X_A / (2.4 * AUR)

Denitrification

Denitrificatio rate: NUR

This parameter is determined by respirometry thanks to the fundamental principle whereby there is a directly proportional relationship between the aerobic rate of oxygen consumption by organic matter removal (U) and the anoxic nitrate removal rate (NUR)

US-EPA, Henze et al 1987 - Illinois Institute of Technology – Andrew Robert Shaw; Heather M. Phillips - Black & Veatch Corporation (WEFTEC10)

$$U\ (1-Y_{H.DN})\ /\ NUR = 2{,}86$$

NUR: Denitrification rate (mg $N\text{-}NO_3$ /l.h)
U: COD removal rate (mg COD/L.h) - automatically calculated in the BM respirometer -
$\mathbf{Y_{H.DN}}$: Heterotrophic yield coerfficient in the denitrification process (O_2/DQO) ≈ 0,83 * $Y_{H.DO}$

Methanol use as rbCOD source

In the event that the wastewater rbCOD does not meet the conditions ($rbCOD_{ww} < rbCOD_{DN}$), it may be necessary to resort to the use of an external source of easily biodegradable COD (normally methanol) with an earlier period of progressive acclimatization to the sludge.

$$\mathbf{rbCOD_m} = rbCOD_{DN} - rbCOD_{WW}$$

$rbCOD_m$: rbCOD from methanol

$rbCOD_{WW}$: rbCOD from influent wastewater to the anoxic zone.

<u>From bibliography</u>

1 mg/L nitrate needs 1,9 mg/L methanol for its denitrification,

1 mg/L methanol has 1,5 rbCOD (mg COD/L)

1 mL methanol = 0.791 mg methanol.

1 mL methnol diluted in 1 L distilled water = 0.791 * 1,5 = 1.18 mg COD/L

Sludge production

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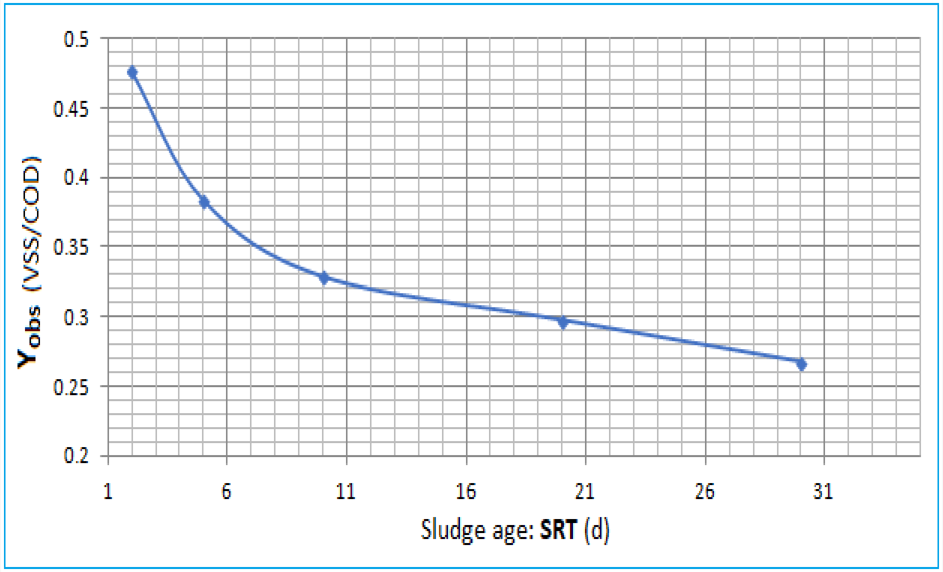
Estimated calculation of the sludge production: P_X

Y_{obs} (VSS/COD)	TRC (d)	F/M (COD/VSS. d)
0,477	2	1,048
0,384	5	0,521
0,329	10	0,304
0,298	20	0,168
0,268	30	0,124

Cicek, 2001;
Macomber, 2005



$$P_X = Y_{obs} * Q * bCOD_e / 1000$$

P_X: Sludge production (kg VSS/d)

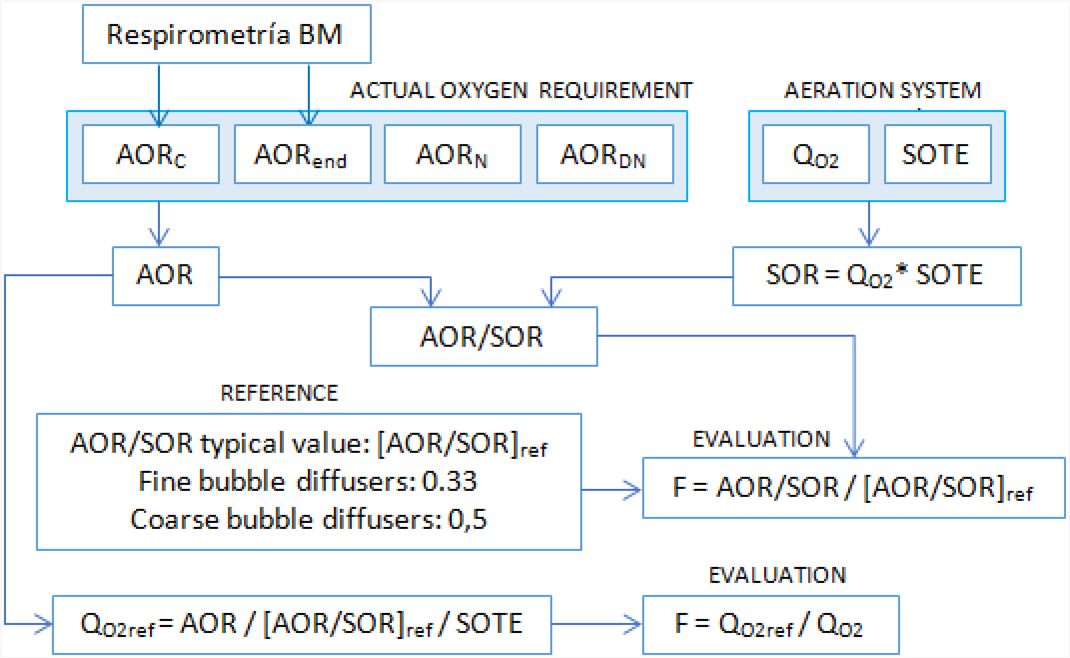
Y_{obs}: Observed yield coefficient (VSS/COD)

Q: Influent flow (m^3/d)

$bCOD_e$: Biodegradable COD eliminated (mg bCOD/L) = bCOD influent – bCOD effluent → bCOD effluent ≈ 1,6 * BOD effluent

Aeration system evaluation and follow-up

Practical 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

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