Advanced respirometry for activated sludge process

Introduction

Respirometry is the measurement and interpretation of the biological oxygen consumption rate under well defined experimental conditions. Because oxygen consumption is directly associated with both biomass growth and substrate removal, respirometry is a very useful technique for monitoring, modeling and control of the activated sludge process

The Respirometry technology is a well known since long. But, on the recent years, it has experimented an important step forward by improving its performance by developing different operation modes and also including, besides the oxygen sensor, some complementary sensors to monitor and assess some conditions, such as Temperature, pH, ORP, that could make a critical influence in the organics and nitrogen treatment.

The advanced multipurpose Respirometry systems are able to combine all the measurements in powerful software which, in a relatively simple way, is able to determine a series of fundamental parameters which can lead to some essential applications that no wastewater treatment process should ignore and that represent the vertebral column of its performance.

In addition, this advanced respirometry system can also include a special reactor to carry out respirometry tests with moving bed biofilms (for MBBR) or granular biomass.

ES France - Département Bio-tests & Industries
127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 90
Fax. 01 47 01 16 22
e-mail : bio@es-france.com
Site Web : www.es-france.com

1. Main specifications of the advanced respirometry system

The following specifications correspond to the model BM-Advance Pro from Surcis S.L:

- Direct oxygen measurements from a maintenance-free oxygen sensor
- No oxygenation restriction during test performance
- Full analyzer control and results by means a specific software already loaded in the PC of the system
- Capacity for test conditions setting and modify them throughout the test performance.
- Three different operation modes: R, OUR and Cyclic OUR
    1. R mode: Modified LFS system - Automatic measurements of Rs (exogenous respiration rate), CO (consumed oxygen), bCOD (biodegradable and readily biodegradable COD), U (COD utilization rate) and q (specific U)
    2. OUR mode: LSS system - OUR (oxygen uptake rate) & SOUR (specific OUR)
    3. OUR cyclic: Cyclic LSS system - OUR & SOUR within a continuous sequential chain of OUR & SOUR measurements
- Last, minimum, maximum and moving average results at any time during the test performance.
- Several results at any time during the test and option to see them simultaneously on tabular or graphic modes (respirograms)
- Option to open several stored tests, overlay and compare their results
- Automatic temperature control (heating-cooling system) integrated in the analyzer assembly.
- Monitoring and automatic pH control system
- ORP monitoring
- Package of measurements at any moment during test performance
- Option for a special reactor assembly for moving beds bio-films (MBBR)

ES France - Département Bio-tests & Industries
127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 90
Fax. 01 47 01 16 22
e-mail : bio@es-france.com
Site Web : www.es-france.com

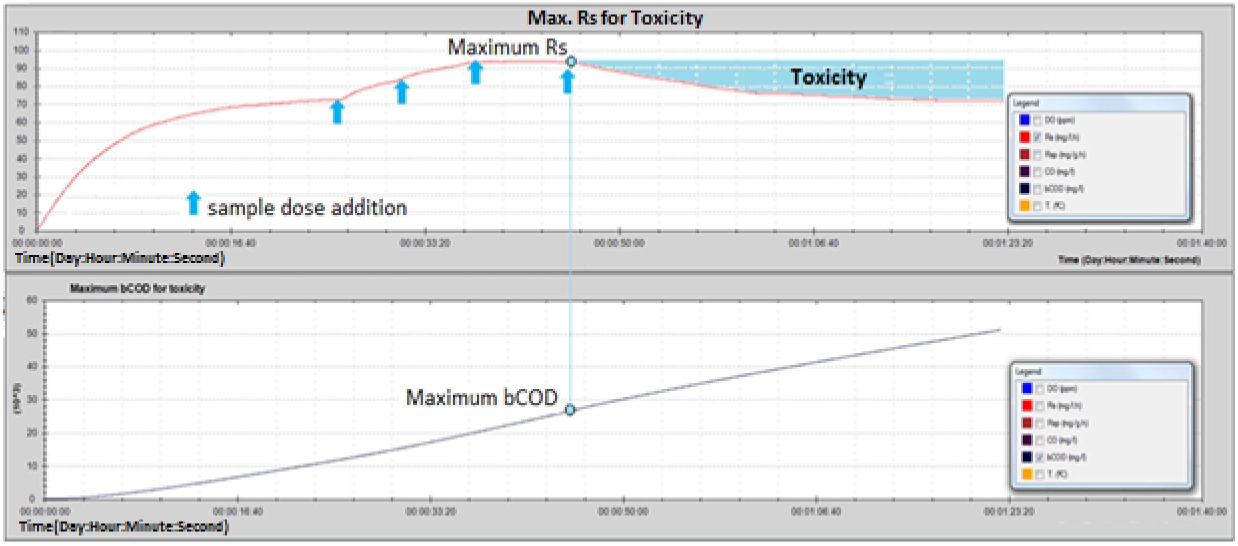
Some respirometry applications in the advanced respirometry

Break-point for maximum allowed flow & bCOD before toxicity

In a R mode respirometric test, we are adding consecutive doses of wastewater sample in a RAS sludge up to the break point where the Rs begins to drop significantly as a clear sign of toxicity.

From the ratio (Accumulated wastewater volume) / (RAS volume) = (Influent flow) / (RAS flow) the maximum allowed flow and bCOD can be then calculated.

Figure 1. Maximum volume and bCOD before Toxicity



Rs (mg O_2/l.h) and bCOD (mg/l) respirograms

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

Tox ratio = V_{WW} / V_{RAS} = $Q_{WW.max}$ / Q_{RAS}

$Q_{WW.max}$ = Q_{RAS} * V_{WW} / V_{RAS}

Where:

- V_{WW}: accumulated waste water volume in respirometer reactor (ml)
- V_{RAS}: RAS volume in the respirometer reactor
- Q_{WW}: Influent flow of wastewater (m^3/h)
- Q_{RAS}: RAS flow (m^3/h)
- $Q_{WW.max}$: Maximum influent flow of wastewater (m^3/h)

ES France - Département Bio-tests & Industries
127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 90
Fax. 01 47 01 16 22
e-mail : bio@es-france.com
Site Web : www.es-france.com

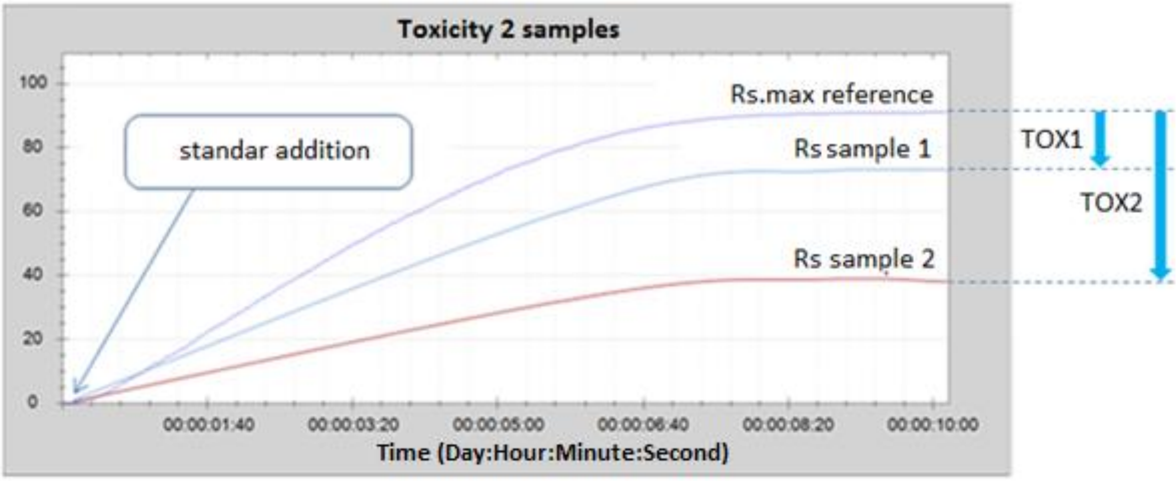
Toxicity in global biomass or specific nitrifier biomass

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

Condition for the mixed-liquors: [sample or distilled water volume / RAS sludge volume] = [Influent flow / RAS flow]

Then, the these mixed-liquors are passed to endogenous respiration to carry out R tests for each one by adding certain amount of standard (sodium acetate or ammonium chloride or both) until achieving the maximum respiration rate (Rs.max). The possible toxicity is then assessed by comparing the Rs.max reference vs Rs of the samples.

Figure 2. Toxicity 2 samples



Overlayed Rs (mg O_2/l.h) respirograms

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

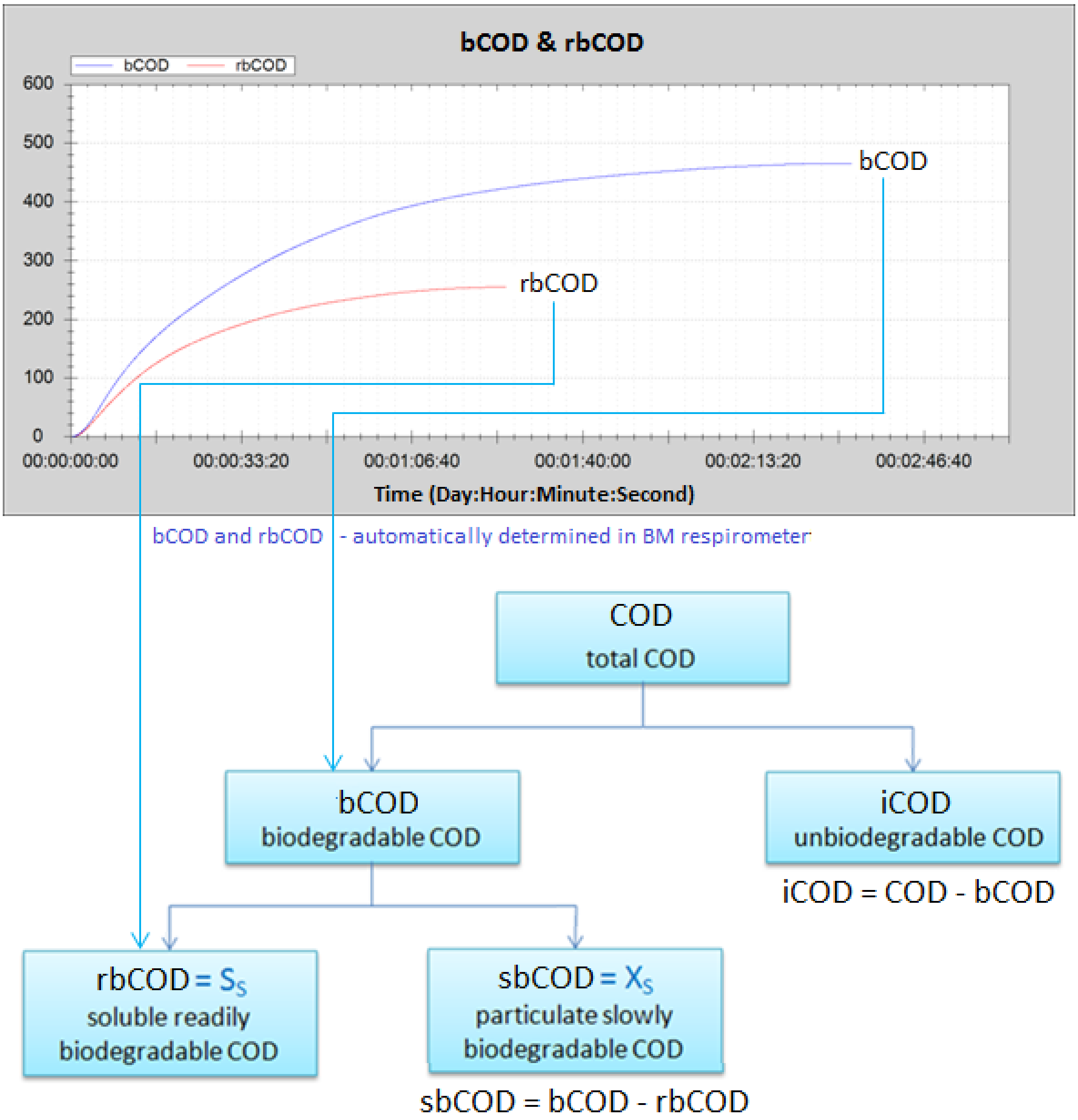
Critical COD fractions

For a wastewater treatment control, the critical COD fractions play an essential role in the wastewater treatment and should be taken into account as a fundamental data for its management, protection and design.

ES France - Département Bio-tests & Industries
127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 90
Fax. 01 47 01 16 22
e-mail : bio@es-france.com
Site Web : www.es-france.com

The BM respirometer automatically calculates the biodegradable COD (bCOD) and readily biodegradable COD (rbCOD), from which the unbiodegradable COD (iCOD) and slowly biodegradable COD (sbCOD) can be calculated.

Figure 3. Critical wastewater COD fractions



When there is a well defined rbCOD, in the same bCOD test the software can exclusively select the respirogram portion corresponding to the rbCOD and automatically get its determination without the need of a second test.

ES France - Département Bio-tests & Industries
127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 90
Fax. 01 47 01 16 22
e-mail : bio@es-france.com
Site Web : www.es-france.com

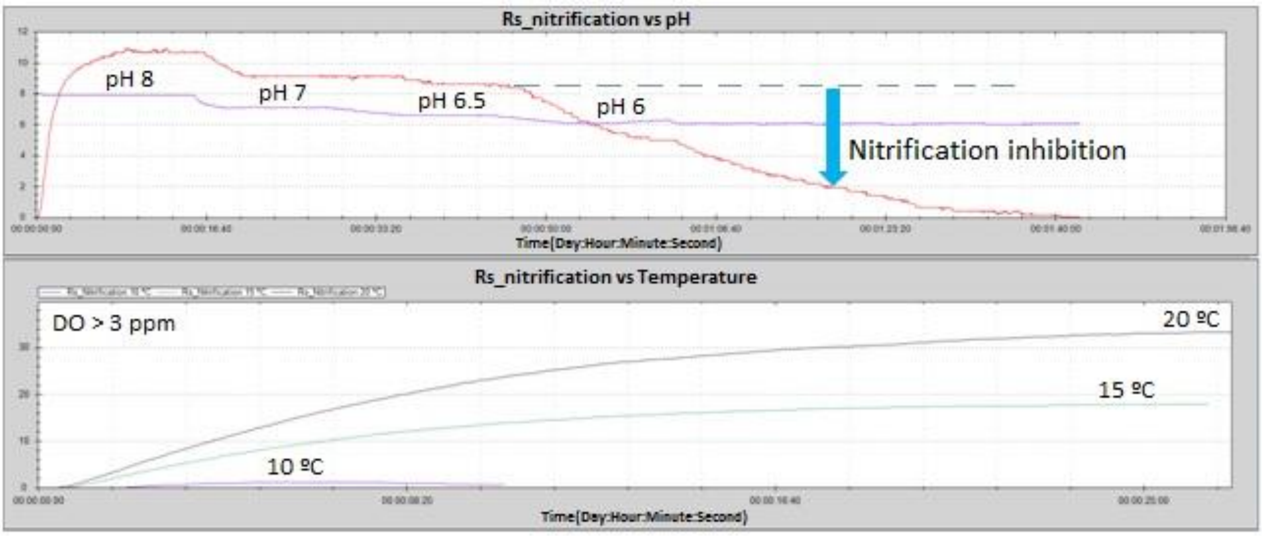
<u>Some considerations on the COD fractions</u>:

- Too high rbCOD can get a high readily COD loading rate, impacting on the nitrification process performance.
- When a high rbCOD is accompanied with also a very high substrate utilization rate, it can lead to extremely fast oxygen consumption (especially at the beginning of the process) and, in case the air / oxygen supply has limited resources, it could create an anoxic zone in the aeration tank.
- Very low rbCOD could create a lack of the necessary soluble carbonaceous matter for denitrification, leading to a poor process performance.
- Too high sbCOD can lead to a nutrients deficiency and bulking.
- Too high iCOD can impact on the global treatment process performance because of too high COD in the final effluent.

Nitrification rate for different conditions of oxygen, temperature and pH

Nitrification rate depends of the corresponding exogenous respiration rate (Rs) as ammonia is being eliminated. The oxygen, temperature and pH have a direct influence in the nitrification rate and therefore the knowledge of this should represent an essential data to get the actual nitrification rate.

Figure 4. Influence of pH and Temperature on nitrification rate



Rs vs pH & Rs @ Temperature respirograms

ES France - Département Bio-tests & Industries
127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 90
Fax. 01 47 01 16 22
e-mail : bio@es-france.com
Site Web : www.es-france.com

$AUR = (Rs / 4.57) * DO / (K_{OA} + DO)$

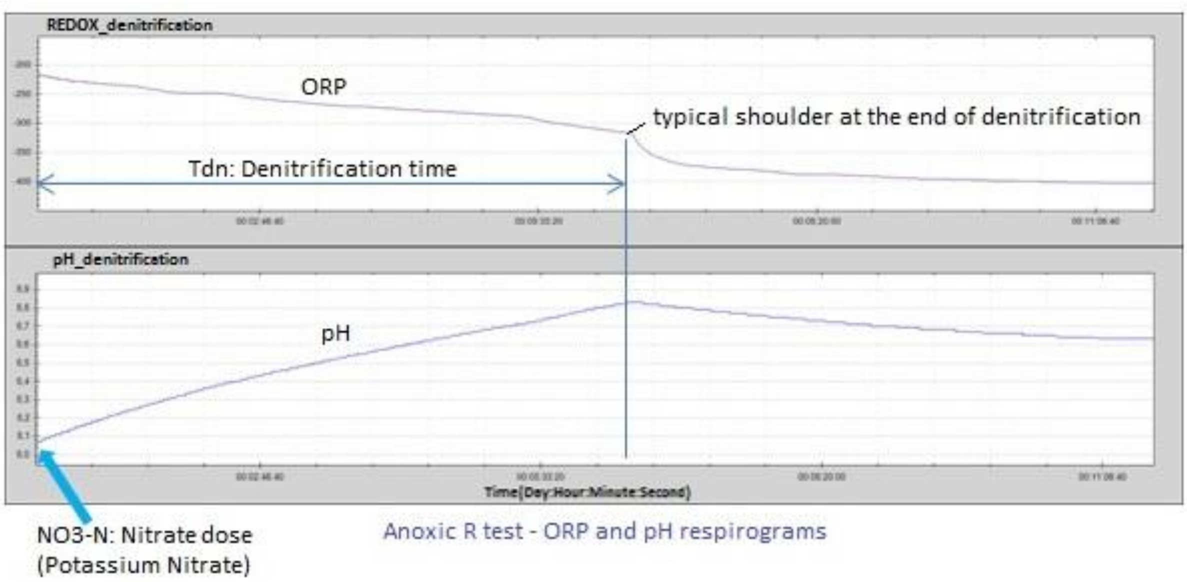
Where:

- AUR: Nitrification rate (mg NH4-N/l.h)
- 4.57: mg O_2 to nitrify 1 mg of NO_4-N
- DO: actual dissolved oxygen (mg/l)
- K_{OA}: Half saturation coefficient ≈ 0.5 (It could also be determined by respirometry)

Denitrification rate from ORP measurements

This application can be carried out by means one single R test where the aeration system is turned off and making use of an standard dose of Nitrate source (NO_3-N)

Figure 5. Denitrification rate determination



From the data obtained in the R test, the denitrification rate can be calculated as follows:

$NUR = [NO3_{-N}] / Tdn$

Where:

- NUR: Denitrification rate (mg NO_3-N/l.h)
- Tdn: Denitrification time (h)

SURCIS, S.L.

ES France - Département Bio-tests & Industries
127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 90
Fax. 01 47 01 16 22
e-mail : bio@es-france.com
Site Web : www.es-france.com