BM Respirometry System for wastewater COD fractionation

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BM Multipurpose Respirometry System

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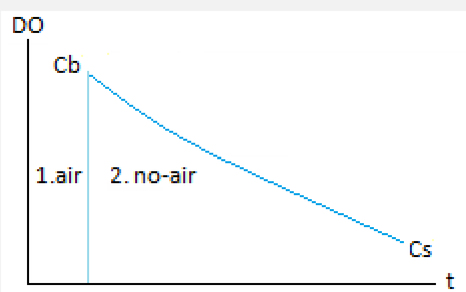
BM Respirometry

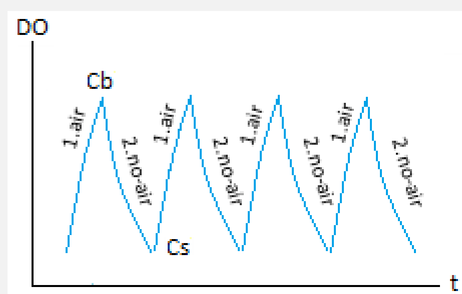
Three different operation modes

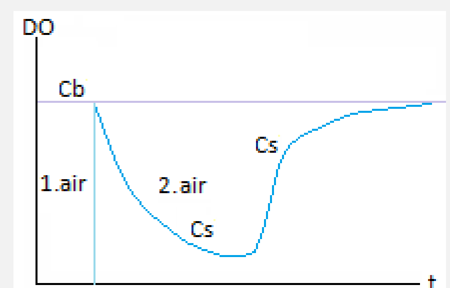
While most of the respirometers on the market offer only one operation mode, the BM respirometers have three different operation modes: OUR mode, Cyclic OUR mode, and R mode. Each mode develops different respirograms for automatic parameters including D.O., Temperature, and pH (in BM-Advance) from where specific applications can be made.

In a single batch reactor, the measuring system can work as LSS and LFS batch respirometry. The system is optimized by a one-sense membrane device, that together with a dividing plate, is able to isolate the measuring chamber and avoid bubbles against the DO sensor.

OUR	**Cyclic OUR**	**R**
This mode is making use of the LSS respirometry type. The OUR mode consists of a single test to measure the OUR and/or SOUR parameters (by manually setting the MLVSS concentration). It also has the option the get a partial SOUR for any period within the respirogram.	The cyclic OUR mode consists of a progressive sequence of OUR measurements, generated from the DO trajectory when it fluctuates between the DO. Low and DO. High set-points that were set at the start of the test.	The R mode corresponds to a modified LFS respirometry type test. The measuring system can be considered as a completely mixed batch reactor. In this mode, we get the important advantage to work with a small volume of samples in order to minimize the test time for an important package of several simultaneous parameters measurement.







Main automatic parameters in BM respirometer for the different operations modes

BM Operation modes

OUR & Cyclic OUR

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

Rs: **Dynamic 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 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.

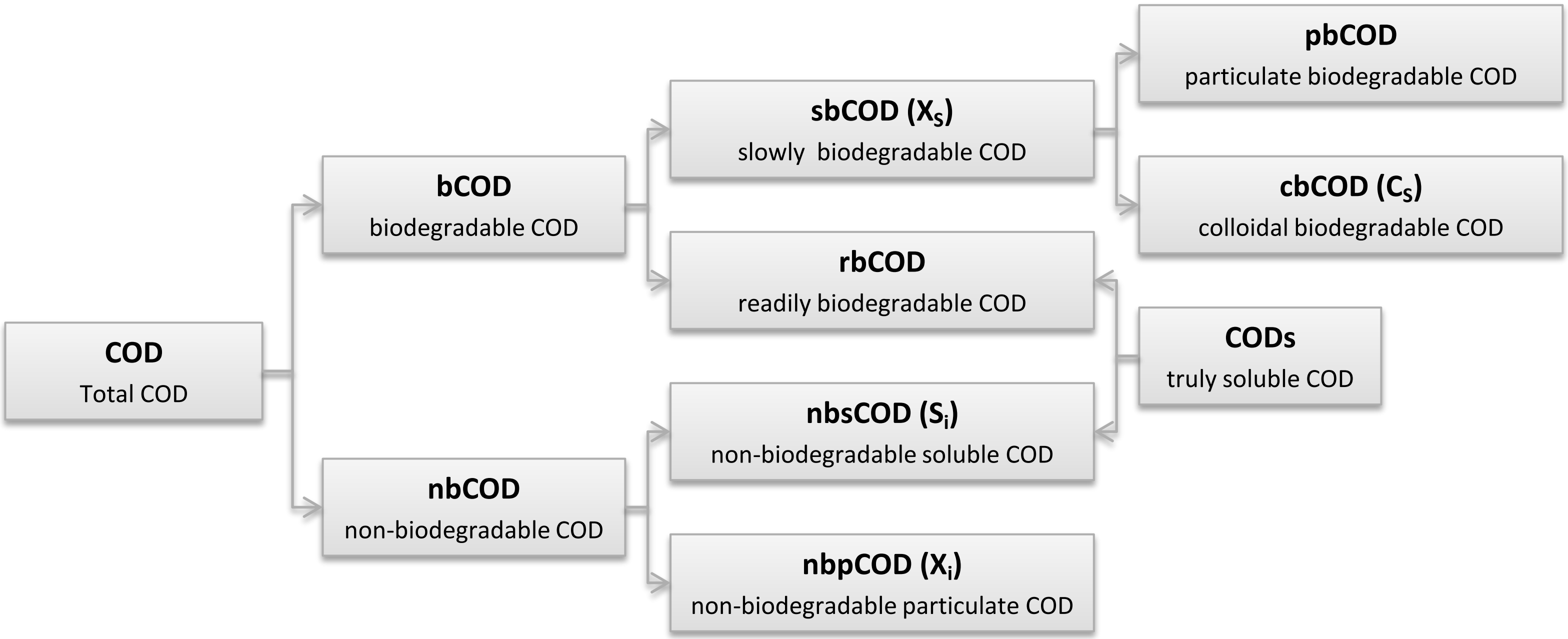
q: **Specific COD removal rate** (mg COD/ mg VSS.d)

Specific U referred to MLVSS concentration.

COD fractions

Wastewater Biodegradable and non-biodegradable COD fractions

COD fractions in the influent wastewater composition has a significant impact on the wastewater treatment operation and performance.

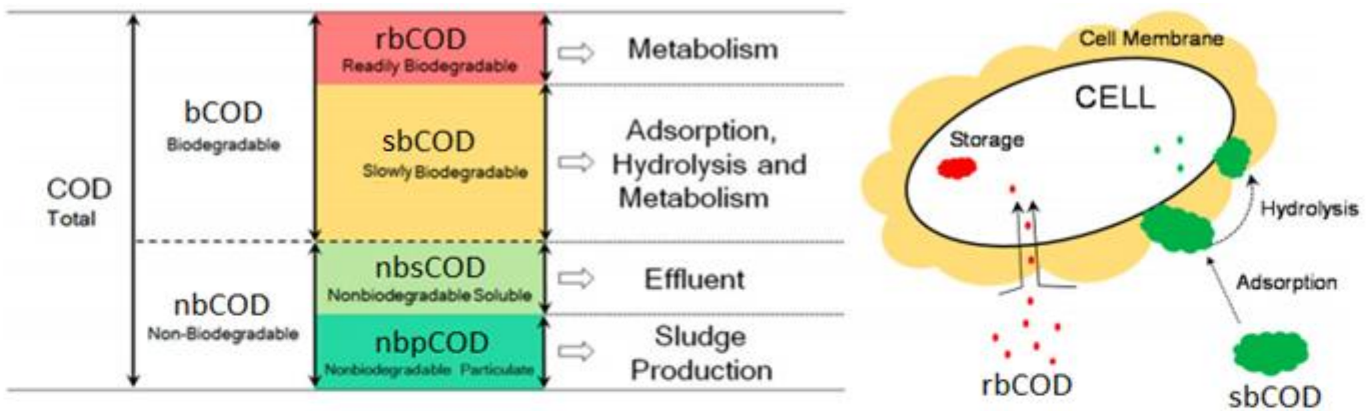


nbCOD = COD – bCOD ‖ **sbCOD** = bCOD – rbCOD ‖ **nbsCOD** = CODs – rbCOD ‖ **npbCOD** = nbCOD – nbsCOD

(*) truly soluble sample: flocculated + filtered at 45 µm or just filterd at 0.1 µm

II. Wastewater biodegradable and non-biodegradable fractions

Habitual raw and settled portion of wastewater COD fractions in total COD			
COD (Raw and settled): 1.0			
bCOD Raw: 0.75 to 0.85 Settled: 0.80 to 0.95		nbCOD Raw: 0.15 to 0.25 Settled: 0.05 to 0.20	
rbCOD Raw: 0.08 to 0.25 Settled: 0.10 to 0.35	sbCOD Raw: 0.50 to 0.77 Settled: 0.45 to 0.85	nbsCOD Raw: 0.04 to 0.10 Settled: 0.05 to 0.20	nbpCOD Raw: 0.07 to 0.20 Settled: 0.00 to 0.10

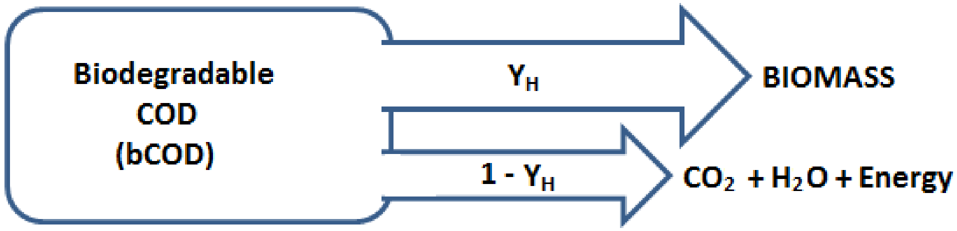


Schematic diagram of COD biodegradble and non-biodegradable fractions and their fates in a WWTP

Note: Non-biodegradable COD = Unbiodegradble COD = Inert COD = Refractory COD

Why biodegradable COD rather than BOD ?

BOD only measures the organics used for respiration and ignores what is converted to bacterial biomass

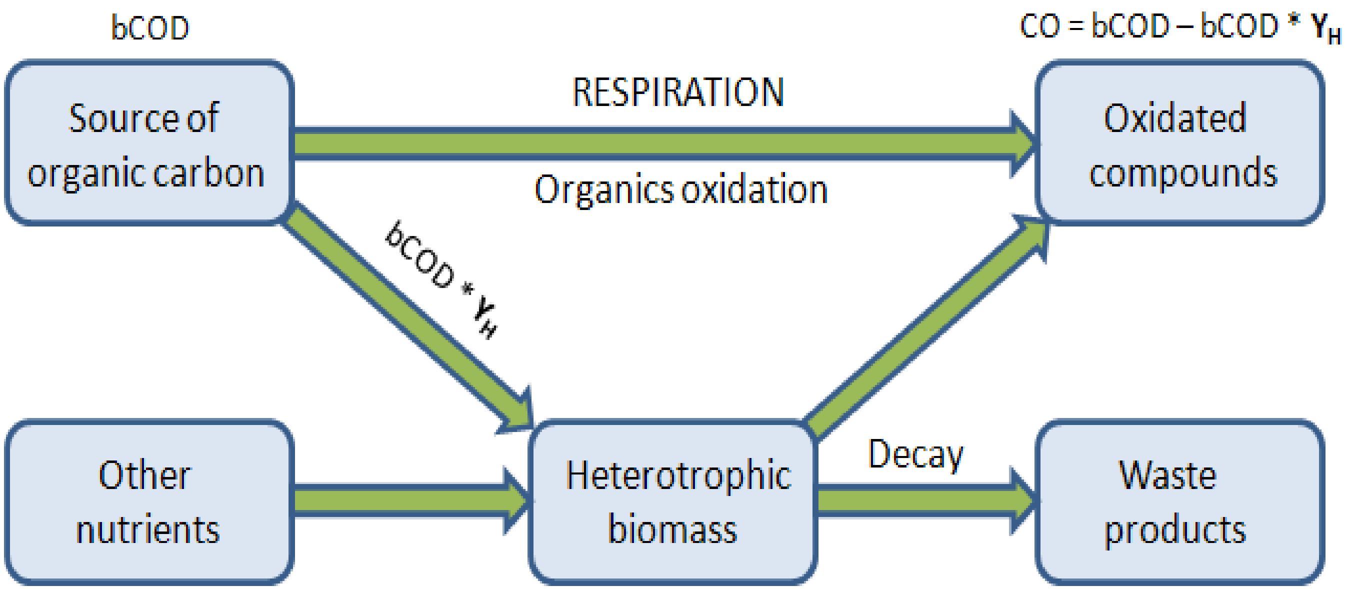


BOD Ignores the unbiodegradable carbonaceous matter

non-biodegradable COD (nbCOD) = COD - bCOD

I. Yield coefficient of heterotrophic biomass

The Y_H is a fundamental parameter bt itself and for the bCOD and rbCOD fractions because it represents the part (percentage) of biodegradable COD that goes to the heterotrophic biomass growing



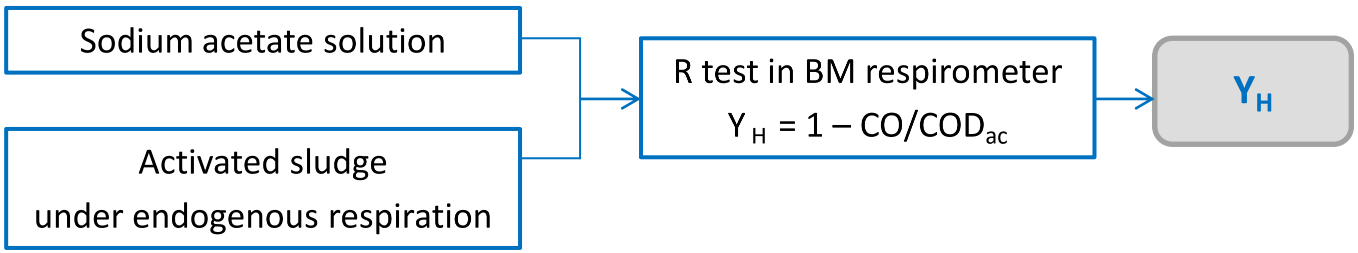
$$\mathbf{bCOD} = CO / (1 - \mathbf{Y_H})$$

II. Yield coefficient of heterotrophic biomass

In the automatic calculation of bCOD and rbCOD there is the intervention of the heterotrophic yield coefficient (Y_H)

$$\mathbf{bCOD} = CO / (1 - \mathbf{Y_H})$$

The software can make use of a Y_H default value (0,67 mg O_2/mg COD), which is already in the settings board, but we can also determine the specific Y_H for the sludge we are currently using by means a simple and fast R test with endogenous sludge and a dose of sodium acetate.

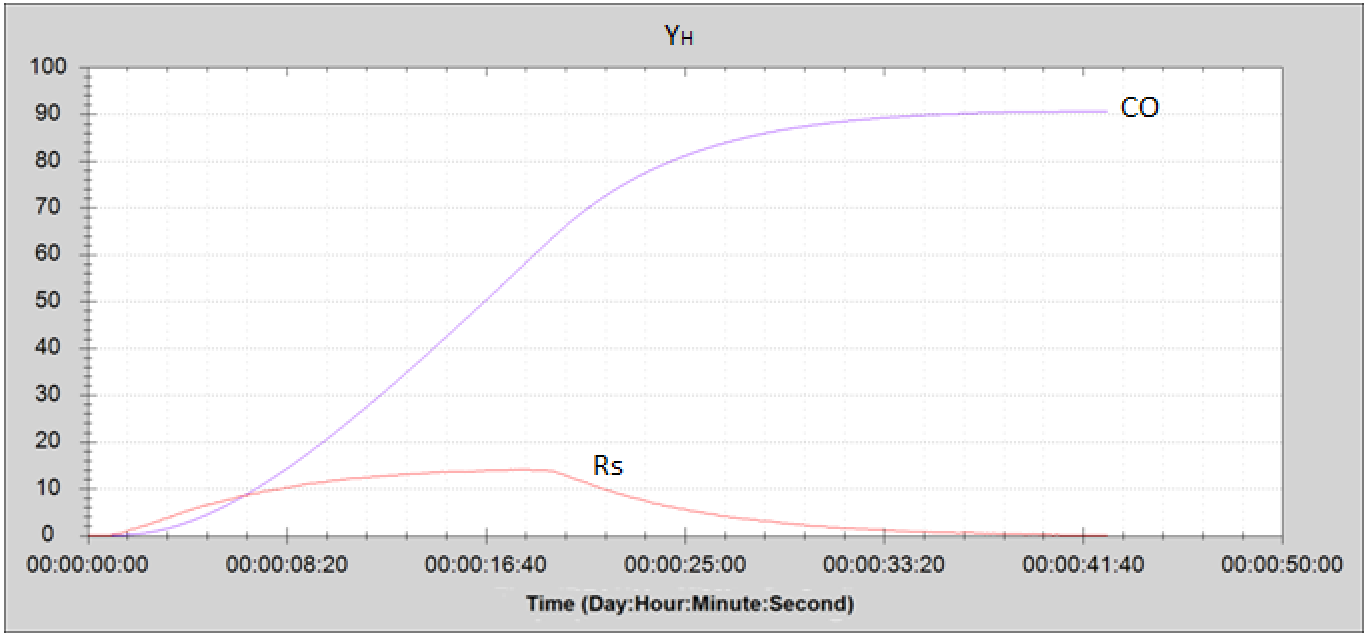


Then, once we have calculated the corresponding Y_H, it can be manually placed in the settings board, before performing the R test for bCOD and rbCOD .

Note: The Y_H and the R test for its determination, are also a good indicators of the actual health of the sludge..

III. BM Respiriometry for yield coefficient determination

Yield coefficent is determined by means a single R test, by making use a sodium acetate solution sample of known COD (COD_{ac}). In that test, the BM software will automatically give out the cosumed oxygen result (CO), and then the yield coefficient is calculated from CO and CODac.



Rs Respirogram for Y_H

$$\mathbf{Y_{H.02}}\ (O_2/COD) = 1 - CO\ /\ COD_{ac}$$

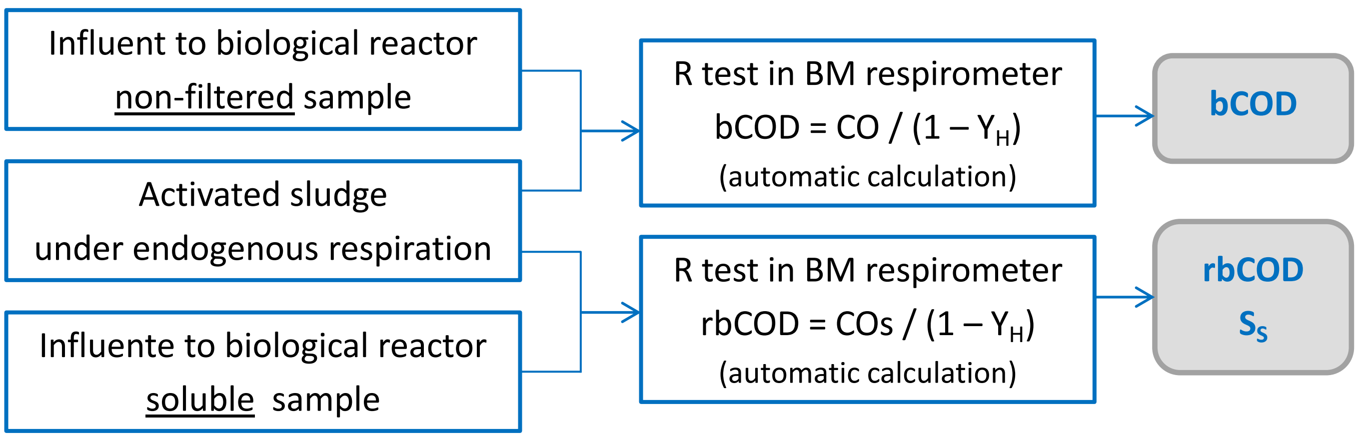
$Y_{H.O2}$: Yield coefficient refrered to O_2 consumption (O_2/COD)

COD_{ac}: COD of the sodium acetate sample = 270 - 320 mg/L)

Wastewater COD biodegradable fractions by BM Respirometery

From endogenous activated sludge and wastewater sample (non-filtered and soluble), the BM respirometer can automatically determine the biodegradable COD (bCOD) and readily biodegradable COD (rbCOD)
The automatic calculation is performed in base of the mathematical formula based on the Consumed Oxygen (CO) and Yield Coefficient (Y_H)

From bCOD, rbCODs, total COD (COD) and soluble COD (sCOD), the main COD fractions can then be calculated.



Note: in case there is nitrification in the actual process, a dose of allyl-thiourea (ATU) must be added to the endogenous sludge before the test performance (normally 3 mg ATU per g of MLVSS)

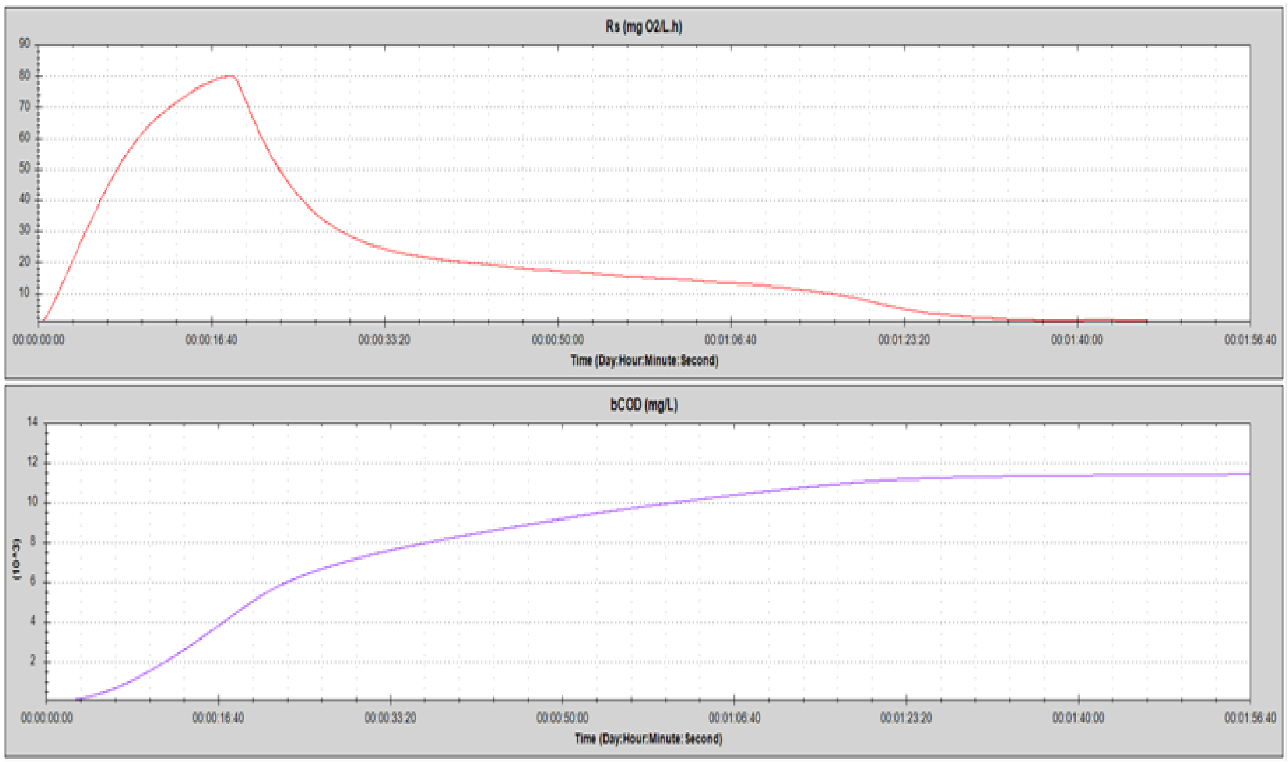
bCOD fraction by BM Respirometry

Influent to biological reactor
non-filtered sample

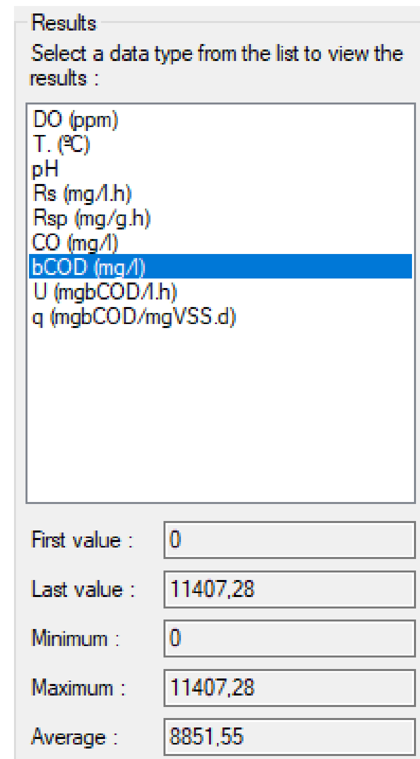
Activated sludge
under endogenous respiration

→ R test in BM respirometer
$bCOD = CO / (1 - Y_H)$
(automatic calculation)

→ **bCOD**



bCOD and Rs respirograms



bCOD result

rbCOD fraction by BM Respirometry

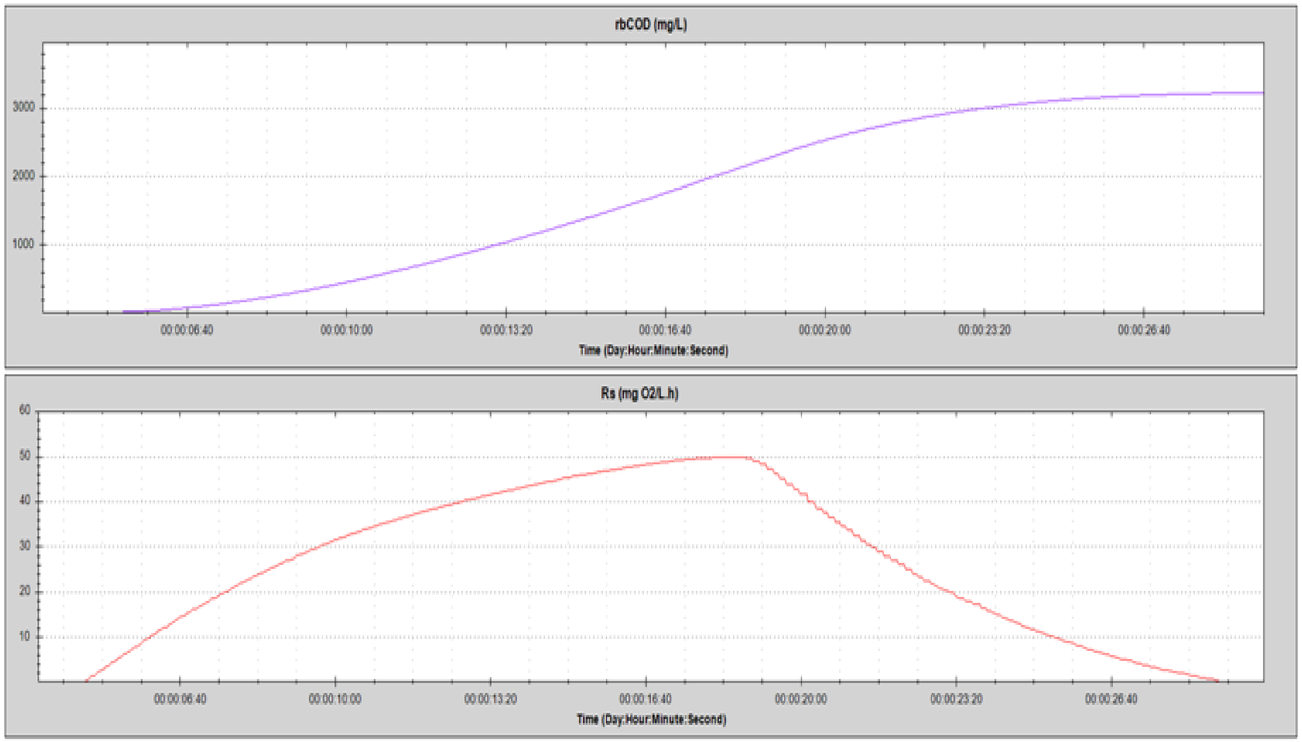
Influent to biological reactor
Truly soluble sample

Activated sludge
under endogenous respiration

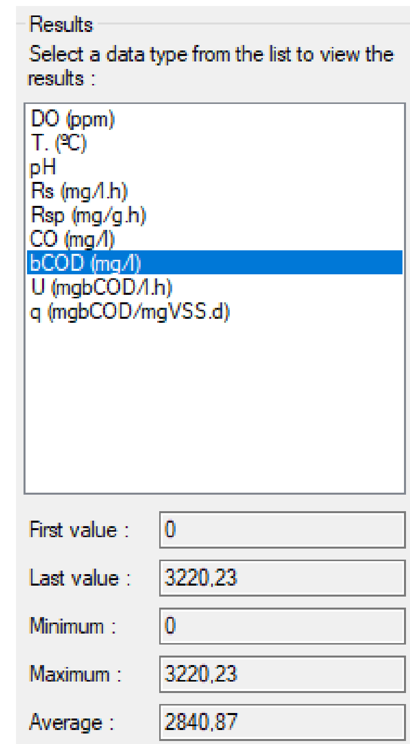
→

R test in BM respirometer
rbCOD = COs / (1 – Y_H)
(automatic calculation)

→ **rbCOD**

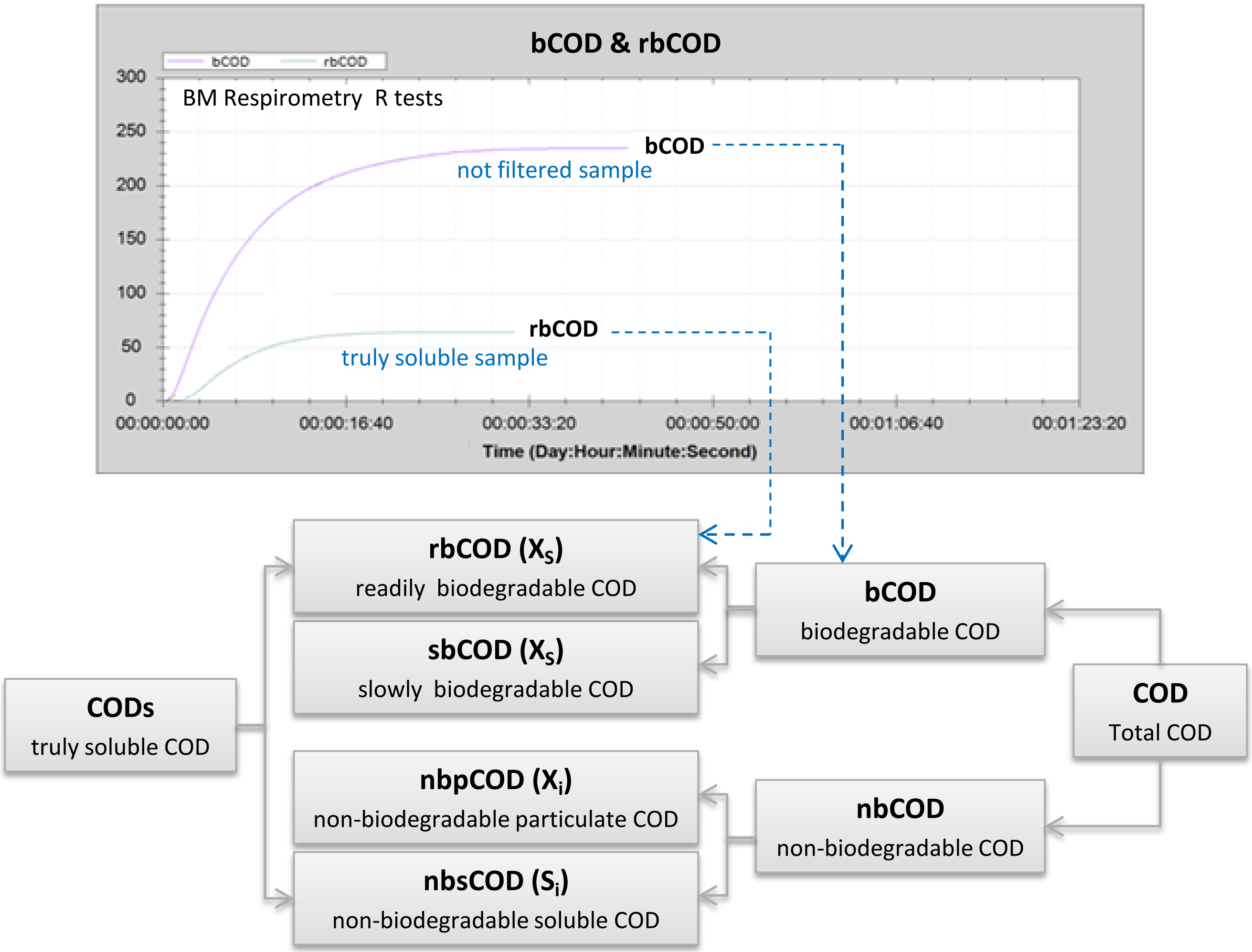


rbCOD and Rs respirograms



rbCOD result

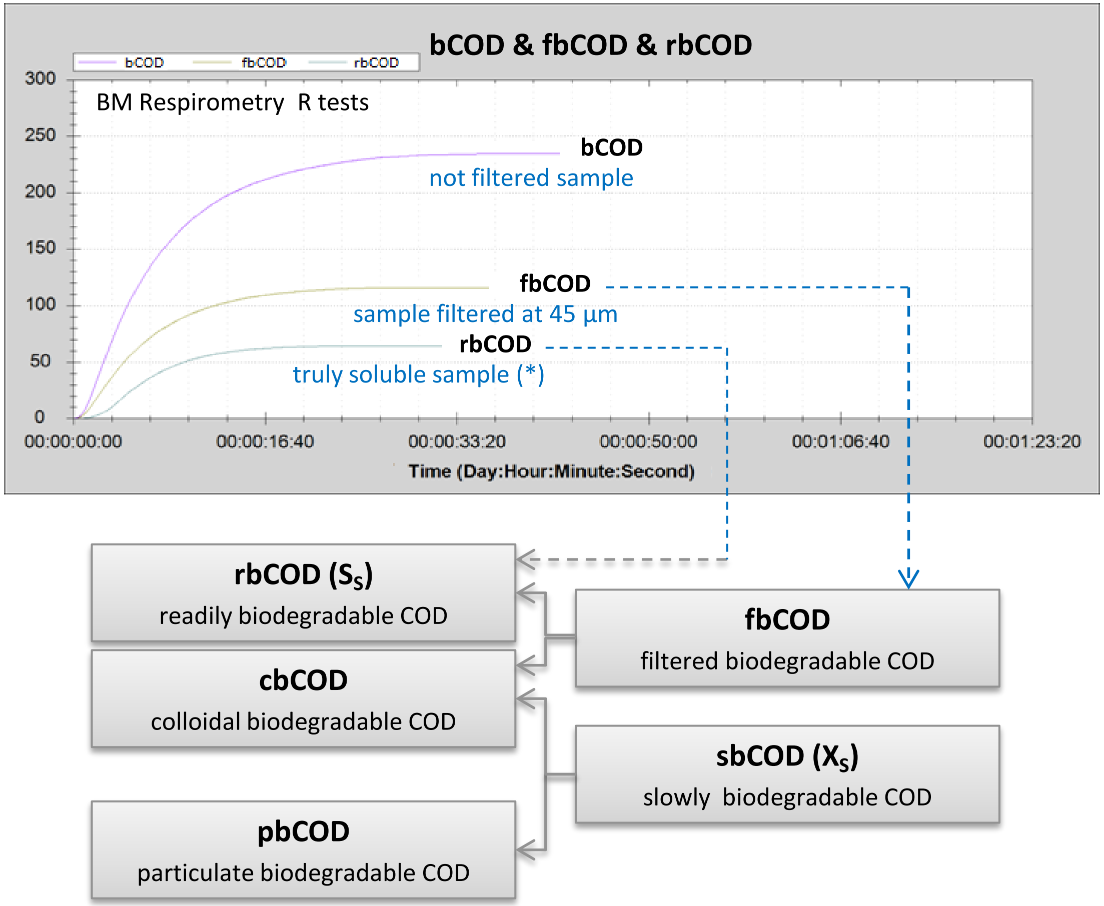
Main COD fractions by BM Respirometry



sbCOD = bCOD – rbCOD ‖ **nbCOD** = bCOD – rbCOD ‖ **nbsCOD** = CODs – rbCOD ‖ **nbpCOD** = nbCOD - nbsCOD

Colloidal and particulate biodegradable COD fractions by BM Respirometry

The colloidal (cbCOD) and particulate biodegradable (pbCOD) fractions can be obtained from the combination of three BM Respirometry R tests: biodegradable COD (bCOD), filtered biodegradable COD (fbCOD) and readily biodegradable COD (rbCOD)



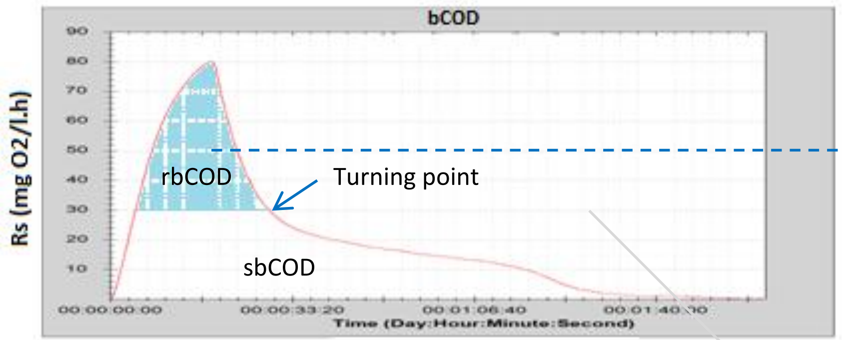
cbCOD = fbCOD – rbCOD ‖ **pbCOD** = sbCOD – cbCOD

(*) truly soluble sample: flocculated + filtered at 45 µm or just filterd at 0.1 µm

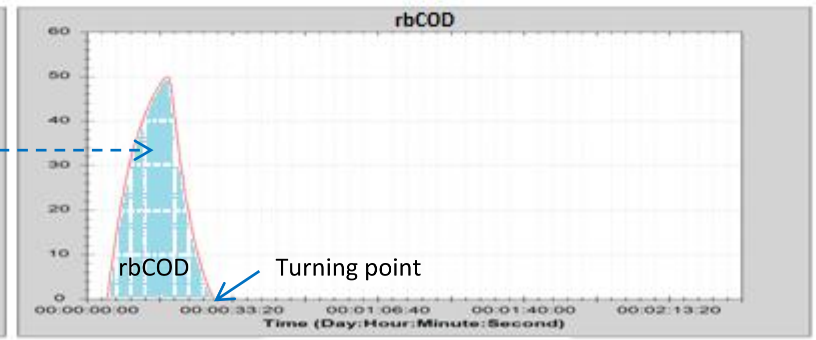
bCOD and rbCOD from a single R test

Wherever possible to distinguish the readily biodegradable part in the Rs respirogram for bCOD, in the settings board we can make use of the option "Force Cb" to raise the base-line to the turning point.

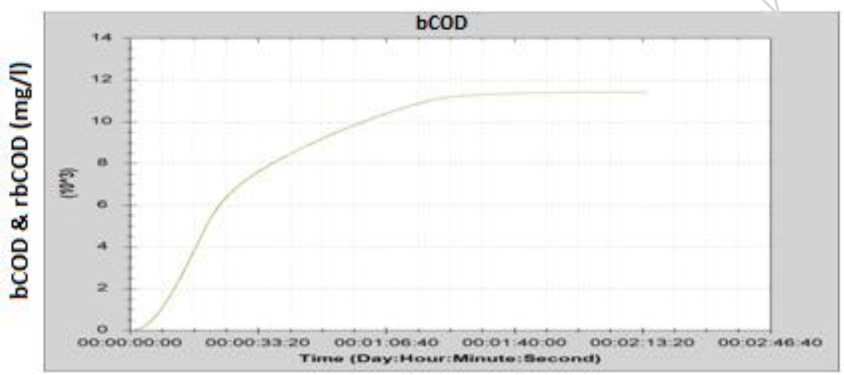
In this way, we can cut the Rs respirogram, convert the turning point level as a new base-line, and automatically create a new respirogram corresponding to the readily biodegradable COD, and thus determine the biodegradable and readily biodegradable COD fractions from a single R test



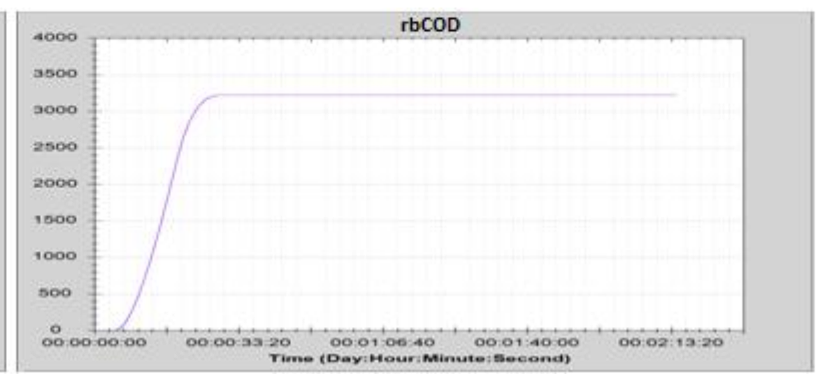
Rs respirogram for bCOD



Rs respirogram for rbCOD (S_{RB})



bCOD respirogram



rbCOD respirogram

Source: Influent fractionation using a respirometric method for the characterization of primary sedimentation

Ellen Vanassche, 2014 - Faculty of Bioscience Engineering – UNIVERSY OF GENT (Belgium)

Influence of COD fractions in the biological wastewater treatment

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Influence of readily biodegradable COD (rbCOD)

- High rbCOD within a high F/M, can lead the process towards a Bulking & Fomaing.

- When the aeration tank is operating under limited oxygenation, a rbCOD with high COD uptake rate can provoke a dramatic fall of the dissolved oxygen level to zero ppm, creating an important anoxic zone in the process start and a possible septicity effect.

- High rbCOD for a limited hidraulic retention time can develop a partial nitrification and risk of nitrite in the effluent.

- The rbCOD, in the influent of the anoxic zone, is the carbonaceous material available for the facultative heterotrophic biomass to develop the denitrification process. For this reason, a lack of rbCOD will lead the process to a poor nitrification performance

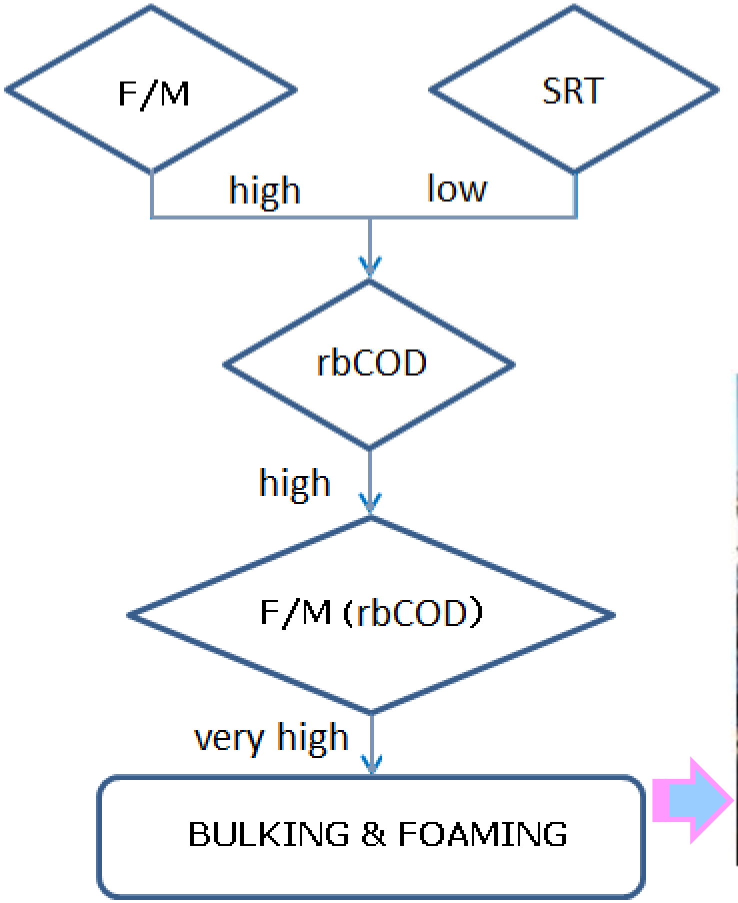
- Denitrification rate develops the same speed as the rbCOD uptake rate during nitrate oxydation.

  For this reason, the denitrification rate (NUR) is proportional to the rbCOD uptake rate (U)

- Very low or very high rbCOD value can disable the advisable ratioof C/N/P = 100/5/1 for nutrients.

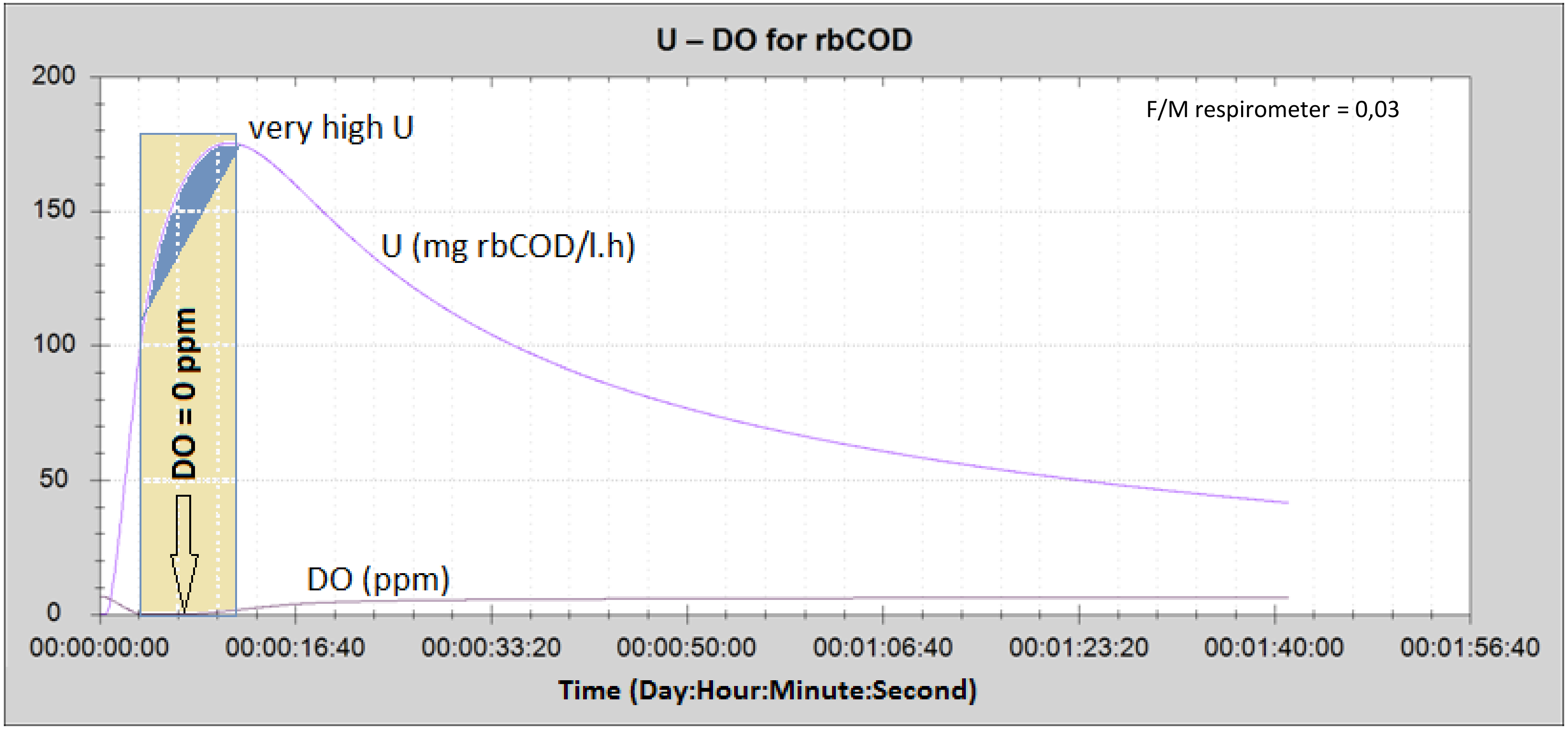
Impact of high rbCOD

When rbCOD is much higher than normal (>> 30%) together with a high F/M, it can generate an important bulking-foaming fenomena



F/M: Food/Microorganisms ratio (BOD/SS.d)
SRT: Sludge Retention Time (d)
F/M (rbCOD): F/M only related to rbCOD

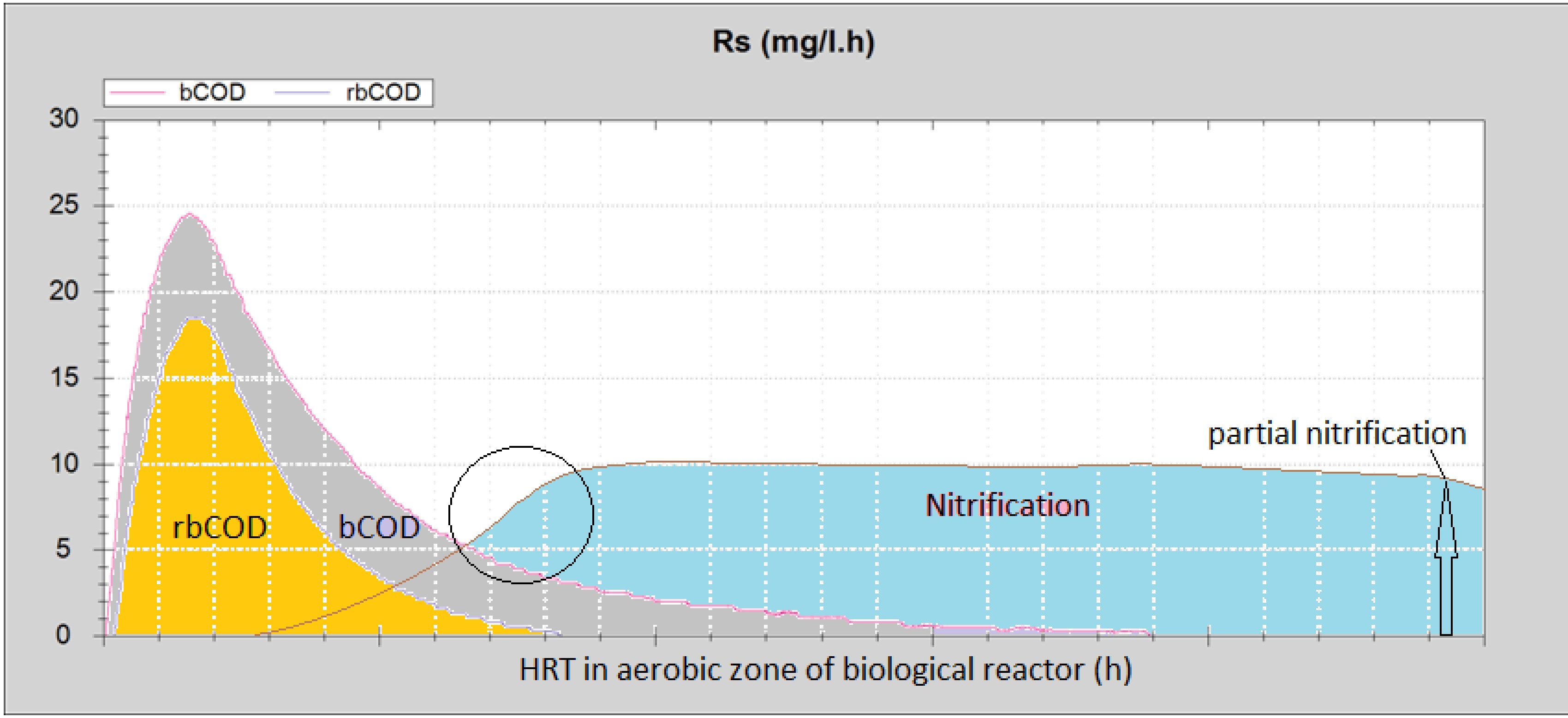
Impact of high rbCOD uptake rate (U) in the dissolved oxygen



Simultaneous DO and U Respirograms in BM respirometer in R test for rbCOD determination

- rbCOD with high substrate uptake rate rate (U) can conduct the dissolved oxygen to zero value at the start of the aerobic treatment process .
- This effect, coming from the lack of oxygen, could create an unwanted anoxic zone which could leads the process towards a poor COD performance and possible septicity.

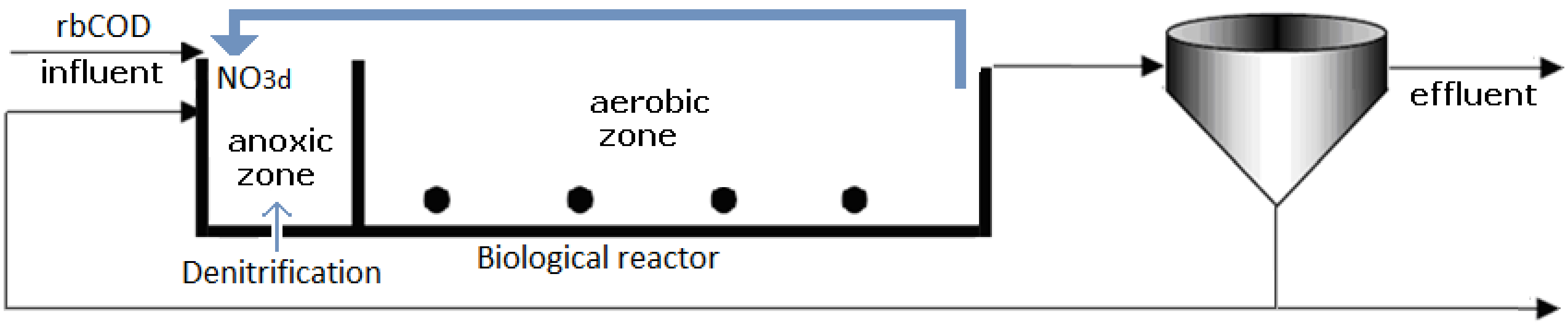
Impact of high rbCOD in the nitrification



For a process operation under limited DO, a high percentage of rbCOD in COD (> 30% of COD) delays the actual nitrification rate starts, making an important impact in the available nitrification time and conducting it to a possible partial nitrification.

The rule of rbCOD in the denitrification

The rbCOD, in the influent of the anoxic zone, should macth the soluble carbonaceous needs of the facultative heterotrophic biomass for the denitrification process.



Soluble carbonaceous matter / Nitrate = [rbCOD $(1 - Y_H)$] / [N_NO_3d] = 2,86

N_NO_3d (mg/l): Nitrate to denitrify

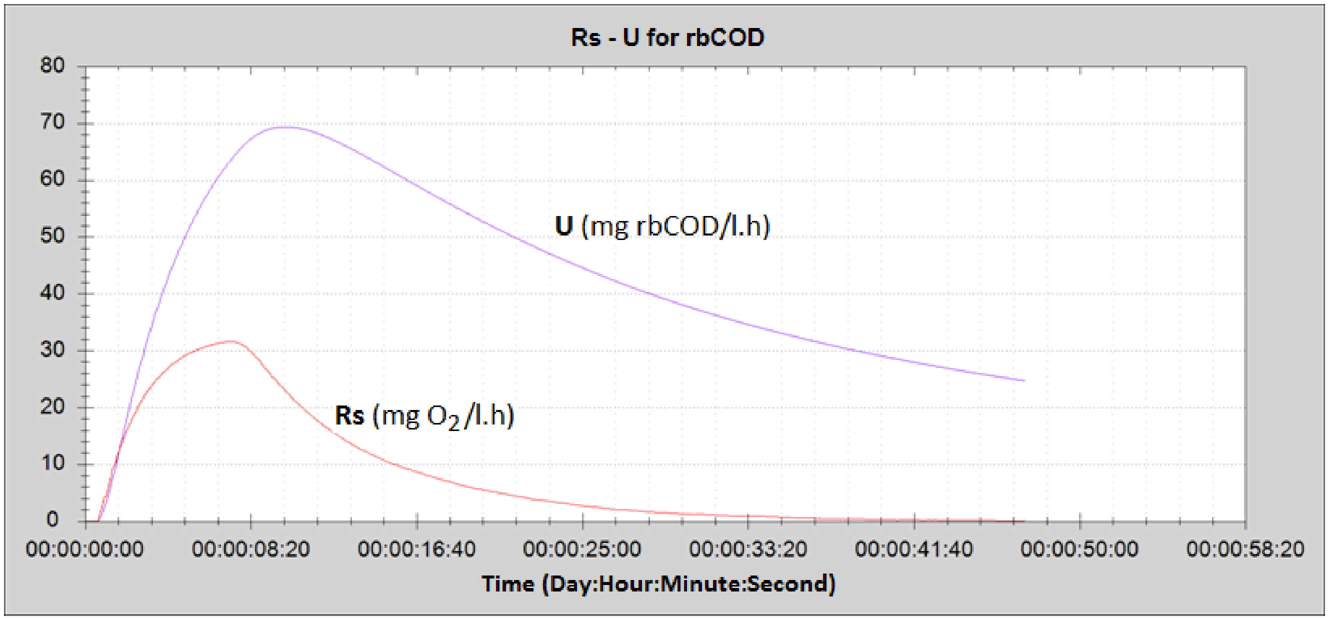
- The Soluble carbonaceous matter / Nitrate should be equal or higher than 2,86 value.

  When the carbonaceous matter / Nitrate ratio is lower than 2,86, the denitrification performance will be proportionally reduced.

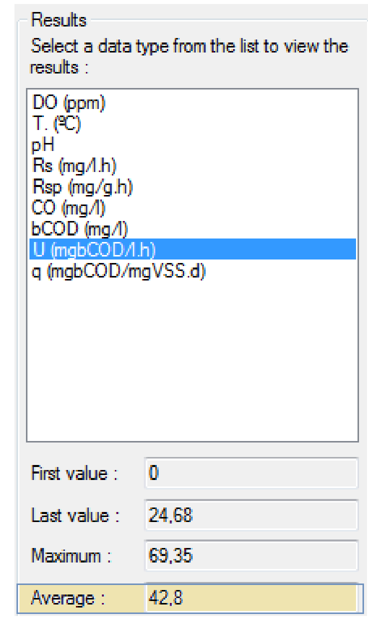
rbCOD utilization rate (U) in denitrification rate (NUR)

Denitrification develops the same speed as the rbCOD uptake rate during nitrate oxydation.

For this reason, the denitrification rate (NUR) is proportional to the rbCOD uptake rate (U) which is one of the simultaneous parameters that a BM respirometer can automatically calculate in the R test for rbCOD.



Simultaneous Rs and U Respirograms R test for bCOD determination in a BM respirometer



Average U result

Denitrification rate : NUR = $U\,(1 - Y_{H.O2}) / 2{,}86$

So, we can calculate the NUR from the U parameter, and check the necessary hydraulic retention time (T_{DN}) in the anoxic zone.

$$\mathbf{T_{DN}} = N\_NO_3d / NUR$$

Influence of the slowly particulate biodegradable COD

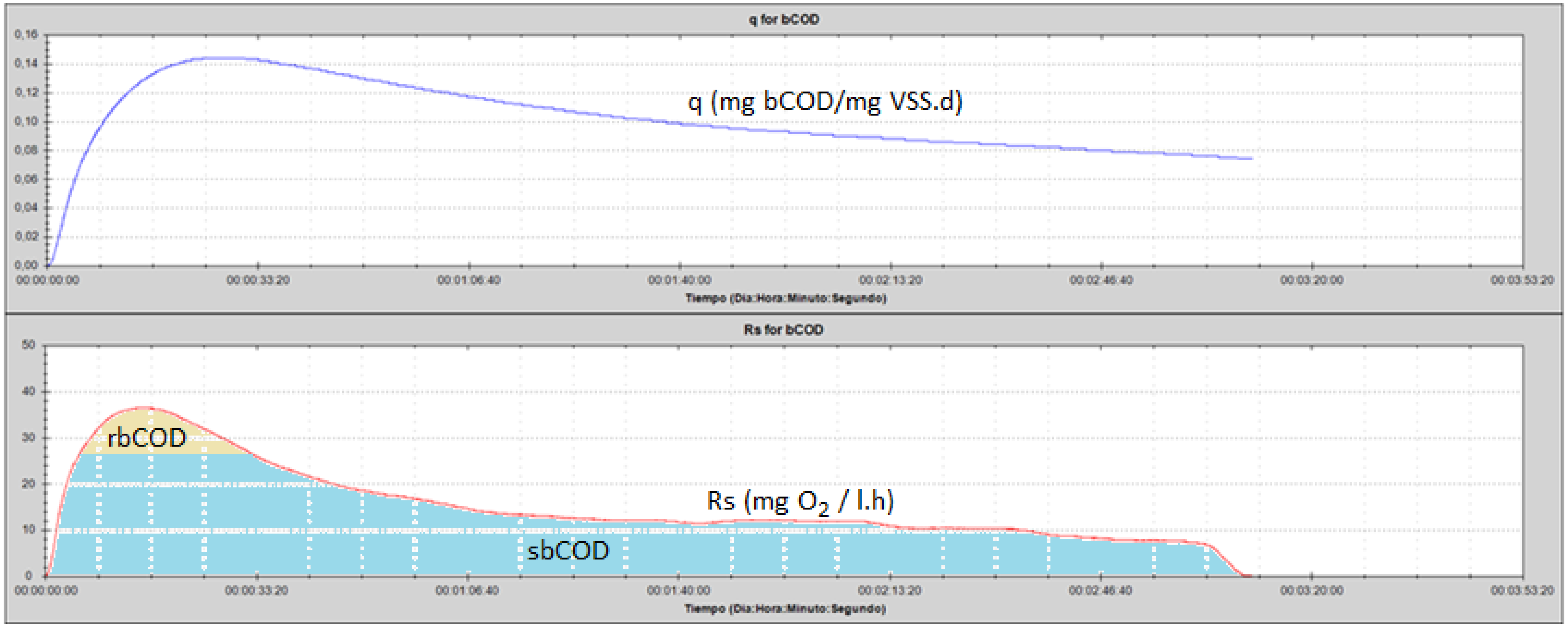
- High value of sbCOD including very low specific COD uptake rate (e.g. FOG) can provoke a nutritional lack, leading the process to a filamentous bacteria generation and possible bulking fenomena.

- When the HRT is very limeted, a high sbCOD could provoke a poor COD performance.

- For wastewater treatments not designed for nitrification, under certain conditions, a high value of sbCOD could lead the process to an unwanted nitrification.

Impact of high slowly biodegradable COD (sbCOD) and low specific substrate uptake rate (q)

When sbCOD is very high (>> 70 % of COD) , together with a low specific substrate uptake rate (q), it can make a high impact in the activated sludge and lead the process to an important foaming & bulking state. :



Simultaneous respirograms of q and Rs for bCOD determination in a BM respirometer

On those conditions, the biomass can experiment a dramatic nutritional lack, leading the sludge to an important defloculation.

When the process is under that state, the relationship between F/M (BOD) and MCRT (sludge age) is not longer working. $1/MCRT \neq F/M - K_d$

Influence of the non-biodegradable COD

- High percentage of nbCOD (>> 25% of COD) can lead the process to a poor performance by getting COD levels out of limits in the effluent.

- When the nbCOD includes a high percentage of particulate portion (nbpCOD), the sludge production can be dramatically increased.

- When the nbCOD includes a high percentage of soluble portion (nbsCOD) it could be a possible lack of soluble biodegradable COD (rbCOD) for the denitrification.

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