Evaluation of the anoxic denitrification process by BM Respirometry

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BM-Respirometry

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BM Respirometry
a state of the art technology

BM Respirometry is a technology where traditional and more advanced respirometry techniques are brought together in an exclusive design developed by the company SURCIS.

BM Respirometry makes use of one or two reactors, where sample and sludge volumes, pH, temperature and others can be programmed into the test configuration, at any time.

BM respirometers use powerful software that provides a series of automatic measurements and calculations of decisive parameters used to manage, design and research the biological processes of wastewater treatment under different conditions.

With this technology, Surcis has developed a series of respirometry applications that cover the main areas of biological wastewater treatment processes, both in terms of organic matter and biological nitrogen removal.

BM-Respirometry System

1. Automatic pH control
2. pH sensor
3. Dissolved oxygen sensor
4. Sirring motor
5. Homogenization peristaltic pump
6. Double chamber Reactor
7. Automatic tempering system
8. Leds for devices control
9. Oxygen and temoerature controller
10. pH controller
11. PC + BM software

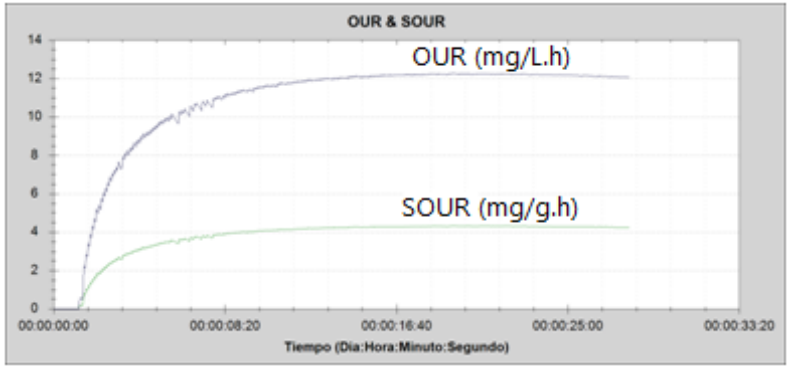
BM- Advance Multipurpose Respirometry System model

Operation modes and automatic parameters in the BM Respirometry

OUR & Cyclic OUR modes

OUR: **Oxygen Uptake Rate** (mg O_2/l.h)
It measures the oxygen uptake rate for only one measurement or series of measurements.

SOUR: **Specific OUR** (mg O_2/g VSS.h)
Specific OUR related to MLVSS. SOUR = OUR / MLVSS



OUR & SOUR respirograms

R mode

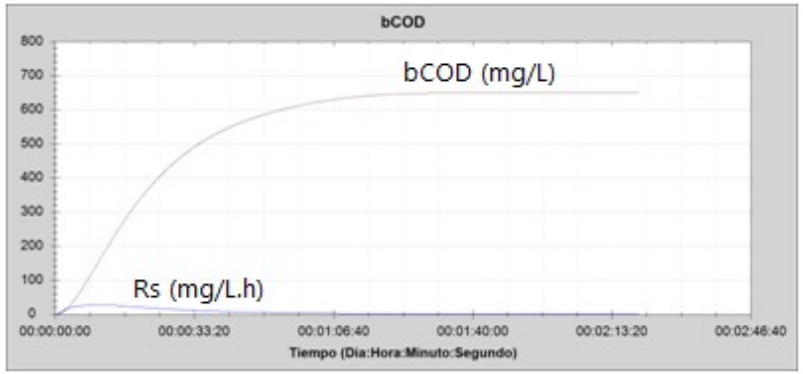
Rs: **Dynamic Respiration Rate** (mg O_2/l.h)
It measures the oxygen uptake rate from the mixture of the activated sludge and certain amount of wastewater sample or compound within a continuous chain of measurements.

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.

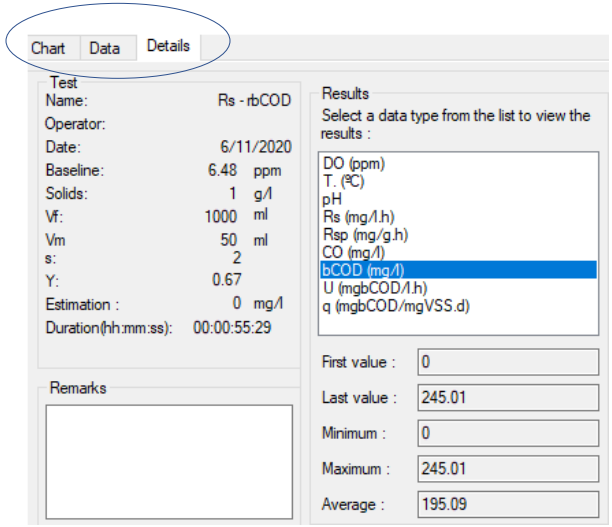
q: **Specific COD removal rate** (mg COD/ mg VSS.d)
Specific U referred to MLVSS concentration.



Rs & bCOD respirograms

Different modes of results presentation at any time in all operation modes: Chart, Data, Details

All results in one click on the respirogram, at the end, and/or during the test



Details

Last, minimum, maximum and average result

Time (Day:Hour:Minute:Second)	T. (ºC)	pH	CO (mg/l)	bCOD (mg/l)	U (mgbCOD/l.h)
00:00:09:16	21,1	9,66	74,16	130,1	32,4
00:00:09:18	21,1	9,66	74,54	130,78	32,45
00:00:09:20	21,1	9,66	74,93	131,46	32,5
00:00:09:22	21,1	9,66	75,32	132,14	32,56
00:00:09:12	21,1	9,66	73,38	128,74	32,29
00:00:09:14	21,1	9,66	73,77	129,42	32,35

Data - Current data values in a table

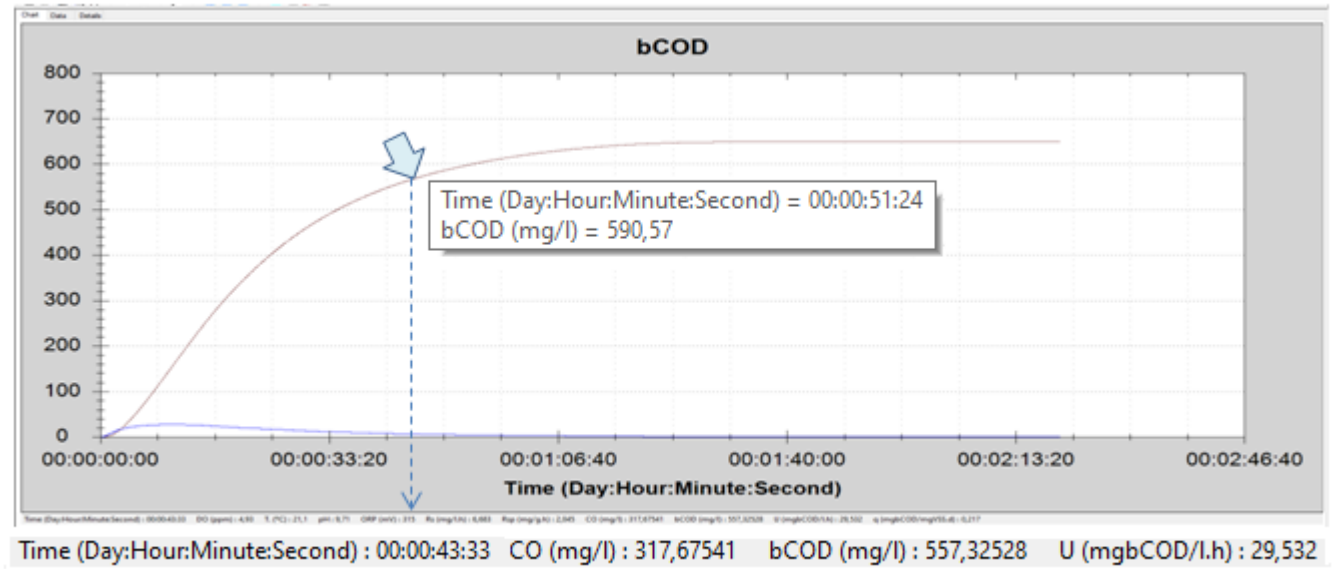


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Chart – Respirogram & Display of the current mesurements

Procedures for the evaluation of the anoxic denitrification by BM Respirometry

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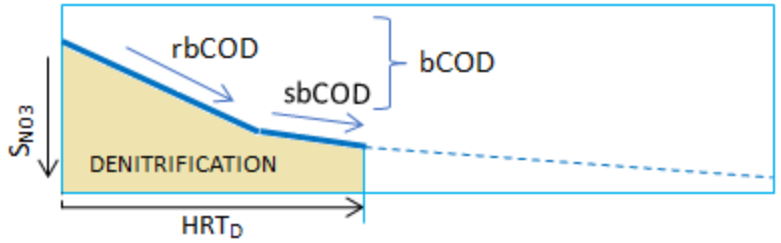
Parameters in play

Symbol	Parameter	Equation, comment
S_{NO3}	Nitrate to denitrfy (mg NO_3-N/L)	Data
bCOD	Biodegradable COD (mg/L)	Automatically measured in the BM respirometer
$bCOD_D$	Biodegradable COD used in the dentrification for a determined nitrate	Automatically obtained in the BM respirometry tests
CO_D	Oxygen for denitrification	$CO_D = 2{,}86 \cdot S_{NO3}$
U_D	Utilization rate of accumulated bCOD used in the denitrification (mg COD/L.h)	Automatically obtained in the BM respirometry tests
CO	Oxygen consumption corresponding to the bCOD being removed (mg/L)	When seleccting CO = CO_D, the software of a BM respirometer automatically obtains the $bCOD_D$ and U_D from the data table
Y_H	Yield coefficient of heterotrophic biomass in aerobic conditions (O_2/COD)	By default: $Y_{HD} = 0.67$
Y_{HD}	Yield coefficient of facultative heterotrophic biomass in denitrification (O_2/COD)	$Y_{HD} \approx 0.83 \cdot Y_H$ (Muller et al., 2003) By default: $Y_{HD} = 0.55$
OUR_D	Net oxygen uptake rate from bCOD used in the denitrification (mg O_2/L.h)	$OUR_D = U_D (1 - Y_{HD})$
NUR	Denitrification rate (mg NO_3-N/L.h)	$NUR = (OUR_D / 2.86) \cdot K_{OD} / (K_{OD} + DO_D)$
K_{OD}	Coefficiente of NUR inhibition due to oxygen in the anoxic zone	$K_{OD} = = 0.2$ (Henze et al 1996)
DO_D	Dissolved oxygen in the anoxic denitrification zone (mg/L)	It should be < 0.3 mg/L
HRT_D	Hydraulic retention time of the anoxic denitrification process (h)	HRT_D = Anoxic volume / Flow in the anoxic zone
C_{NO3}	Nitrification capacity (mg NO_3-N/L)	$C_{NO3} = NUR \cdot HRT_D$

Basic principles for evaluating anoxic denitrification using aerobic Respirometry

- Denitrification takes total biodegradable COD (bCOD) as the source of organic carbon, giving absolute priority to the readily biodegradable COD fraction (rbCOD)



- There is a fixed ratio of the oxygen from the organic source (CO_D) to nitrate removed (S_{NO3}) of 2.86

$$CO_D / S_{NO3} = 2.86$$

- In the same way, the ratio between the accumulated oxygen uptake rate (OUR_D) from bCOD removal and nitrification rate (NUR) is also 2.86

$$OUR_D / NUR = 2.86$$ (Henri Spanjers, Peter A. Vanrolleghem - 2004, GA Ekama - 2004, others)

- The utilization rate of bCOD in the aerobic zone is equivalent to that in the anoxic zone. Therefore, this data, obtained from an aerobic respirometry test, can be used for the determination of the denitrification rate (NUR) and denitrification capacity (C_{NO3})

- In addition to the process conditions, the denitrification rate depends largely on whether readily biodegradable (rbCOD) or slowly biodegradable COD (sbCOD) is used: for rbCOD → normal NUR, for sbCOD → low NUR.

- With BM Respirometry it is possible to analyze how much rbCOD and/or sbCOD are being used in the denitrification and thus evidence the NUR value obtained.

Why biodegradable COD rather than COD or BOD?

1. COD and BOD Ignores the unbiodegradable carbonaceous matter

non-biodegradable COD: nbCOD = COD - bCOD

2. COD and BOD Ignores the readily biodegradable carbonaceus matter

readily-biodegradable COD: Directly obtained from a BM respirometry test

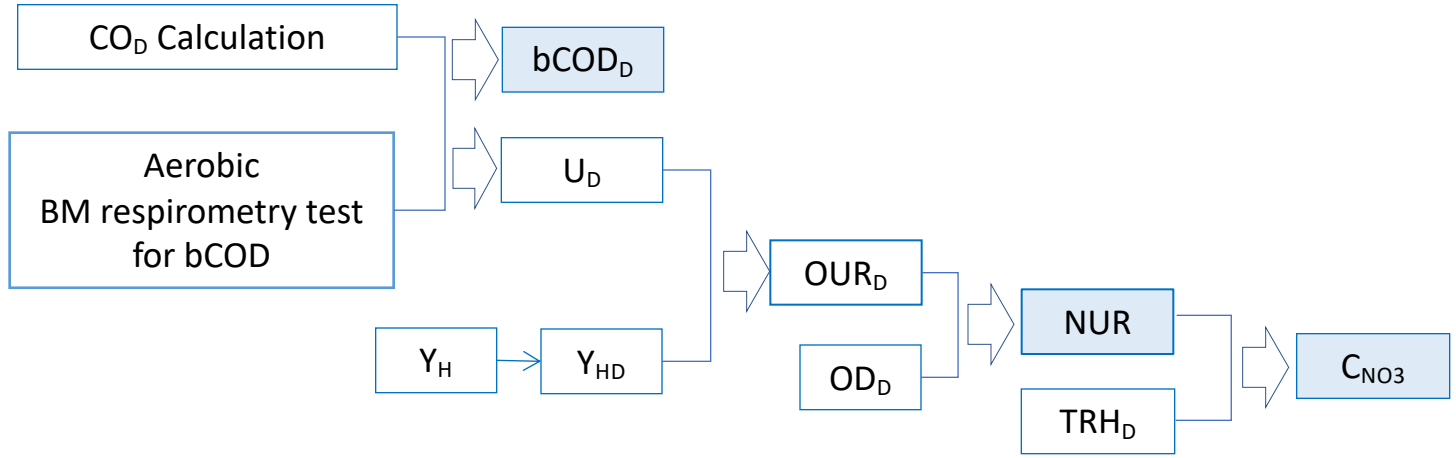
3. COD and BOD Ignores the slowly biodegradable carbonaceus matter

slowly-biodegradable COD: sbCOD = bCOD - rbCOD

4. Both fractions (nbCOD, rbCOD and sbCOD) play a key role in the denitrification process:

   - Denitrification uses rbCOD as a priority and a low percentage of this fraction in the total COD can lead to poor process efficiency.
   - Denitrification rate (NUR) depends on the utilization rate of the bCOD and this rate depends, in turn, on the percentage of rbCOD and sbCOD in the total COD.
   - Therefore, it is possible that the COD/N is within range and yet the required efficiency is not achieved because nitrate is mainly utilizing the sbCOD fraction due to the lack of rbCOD.

Diagram of the procedure for the determination of bCOD used in the process, denitrification rate and denitrification capacity by BM Respirometry



Symbol	Parameter
$bCOD_D$	Biodegradable COD used in the dentrification for a determined nitrate
CO_D	Oxygen for denitrification
U_D	Utilization rate of the accumulated bCOD used in the denitrification (mg COD/L.h)
Y_H	Yield coefficient of heterotrophic biomass in aerobic conditions (O_2/COD)
Y_{HD}	Yield coefficient of heterotrophic biomass in denitrification (O_2/COD)

Symbol	Parameter
OUR_D	Net oxygen uptake rate from bCOD used in the denitrification (mg O_2/L.h)
NUR	Denitrification rate (mg NO_3-N/L.h)
DO_D	Dissolved oxygen in the anoxic denitrification zone (mg/L)
HRT_D	Hydraulic retention time of the anoxic denitrification process (h)
C_{NO3}	Nitrification capacity (mg NO_3-N/L)

Part of the procedure for the determination of biodegradable COD ($bCOD_D$) and COD removal rate (U_D) used in the denitrification from an aerobic BM respirometry test

1. Once the test is finished, all the results obtained as a function of time can be found in the "Data" tab, so for each time interval the corresponding series of automatically measured and calculated parameters appears

2. From this table, the value corresponding to the CO_D, which was previously calculated according to the mathematical formula, is located.

3. From there, following the same time interval, the U_D and $bCOD_D$ values are obtained.

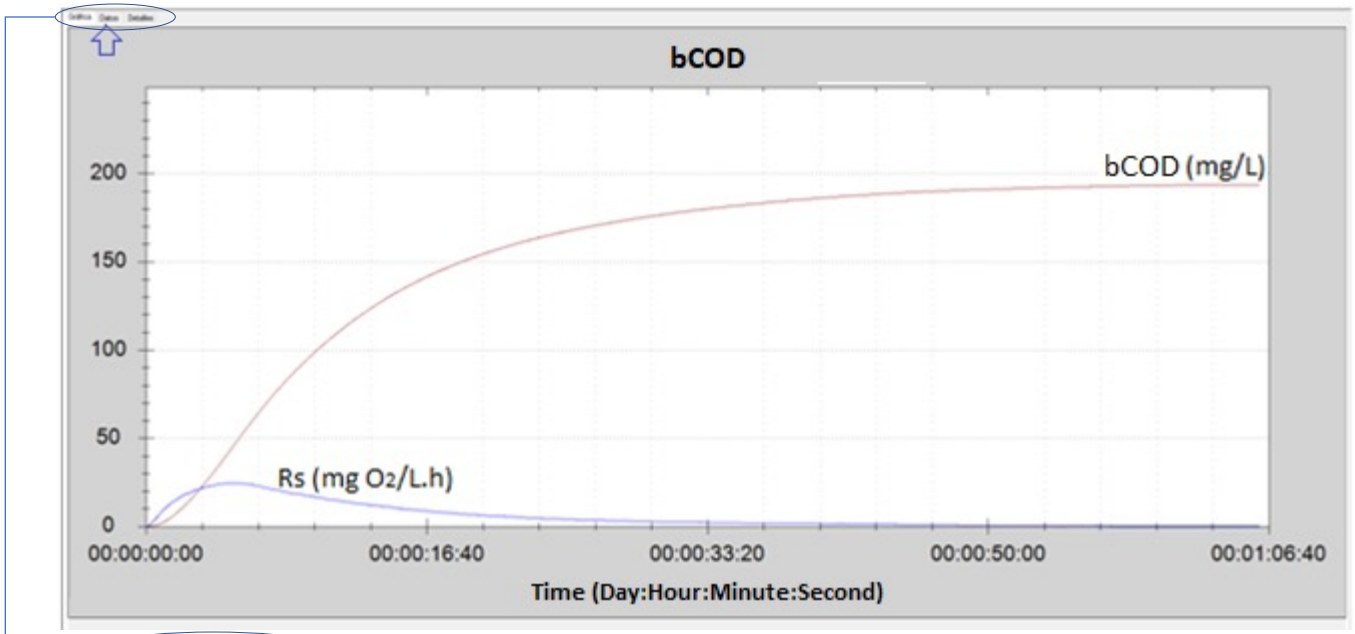


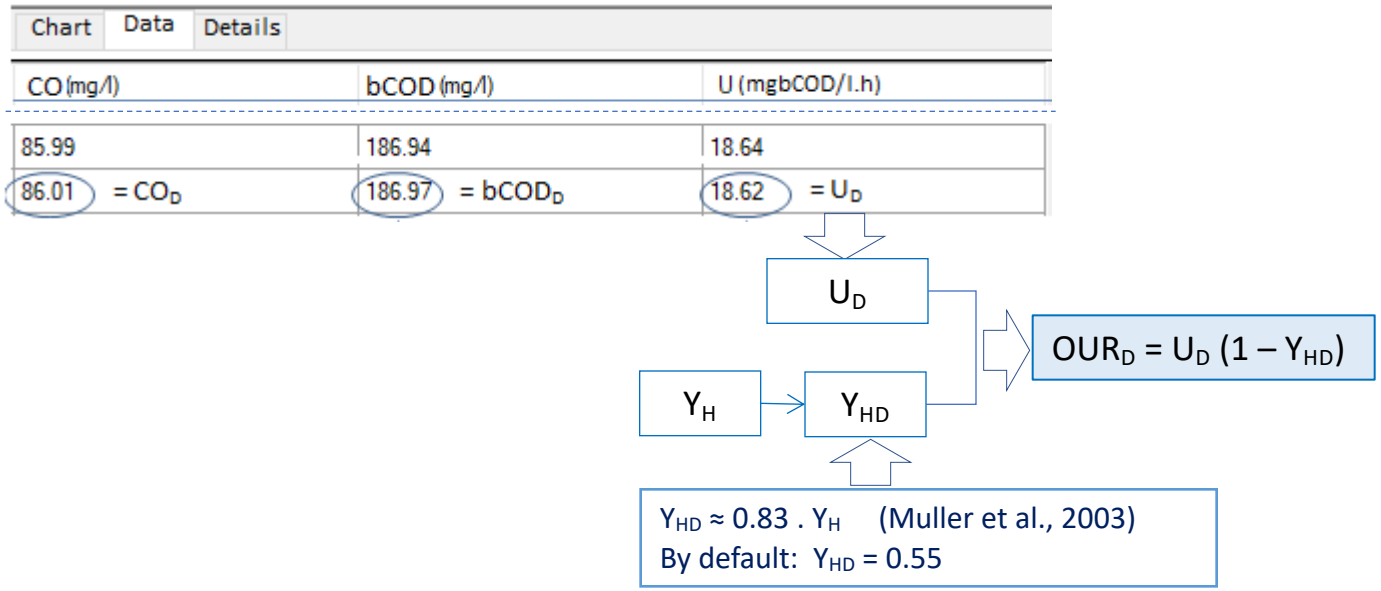
Chart | Data | Details

CO (mg/l)	bCOD (mg/l)	U (mgbCOD/l.h)
85.99	186.94	18.64
86.01 = CO_D	186.97 = $bCOD_D$	18.62 = U_D

$CO_D = 2{,}86 \cdot S_{NO3}$ | $bCOD_D$ | U_D

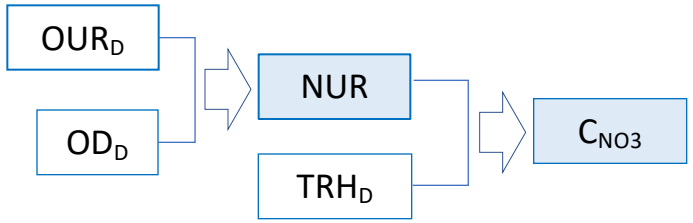
Part of the procedure for the net oxygen uptake rate (OUR_D) from bCOD used in the denitrification

OUR_D (mg O_2/L.h) refers to the net oxygen uptake rate used in denitrification.
It is based on the $bCOD_D$ removal rate (U_D) to which the factor (1 - Y_{HD}) is applied to discount the portion of biodegradable COD destined for biomass production.



OUR_D: Net oxygen uptake rate from bCOD used in the denitrification (mg O_2/L.h)

Part of the procedure for denitrification rate (NUR) and denitrification capacity (C_{NO3}) calculation



NUR

Since the direct relationship between the aerobic oxygen consumed by the biodegradable COD and nitrate removed is 2.86, likewise there is this same relationship between the rate of aerobic oxygen uptake rate by the used bCOD (OUR_D) and the rate of nitrate removal (NUR) in the anoxic denitrification.

$$NUR = \frac{OUR_D}{2.86} \cdot \frac{KO_D}{KO_D + OD_D}$$

K_{OD}: Coefficiente of NUR inhibition due to oxygen in the anoxic zone = 0.2 (Henze et al 1996)
DO_D: Dissolved oxygen in the anoxic denitrification sone (mg/L)

C_{NO3}

Nitrification capacity calculates the nitrate that the process is able to eliminate according to the hydraulic retention time available (HRT_D)

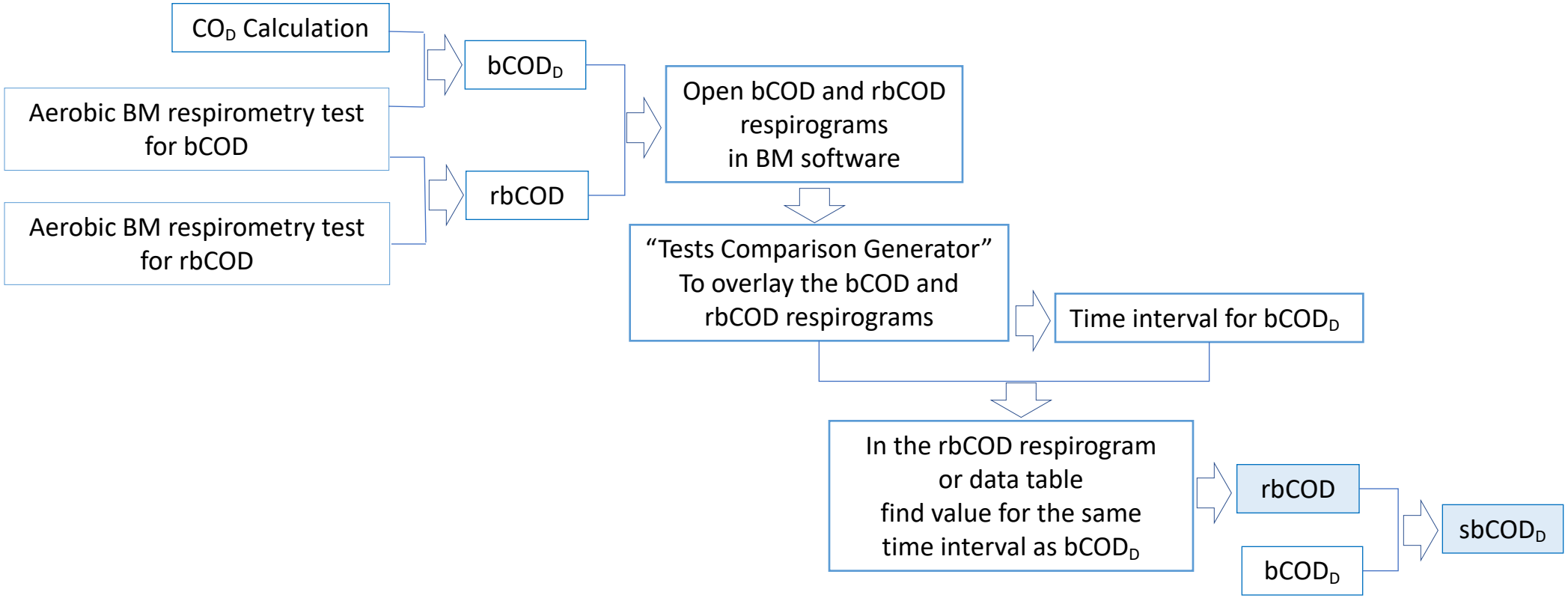
$$C_{NO3} = NUR \cdot HT_DR$$

V_D

On the other hand, for design purposes and making use of the same principle, the necessary volume of the anoxic zone (V_D) for a given flow rate (Q_D) could also be calculated.

$$V_D = Q_D \cdot HRT_D$$

Diagram of the procedure for the determination of the readily biodegradable COD and slowly biodegradable COD involved in the anoxic nitrification



Procedure for readily biodegradable COD and slowly biodegrable COD in the denitrification

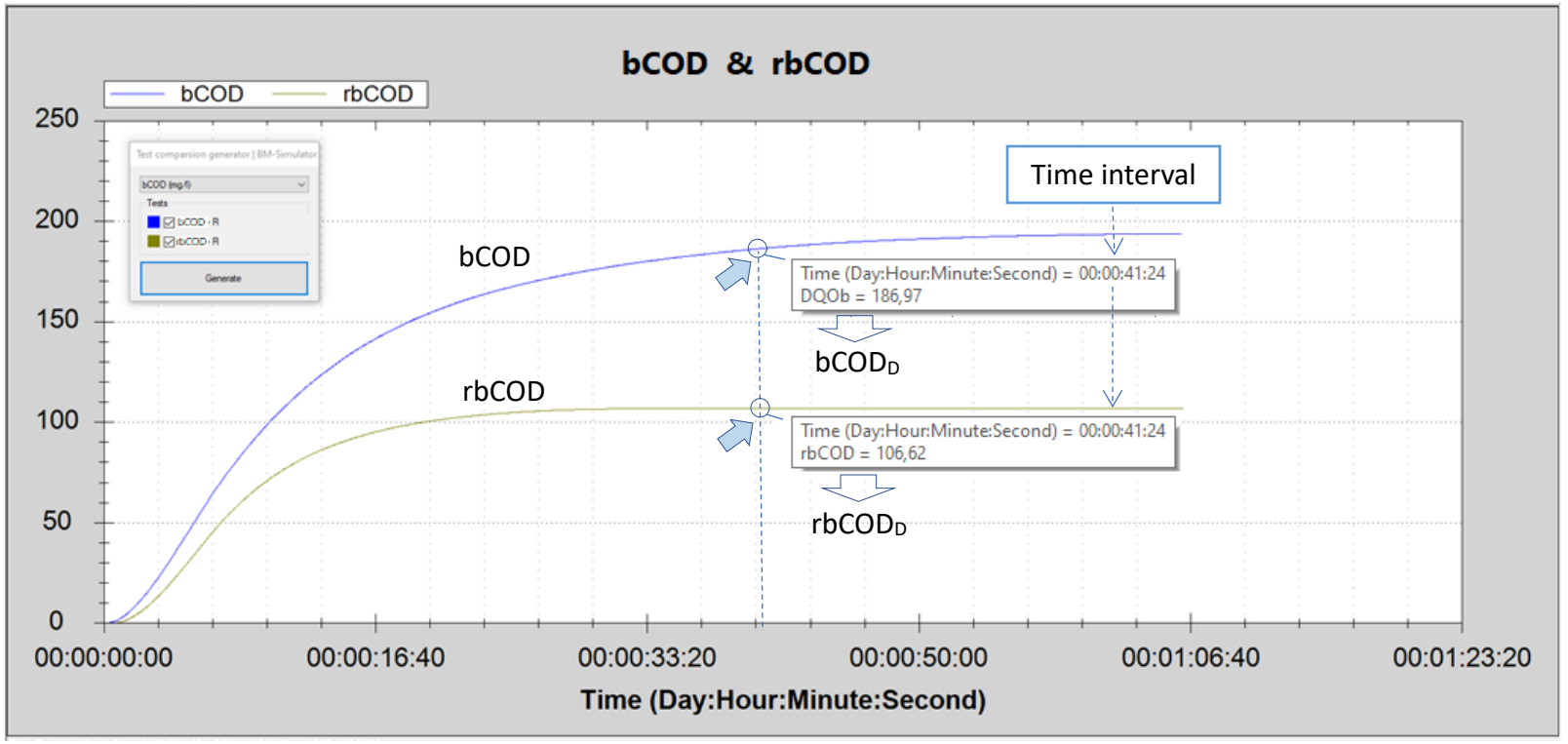
1. To determine the rbCOD fraction corresponding to denitrification, another aerobic respirometry R test must be performed with soluble wastewater.

2. We open the tests for bCOD and rbCOD and, by making use of "Test Comparison Generator" option from the software, the respirograms of both tests are then overlied.

3. On the bCOD graph (with the mouse pointer) we select the point that corresponds to the $bCOD_D$ value.

4. In the same way, we select the same time interval on the rbCOD graph and click right on that point so that the $rbCOD_D$ value appears automatically.

5. The slowly biodegradable COD in the denitrification ($sbCOD_D$) would be simply calculated by the difference between $bCOD_D$ and $rbCOD_D$



$$sbCOD_D = bCOD_D - rbCOD_D$$

$rbCOD_D$: Portion of readily biodegradable COD in denitrification
$sbCOD_D$: Portion of slowly biodegradable COD in denitrification

Possible causes for low or no denitrification

1. The process does not meet the minimum conditions required for denitrification:
   - pH between 6.5 and 8.5
   - Temperature between 15 and 35 ºC
   - COD/TKN between 6 and 20
   - Dissolved oxygen < 0.3

2. Low $bCOD_D$ for the nitrate load to be denitrified. So that, being depleted of organic matter, only partial nitrification is achieved.

3. Low percentage of $rbCOD_D$ the total $bCOD_D$, with a majority utilization of $sbCOD_D$ resulting in a low NUR value, which is not sufficient to meet the required denitrification capacity.

4. Low nitrification capacity, due to a HRT_D too short to obtain the required performance.

5 Toxicity in the heterotrophic biomass.
Any application of BM respirometry targeting aerobic heterotrophic biomass will be equally valid for anoxic heterotrophic biomass.

6. Presence of nitrite in the denitrification process due to incomplete prior nitrification.

BM Respirometry is not limited

THERE IS ALWAYS THE POSSIBILITY OF DEVELOPING NEW APPLICATIONS