RESPIROMETRY SERVICE

Respirometry study of two different wastewater samples on COD fractioning & biodegradability for a specific activated sludge process and nitrification

SURCIS

Preliminary

This service was made according to customer order points and indications from Hydrolab Microbiológica (Surcis collaborator)

The client wanted Surcis to carry out a study about COD fractioning and nitrification.
For this study the client has provided to Surcis the following:

- Process type: Activated sludge - Extended aeration
- 2 wastewater samples: the first one is a punctual sample from an irregular wastewater influent (sample 1) and the second one is coming from one-day composite wastewater from the normal influent to the activated sludge process (sample 2)
- Activated sludge from the biological reactor.
- Some wastewater data in the process.

Date of the study: weeks 17 (April) and 18 (May) - 2012

Note: As usual, in the complete report presented to the client, Hydrolab Microniológica could also include a part of the microscopic bio-indication.

Instruments

The instruments utilized in this study:

- Respirometry system: Model BM-Advance – from SURCIS.

BM-Advance

BM software

- Lab. Photometer analyzer: Model DINKO D-500 - from DINKO Instruments

Analytical data for this study

Wastewater sample 1

Parameter	Value (mg/l)
COD	814
P	16,5
NT	113

Wastewater sample 2

Parameter	Value (mg/l)
COD	422
P	10.5
NT	90

Actual ASP

Parameter	Value (mg/l)
BOD_{avg}	300
MLSS	2000
MLVSS	1800
$N\text{-}NH_{4,avg}$	60

Sodium acetate solution

Paremeter	Value (mg/l)
COD_{ac}	300

In this study, the client did not provide the data corresponding to flows, biological reactor volume, global HRT and available HRT for nitrification. For that reason, there are not calculations related with those data and only some references when necessary.

Summary of the study results

Activated sludge

Biologic	Parameter	Result	Habitual range	Assessment	Comments
Heterotrophic yield coefficient	$Y_{H.DQO}$ (O_2/COD) $Y_{H.VSS}$ (VSS/COD)	0,57 0,38	0,5 – 0,7 0.3 – 0,5	Normal	Rather low.

Specific biodegradability of the wastewater samples to the activated sludge

Wastewater sample 1	Parameter	Result	Habitual range	Assessment	Comments
Total COD total	**COD** (mg/l)	814			
Biodegradable COD	**bCOD** (mg/l)	368			
% bCOD in COD	**b** (%)	45	65 - 99	Very low	There is a problem in the biodegradability of the wastewater sample 1.
bCOD removal rate	$\mathbf{u_b}$ (mg COD/l.h)	18			
Time for bCOD removal	$\mathbf{T_{bCOD}}$ (h)	20.5			
Readily biodegradable COD	**rbCOD** (mg/l)	336			Very close to bCOD
% rbCOD in COD	**rb** (%)	41	15 – 50	Normal	It is in the higher range
% lbCOD en COD	**lb** (%)	4	10 - 30	Very low	Practically there is not any slowly biodegradable COD
% iCOD en COD	**i** (%)	55	5 - 25	Very high	The high inert fraction will provoke a low COD removal efficiency in the biological process

Wastewater sample 2	Parameter	Result	Habitual range	Assessment	Comments
Total COD total	**COD** (mg/l)	422			
Biodegradable COD	**bCOD** (mg/l)	352			
% bCOD in COD	**b** (%)	83	65 - 99	Normal	
bCOD removal rate	$\mathbf{u_b}$ (mg COD/l.h)	9,14			
Specific bCOD removal rate	$\mathbf{q_b}$ (COD/VSS.d)	0,12	>F/M		
Readily biodegradable COD	**rbCOD** (mg/l)	269			
% rbCOD in COD	**rb** (%)	63	15 – 50	High	High % rb has a direct influence in the available HRT for nitrification.
rbCOD removal rate	$\mathbf{u_{rb}}$ (mg DQO/l.h)	8,43			
Time for rbCOD removal	$\mathbf{T_{bCOD}}$ (h)	17.5			Influence in the available HRT for nitrification
% lbCOD en COD	**lb** (%)	20	10 - 30	Normal	
% iCOD en COD	**i** (%)	17	5 - 25	Normal	

Nitrification

Mixed-liquor + amonium	Parameter	Result	Habitual range	Assessment	Comments
Maximum nitrification rate	AUR (mg N-NH4/l.h)	4,19	2 - 8	Normal	
Specific nitrification rate	SAUR (N-NH4/gVSS.d)	5,86			
Time for a complete nitrification	T_N (h)	14,32			
Estimated autotrophic biomass concentration	X_A (mg/l)	126			
% X_A in MLVSS	F_N (%)	7	5 - 20	Normal	Coherent with the actual C/N ratio
Minimum sladge age for nitrification	SRT_N (d)	10	5 - 30	Normal	

Nutrients ratio

WW sample 1	Parameter	Result	Habitual range	Assessment	Comments
rbCOD	C (mg/l)	336			
Nitrogen	N (mg/l)	113			
Fosfore	P (mg/l)	16,5			
Nutrients ratio	C/N/P	100/33/5	100/5/1	High	Higher than normal

WW sample 2	Parameter	Result	Habitual range	Assessment	Comments
rbCOD	C (mg/l)	269			
Nitrogen	N (mg/l)	90			
Fosfore	P (mg/l)	10,5			
Nutrients ratio	C/N/P	100/33/4	100/5/1	High	Higher than normal

Operational parameters

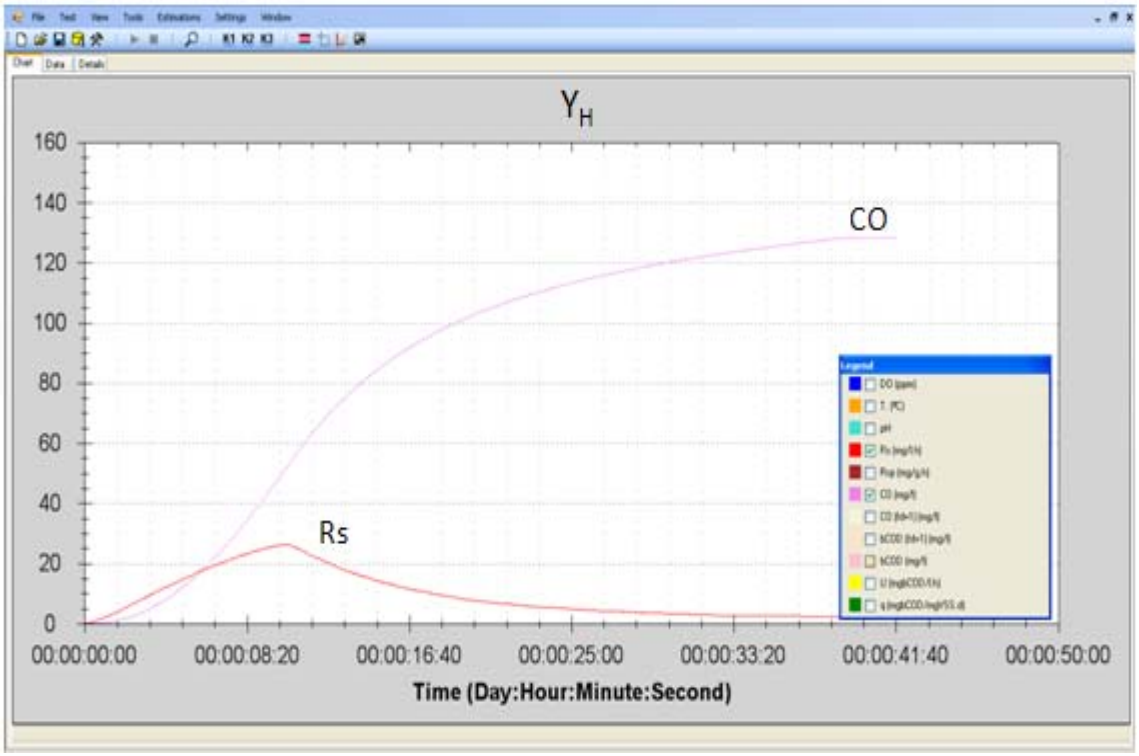
Activated sludge process	Parameter	Result	Habitual range	Assessment	Comments
Minimum sludge age	SRT (d)	17	5 – 30	Normal	
BOD loading rate	F/M (d^{-1})	0.15	0.05 – 0.15	Normal high	Depending of the conditions, it might be too high

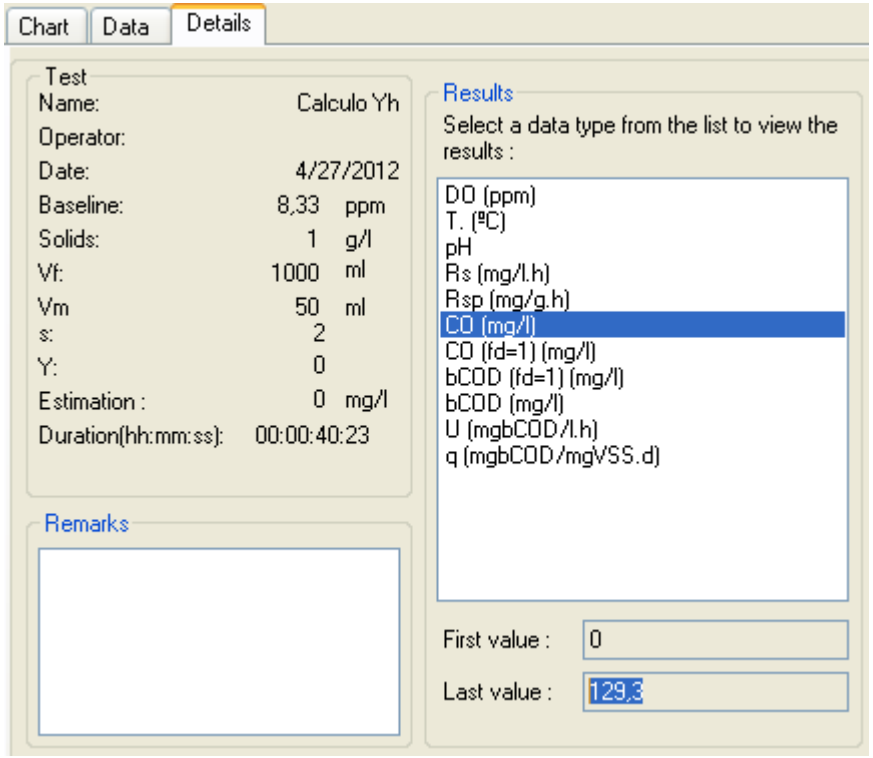
Respirometry

1. Heterotrophic yield coefficient (Y_H)

1. Heterotrophic yield coefficient (Y_H)

The determination of the Y_H allows knowing the growing biomass capacity and it is directly related with its health.
By other side, it is also utilized in the biodegradable COD fractions determination.
In this study, to the Y_H determination we have made use of a sodium acetate solution of known COD (CODac = 300) as standard





$Y_{H.DQO}$ (mg COD{bact.}/mg COD) = 1 – OC / DQO_{ac}

Y_H = 1 – 129 / 300 = 0.57

$Y_{H.VSS}$ (mg VSS{bact.}/mg COD)= $Y_{H.DQO}$ / 1.48 = 0.57 / 1.48 = 0.38

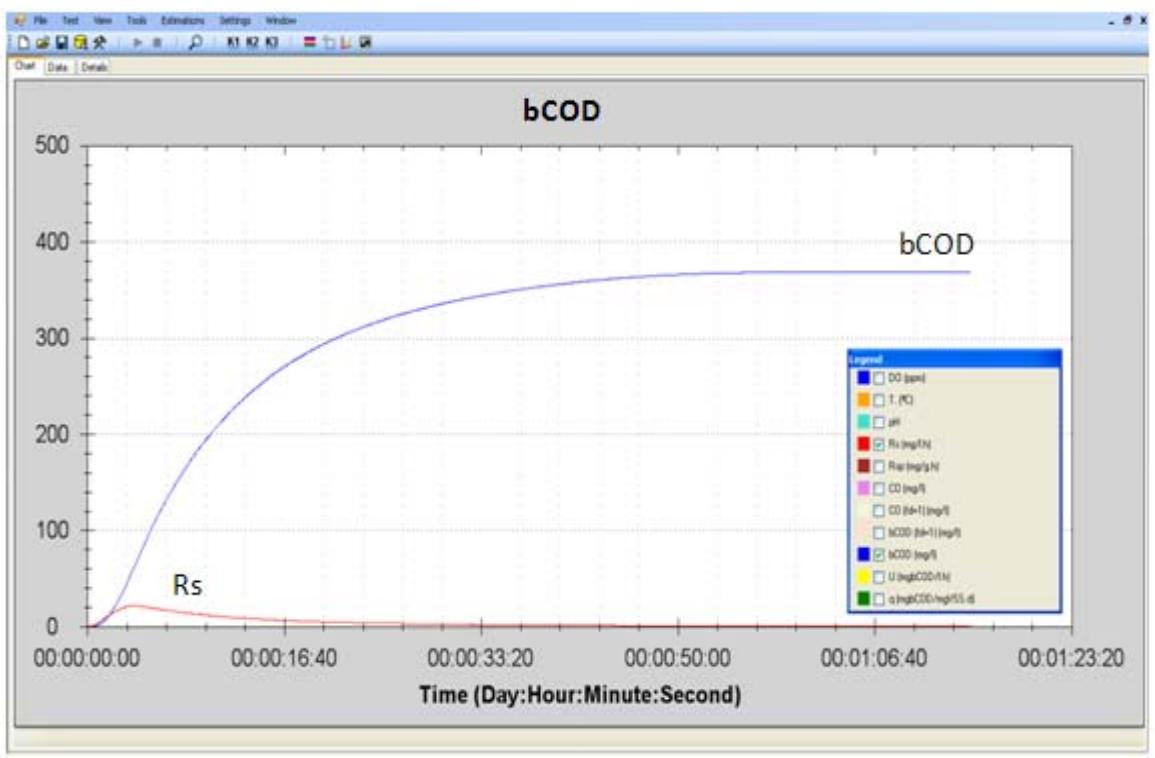
Analysis

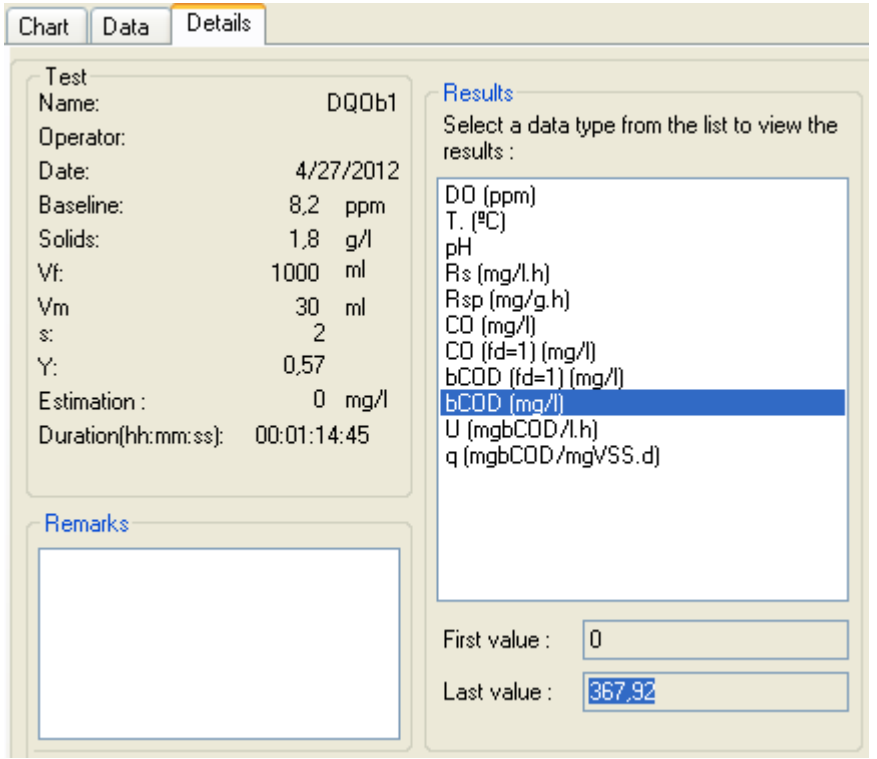
The values of 0.57 and 0.38 are rather low, representing a possible slow rate on heterotrophic biomass growing.

2. COD fractions characterization in wastewater sample 1

2.1. Biodegradable COD (bCOD) and its percentage (b) in total COD

We carry out this determination by means a test in dynamic R mode. On this mode we make use of small amount of wastewater sample in endogenous activated sludge, and the software automatically calculates the corresponding bCOD vale by applying the corresponding algorithm for extrapolation.





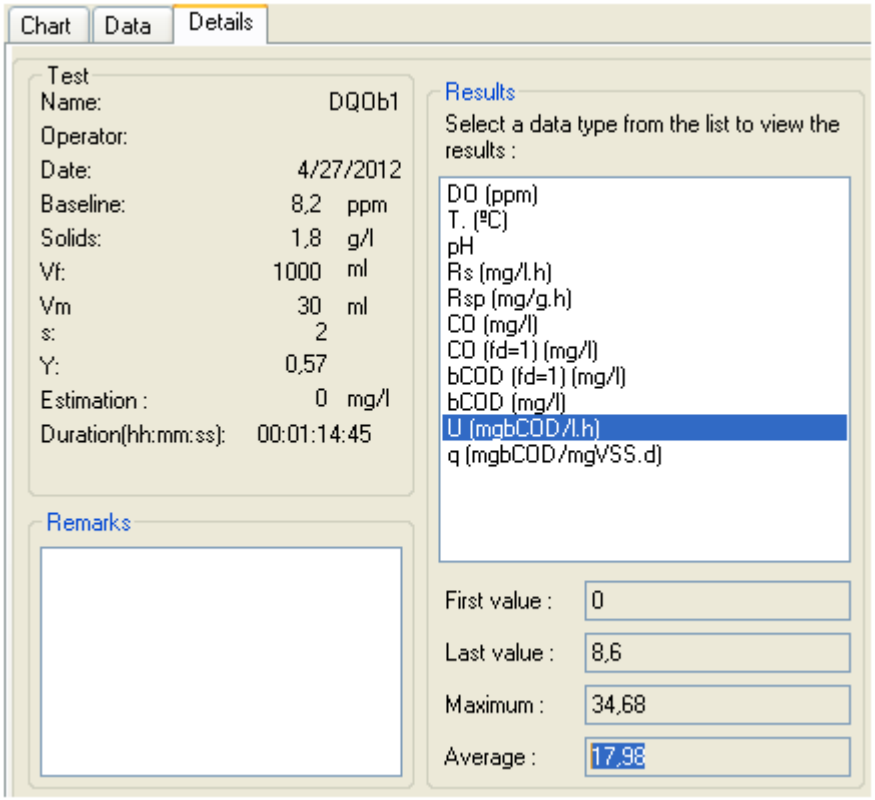
bCOD = 368 mg/l

b = 100 * (bCOD / COD) = 100 * (368 / 814) = 45 %

Analysis

The value of 45% represents a very low percentage of bCOD in COD and, therefore a very low biodegradability specifically referred to this actual activated sludge process. By other side, this low biodegradability is giving pass to a very high refractory non-degradable COD.

2.1.1. bCOD removal rate (U_b)



u_b (average) = 18 mg DQOb/(l.h)

T_b = 368 / 18 ≈ 20.5 h

T_b (h): Average time to remove a bCOD of 368 mg/l

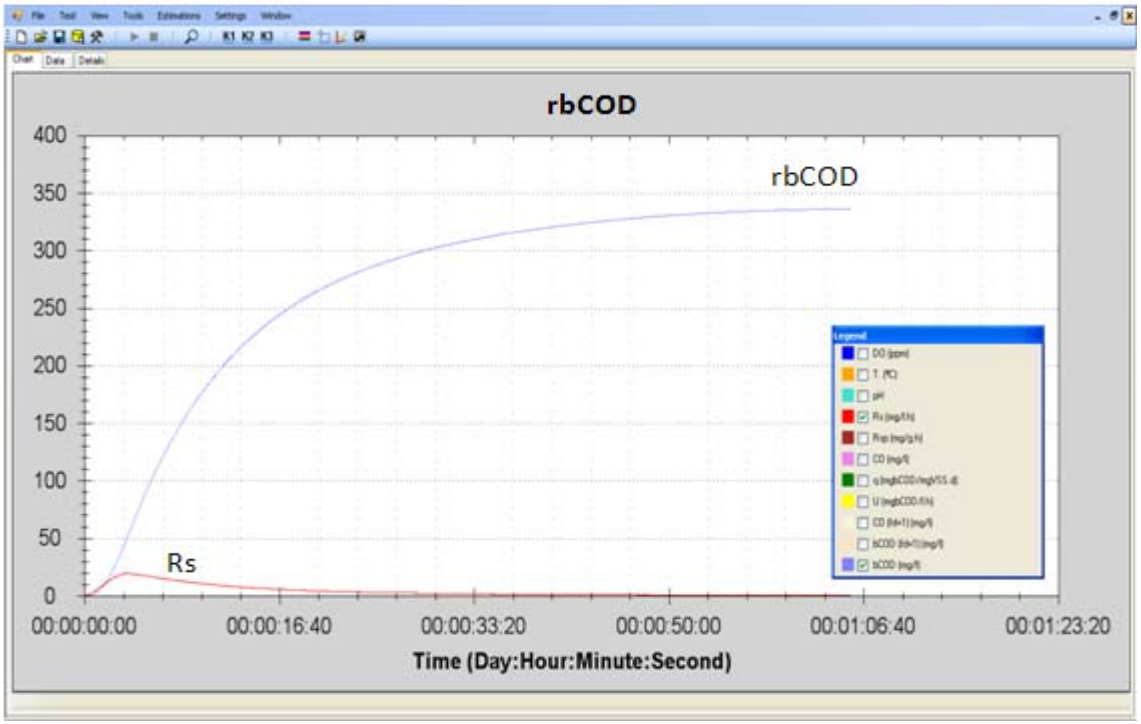
Analysis

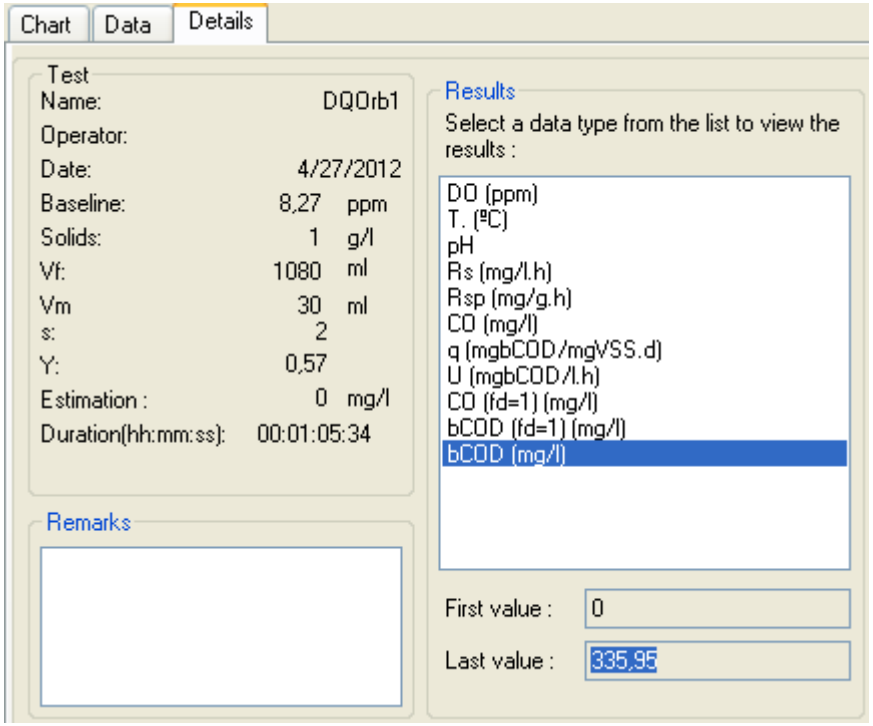
The time to remove the bCOD will be good or not depending of the actual HRT (*) available for it.

(*) HRT data was not provided to SURCIS in this study

2.2. Readily biodegradable COD and its percentage (rb) in total COD

This determination is carried out on the same way of the biodegradable COD but making use of a soluble wastewater sample (filtered to 0.45 micron)





rbCOD = 336 mg/l

rb = 100 * (rbCOD / COD) = 100 * (336 / 814) = 41 %

Analysis

The value of 41% represents a relatively high percentage of the rbCOD fraction in the total COD.
Because of the very close value to the bCOD, we could affirm that all the the biodegradable fraction in wastewater sample 1 is practically readily biodegradable.

2.3. Percentage of slowly biodegradable COD (sb) in total COD

Sb = b – rb = 45 – 41 = 4 %

Analysis

The percentage of sbCOD in COD is insignificant and, for practical purposes, we could consider bCOD ≈ rbCOD

2.4. Percentage of inert COD (i) in total COD

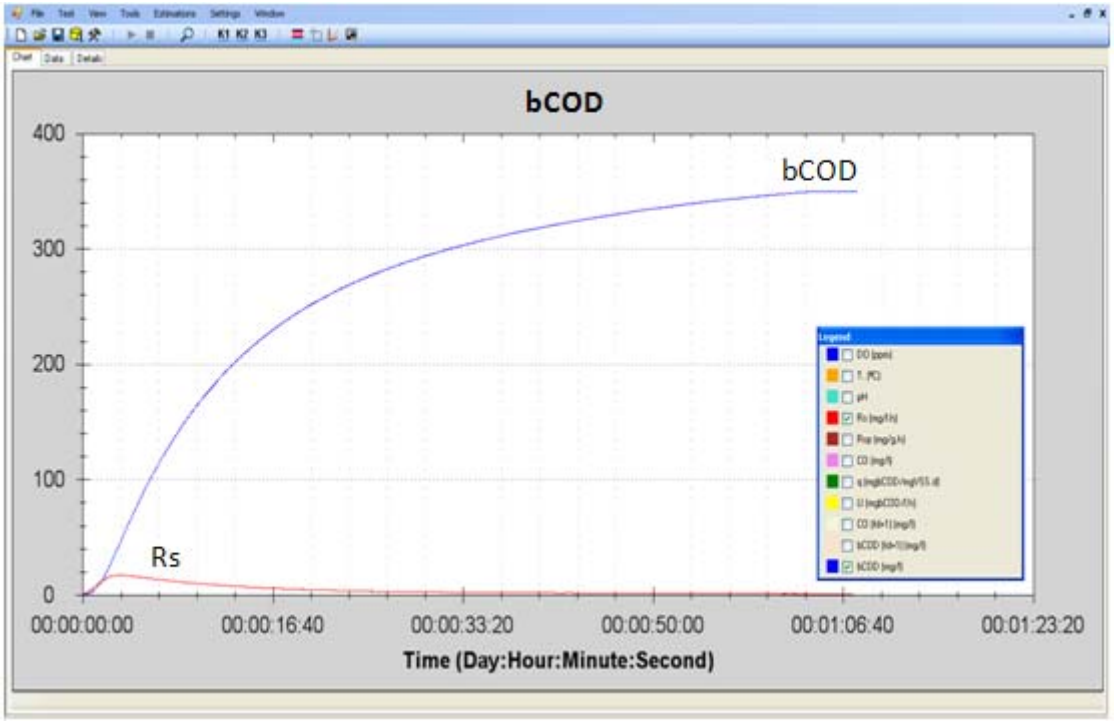
i = 100 – b = 100 – 45 = 55 %

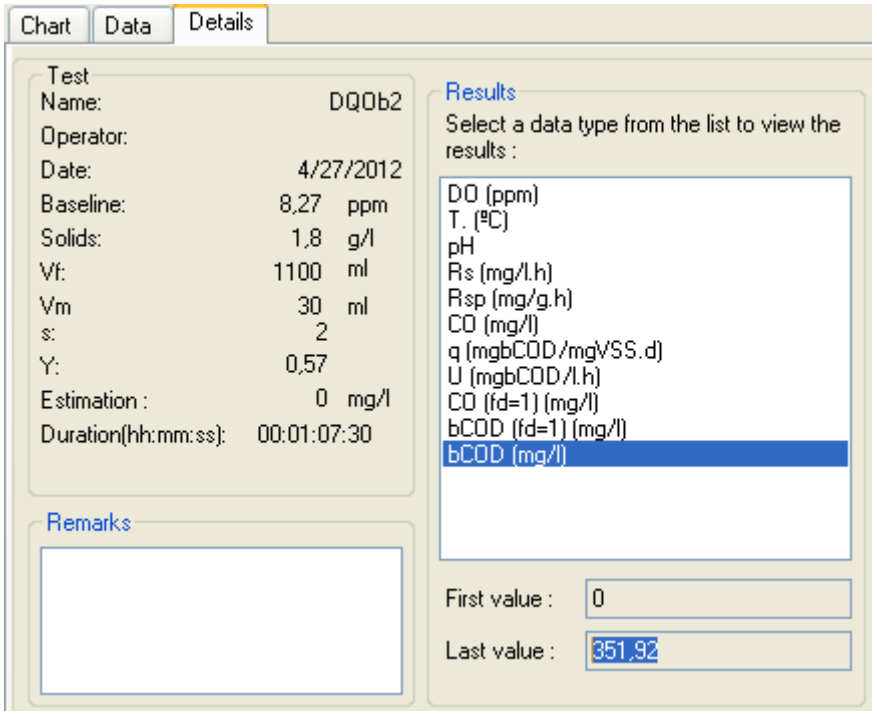
Analysis

The percentage of refractory or inert COD in total COD is extremely high and this fact will bring the logical consequence of a very poor COD removal of the wastewater 1 in the activated sludge process.

3. COD fractions characterization in wastewater sample 2

3.1. Biodegradable COD (bCOD) and its percentage (b) in total COD





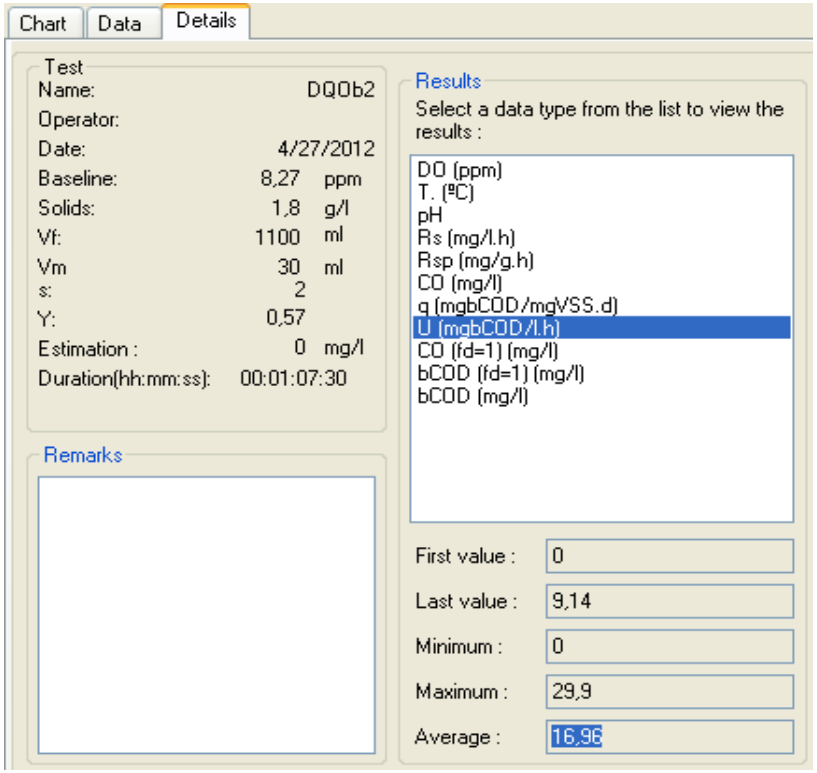
bCOD = 352 mg/l

b = 100 * (bCOD / COD) = 100 * (352 / 422) = 83 %

Analysis

The value of 83 % represents a normal biodegradability referred to the actual activated sludge process.

3.1.1. bCOD removal rate (U_b)



U_b (average) ≈ 17 mg DQOb/(l.h)

T_b = bCOD / U_b = 352 / 17 = 20,7 h

Tb (h): Average time to remove the bCOD

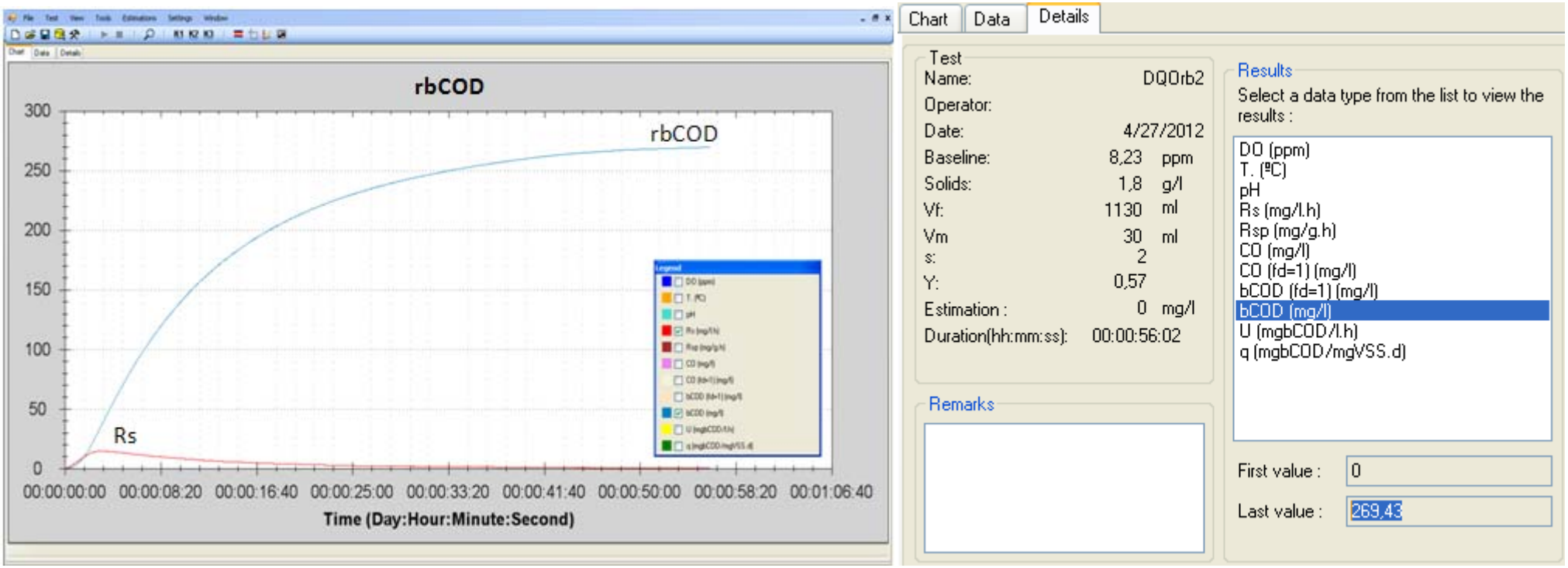
Analysis

The time to remove the bCOD (T_b) will be good or not depending of the actual HRT (*) available for it.

(*) HRT data was not provided to SURCIS in this study

3.2. Readily biodegradable COD and its percentage (rb) in total COD

This determination is carried out on the same way of the biodegradable COD but making use of a soluble wastewater sample (filtered to 0.45 micron)



DQOrb = 269 mg/l

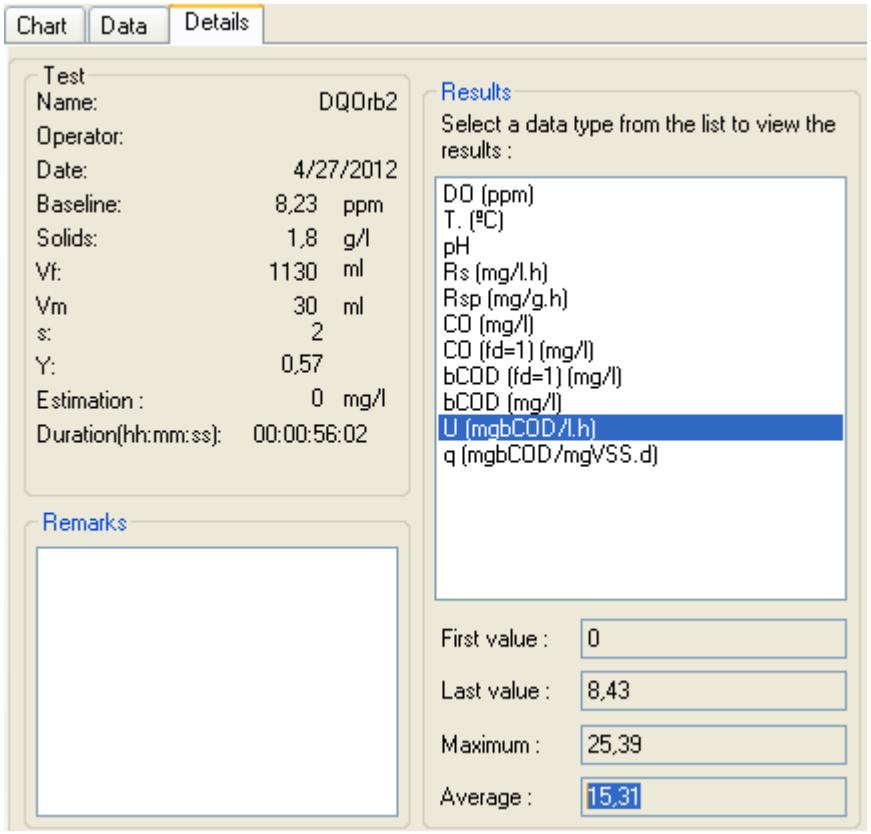
DQOrb / DQO = 269 / 422 = 0,63

Porcentaje de DQOrb en DQO: b = 63 %

Análisis del resultado

El valor de 0,63 de la relación DQOrb / DQO es muy alta.

3.2.1. rbCOD removal rate (U_{rb})



U_{rb} (average) ≈ 15.31 mg DQOb/(l.h)

T_{rb} = bCOD / Ur_b = 269 / 15.31 = 17.5 h

Analysis

The time to remove the rbCOD (T_{rb}) will be good or not depending of the actual HRT (*) available for it.

(*) HRT data was not provided to SURCIS in this study

3.3. Percentage of slowly biodegradable COD (sb) in total COD

sb = b – rb = 83 – 63 = 20 %

Analysis

The percentage of sbCOD in COD is normal.

3.4. Percentage of inert COD (i) in total COD

i = 100 – b = 100 – 83 = 17 %

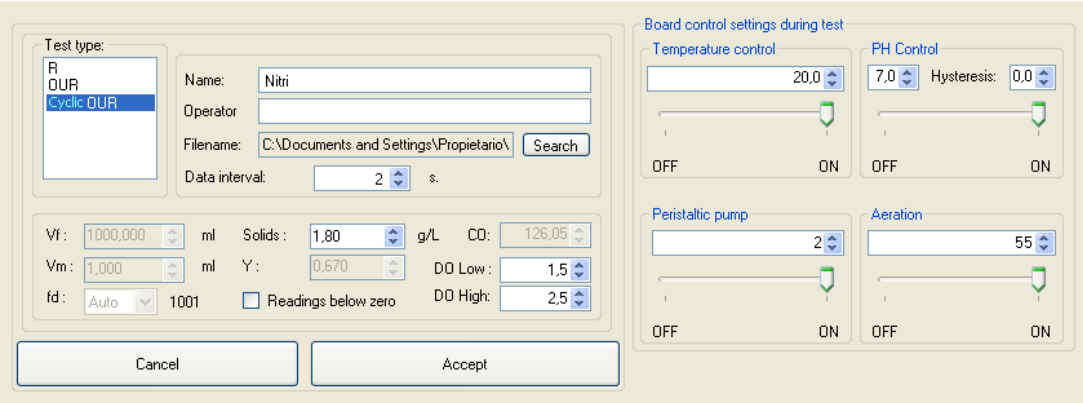
Analysis

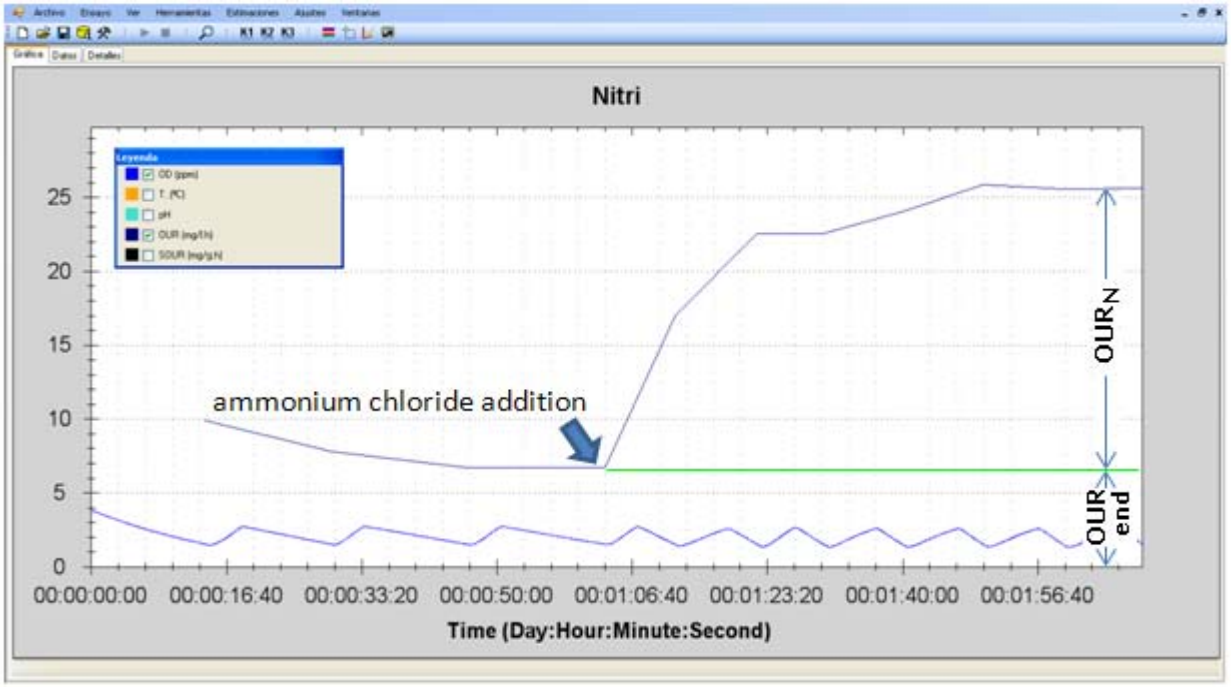
The percentage of iCOD in COD is normal (a bit high)

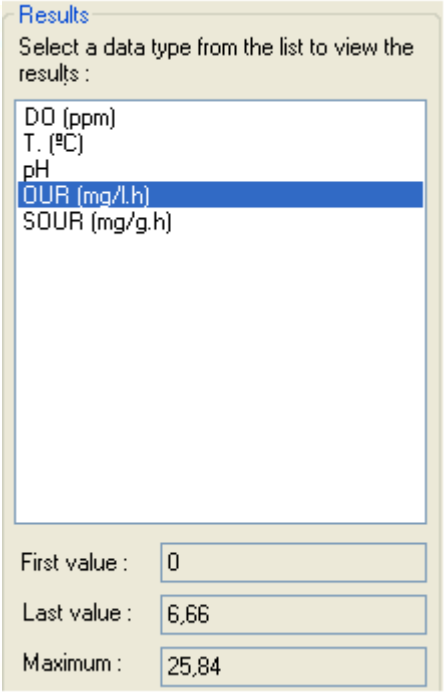
4. Nitrification

4.1. Maximum ammonium uptake rate (AUR) & Nitrification timen (T_N)

For the nitrification test we are making use of ammonium chloride with equivalent values of N-NH4 concentration, oxygen (1.5 – 2.5 ppm), temperature (20ºC) and pH (7) to the actual process in a cyclic mode respirometry test.







$OUR_N = OUR - OUR_{end} = 25.84 - 6.66 = 19.18$ mg/l.h

$AUR = OUR_N / 4.57 = 19.18 / 4.57 = 4.19$ mg $N\text{-}NH_4$/(l.h)

$SAUR = 24 * AUR / VSS = 24 * 4.19 / 1.8 = 55.86$ mg $N\text{-}NH_4$/(g VSS.d)

$T_N = S_N / AUR = 60 / 4.19 = 14.32$ h

OUR_N (mg/l.h): Oxygen uptake rate due to nitrification
AUR (mg $N\text{-}NH_4$/l.h): Nitrification rate
SAUR mg $N\text{-}NH_4$/g VSS.d): Specific nitrification rate
T_N (h): Time that process needs to completely nitrify the ammonium S_N
S_N ($N\text{-}NH_4$/l): Mean concentration og ammonium nitrogen ≈ 60 mg N-NH4/l

Nitrification capacity

N_C ($N\text{-}NH_4$/l) = $AUR * TRH_N = 4.19 * TRH_N$

N_C ($N\text{-}NH_4$/l): Maximum ammonium concentration that the process is able to remove
TRH_N (h): Available hydraulic residence time for nitrification (this data was not provided to SURCIS)

4.2. Autotrophic biomass concentration (X_A)

$F_N = Y_{A.VSS} * S_N / (Y_{H.VSS} * S_S + Y_{A.VSS} * S_N)$

S_N (mg/L): Actual eliminated ammonium-nitrogen in nitrification.
S_S (mg/L): Readily biodegradable COD (DQOrb)
$Y_A \approx 0.13$ (by default - for normal nitrification activity)

$F_N = 0.13 * 60 / (0.38 * 269 + 0.13 * 60) = 0.07$

$X_A = F_N * X_V = 0.07 * 1800 = 126$ mg/l

$X_A = 126$ mg/l

Source: Activated sludge treatment of industrial wastewater – W.W. Eckenfelder, J.L. Musterman - 1995

Analysis

We can assess the X_A value by comparing the result with a guide table of F_N values from different BOD/N ratios

BOD/N	0.5	1	2	3	4	5	6	7	8	9
F_N	0.35	0.21	0.12	0.083	0.064	0.054	0.043	0.037	0.033	0.029

Source: Metcalf & Eddy. 1995

Current BOD/N = 4 → 0.064 (table)

The 0.07 (>0.064) is coherent with the corresponding BOD/N ratio

5. Operational parameters

5.1. Minimum sludge age for nitrification (SRT)

SRT = 1 / [(0.13 * AUR * 24 / X_A) – b_A] = 1 / [(0.13 * 4.19 * 24 / 126) – 0.04] = 17 d

TRC_N = 17 d

Temp	Death & Decay Rate b_A ($days^{-1}$)
10°C	0.02
15°C	0.03
20°C	0.04
25°C	0.05

5.2. F / M

F/M should be calculated in full coherence with SRT.

F/M = 1 / (SRT * $Y_{H.VSS}$) = 1 / (17 * 0.38) = 0.15

F/M = 0.15

Analysis

SRT is in range but F/M is the higher limit (range: 0.01 - 0.15) for a normal nitrification. The reason of this relatively high F/M is mainly coming from the low $Y_{H.VSS}$. That means, if the process could increase the Y_H value the F/M could decrease into more normal values for nitrification.

6. Conclusions of the study

Conclusions

Activated sludge

The activity is normal. However the yield coefficient is slightly low, the biomass growing might be slow.
This relatively low value is also affecting the COD fractions and F/M.
Discarding the causes of a lack of nutrients, low temperature or sporadic toxicity, the cause of this low Y_H is unknown and it might be worth to carry out a specific study to find out the reasons of it - it exist some probabilities because of too low MLSS concentration for this type of process -

Wastewater sample 1

In this simple, the % of biodegradable COD (bCOD) in total COD is 45%. This value is very low compared with the habitual range and, for that reason, we can qualify its biodegradability as very low.
This relatively very low bCOD brings with it a logical very high (55 %) non-biodegradable inert COD (iCOD) in the total COD.
By other side, its bCOD removal rate gives a total removal time of 20.5 hours that, in principle, it seems to be rather high.

Wastewater sample 2

In this simple, the % of biodegradable COD (bCOD) in total COD is 83%. This value is very normal compared with the habitual range and, for that reason, we can qualify its biodegradability for this specific activated sludge as normal.
However, the % of soluble readily biodegradable COD (rbCOD) is very high; and this high percentage, depending of the process and their actual conditions, can bring the possible foaming generation and some influence in the actual available hydraulic residence time for nitrification.

Nitrification

In principle, the nitrification activity is normal.
In this study we had not the HRT available for nitrification in the process. We are however advising that, when there are not ideal conditions (DO, pH, Temperature), the high rbCOD value (wastewater sample 2) can create some lack of residence time for a complete nitrification performance.
For that reason, it will acquire special importance to get the process within the best possible conditions; and work with a SRT higher than the minimum value (17 days) here calculated.

Operational parameters

Maximum F/M and SRT are keeping some coherence. However F/M might be in the higher limit (0.15) for a normal nitrification; and this is mainly due to the low Y_H value.
In case that the high F/M could cause some problems in the nitrification performance, the advice should be to increase the MLSS concentration; thus, the F/M will be reduced.

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