Why BM Respirometry in my wastewater treatment plant?

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BM-Respirometry
in a biological wastewater treatment process

can ...

1. Find out the cause of low BOD or COD performance.
2. Find out the cause of low nitrification performance and give possible solutions.
3. Find out the cause of poor denitrification performance and give solutions.
4. Calculate the minimum oxygen level at which the nitrification process can operate for a given performance.
5. Calculate the optimal SRT and F/M within the framework of energy optimisation.
6. Calculate and analyse the actual oxygen requirement (AOR) of the process for the current SRT and dissolved oxygen.
7. Detect and assess possible toxicity.
8. Research on the behaviour of the process at different conditions of pH, temperature, oxygen…
9. Education

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 sludge in 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
- …

Multi-purpose Respirometers BM™ Series

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

Key applications in BM Respirometry

- Oxygen requirement and energy optimization
- Bioaugmentation control and tracking
- COD fractions: Automatic rbCOD (S_S) and bCOD - nbCOD (X_i) and sbCOD (X_S)
- Influence of different conditions (pH, Temp., Oxygen, ...) in the biological treatment process
- Operative parameter optimization: SRT, F/M
- Nitrification rate – Nitrification capacity
- Denitrification rate - bCOD necessary for denitrification – Denitrification capacity
- Global Toxicity referred to a specific biomass
- Specific Toxicity to nitrification
- Specific Toxicity to denitrification
- Kinetic parameters
- Support for simulation programs
- Many others

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

To detect actual problems in the wastewater treatment process

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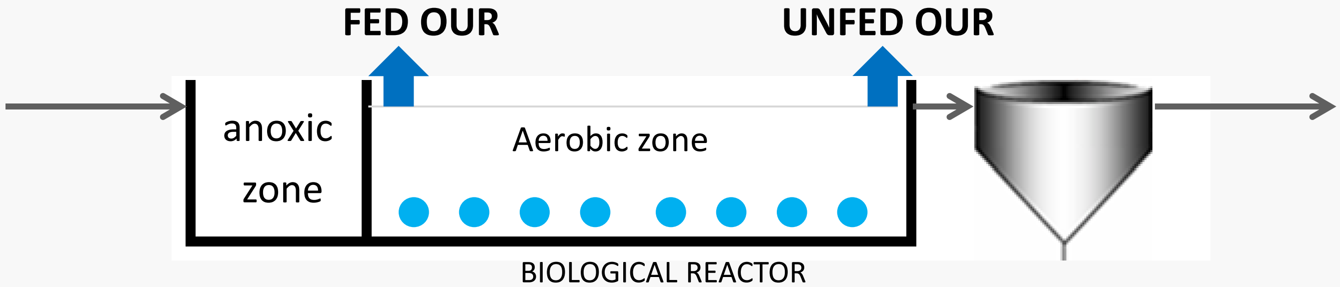
Primary assessment of the activated sludge process

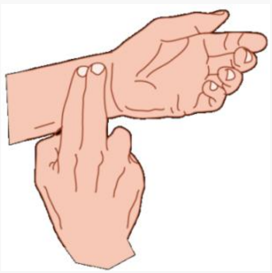
Taking the pulse of the process by the Loading Factor

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

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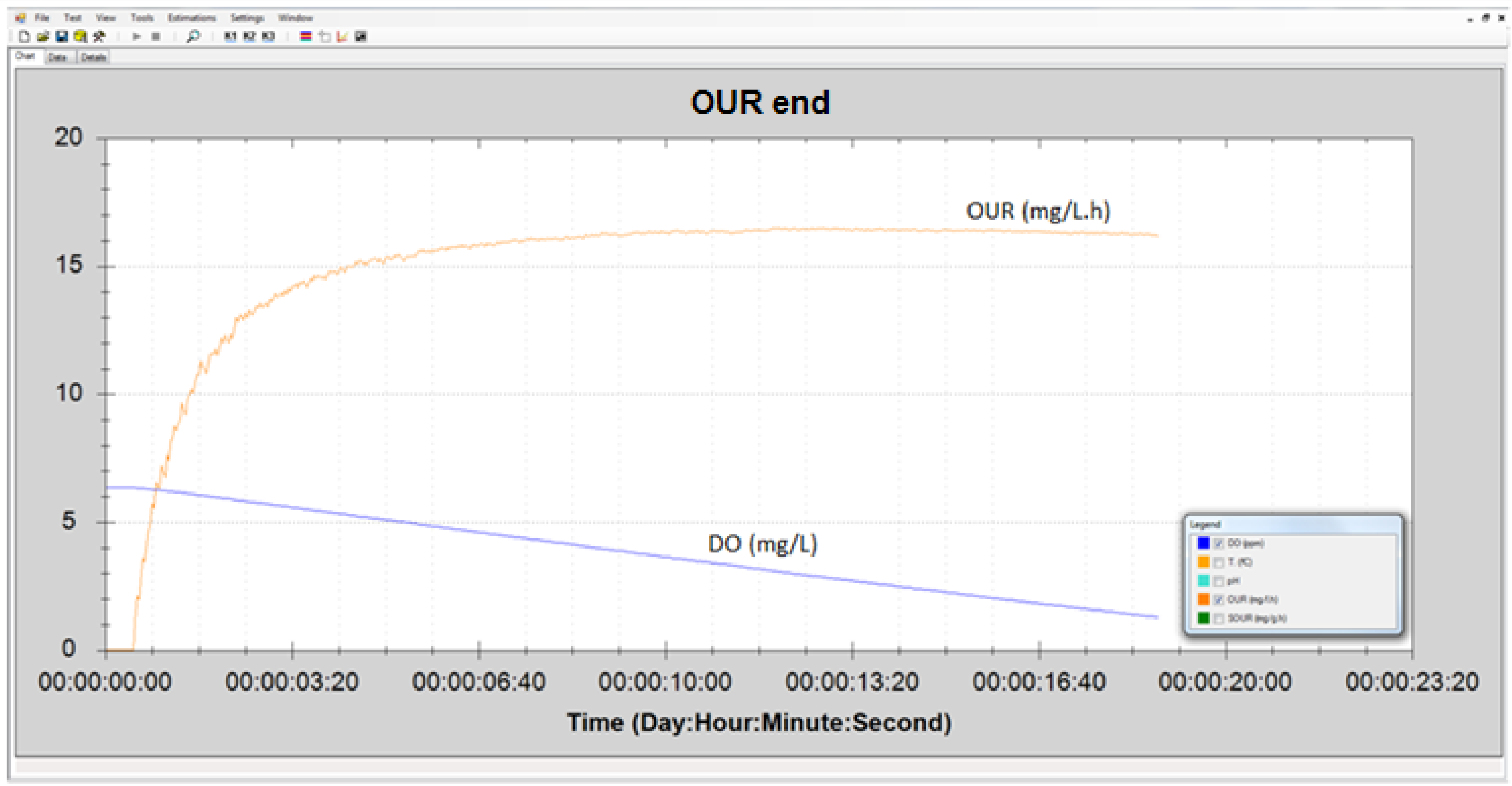
Endogenous respiration rate

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 for a certain long time within its oxygen saturation level.



DO and OUR respirogram for OUR end

Detection of low active biomass concentration by evaluating the endogenous uptake rate (OUR end)

Table guide of usual OUR_{end} values

MLVSS (mg/l)	OUR_{end} (mg/l.h) range
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

Low active biomass concentration is detected when the OURend value falls below its normal range, and the reasons may be as follows:

1. Any of the current process conditions (Temperature, Oxygen, pH, Nutrients,…) are out of their normal range.
2. Too high % of slowly biodegradable COD (sbCOD) in total COD → Biomass starvation
3. Toxicity already present in the biological reactor

COD fractions

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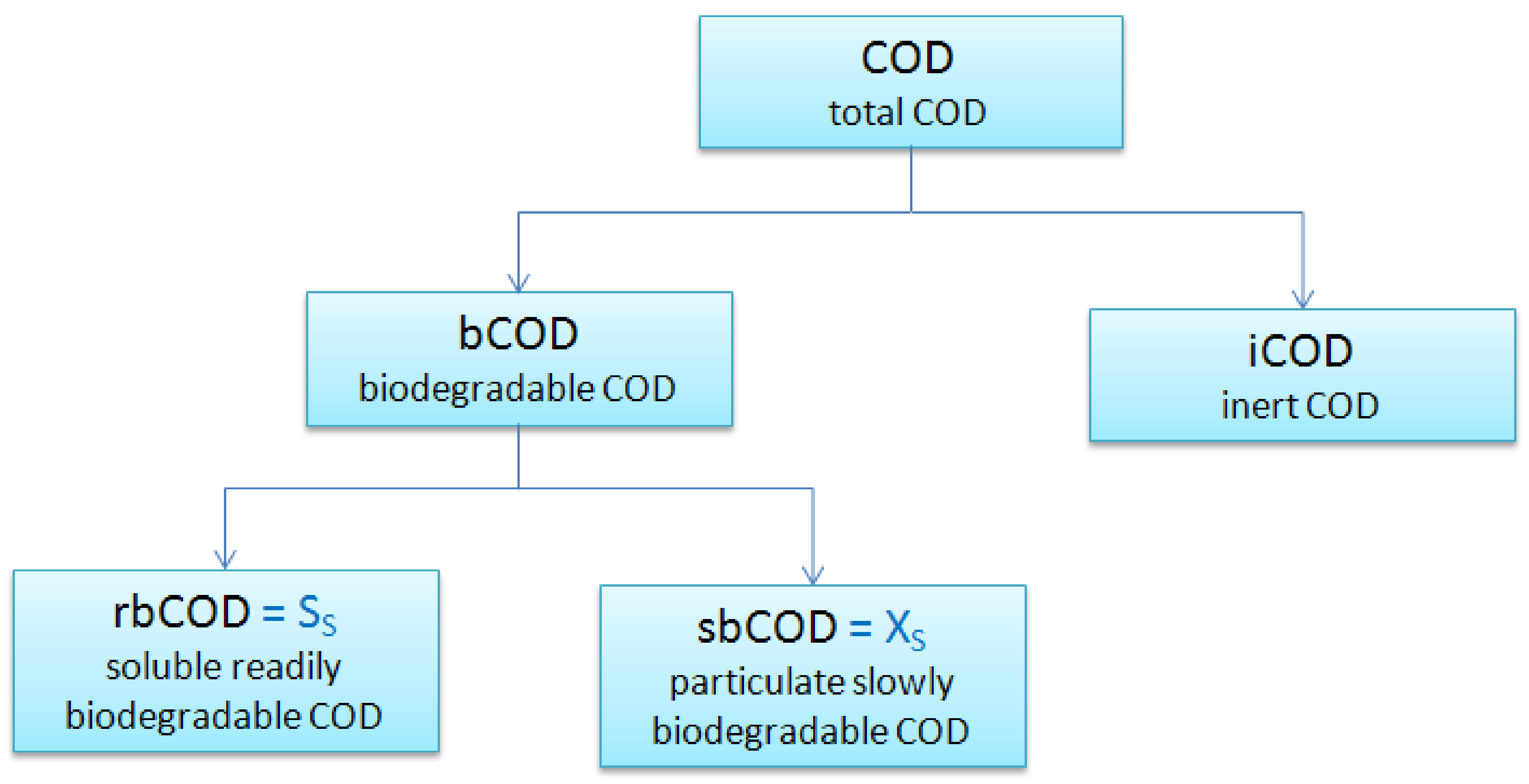
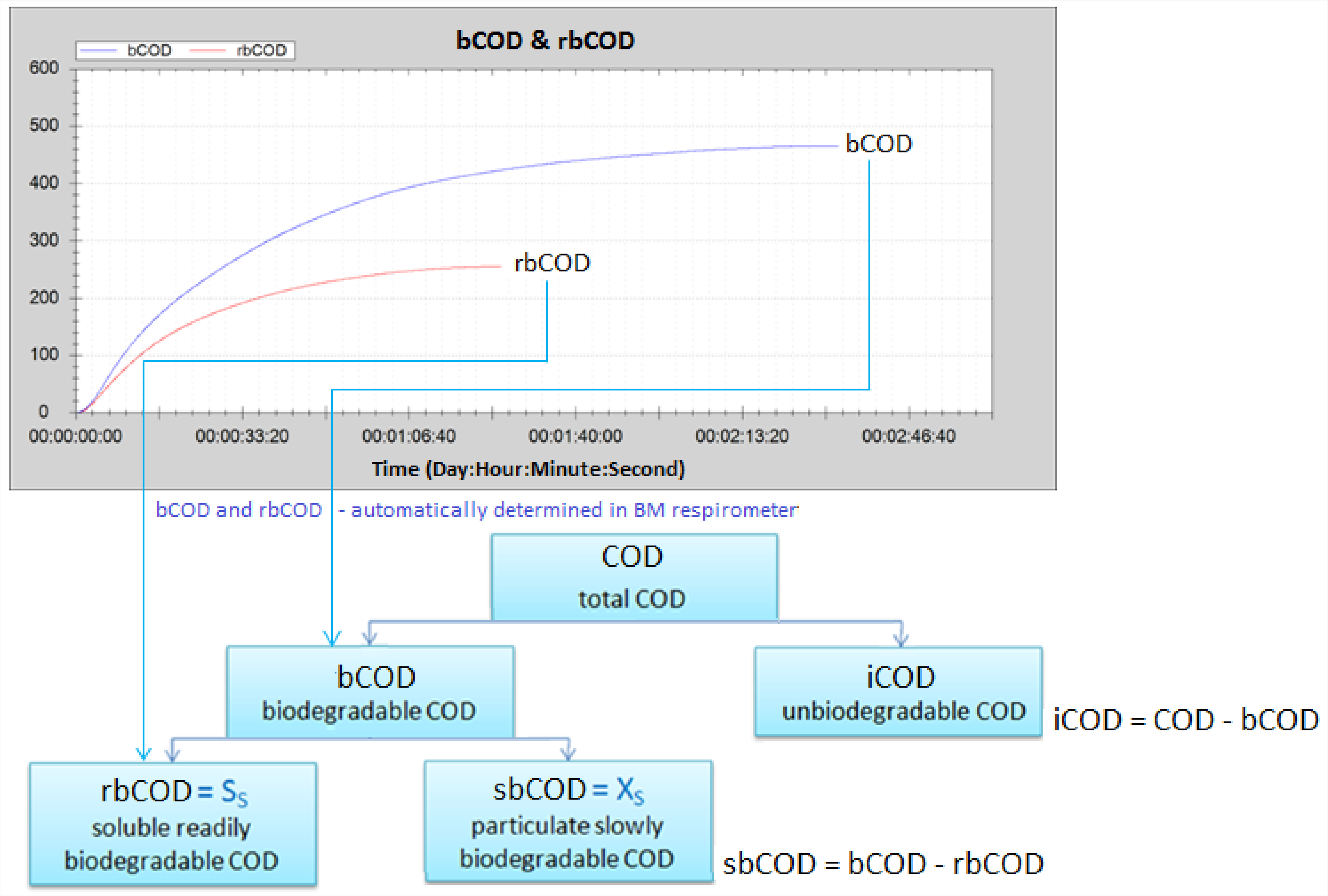
Main COD fractions (1)



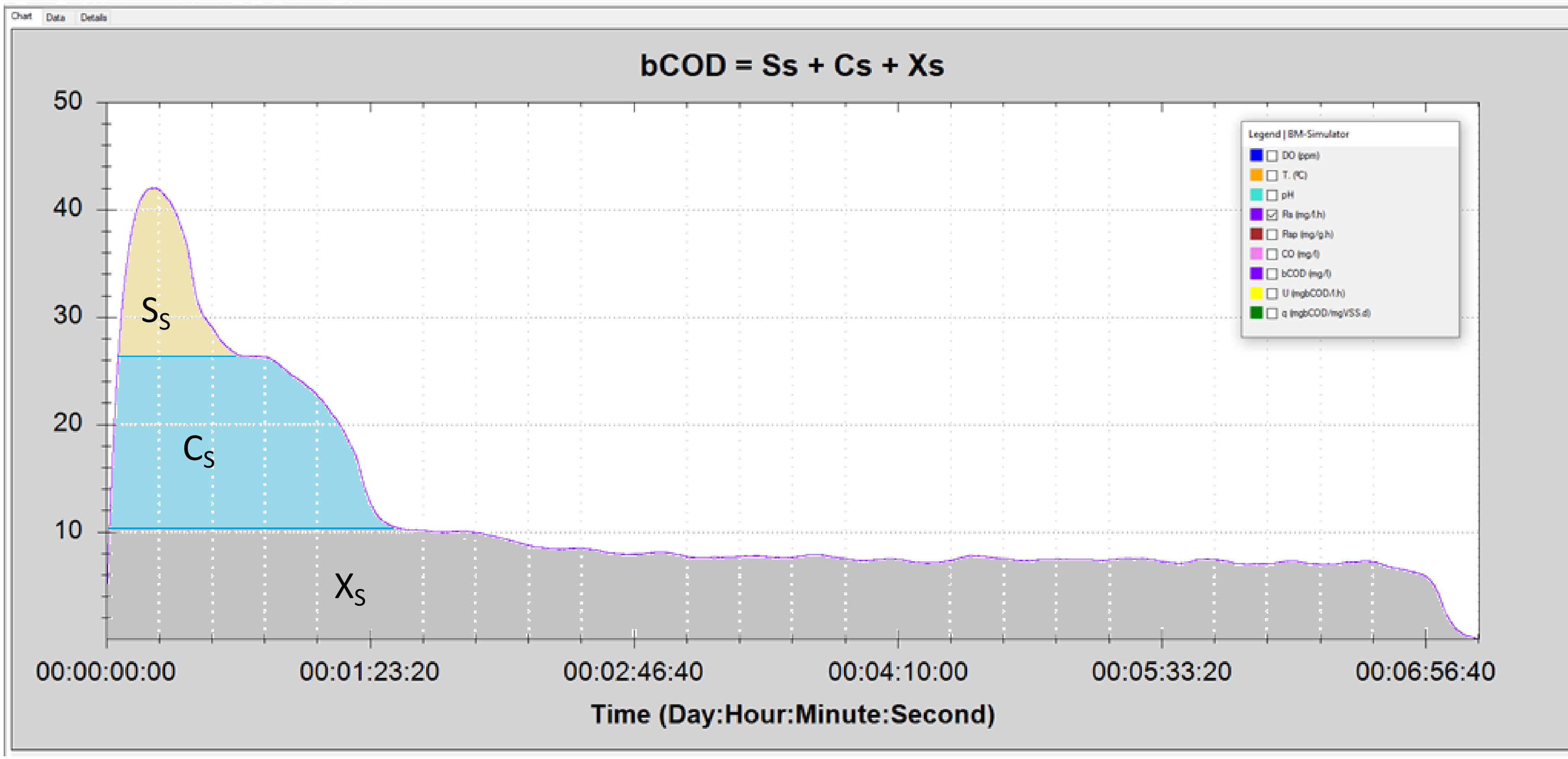
Main COD fractions (2)

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)

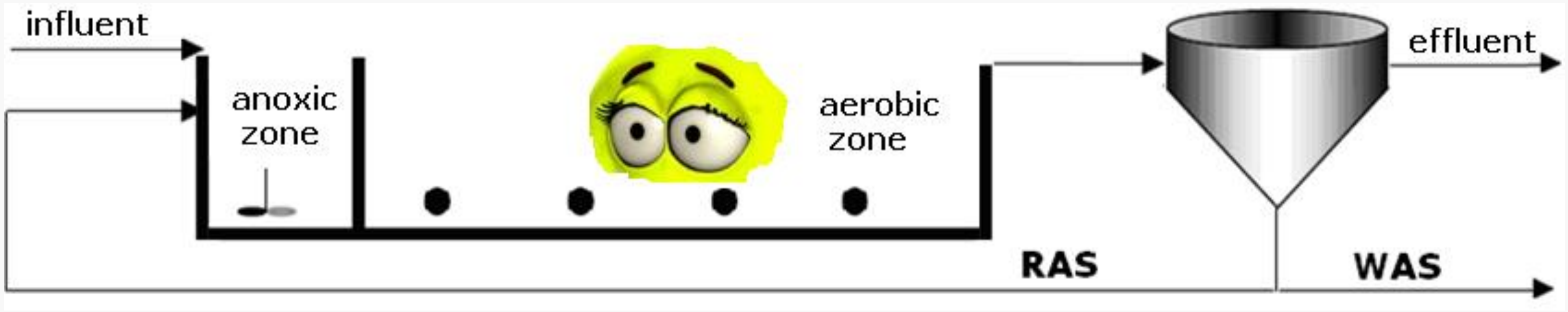
C_S : Colloidal slowly biodegradable COD (mg/l)

X_S : Particulate biodegradable COD (mg/l)

Toxicity

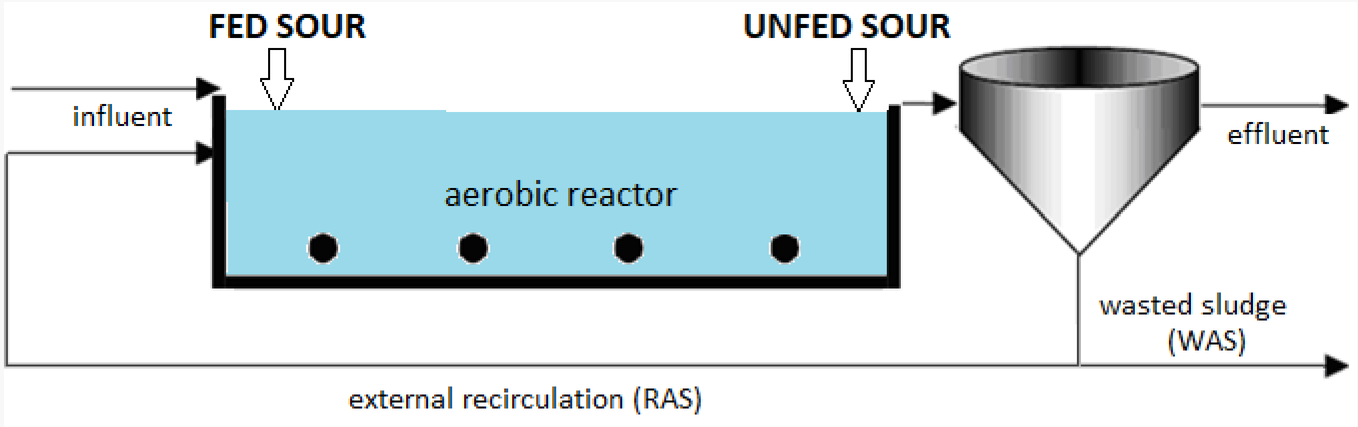
Basically we can see two cases of toxicity

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



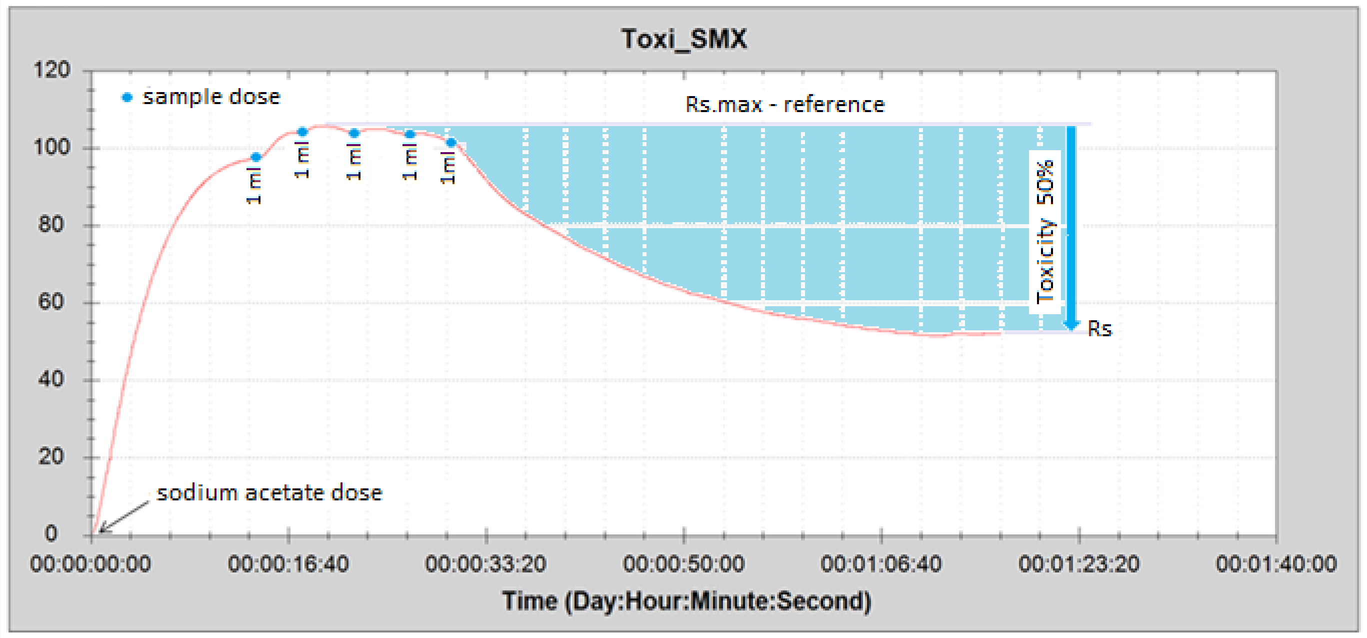
FED SOUR: SOUR in mixed-liquor from the process start

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

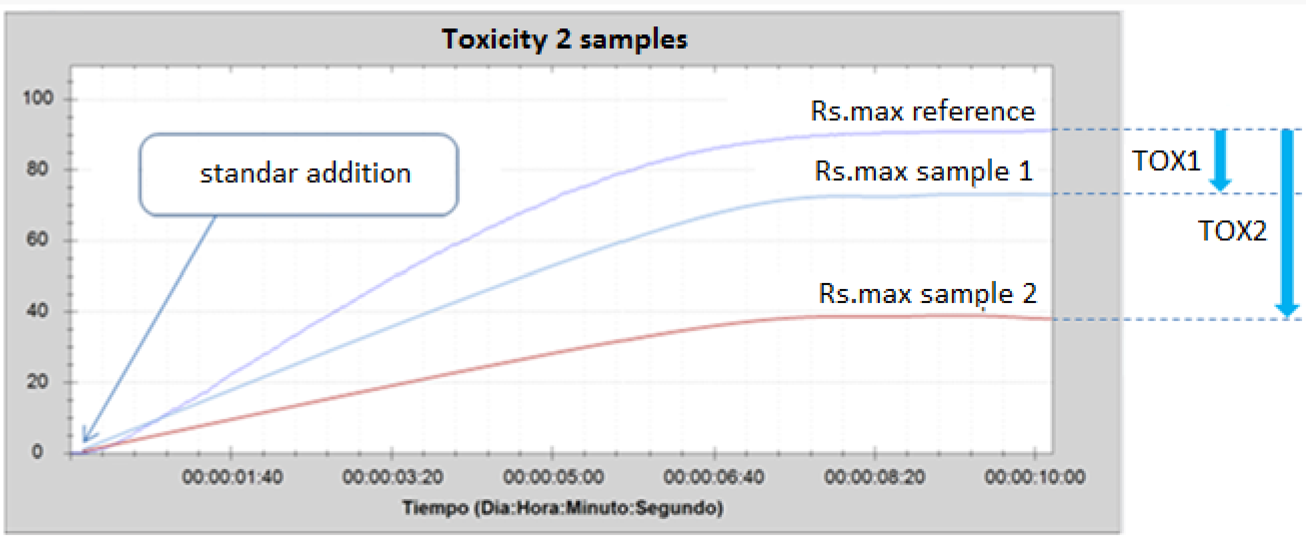
Toxicity (%) = 100 * (Rs.max – Rs) / Rs.max

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)



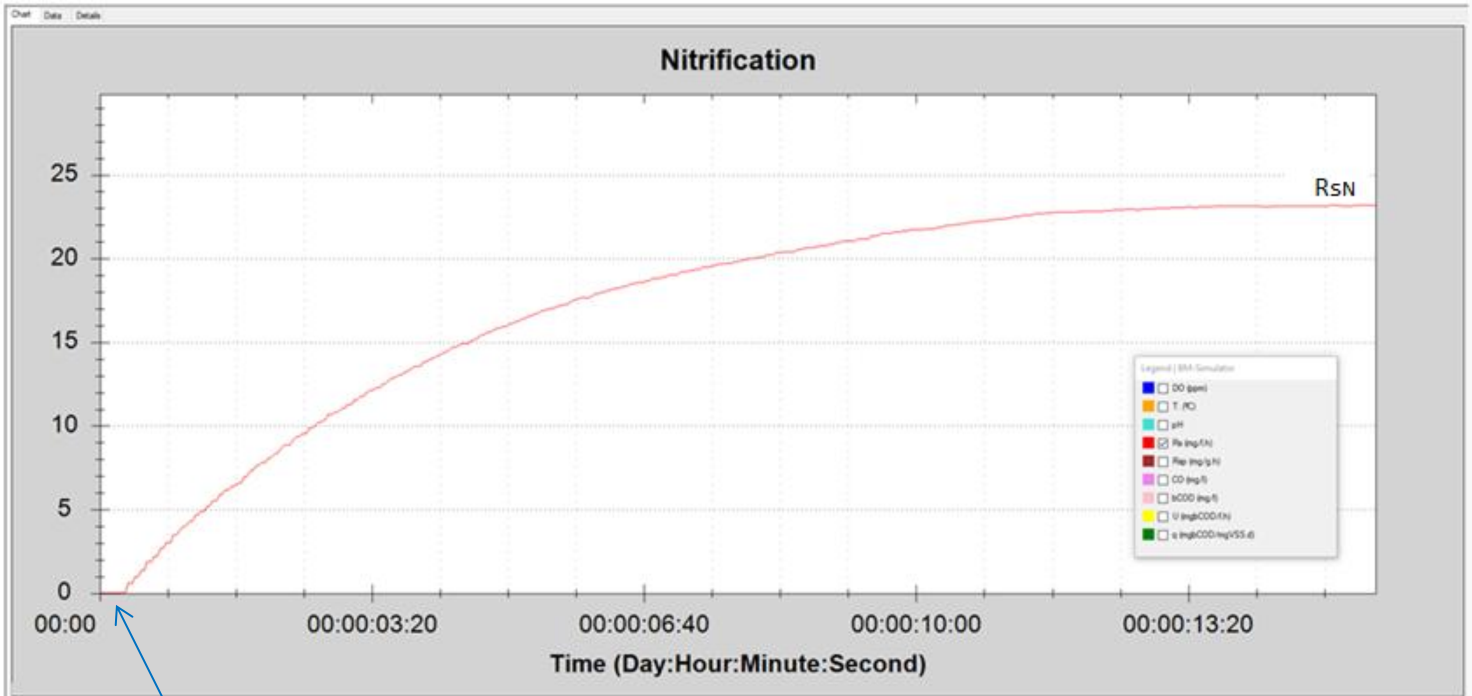
Combined Rs respirograms to asses 2 samples toxicity

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)



Ammonium chloride addition

Rs respirogram

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

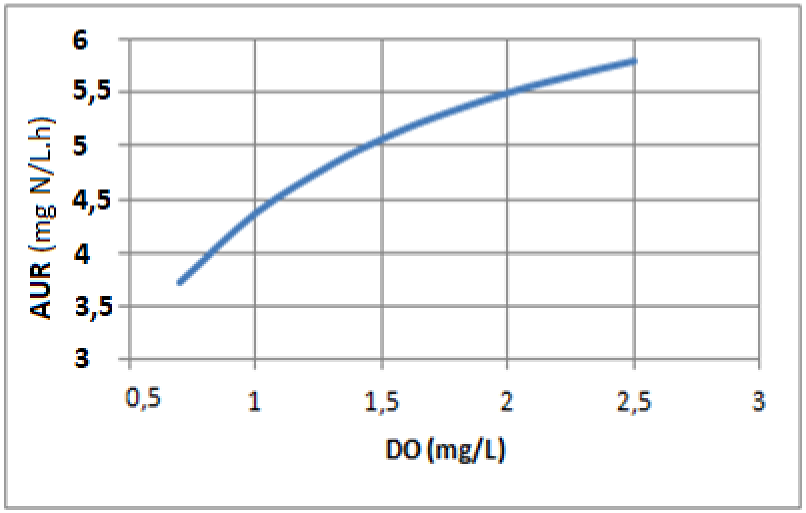
Rs_N: Respiration rate due to nitrification (mg O_2/l.h)

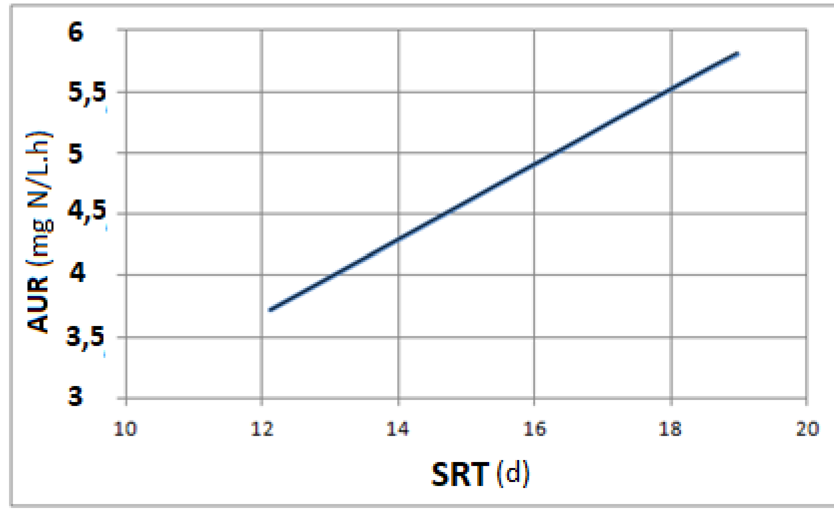
4,57: mg O_2 / mg Ammonium oxidized

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

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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 -
$Y_{H.DN}$: 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.

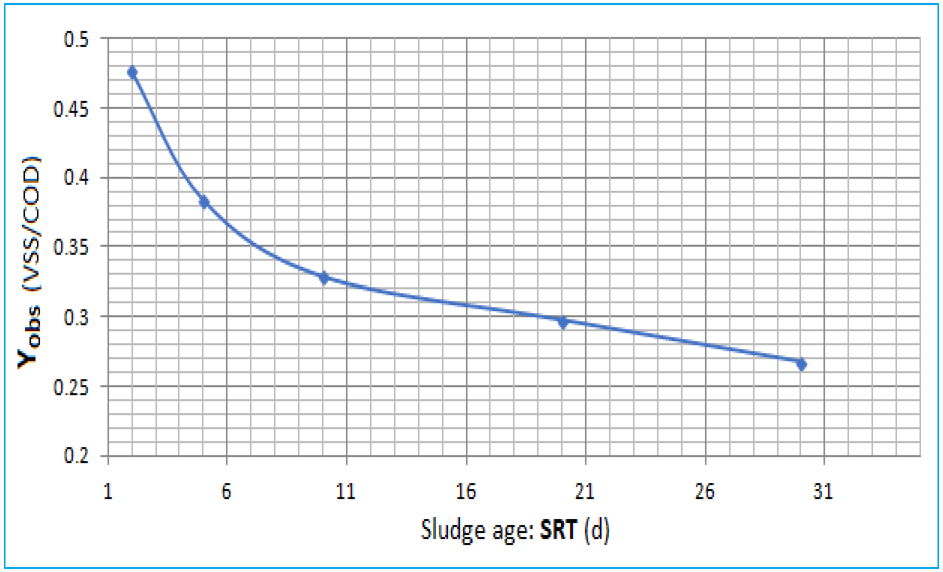
1 mL methnol diluted in 1 L distilled water = 0.791 * 1,5 = 1.18 mg COD/L

Sludge production

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)

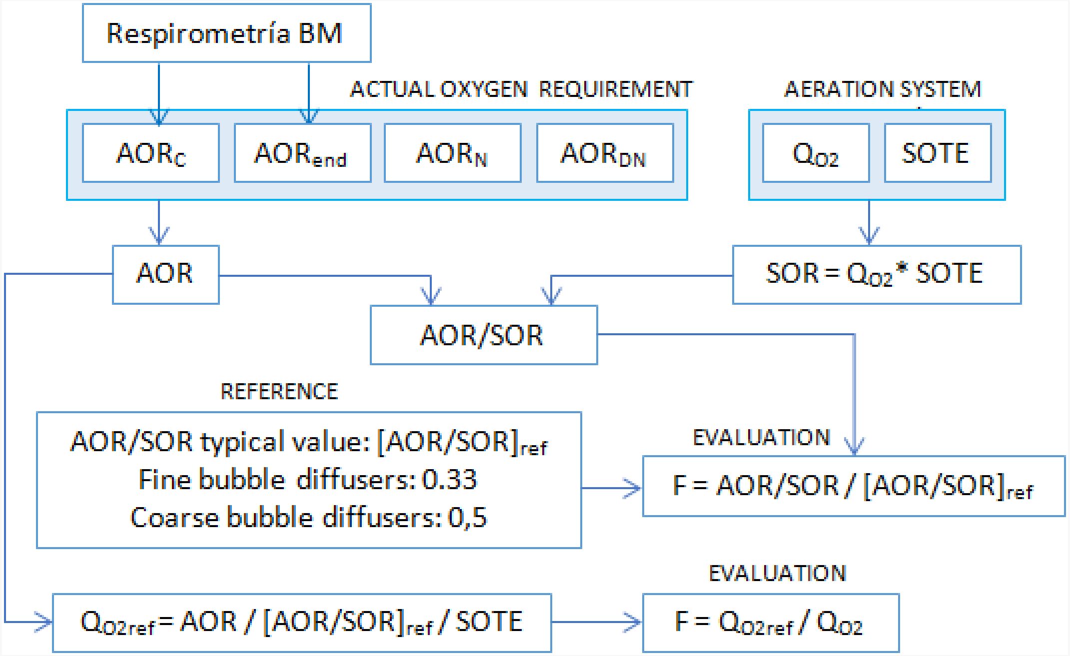
Y_{obs}: Observed yield coefficient (VSS/COD)

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

SURCIS, S.L.
Teléfono: 932 194 595 / 652 803 255
E-mail: surcis@surcis.com / eserrano@surcis.com
Internet: www.surcis.com

BM-Respirometry
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Can ...

1. Find out the cause of the poor BOD or COD performance
2. Find out the cause of the poor nitrification performance and solutions
3. Find out the cause of the poor denitrification performance and solutions
4. Calculate the optimal operational parameters in the energy optimization

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7. Research
8. Educate

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