BASIC PROTOCOL OF BM RESPIROMETRY MEASUREMENTS AND APPLICATIONS FOR ACTIVATED SLUDGE PROCESS MANAGEMENT AND ENERGY OPTIMIZATION

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Introduction

The use of the BM advanced respirometry system enables the user to get the precise calculation of the operating parameters and limit set points that any activated sludge actually needs within the framework of an energy optimization. For that reason, the proper use of this respirometry is more than justified; and not only because of getting the parameters for a good process performance, but also to keep a healthy biomass and prevent possible potential problems.

However, because of the wide range of applications and possibilities that BM respirometry can offer, it is critical to get a protocol that can be adapted to any specific process and carried out by the plant operator within his available timeframe.

For this protocol here explained we can use any of the BM respirometers, but in case the pH could play a critical role in its performance, it would be recommended the model BM-Advance which includes an automatic pH monitoring and control system.

Figure 1. BM-Advance respirometry system

The BM respirometer can be programmed with three different operation modes (OUR, Cyclic OUR and R) and can be set for different conditions of DO, Temperature, pH, sample volumes. Those conditions can be changed during the test performance. All simultaneous measurements can be displayed on tabular or graphic mode during the test and respirogramas can be overlaid. The R test, since we can use small amount of wastewater sample, the tests can be run in very short term.

Methods

There is not a unique protocol for all plants, but here we describe the most common that can be used as a base to make the final protocol for a specific proces
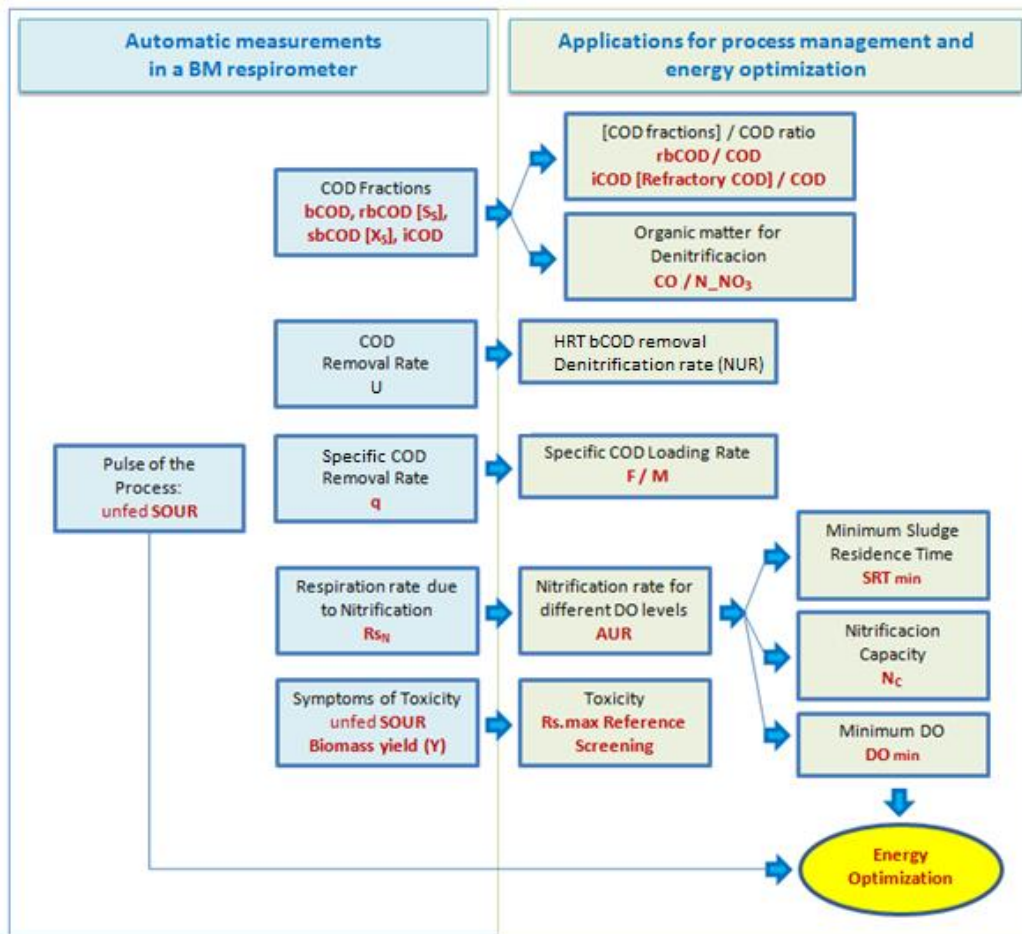
Figure 2. Protocol for BM respirometry

Pulse of the process by means UNFED SOUR

By means a simple SOUR test in the effluent sludge (UNFED SOUR) and the checking of the value obtained with a guide table, we can find a quality assessment of how the process is performing and if it has got any possible inhibition symptoms already present in the biological reactor.

Just in case the SOUR value remains within certain range below or above the reference value of the table, we could update the aeration conditions (e.g. readjusting DO set-points) and in this way get an energy optimization
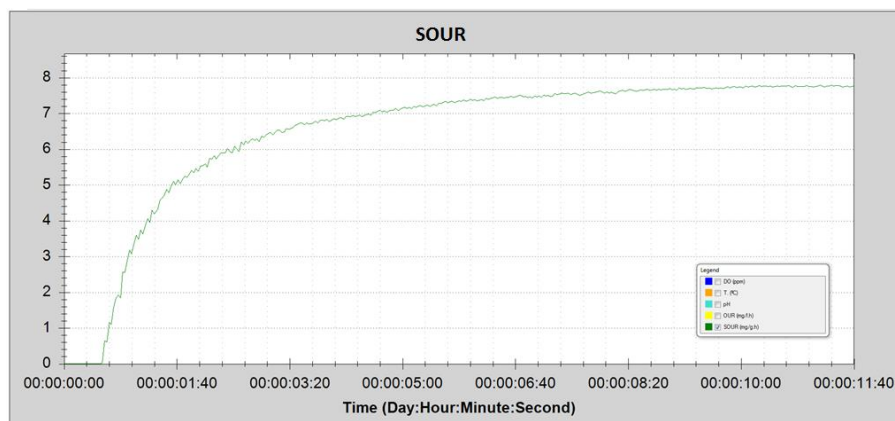

Figure 3. SOUR respirograms

This test could take about 15 minutes and it is recommended to collect a representative activated sludge for a normal loading rate.

It is recommended to do this test once or twice a day; except if it is suspected the process could show long-term overloading or toxicity.

In case of clear symptoms of toxicity already present in the biological reactor, we could not continue with the normal protocol and then we have to approach the respirometry test for toxicity applications (Applications Manual for BM respirometers)

COD fractions

For the task of the COD fraction we have to make use of the heterotrophic yield coefficient (Y_H), which is also determined by means of simple respirometry. For some situations, we could also use the Y_H default vale (0.67 O_2/COD) already set in the test settings-board.

Once we have set the conditions, the Y_H and sample volumes (wastewater and sludge) the test is able to start and automatically and calculates the readily biodegradable COD (rbCOD).

Then, together with the total biodegradable COD, by simply math subtractions it is possible to calculate the recalcitrant or slowly biodegradable COD (sbCOD) and refractory or inert COD (iCOD)

Since we want to know how biodegradable the COD to be treated is in our specific activated sludge process, the importance to get the COD fractions is evident.
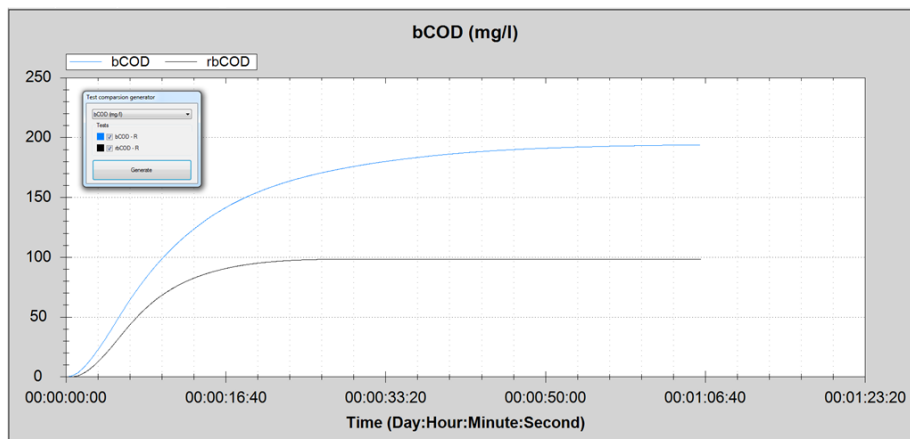
Fig 4. Overlying of bCOD and rbCOD respirograms

In addition, by analyzing the influent to the denitrification zone of the reactor, we can also get the soluble biodegradable COD necessary for the denitrification process.

Unless there are exceptional situations, it would not be necessary to do a daily complete COD fractions test.

Specific bCOD removal rate

Simultaneously to the bCOD measurement by the BM respirometer, it is also automatically calculated the specific rate at which the COD is being removed (q) per unit of SS, in the same units as the COD loading rate (COD/SS.d)

Fig 5. q respirogram

By making use of the BOD/bCOD ratio, we can easily transform the q units into the habitual units of F/M (BOD/SS.d) Therefore, by comparison with the actual /F/M, the q parameter can be an important tool to assess if the process has enough F/M (for COD or BOD) capacity and what is the loading threshold at which the process could operate.

bCOD removal rate – Denitrification rate
Together to the parameter q, the software also calculatesthe bCOD removal rate (U)
This parameter can be used to the necessary HRT to remove the bCOD.
It can also be used as a basis for calculating the denitrification rate (NUR), taking into account that this rate is proportional to the nitrate removal rate in the anoxic zone.

Nitrification rate
The respiration rate at maximum oxygen due to nitrification can be obtained by means a R respirometry test, by adding a controlled dose of ammonium chloride (with an equivalent concentration of ammonium nitrogen) to the activated sludge under endogenous respiration.

Fig 6. Respiration rate due to nitrification respirogram

We get the nitrification rate (AUR) by dividing the maximum respiration rate by 4.57 (mg of O_2 necessary to nitrify 1 mg of ammonium)

Now we want to apply the half-saturation constant (K_{OA}). But the fact is that, depending of the source (ASM1, ASM2, ASM3, USEPA, IWA, BioWin, GPS-X, Henze, Contreras,…), we can find reported concentrations ranging between 0.15 and 2 mg/L O_2 !! For that reason, it is important to not go to a default value and only make use of the actual K_{OA}. In this sense, we can apply a relatively easy way to calculate the actual oxygen half-saturation coefficient (K_{OA}) by means of a simple equation made from the actual AUR at current DO and AUR at maximum oxygen.

By making use of the actual K_{OA}, based on a Monod principle, we will be able to get the corresponding values of nitrification rate for a representative set of different DO levels and calculate the nitrification capacity for each of them on different conditions of pH and temperature. In this way, we can get the minimum DO range on which the nitrification can efficiently perform without any detriment of the requested efficiency.

If the process has a steady behavior, it would not be necessary to make all this chain determinations every day (may be once a month) The fact is that we could plot the diagram of the nitrification capacity for a specific DO range vs ammonium concentration to nitrify (S_N) and manage the process / aeration within an important framework of energy optimization.

Minimum sludge age

From the operating AUR range, and by applying some well known math formulas, we can find out the proper values of the minimum sludge age (SRT) for any specific DO level and condition. In this way, we can use the AUR for a specific DO range not only to calculate the corresponding nitrification capacity but also the proper SRT and, from here, the sludge concentration.

We can also plot a diagram of SRT for DO vs different ammonium concentrations to nitrify.

MBBR process

In case the process is a moving bed bioreactor (MBBR) or any other type of moving bio-film, the BM respirometer can adapt a special reactor device for it, and we can carry out the protocol in the same way.

Fig 7. Biomass-carrier reactor device in BM-Advance

Results

Here is a summary of the main results we can get:

- Specific oxygen uptake rate of the effluent sludge: UNFED SOUR
  Application: Pulse of the process and inhibition / toxicity symptoms detection

- Readily/ total biodegradable COD: b/rbCOD
  Application: COD fractions

- Innert COD: iCOD - Non biodegradble COD
- Application: Refractory COD

- Specific COD utilization rate: q
  Application: COD removal capacity, F/M assessment.

- AUR for a determined DO range: AUR_{OD}
  Application: Nitrification activity for a determined set of DO levels.

- Nitrification capacity: N_C
  Application: Amount of ammonium the process is able to nitrify.

  Denitrification rate: NUR
  Application: COD remuval rate

- Minimum dissolved oxygen: DO_{min}
  Application: Minimum DO at which the nitrification process could operate.

- Sludge age: SRT
  Application: MLSS in the reactor, coherence with actual F/M.

We can get a very useful combined N_C & SRT vs DO diagram
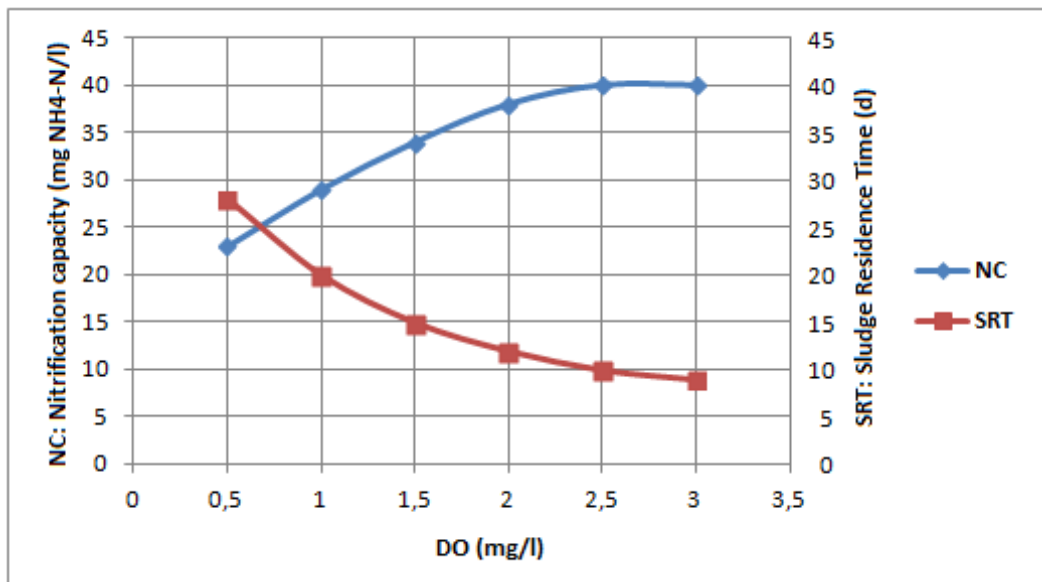

Fig 8. Combined N_C and SRT vs DO diagram

Discussion

In the methods for the protocol described in this paper there are some important key points:
With only one simple and fast respirometry test we could get a practical detection of how the process is performing and possible inhibition symptoms already present in the reactor.
With a couple of respirometry tests we could get the readily biodegradable and refractory COD.
In the same test to determine the biodegradable COD we get the COD removal rate.
The actual nitrification rate at current DO, together with the nitrification rate at maximum oxygen can figure out the actual oxygen half-saturation constant, and from here, we can go to determine the minimum oxygen at which the nitrification could operate and plot one or two important diagrams: Nitrification capacity & SRT vs DO.

Conclusions

1. The use of an advanced multifunction respirometry system able to run a constantly aerated R test at equivalent conditions of substrate concentration, pH, and temperature allows one to obtain the actual maximum respiration rate and endogenous respiration rate due to nitrification.

2. By making use of those parameters obtained in the respirometry test, the method described in this paper is able to calculate a diagram for the different values of nitrification capacity (N_C) corresponding to different representative oxygen levels and, from this curve, to determine the minimum DO range and SRT in which the treatment process could operate.

3. The values of minimum DO, DO range and SRT can be used as the basis to implement an energy efficient strategy of aeration and activated sludge control. In this way, when process conditions allow, there is the real possibility to save energy without any detriment to treatment efficiency.

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