Monitoring the biomass content in the aerobic digestor of a WWTP: correlation between gravimetric and optical methods

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Abstract

The aim of this work is to develop reliable and quick methods to quantify the amount of active biomass in the aerobic reactor of a Wastewater Treatment Plant (WWTP). The removal of pollutants contained in wastewaters is carried out by several processes involving physical, chemical and biological treatments. The biological treatment renders the elimination of the organic matter and takes place in aerobic reactors. A constant concentration of microorganisms in the reactor system ensures a high degradation performance, since an inappropriate biomass amount would hinder the process efficiency. Although the most used method to control microorganisms' growth is based on the measurement of the solids content in the mixture, this simple determination has several drawbacks. First, it is a tedious procedure, which requires more than 24 h-performance, delaying the decision-making and proper control of the sludge recirculation rate. The second disadvantage is the lack of a standardized method for result calculation. Finally, high solids content is not directly related to a big amount of active biomass. In this study, absorbance and turbidity have been selected as additional parameters in order to obtain a reliable correlation between those optical parameters and dry weight measures. A quick measurement of absorbance or turbidity, related to the quantity of solids in the sample, makes the decision-making easier in the everyday operation of the plant.
Keywords: WWTP, biomass, solids content, absorbance, turbidity, correlation.

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1 Introduction

Wastewater Treatment Plants (WWTP) are necessary to reduce the contaminants contained in sewage, before water returns to the environment. The biological reactor is the stage in which organic matter degrades, due to the activity of the microorganisms contained in the sludge. Most plants operate in aerobic conditions, recycling part of the sludge to maintain the level of microorganisms in the vessel and removing their excess. The aeration tank volume of the plant selected in this study is 860 m^3. There, bacteria and protozoa from the activated sludge are fed by pollutants and consequently pollutants are degraded. The key parameter to control that process is the viable biomass, which is troublesome to measure. There have been several proposals to seek an indicator which provides a good measure of the active biomass, such as gravimetric, optical or electrical methods.

One of the most used parameter is the solids content. However, whereas some authors [1] determine Volatile Suspended Solids (VSS), others [2, 3] use Total Suspended Solids (TSS). Methods based on solids content appear to be a good alternative, but they are not immediate and they are not directly associated with viable biomass.

Absorbance can also be a good indicator of microbial growth, although there is no agreement about the most appropriate wavelength. Thus, Muñoz *et al.* [4], selected 650 nm, Jiang *et al.* [5], used 480 nm. Other optical method which can be applied is turbidity, employed by van Benthem and de Grave [6]. Optical methods have the advantage of their immediacy, but interferences can be significant.

Other methods, based on respirometric procedures, may also be suitable for the determination of microbial activity. Oxygen Uptake Rate (OUR) is frequently used [7]. The great advantage of these methods is that they are directly linked to the biological activity of the sludge. However, respirometric rate changes with the age of the sludge, so an exhaustive knowledge of the state of the biocenosis is required.

Finally, studies concerning microbiological procedures could give very detailed information about the sludge. But these processes are complex and costly.

This study has been carried out to compare different parameters used to control the viable biomass in activated sludge. Since all the methods present advantages and disadvantages, we have used some of them to assess the best one as far as time, simplicity and accuracy are concerned.

2 Materials and methods

2.1 Sampling

Activated sludge was sampled from January to May 2010 in the aeration tank of the WWTP in Muskiz (Spain). The samples were taken with a bucket from 6 different points of the tank, and collected in 2-L, polyethylene bottles. They

Figure 1: Aeration tank in Muskiz.

were kept refrigerated during transport to the laboratory, and analysis was made immediately, never exceeding 24 h [8].

2.2 Conductivity, pH and temperature

These three factors were considered as control parameters to verify the correct running of the plant. Conductivity, pH and temperature were measured, just after the sampling, with a *Thermo Scientific Orion 4-Star Plus* portable meter.

2.3 Settleable solids

Settleable solids were measured according to the Standard Methods for the Examination of Water and Wastewater [8] and following the volumetric procedure. The procedure involved filling an Imhoff cone with 1 L of mixed sample. The volume of settleable solids in the cone was recorded after 1 h.

2.4 Biomass estimation

2.4.1 Solids content

Solids content include suspended or dissolved matter in the mixed liquor. The determination of Total Solids (TS) was carried out by sampling 50 mL of mixed liquor and evaporating in an oven at 105ºC during 24 h. Volatile Solids (VS) were determined by heating the residue at 550ºC in a muffle during 1 h,.

The *Whatman GF/C* filters used for the measurement of Total Suspended Solids (TSS) were washed with three successive 20-mL portions of deionised water, and ignited at 550ºC, for 15 min, before use. For the determination of TSS, a 100-mL sample was filtered and the filter was dried at 105 ºC, during 1 h. Finally, the weigh loss after ignition at 550ºC during 1 h, was the Volatile Suspended Solids (VSS).

Total Dissolved Solids (TDS) and Volatile Dissolved Solids (VDS) were measured following the same procedure of the TS and VS, but taking a sample from the filtered liquid.

2.4.2 Absorbance

Absorbance was measured with a *Hελios-α* spectrophotometer. Prior to use, the device was equilibrated, and the baseline was adjusted with a glass cell full of deionised water. Next, the cell was filled with original sample. Since the solids content was high, and they settled fast, the sample was carefully homogenized by magnetic stirring before filling the cell. Absorbance was determined at 400, 500 and 600 nm.

2.5 Turbidity

Turbidity of the mixed liquor was quantified with a *HACH 2100-P* turbidimeter. Two calibration standard solutions of 10.0 and 500 NTU were used. After the calibration, each sample was introduced in the cell to measure the turbidity.

2.6 Experimental design

2.6.1 Calibration curve

In order to correlate the gravimetric and optical results the original mixed liquor was previously mixed with deionised water at different dilution ratios. Mixtures with a 0:10, 1:9, 2:8, 3:7, 4:6, 5:5, 6:4, 7:3, 8:2, 9:1 and 10:0 (v/v) ratio were prepared. The absorbance and turbidity of each solution was measured and results are shown in figure 2. In order to achieve a high correlation coefficient, the last three points of each curve were not considered.

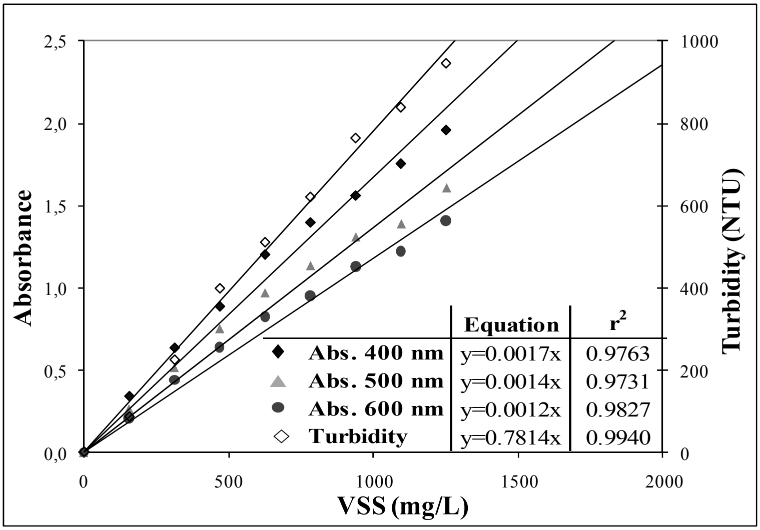

Figure 2: Calibration curve between VSS and optical parameters.

As shown in figure 2, gravimetrical and optical methods correlated well. Nevertheless, if the sample has a high VSS content, dilution of the sample until VSS values lower than 1500 mg/L is recommended before measuring the absorbance or turbidity. Thus, the experimental results will be within the studied range and within the best fit.

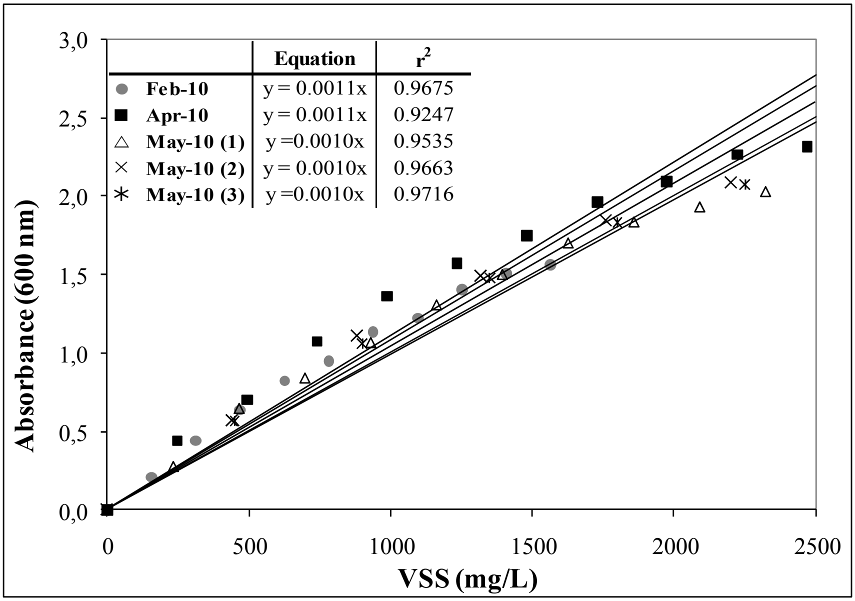

Figure 3: Calibration curves between VSS and Absorbance at 600 nm.

As shown in figure 3, calibration curves with samples collected at different dates showed similar equations. The absorbance results of samples collected during consecutive months revealed that the ratio between this parameter and the VSS content remained constant.

3 Results

The control of the "quality" of the incoming wastewater, in terms of pH, conductivity and solids content, is compulsory.

The sewage pH and conductivity values throughout 8 months of operation are represented in Figure 4 (data provided by the operators at the WWTP in Muskiz). The pH values ranged between 7.1 and 7.8. However, in some unexpected moments (November, February and April), certain values were out of this range, probably due to sporadic industrial spilling or sea-water intrusion episodes. During, those episodes, high conductivity values (up to 1500 µS/cm) were also recorded. Conductivity values usually ranged from 500 to 1000 µS/cm during regular operation.

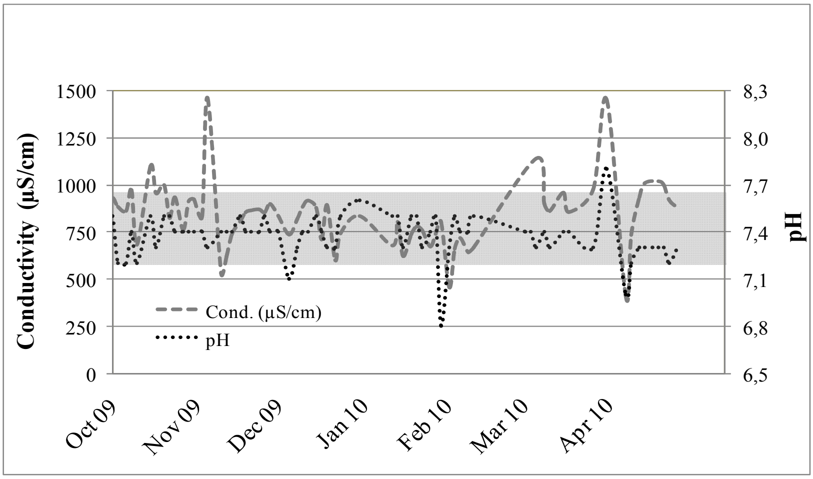

Figure 4: Evolution of incoming sewage pH and conductivity.

During the project, several samples were taken and experimental work was carried out once a week. The results obtained in different sampling points, as well as in different operations times, were very similar. According by, and in order to avoid repetitivity some of the results have been omitted and the average representative value for each month has been shown.

The results of the solids content from January to May are shown in Table 1.

Table 1: Solids content average in the mixed liquor.

	TS (g/L)	VS/TS	VSS (g/L)	VSS/TS
Jan-10	2.43	0.62	1.56	0.64
Feb-10	2.42	0.64	1.56	0.64
Mar-10	2.90	0.69	1.85	0.64
Apr-10	3.99	0.73	2.47	0.62
May-10	3.19	0.71	2.26	0.71

The TS values were constant for the first months. Nevertheless, these values were higher during the last sampling months due to the increase in the sludge recirculation rate in the aerobic step.

During this period of time, calibration curves were obtained to correlate the absorbance and turbidity with the solids content. The criterion followed to validate calibration curves was that VSS values obtained by gravimetrical methods differed less than 10% from those calculated from the correlation curve, obtained by optical parameters.

4 Conclusions

The following conclusions were obtained:

- Optical methods, such as turbidity and absorbance, are highly recommended as reliable and fast alternatives to measure the VSS content in wastewater.
- The selection of a high wavelength is recommended to minimize the interference generated by the TDS.
- When the sample has a high VSS content, dilution until VSS values lower than 1500 mg/L is advisable before measuring the optical parameters.
- The absorbance results of samples collected during consecutive months revealed that the ratio between this parameter and the VSS content remained constant.

Nevertheless, further research about microbiological parameters is required. Consequently, in order to reach a better knowledge of the viability of the biomass in the aeration tank, we are currently conducting a further study about the microbiological state of the biomass.

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