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DOSES REGULATION IN ANAEROBIC TREATMENT OF WASTE WATER: THE CASE OF A MOROCCAN PAPER INDUSTRY

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ABSTRACT: Since 2012, Moroccan kingdom had established new laws concerning the regulation of the waste water quality that should require certain qualifications to be thrown to nature. The problem was that by making the choice of having an anaerobic treatment trough an UASB (for Upflow Anaerobic Sludge Blanket) to get rid of the pollution we were confronted to an important sensitivity related to the dosing of the different reagents made to regulate the nutrition of the anaerobic cultures which ensure the pollution degradation. This paper was made to reduce the gap between the doses of reagents that are injected in every stage of the treatment and the doses that should be injected to insure the environmental requirement at the output of the station by considering the HRT “hydraulic retention time” and the large variability of the waste water composition that heads to the station, normally we can’t rely on the analyses made at the output of the treatment to adjust the doses that’s why we chose to combine the analyses made at the input of the treatment with the ratios mentioned earlier to find a way to adjust the doses to avoid an excessive injection or a lack of nutriment that may reduce the effectiveness of the treatment. This way, it will be economically and environmentally optimized to correct the doses just in time according to the input composition of the waste water.

Keywords: Anaerobic Treatment, Paper Industry, Waste Water Calibration.

1. INTRODUCTION

This paper summarizes a large study which was conducted on a water treatment station recently implemented within a Moroccan paper industry to reduce the pollution of its waste water, generated from the manufacturing process. This study was conducted during a period of five months to analyze the reaction of the biological treatment to different combinations of waste water composition.

The problem was that the paper industry generates an unbalanced waste water composition which lacks the nitrogen element considered as an important element of the bacterial growth.

The actual managing way was by adjusting the different doses of each nutritive element based on the output performance of the station, thus the hydraulic retention time delays the response of the methanation by at least five hours, which may induce a large difference between the actual needs in the input and the doses made relying on the output analysis. Otherwise the input characterization of the waste water is very inconstant because of the changing pace of the manufacturing process due to maintenance issues.

Through this paper we managed to elaborate a just in time injection mode to adjust the doses so that the waste water can be nutritionally balanced, because we cannot afford destabilizing the micro-organic anaerobic cultures known to be very sensitive to composition changes of waste water

2. WASTE WATER CONDITION

2.1 The Chemical Composition

2.1.1 The nutritional composition

The analysis results of the waste water revealed the specific lack of nitrogen and phosphorous in the chemical constitution of the paper industry’s waste water. But theses chemical elements are irreplaceable to perform a biological degradation of any pollution, and if any of these tow must be less than what is needed, the depollution process will fail.

This paper will be limited to the result related to nitrogen and phosphorous, considered as the most important element that our waste water is short of.

2.1.2 The concentration variability

The Chemical oxygen demand (COD) of the waste water is very inconstant due to the different causalities that happen through the manufacturing process. This variability is presented on the figure 1 below:

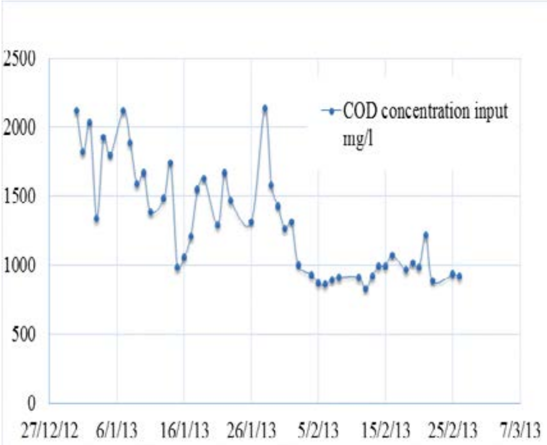

Fig.1. COD concentration at the input of the Upflow Anaerobic Sludge Blanket

As shown in the Fig.1, the COD concentration is varying considerably between 2120 mg/m3 and 830 mg/m3. This concentration variability of the COD may induce a great disorder to the biological activity among the methanation, and especially if the nitrogen and phosphorous doses injected are not enough to insure the needs of the biological cultures.

2.1.3 The total alkalinity

We are going to consider it as a “second plan “parameter of the study compared to the nitrogen and the phosphorous. The regulation of this parameter based on the output analysis results was summarized through Fig.2:

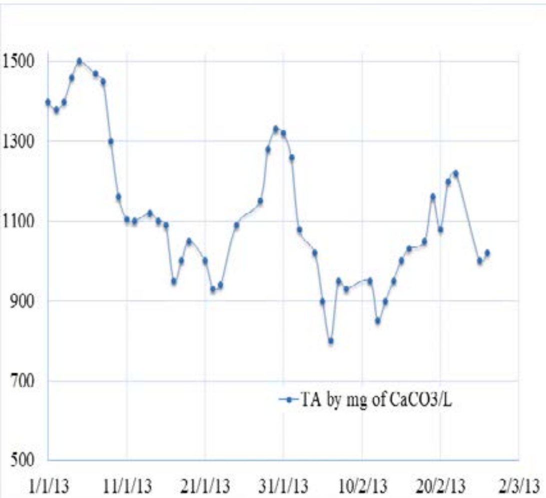

Fig.2. Variation of alkalinity inside the Upflow Anaerobic Sludge Blanket

Through the literature we found that the total alkalinity must remain above a value of 1500 mg of CaCO3 per liter to ensure optimal results of the biodegradation and its stability.

2.1.4 Temperature

During the period of the study we’ve recorded the multiple values of the temperature among the bioreactor that we presented in the following graph:

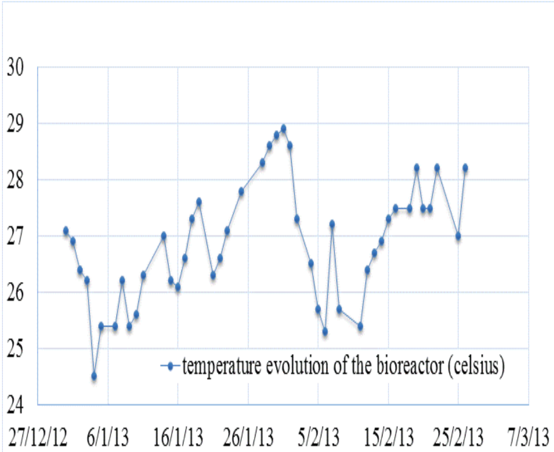

Fig. 3:Variation of temperature at the output of the Upflow Anaerobic Sludge Blanket

As we can see in Fig.3, the temperature varies between 24,5°C and 29°C during the winter considered sufficient to the biological activity through a mesophilic treatment that requires an optimal temperature between 25°C to 40°C.

3. DATA ANALYSIS AND RESULTS

3.1 Nitrogen Calibration

As presented on Fig 4, the managing process used to adjust the doses of nitrogen seems to present a large difference between the quantity injected and the one needed to ensure satisfying purification efficiency at the output of the station.

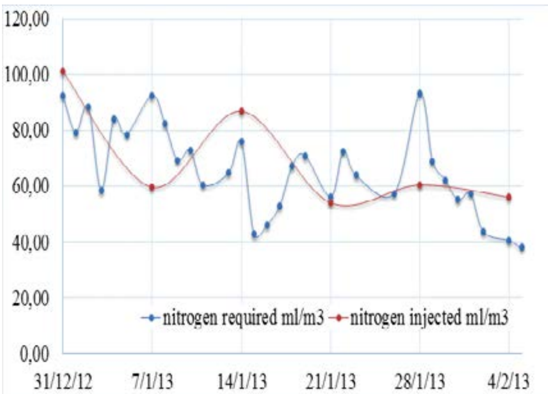

Fig. 4: The difference between nitrogen required and the dose injected for calibration

This gap is generated by the dependence of the managing process on the output analysis results that doesn’t reflect the actual need for nitrogen in the waste water composition.

The curve of the nitrogen needed was generated based on ratios COD:N found by (Henze and al 1983, Stronach and al 1987) and was given a value between 400:7 to 1000:7 depending on the volumic load, high and low respectively. We assumed, based on the variation of the volumic load of the reactor that it was working under a low organic loading. Under these circumstances we chose the ratio COD:N with the value of 1000:7.

The nitrogen supply was made by a solution of urea with the chemical formula $\mathbf{CH_4N_2O}$ the concentration of the solution was about 33% and a density of 1.09 g/ml and 60 g/mole. The following equation was elaborated based on the ratio given by "Henze and al 1983, Stronach and al 1987" combined with the specific characteristics of the urea:

$$V_{CH_4N_2O} = \frac{COD * 7}{1000} / (\alpha * d)$$

α=0.15
d= 1.09, the density of the urea solution.
$V_{CH_4N_2O}$: represents the dose of urea that should be injected to the waste water to satisfy the needs of the anaerobic bacteria inside the methanation reactor. The α value represents the mass representative share of the nitrogen atom in the solution weight.

3.2 Phosphorous Calibration

The same goes also for the dose of phosphorous that is added to the waste water at the entrance of the station as we can clearly see trough Fig 5.

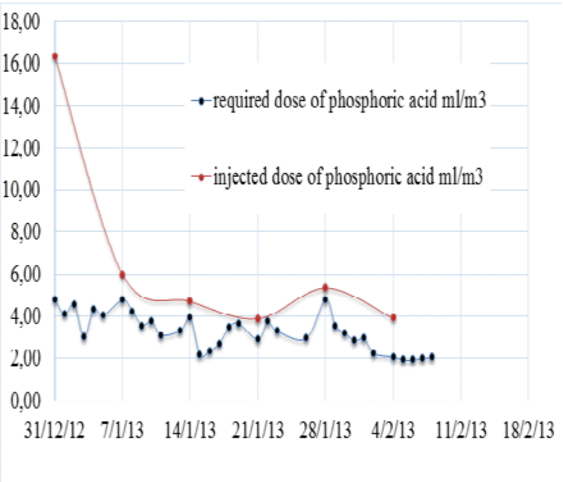

Fig.5. The difference between the doses of phosphoric acid needed and the one injected to the bioreactor

The phosphorous supply is realized by a solution of phosphoric acid with the chemical formula H_3PO_4 and a concentration of 85% and a density of 1.686. The N:P ratio was evaluated to 7:1 (Henze and al 1987).

By combining the result of the last equation and the ratio N:P estimated to be sufficient at a value of 7:1 we get the following equation that gives the actual need of phosphoric acid for the biologic cultures:

$$V_{H_3PO_4} = m_P * \frac{M_{H_3PO_4}}{0.85 * M_P * d}$$

m_P: Mass of phosphorous required by g/m^3 of waste water
Mp: Molecular weight of phosphorous
$\boldsymbol{M_{H_3PO_4}}$: Molecular weight of the phosphoric acid
d: is the density of the solution
The concentration of the solution is 85%

As we've presented earlier, the composition of the waste water lacks completely the presence of any of these two elements. So the doses needed must be completely provided from the outside.

3.3 Ratios Evolution

3.3.1 Ratio COD:N

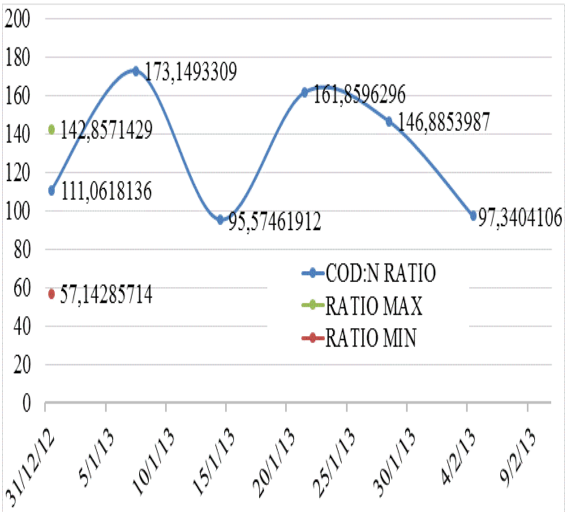

Fig.6. the variation of COD:N ratio under the minimum needed

The ratio COD:N must be kept around the 1000:7 value, considering that the reactor works under a low organic charge. Every time that the ratio COD:N goes above 1000:7, the anaerobic reactor lacks nitrogen. This means that the methanation yield drops under the desired value, and the bacterial activity may be damaged irreversibly.

3.3.2 N:P Ratio

This ratio must be kept around the 7:1 value, and by analyzing the graph below we can see that we never manage to get it near the desired value. This means that we are short of nitrogen or that we are excessively injecting the phosphoric acid, in both cases the methanation process fails.

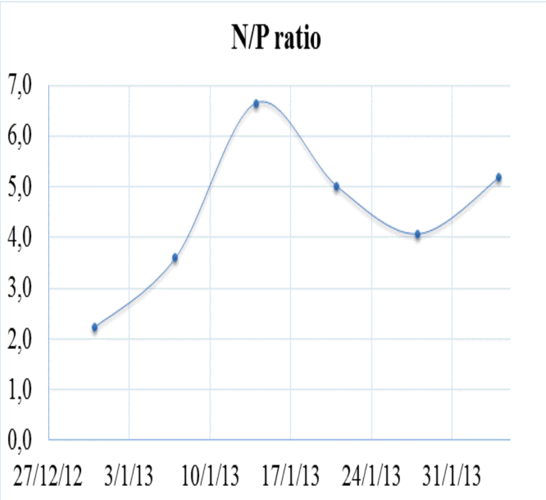

Fig. 7: variation of the N:P ratio

4.1 Nitrogen graph

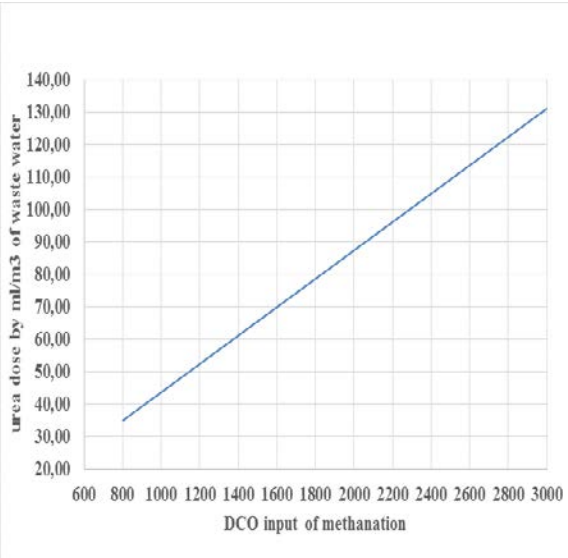

Fig.8. the need of urea to be injected calculated from the result of the input value of COD

We can directly evaluate the actual need of urea once we have the results of the waste water analysis at the input of the methanation reactor.

3.2 Phosphorous graph

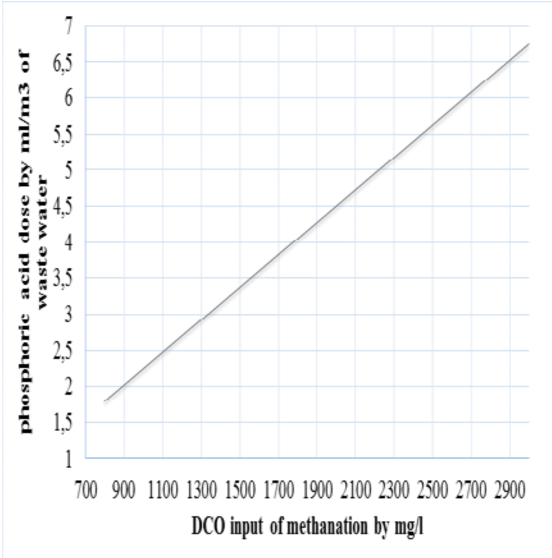

Fig. 9 the need of phosphoric acid to be injected calculated from the result of the input value of COD

The dose of phosphoric acid can be evaluated directly from the graph based on the COD concentration at the input of the methanation.

4.3 Main Target

By making the right adjustment at the right moment the methanation yield may reach 90%, but only with these two important elements adjusted at the right time we will be able to achieve at least 70% degradation of the COD. The difference between the actual managing process and the one proposed, may be more explicit through the graph below:

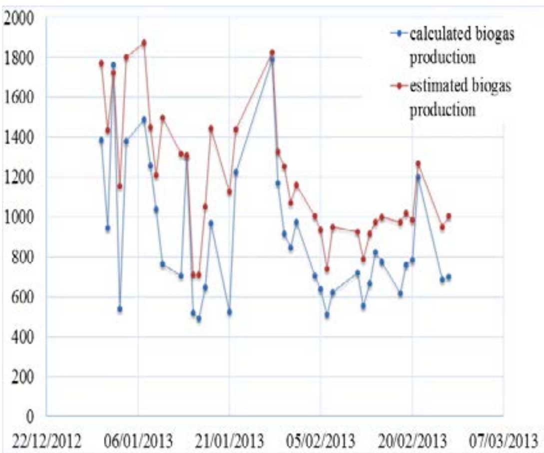

Fig.10. The difference between the actual production of biogas and the one that should have been producted if calibration is done based on the graphs above.

The surface between the two curves represents the large amount of biogas that can be disposed of in case we provide the nutriments to calibrate the waste water before it reaches the microbiological cultures. The graphs that provide the required doses of nitrogen and phosphoric acid can be generated for every station based on its specific organic load and the characteristics of the solutions ensuring the supply.

4. CONCLUSION

By using the previous equations we may maintain the methanation yield, at least, up to 60% and reduce the excessive injection of any one of the reagents, specially the phosphoric acid that may reduce the potential of hydrogen below the methanation adequate pH, reducing by that the bacterial activity. We manage to combine all these data to come up with a quicker way to adjust the nitrogen and phosphorous doses based on graphs corresponding the COD concentration of the waste water to the required dose of the reagent.

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