

**REPORT:** Monitoring report

**COMPANY:** Mecàniques Segalés, S.L.

**TITLE:** Results of the standard sampling of the NDN plant of " El Banús ".

**DATE:** November 2017



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**TREATMENT EFFICIENCY EVALUATION OF A NDN PLANT PROCESSING SLURRY:  
AUTUMN STANDARD SAMPLING.**

**ACTIVITY MONITORING REPORT**

**Revision: 1**

**Date:** 18th November 2017

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## 1. PRECEDENTS

The objective of the present study is the determination of the treatment efficiency, with special emphasis on nitrogen, of an NDN plant that processes slurry. A total of 4 samplings will be carried out, one for each season of the year, to see the influence of the ambient temperature in the process. Two types of sampling will be carried out, that are called standard sampling process photo and intensive sampling of the NDN reactor.

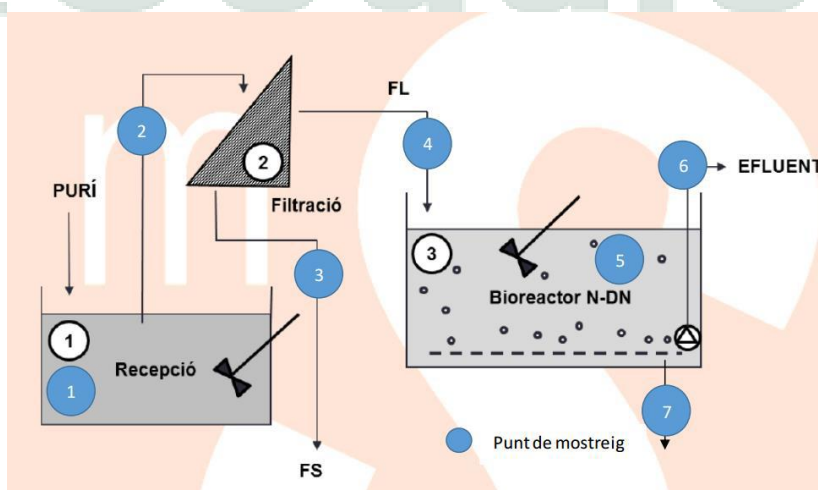
Los resultados que se presentan en este informe son del muestreo realizado en otoño (2 de Noviembre de 2017).

## 2. METHODOLOGY

In this sampling campaign, a standard sampling process photo was carried out, as agreed in the collaboration agreement. Samples have been taken of the different inlet and outlet streams of the plant as well as the mix liquor of the reactor after bringing 45 minutes into the aeration phase. Finally, the data of the flow meters installed in the same plant have also been collected to quantify the flows that circulate through the system and be able to perform the efficiencies of elimination of the separator and of the biological reactor in charge of nitrification-denitrification (NDN).

### 2.1 Description of the plant and the NDN reactor cycle

The pig slurry treatment plant that has been evaluated is located at the livestock farm of " El Banús " (Tavèrnoles, Osona). The flow chart and sampling points are indicated in Figure 1.



**Figura 1:** Diagrama de flujo de la planta NDN los puntos de muestreo

The pig slurry arrives at a reception and homogenization raft. This passes through a Solid-Liquid separator consisting of a static sieve and a screw press of Segalés brand. The liquid fraction (FL) of the slurry passes to the NDN reactor and the solid fraction (FS) to the storage of solids. In the NDN reactor is where the elimination of nitrogen occurs through the process of nitrification and denitrification of slurry. The cycle lasts 12 hours with two feeds per day. The separator starts up for 15 minutes and the FL enters directly to the reactor; the aerobic stage begins with submerged aeration (nitrification) for 2 hours and then 1 hour of non-aeration stage (denitrification) without agitation for the first 45 minutes. These alternations of stages with and without aeration are repeated 3 more times until reaching 12 hours of cycle and then a void is made, that goes to the final raft. The mud purge is made according to the V30, with an approximate periodicity of a weekly purge. The purge is returned to the head of the plant and mixed with the inbound slurry.

## 2.2 Standard sampling process photo

This sampling consists of taking the liquid and solid samples in the different sampling points of the installation. A sample has been taken before and another sample after each treatment unit, lungs or storage tanks and for each of the resulting streams. The sampling points are indicated in the flow diagram of the plant (Figure 1). Likewise, the flow of each one of the currents of the installation has been noted, on the points where totaling flowmeters were available. In this case, the efficiency of the solid-liquid separator was also made.

Sampling was done on November 2017. The samples were kept refrigerated until the moment of analysis. For each of the samples of the standard sampling the following analytics have been carried out (Table 2).

**Table 2.** Characterizing parameters of the samples.

Standard sampling	Analytics
Indicated samples Figure 1	pH, CE, ST, SV, DQOt, NTK, N-NH <sub>4</sub> <sup>+</sup> , NO <sub>x</sub> <sup>-</sup> , PT, K.

*CE: Electric conductivity / ST: Total solid / SV: Volatile solids / DQOt: Chemical Demand of Oxygen / NTK: Nitrogen Kjeldhal Total / N-NH<sub>4</sub><sup>+</sup>: Ammoniacal nitrogen / NO<sub>x</sub>: Nitrites i Nitrates / PT: Total phosphor / K: Potassium*

## 2.3 Physicochemical analytical methods

The majority of the analytical characterization of the samples of the different plants are carried out in accordance with the methods described in the IRTA-GIRO quality manual (ISO 9001),

adapted from specific methodologies of the Standard Methods for the Examination of Water and Wastewater (APHA, 1995). The analytics made were the following ones:

- PH measurement by specific electrode, IT-MI-004.
- Determination of electrical conductivity (CE), IT-3006-L-004.
- Content in total solids (ST) and volatile (SV) by drying and calcination, IT-MI-L-0001.
- Content in organic matter by determining the Chemical Oxygen Demand (COD), IT-MI-003.
- Total Kjeldahl nitrogen content (NTK) by digestion and distillation-valuation; IT-3006-L-011.
- Content of ammoniacal nitrogen ( $\text{N-NH}_4^+$ ) by distillation-valuation; IT-3006-L-010.
- Determination of anions by ion chromatography, ( $\text{NO}_3^-$ ,  $\text{NO}_2^-$ ); IT-3006-L-009.
- Potassium content by cation chromatography ( $\text{K}^+$ ); IT-3006-L-046.
- Content of total phosphorus by acid digestion and measured by spectrophotometry, IT-3006-L-044.
- Solid content total suspended (SST) and volatile (SSV) by drying and calcination, IT-MI-0002.
- Determination of alkalinity measured by valuation, IT-MI-L-005.

#### **2.4 Efficiency of the solid – liquid separator**

The efficiency of the liquid solid separator has been calculated by measuring the excess of solid fraction (FS) obtained from the treatment of a known volume of slurry and the composition of the slurry and the resulting fractions (liquid fraction and solid fraction) have been analyzed. The volume of slurry treated has been calculated from the reading of the totalizer flowmeter installed in the separator and the excess of FS has been measured by collecting it in a drum and weighing it in a balance.

### **3. RESULTS**

#### **3.1 Samplings and readings y lecturas meter**

The ambient temperature at the beginning of the sampling was 18°C and there wasn't so much wind. 6 points of the plant were sampled. The samples that were collected are consolidated in Table 3.

Also the reading of the 3 totalizing flowmeters that there are into the plant was made, as well as the value of the electrical consumption until the moment of the sampling; the readings made are summarized in Table 4.

**Table 3.** Samples collected in the Segalés plant and description of the sampling point.

Nº		Sampling name	Description sampling point
1	P	slurry	At the entrance of the separator
2	FS	Solid fraction	Separator's exit
3	FL	Liquid fraction	Entry pipe to the reactor
4	LM	Mix liqueur	Raft reactor surface (4 samples in different stages of the cycle)
5	E	Efluent	Exit pipe reactor towards the final raft
6	Fg	Purge of mud	Sample sent by Segalés on 07/07/17

**Tabla 4:** Lecturas de los caudalímetros y consumo eléctrico de la planta recogidas el día 02/11/17.

VTn	Lectura		m3	Descripción lugar caudalímetro
	03/07/2017	02/11/2017		
VT1	63,06	2897,16	m3	Volumen total entrada a la planta. A la salida balsa recepción. Caudalímetro situado en la plataforma del separador.
VT2	140,28	2511,469	m3	Volumen total de salida del reactor. Caudalímetro situado en la entrada de la balsa final
VT3	37,5	265,1766	m3	Volumen total de la purga de barro
Contador eléctrico	3184	11943,8	kW	

### 3.2 Characterization standard sampling treatment system

The results of the characterization of the treatment plant samples as described in the standard sampling are collected in Table 5. The most relevant aspects are detailed below.

The entering slurry to the treatment plant (sample 1) has a pH of 7.90 and a total solids content of 2.48%. The initial slurry sample is characterized by high values of organic matter and total and ammoniacal nitrogen of 25.976 mg COD / L, 2.082 mg NTK / L and 1.510 mg N-NH4 + / L, respectively, higher values than in the samples taken in July 2017 (table 7 of the sampling report for the month of July 2017). It also should be noted that the presence of nitrates in the entering slurry (14.0 mg N-NO3- / L), perhaps due to the oxidation of a small amount of ammonium thanks to the oxygen from the slurry transfers in the different rafts.

The liquid fraction obtained in the solid-liquid separator has a lower number of solids concentration than the entering slurry, the expected result in this equipment. The DQO in this current also decreases substantially because part of this DQO is found in a particulate way and is separated in the solid fraction of the separator's way out. Regarding the nitrogenous species, NTK and  $\text{N-NH}_4^+$ , this decrease is not relevant, therefore it is considered that the nitrogenous compounds are dissolved in the liquid and leave in the same liquid fraction of the separator.

In the NDN reactor exit effluent (sample 5) a decrease in the total solids is observed, although the volatiles remain quite constant respecting the inbound current to the reactor (liquid fraction). If we look at the DQO at the exit of the reactor, a decrease in this parameter can be observed, indicating a microbial activity in the reactor itself due to the oxidation of the organic matter in both phases of the reactor, aerated and not aerated.

Regarding the nitrogen and especially if we focus on the ammonium, we see a clear decrease in these parameters indicating that the NDN system works correctly by oxidizing the ammonium present at the beginning of the SBR cycle and without observing the presence of nitrites or nitrates in the mixed liquor sample collected.

Even so, the ammonium concentrations inside the reactor ( $297 \text{ mg N-NH}_4^+ / \text{L}$ ) are higher than would in an optimal work that is bibliographically described, that they would have to be lower than  $150 \text{ mg N-NH}_4^+ / \text{L}$  to avoid possible inhibitions of microorganisms. This may suggest that there is acclimatization on the part of the bacteria in charge of nitrogen elimination, as mentioned in the previous report corresponding to the July 2017 sampling.

Turning to phosphorus, observing the results at the entrance and exit of the biological system we can see a decrease in this parameter, indicating elimination of this compound.

With the results collected to the plant, in referent to the electrical consumption and the flows of the different currents, it has been calculated that the energy consumption per cubic meter of slurry treated is  **$3.09 \text{ kW} / \text{m}^3$** .

**Table 5.** Results of the characterization of the samples of the monitoring of the NDN plant of " El Banús " November 2017..

Codi	nº	Nom	Descripció	pH	CE mS	ST %	SV %	DQO mg/kg	NTK mg/kg	N-NH <sub>4</sub> <sup>+</sup> mg/kg	N-NO <sub>3</sub> <sup>-</sup> mg/kg	N-NO <sub>2</sub> <sup>-</sup> mg/kg	K <sup>+</sup> mg/kg	Ptotal mg/kg
17-06795-LMG	1	P	Purí entrada sistema.	7,9	12,14	2,48	1,59	25.976	2.082	1.510	14	0	1.165	302
17-06797-LMG	2	FS	Fracció Sòlida	8,25	2,27	29,48	25,07	482.043	8.241	2.486	0	0	776	1582
17-06796-LMG	3	FL	Fracció Líquida a NDN	7,89	12,27	1,74	0,86	18.663	1.939	1.468	19	0	1.180	335
17-06809-LMG	4	LM	Reactor LM Segalés	8,11	5,8	1,47	0,75	11.365	764	297	0	0	813	259
17-06798-LMG	5	Ef	Efluent NDN	8,06	5,72	1,43	0,75	11.151	713	276	0	0	1.117	264
17-06799-LMG	6	Fg	Purga NDN	-	5,92	1,44	0,44	15.134	797	297	0	0	-	-

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### 3.3 Efficiency of the solid – liquid separator

Table 6 shows the reduction of the different compounds analyzed in the liquid fraction in relation to the inbound slurry.

**Table 6.** Efficiency of the separator for the different compounds..

Reducción en la Fracción Líquida (%)	
ST	14,03
SV	18,61
DQO	21,90
NTK	4,67
N-NH4+	1,94
N-NO3-	0,00
N-NO2-	n.d
K	0,79
P	5,1

The separator has lower efficiencies than those presented in the report of the samples collected from July 2017 (table 9 of the sampling report for the month of July 2017). The separation of volatile solids was reduced by 14%, from 32.45% in July 2017 to 18.61% in November of the same year. The separation in the total solids that currently represent 14.03% has also decreased, decreasing almost 10 percentage points respect the sampling separation efficiencies of the month of July. As for the other species there is also a slight decrease in respect to the first sampling, but to the compounds that are normally dissolved in the liquid itself, this decrease in the efficiency of the separator does not affect them as much.

### 3.4 System balance

Table 7 and Figure 2 show the distribution of too much nitrogen in the different input stream and output stream of the treatment system, and Figure 3 shows the distribution of the different components in the treatment system flows.

**Table 7.** System N flows

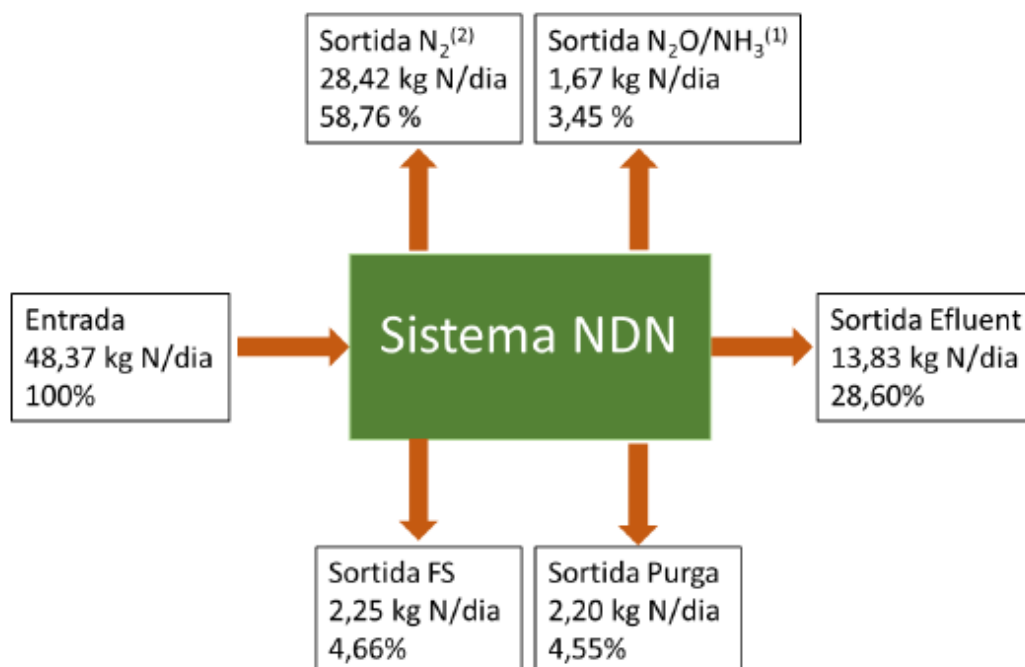
	Entrance		Solids outletsalida		Output Purge		Emissions (1) N2O/NH3		Emissions (2) N2		Effluent	
	Kg/día	%	Kg/día	%	Kg/día	%	Kg/día	%	Kg/día	%	Kg/día	%
<b>N (kg/día)</b>	48,37	100	2,26	4,66	2,20	4,55	1,67	3,45	28,42	58,76	13,83	28,60

(1) This value is calculated from the results obtained in the emissions that were measured and analyzed in the sampling of the month of July.

(2) Estimated value from the closure of the global nitrogen balance.

During this last sampling that took place on November 2, 2017, it can be observed that during this period a total of 2,834.1 m<sup>3</sup> equivalent to 48.37 kg N total / day was treated, about 10 kg N / day more than in the same system sampling from July of the same year. In the solid-liquid separator a total of 95 tons of solid fraction was obtained during this period, equivalent to 2.26 kg N total / day, which represents 4.66% of all the nitrogen that enters the system. At the outlet of purged sludge from the reactor, 4.55% of the total nitrogen entering the system is eliminated, which represents 2.20 kg N / day. This sampling did not analyze the atmospheric emissions of the different forms of nitrogen (NH<sub>3</sub> and N<sub>2</sub>O) that can leave, but these emissions have been estimated taking into account the results obtained in the previous report, where 3.45% of the total nitrogen at the entrance to the plant was issued in the form of N<sub>2</sub>O and NH<sub>3</sub>. Thus, with this estimate, 1.67 kg N / day are emitted in the form of N<sub>2</sub>O and NH<sub>3</sub> and the rest, 28.42 kg N / day in the form of N<sub>2</sub>, which represents 58.76%, a value higher than that obtained in the previous sample corresponding in July of 2017 it was 50.93%.

With all this we can say that the efficiency of the treatment system in relation to incoming Nitrogen is 67.97% counting the different outputs of the system, plus emissions in the form of NH<sub>3</sub> and N<sub>2</sub>O of 3.45%. This nitrogen that comes out through the Solid Fraction and the purge must be managed correctly. A graphic representation of the distribution of flows is shown in Figure 2.



(1) This value is calculated from the results obtained in the emissions that were measured and analyzed in the sampling of the month of July.

(2) Estimated value from the closure of the global nitrogen balance.

**Figure 2.** Balance of the global nitrogen system

Regarding the material balance (Figure 3) it indicates that the system eliminates a large amount of organic matter (66.87% of COD elimination), although how in the previous sampling this elimination could be in the form of CH<sub>4</sub> that would be emitted to the atmosphere in an uncontrolled way. There is also a high biological elimination of nitrogen and ammonium present in the inlet stream (about 62% and 82% biological removal respectively). As for phosphorus (P) it is reduced by 36.64% and potassium (K) also decreases, possibly partitioning comes out in the mud purge.



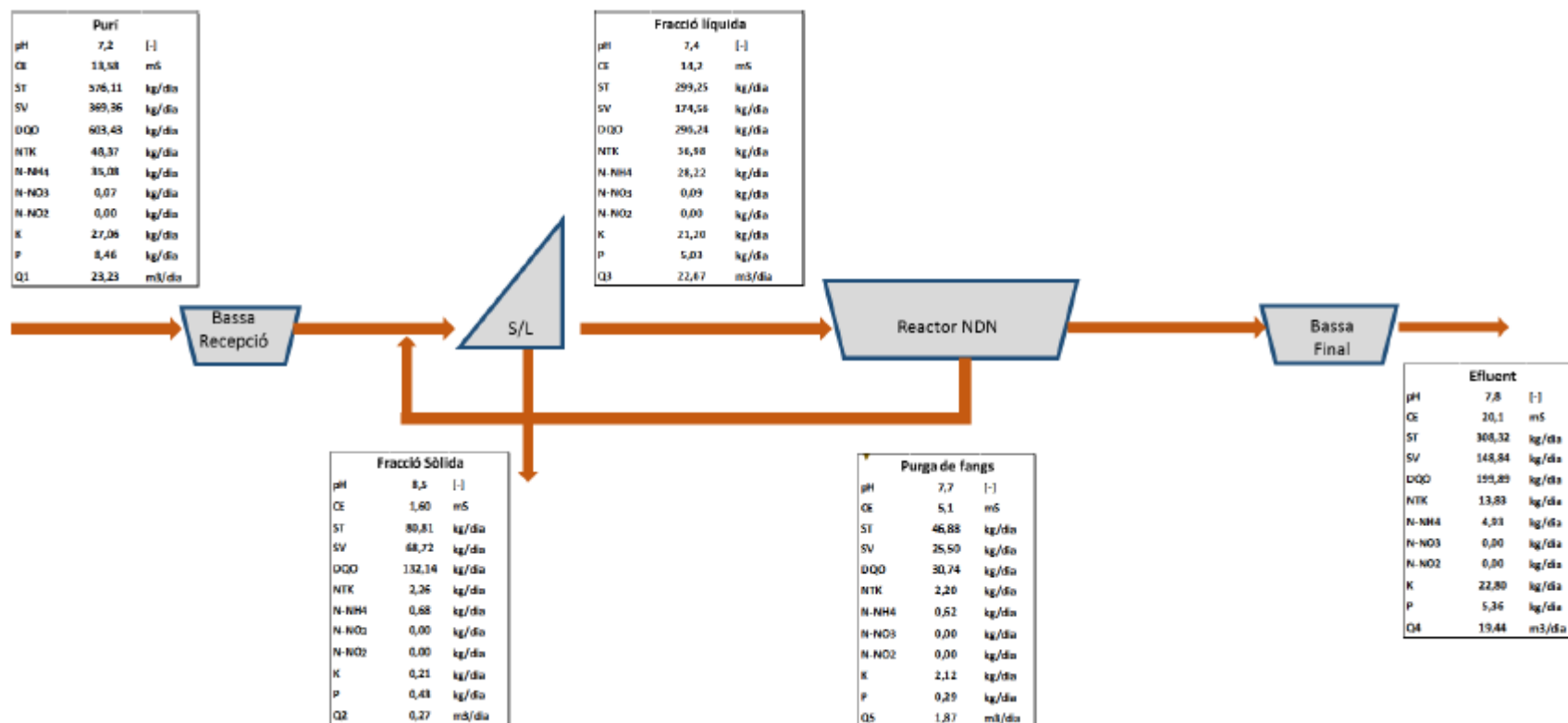


Figure 3. Balance de materia del sistema

#### 4. CONCLUSIONS

1. Comparing the results obtained in the November 2017 sampling with those made in July of the same year, an increase in the input concentrations of the nitrogenous species and organic matter (COD) can be observed.
2. From the readings of the different flowmeters-totalizers it can be indicated that the plant treated a total of 2,834.10 m<sup>3</sup> during the period July 2017 (03/07/2017) - November 2017 (02/11/2017). And has treated a total of 48.37 kg N / day.
3. From the characterization of the samples of the standard sampling and considering the gaseous emissions of the sampling of July of 2017, a balance has been made of the different components of the system:
  - a. Regarding the organic matter, the treatment system eliminates 25.51% in the form of volatile solids and close to 67% in the form of COD.
  - b. Phosphorus is eliminated by 36.64%, mostly by purging muds, where part of the potassium content is also eliminated, which is reduced by 15.74%. En cuanto al nitrógeno este se elimina en un 4,66% a través de la fracción sólida, un 4,55% a través de la purga y se estima que un **58,76%** en forma de N<sub>2</sub>.
  - c. Considering that the solid fraction and the purge are exported from the system, a total nitrogen removal of **67.97%** can be considered.
4. For the one that makes the energy consumption, taking into account the readings of the flow meters and the electricity meter, it has been calculated that the NDN plant of " El Banús " has a consumption of **3.09 kW / m<sup>3</sup> treated**.

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Elaboration template: Working group Data: February 2013	Template approval: Agustí Fonts Data: 29 July 2014
Template review: Rev.1 / Data: February 2013 Modifications to previous versions: Rev.1 February 2013 Rev.4 The logo of the template results has been removed	

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