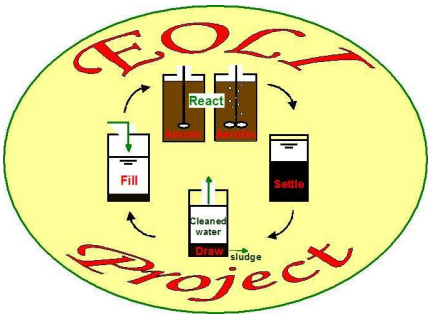
INCO : International Scientific Cooperation Projects (1998-2002)

Contract number : ICA4-CT-2002-10012

ANNEXES

OF THE FIRST ANNUAL REPORT:
covering period from 1 November 2003 to 31 October 2003

Efficient Operation of Urban Wastewater Treatment Plant (EOLI)



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CONTENTS

MEETING REPORTS

November 2002 -October 2003

Minutes of the EOLI Kick-off Meeting in Narbonne – France
November 7-9, 2002

Present: Denis Dochain (Coordinator) and Hadyan Fibrianto [Cesame-UCL], Jérome Harmand, Jean-Philippe Steyer, Michel Torrijos, Djalel Mazouni and Abdou Dramé [LBE-INRA], Germán Buitrón, Jaime Moreno and Cristina Verde [UNAM], Rafael Canetti [UU], Jorge E. Lopez [IBTech], Alberto Rozzi and Elena Ficara [DIIAR-Polimi], Luca Luccarini [ENEA], Paolo Ratini [SPES], André Pauss and Thierry Ribeiro [Gradient-UTC].

1. Introduction

According to the EEC news, the EOLI project start officially on November 1st, 2002. All contacts to the EEC must be done via the coordinator. Mrs. Isabelle Hisette (hisette@auto.ucl.ac.be) of the Cesame, UCL is the secretary of the project.

All works must respect the contract schedule.

In this first meeting, 4 work packages are discussed: WP1 (process experiments), WP2 (model selection and parameter identification), WP3 (hardware sensor) and WP8 (validation and integration).

2. WP1 – Process experiments

This work package is coordinated by Germán Buitrón of the UNAM. Five partners (+1 subcontractor) are directly involved in this WP: UNAM, IBTech, UU, LBE and POLIMI (+ENEA as subcontractor). Seven reactors are used in this project: one of UNAM, one of IBTech, 2 of UU, one of LBE Narbonne and 2 of ENEA (POLIMI).

2.1. UNAM and IBTech Reactors

The capacity of the reactor is 7 *l*. The inlet flow rate of the reactor is controllable. Therefore, a *fed-batch* reactor can be considered here. This reactor is equipped with a mixer (to have STR configuration), of which the speed is adjustable, and aeration circuit (aerobic digestion) with adjustable flow rate.

The substrate to be treated is Chlorophenol. The measurements can be effected on pH (but not controllable), temperature in the reactor, dissolved oxygen (on-line) and TOC (off-line). The sampling time is between 10 minutes (min.) and 30 minutes (max.).

The control variables can be the inlet flow rate and temperature.

The acclimation effect of the biomass is studied. PhD and Master students and some technicians are working using this reactor. There is also cooperation with Claudia Etchebere from UU.

2.2. UU Reactors

The wastewater to be treated is milk effluent dairy industry). Two batch reactors will be available (06/2003).

The possible measurements are pH, T, OUR, redox potential (on-line), NH_4^+, NO_2, NO_3, total and soluble COD (off-line). The control variables are pH and temperature.

Three organizations are involved: Reactor dept. of the Chemical engineering institute (Maria Viñas), Microbiology dept. of the Chemical faculty (Lucia Muxi, Claudia Etchebere), and Control dept. of the Electrical engin. institute (Rafael Canetti).

PhD students are working in this project.

2.3. LBE/ INRA Reactor

The capacity of the SBR that will be available (before 06/2003) is 200 litres. The wastewater to be treated is cheese effluent (dairy industry). Its characteristics are:

- $2.5 < COD\ (g\ COD_t/l) < \sim 10\text{-}15$ (possibility of high variations between 2 cycles);
- $COD_t/BOD_s = 2$ (high biodegradability);
- $0.1 < SS\ (g/l) < 1$ ($COD_s \sim COD_t$);
- $15 < N\text{-}TKN\ (mg/l) < 120$.

The possible measurements are:

- *In the liquid phase*: DO, Temperature, Redox, sludge blanket level, pH, Input vol. GFR (on-line) and COD, SS, Bacteria pop (off-line).
- *In the gas phase*: input/ output of O_2.

Good sludge settlement is when the process is operated with volumetric load < 0.7 kg $COD/m^3/day$. Therefore, the settlement matter will be studied at the LBE.

2.4. ENEA and POLIMI Reactors

A lab scale SBR (20 *l*) and a pilot scale SBR (500 *l*) are available. They will be fed by synthetic wastewater and also toxicant. The cycle time is 6 h. The monitoring is on pH, DO, ORP, T (on-line), AO max. activity, HB max, SS, SVI, NH_4, NO_2, NO_3 (off-line).

The control variable will be pH, DO, inlet flow rate.

The data sampling can be effected until 30 data/ second.

3. WP2 – Model Selection and Parameter Identification

This work package is coordinated by Rafael Canetti of the UU and it involves the UNAM and UCL. This part deals with the determination of the input/ output of the process: measurements, control variables, biomass acclimation … In order to establish a good model, the data must be reliable. Therefore, a general protocol must be defined.

The model must be general enough to be used in different types of process. There are 2 types of wastewater: without Nitrogen consideration and with Nitrogen (in this case nitrification/ denitrification are needed).

3.1. Reaction scheme

As two kinds of wastewater are considered, two models will be proposed:

$$\begin{cases} S + C \rightarrow X_1(+CO_2 + IP) \\ C + IP \rightarrow X_2(+CO_2) \qquad \text{(model 1 - bis)} \end{cases} \tag{1}$$

with S: Chlorophenol, C: oxygen (O_2), X_1 and X_2: biomasses, IP: metabolite (with acclimation), and

$$\begin{cases} S_1 + C \rightarrow X_3 + CO_2 \\ S_2 + C \rightarrow X_4 + NO_3 \\ NO_3 + S_1 \rightarrow X_3 + N_2 \end{cases} \tag{2}$$

+ endogenous respiration:

$$NO_3 + C \rightarrow \dots$$

$$X \rightarrow X_d$$

where S_1 is carbon, S_2 is ammonia (NH_4^+), C is oxygen, X_3 and X_4: biomasses.

3.2. Measurements

In order to determine the components that will me measured, the target must be clear. The objectives of the work are:

1. Toxic compound control;
2. Sludge age control;
3. Carbon and nutrient removal;
4. Optimization, which can concern cycle time, phase-time distribution (according to Carbon/ Nitrogen ratio), energy (mixing speed, aeration);

5. Acute toxicant monitoring;
6. Δbiomass characteristics (with respect to process experiments). This will be useful especially in FDI and supervision;
7. Sensor-actuator monitoring;
8. Influent estimation.

Hence, the measurements will be:

1. Dissolved oxygen, NH_4^+, NO_3, NO_2, TKN (Total Kjeldahl Nitrogen);
   Needed information:
   * Influent concentration (initial + on-line)
   * Influent liquid flow rate(s)
   * Aeration flow rate (input + output)
   * Gas flow rate (output) →*optional*
2. Biomasses: VSS (Volatile Suspended Solide) + "activity" measurements;
3. SVI (Sludge Volume Index);
4. Temperature, pH, rpm (mixing speed);
5. History (including cleaning of sensors);
6. Organic carbon: COD (total + soluble), TOC (total + soluble) [*if available*]
7. k_la parameter;
8. Phase duration.

The sampling period is equal to 5 measurements per phase.

3.3. Experiment plan

We will begin with 20 experiments. These experiments are organized in order to obtain data with respect to:

-	different Carbon/Nitrogen ratios	[= 6 experiments]
-	acute toxicant (smaller size, same sludge)	[= 3 experiments]
-	different O_2/Carbon ratios	[= 2 experiments]
-	different C/*X* ratios (including overload condition)	[= 4 experiments]
-	standard conditions	[= 1 experiment]
	Total	16 experiments + 4 replicates

Independently of these results, the following data are expected:

- Biomass acclimation/ deacclimation (especially for the UNAM)
- Settleability (especially for the LBE)

3.3.1. Standard conditions

This is considered as the nominal process. One experiment is dedicated to this.

	UNAM	UU	LBE	POLIMI	ENEA
Type	fed-batch	batch	batch	fed-batch	fed-batch
C_{in} [*mg COD/l*] $C_{(t=0)}$	350 200	1500-2000	5,000 700	400	400
$X_{(t=0)}$ [*mg/l*]	2,000	1500-2000	5,000	80	50
NH_4^+ [*mg/l*]	-	150	125		
O_2 [*l/min.*]	1.5				
pH	7	7	7	7	7
T [°*C*]	20	20	20	20	15
$V_{(t=0)}$ [*l*]	2	5-8	200	15	400
$V_{(t=tfin)}$ [*l*]	7	10	200	20	500
t_{cycle} [*h*]: F+R Settl. Drain	1.4 0.5 0.1	} 6-12	} 24	} 6	} 6
SRT [*days*]	20	20	20	20	20

3.3.2. Carbon/Nitrogen ratio

For six experiments, the ratios to be varied are: -50%, -35%, -20%, +20%, +35% and 50% (with respect to standard conditions). Only nitrogen is changed (*C* is fixed) for different time (Δt).

3.3.3. Acute toxicant

Two experiments are dedicated to measure Chlorophenol. One experiment deals with ATU (Allyl Thiourea).

3.3.4. Oxygen/Carbon ratio

Two experiments are required to measure this ratio. The desired variations are: -50% and +50%. This can be obtained by modulating the airflow rate (O_2).

3.3.5. Carbon/Biomass ratio

Only carbon is varied. Four experiments are required, and the desired ratios are: -50%, +25%, +50% and 75%.

Note:
These changes, mentioned in 3.3.2 to 3.3.5, will only be carried out during 1 cycle.

4. WP3 – Hardware Sensor Development

This work package involves directly the following partners: Gradient (UTC), POLIMI, ENEA and SPES. The coordinator of this WP is Alberto Rozzi.

Elena Ficara and Alberto Rozzi presented pH and DO-stat titration biosensor. Experiments for this will take place in Milano (POLIMI) and Bologna (FUNO WWT).

Paolo Ratini presented the development of a combined titration biosensor to monitor nitrification, by measuring: activity, inhibition, NH_4 concentration.

André Pauss presented the UV-instrument/ analyser. For the validation of the UV-photometry sensor, the model of the UU process will be used (using dairy wastewater).

5. WP8 – Validation and integration

Paolo Ratini of the SPES is the coordinator of this WP. He presented embedded software allowing the integration of all the elements in the project: data acquisition (sensors), fault detection & isolation and control. He proposed a plug-&-play actuator, such as PLC.

The validation test of the embedded software is envisaged to take place in Narbonne (LBE) → to be discussed furthermore!

More detail will be presented at the next meeting in Mexico.

6. Budget

The EEC transfers the budget to the UCL as the project coordinator, and the UCL distributes this to all the partners.

In the beginning of the project, the European Commission gives in advance 40% of the EC contribution.

Every year, each partner writes a cost statement in order to have reimbursement of its expenditure up to 85% of the total EC contribution.

The total budget will be transferred when the final report of the project is approved.

Notes:

- For the purchases of equipments, be careful to the possible depreciation.
- The EEC does not finance participation to workshops or scientific conferences.

Fund transfers are assured via banks.

7. Reports

The first annual report must be written at the 3rd meeting. All WP leaders must write reports every 6 months (internal reports). A mid-term review will be necessary.

Technology implementation plan will be required.

8. Next meetings

The next meetings will take place in:

- Mexico: 8-9-10th May 2003
- Milano: annual report
- Louvain-la-Neuve: mid-term review
- Montevideo: annual report
- Compiègne

9. Others

A WEB-site will be created for the EOLI project.

Data protection policy: all data and project results belong to the project. Only partners can use the data.

All publications that are involved in the project must mention the project. The contract number is: ICA4-CT-2002-10012.

Minutes of the First Mid-Term Meeting

May 7-9, 2003, Mexico City - Mexico

Present:	Denis Dochain (Coordinator)	Cesame – UCL, Belgium
	Hadyan Fibrianto	Cesame – UCL, Belgium
	Germán Buitrón	UNAM, Mexico
	Jaime Moreno	UNAM, Mexico
	Cristina Verde	UNAM, Mexico
	Manuel Betancur	UNAM, Mexico
	Dieter Wimberger	UNAM, Mexico
	Ivan Moreno Andrade	UNAM, Mexico
	Gloria Moreno Rodríguez	UNAM, Mexico
	Alberto Noyola	UNAM/IBTech, Mexico
	Jérome Harmand	LBE – INRA, France
	Michel Torrijos	LBE – INRA, France
	Djalel Mazouni	LBE – INRA, France
	Rafael Canetti	UU, Uruguay
	Soledad Gutiérrez	UU, Uruguay
	Nicola Fiocchi	POLIMI, Italy
	André Pauss	Gradient – UTC, France
	Thierry Ribeiro	Gradient – UTC, France
Excused:	Elena Ficara	POLIMI, Italy
	Paolo Ratini	SPES, Italy

1. Introduction

Denis Dochain opens the meeting by asking “a minute of silence” in memory of Maria Viñas [UU, Uruguay] and Alberto Rozzi [Polimi, Italy].

The meeting has been mainly dedicated to the evaluation of the progress of 4 work packages, which deal with the first deliverables (from t0 until t0+12). These are: WP1 (process experiments), WP2 (model selection and parameter identification), WP3 (hardware sensor) and WP8 (validation and integration). For that, each WP leader has prepared an internal report about the past and future activities of his WP, in the last 6 months.

This report includes:

– the WP tasks to complete during the defined period (corresponding to the Technical Annex) and what results have been obtained.

– the results analyses: do they satisfy the objectives expected from the Technical Annex? Is there any variation or discrepancy from the TA? What kind of difficulties has been encountered? What kind of solution(s) is (are) proposed to solve possibly encountered problem(s)?

– the work to be performed over the next period, and emphasize the interconnections with the other WP.

2. WP1 – Process experiments

After recalling the objectives (see slides (ppt)), German Buitrón, the WP1 task leader, asked the concerned partners to present their reports.

2.1. Internal Reports

The LBE – INRA report (ppt) of Narbonne, France, is presented by Jérôme Harmand and Michel Torrijos.
The experiments are ready to carry out. Measurement data at different positions are possible to obtain. The first complete data will be available in October 2003.
The denitrification (corresponding to the anoxic phase) takes place in the beginning of the process, before the aerobic phase. The concentration of NH_4^+ has been increased, i.e. 400 mg/L, to enable the denitrification reaction.
The sludge index is decreasing at the end of the process. In denitrification phase, it is not as good as that in aerobic phase.
About the COD, absorption may exist in the reactor according to what we see on the figures from some experiments. It has to be checked if there is any problem of homogeneity?
All these phenomena have to be taken into account in the modelling.

German Buitrón presented the report of the UNAM, Mexico. For more details, please look at the slides (pps). The UNAM is ready to obtain data. The first data will be available on July 2003.
Alberto Noyola from UNAM is also representing of IBTech. IBTech asked the flexibility of the date of the material purchase. Then it has been confirmed that the EC is quite flexible as far as the final objective is reached. However, all changes have to be noted in the financial report.

From the Polimi, Italy, there was a new member. It is Nicola Fiocchi, a PhD student of Polimi. He works with Elena Ficara and is directly involved in experiments. Actually, the Polimi has started lab-scale experiments using synthetic wastewater (see slides (ppt)).

Soledad Gutiérrez presented the UU report. The experiments will begin at the end of June 2003 using 2 reactors (see slides).

2.2. Modifications in the experiment protocol

2.3. Measurements

There are changes in measurement objectives in regard with those defined at the kick-off meeting. Now, the measurement objectives are as follows:

1. Toxic compound control;
2. Sludge age control;
3. Carbon and nutrient removal **control**;
4. Optimization, which can concern cycle time, phase-time distribution (according to Carbon/ Nitrogen ratio), energy (mixing speed, aeration);
5. Acute toxicant monitoring, in which the Polimi is responsible of this task (the corresponding experiments will start at the end of June 2003);
6. Biomass variation characteristics (with respect to process experiments) in order to distinguish bioactivities. This will be useful especially in FDI and supervision;
7. Sensor-actuator monitoring;
8. Influent estimation.

Hence, the measurements will be:

1. Dissolved oxygen, NH_4^+, NO_3, NO_2, TKN (Total Kjeldahl Nitrogen);
   Needed information:
   * Influent concentration (initial + on-line)
   * Influent liquid flow rate(s)
   * Aeration flow rate (input + output)
   * Gas flow rate (output) → optional
2. Biomasses: VSS (Volatile Suspended Solids) + "activity" measurements;
3. SVI (Sludge Volume Index),
   → German Buitrón (UNAM) is in charge to choose the standard method to be used;
4. TSS (Total Suspended Solids) at the effluent of the reactor;
5. Temperature, pH, rpm (mixing speed);
6. History (including cleaning of sensors);

7. Organic carbon: COD (total + soluble), TOC (total + soluble) [if available],
   → Soledad Gutiérrez (UU) is in charge to determine the COD measure method;
8. $k_l a$ parameter,
   → Michel Torrijos (LBE) will study the adapted method to determine this parameter, because it can vary according to the water volume;
9. Phase duration;
10. Settling velocity, especially to the LBE-Narbonne.

The sampling period of the reaction phases is equal to 5 measurements per phase: 5 measurements in the anoxic phase and 5 measurements in the aerobic phase.

2.4. Experiment plan

We will begin with 20 experiments. These experiments are organized in order to obtain data with respect to:

- different Carbon/Nitrogen ratios	[= 6 experiments]
- acute toxicant (smaller size, same sludge)	[= 3 experiments]
- different O_2/Carbon ratios	[= 2 experiments]
- different C/X ratios (including overload condition)	[= 4 experiments]
- standard conditions	[= 1 experiment]
Total	16 experiments + 4 replicates

Independently on these results, more data are expected to treat the following cases:

- Biomass acclimation/ deacclimation (especially for the UNAM),
- Settleability (especially for the LBE).

Notes:

The persons in charge for the experiments are German Buitrón (UNAM), Soledad Gutiérrez (UU) and Nicola Fiocchi (POLIMI).

The deliverable date of the data with first experiments using standard definitions (≈ 5 experiments) is July 31st, 2003.

2.4.1. Standard conditions

The table corresponding to the standard conditions has been up-dated in the Mexico meeting (May 8th 2003):

	UNAM	UNAM	UU	UU	LBE	POLIMI	ENEA
Filling/Reaction Ratio [%]	6.7 Acclimation/ deacclimation	Aprox. 100	4.5 (or 2.3)	4.5	1	4.5	_
C_{in} [*mgCOD/l*] $C_{(t=0)}$	375 (350)$^{+}$ 214 (50-200)$^{+}$ $^{+}$ as 4CP	375 (350)$^{+}$ 214 (200)$^{+}$ $^{+}$ as 4CP	3,000	1500 – 2000	5,000 700	400	400
Type of compounds	Synthetic WW 4CP	Synthetic WW 4CP	Synthetic dairy raw WW	Output from an anaerobic lagoon	Diluted whey	Synthetic urban sewage	
$X_{(t=0)}$ [*mg/l*]	2,000	2,000	3000 – 4500	3000 – 4500	> 5,000	3,000	
Volume loading rate [*gCOD/L-d*]	2.25	2.25	0.6	0.6	> 1.0	0.32	
Mass loading rate [*gCOD/gVSS-d*]	1.12	1.12	0.2	0.2	0.2	0.1	
Total *N-TKN* [*mg/L*]	NA	NA	100	150	350	65	
NH_4^+ [*mg/l*]	NA	NA		Aprox. 150	Aprox. 0	60	
COD/N-NTK			30	10 – 17	14.2	6.2	
O_2 [*l/min.*]	1.5	1.5					
pH	7	7	7	7	7	7	7
T [°*C*]	20	20	20	20	20	22	15
$V_{(t=0)}$ [*l*]	3	3	11	11.5	170	16	400
$V_{(t=tfin)}$ [*l*]	7	7	15	15	200	20	500
Total cycle time [*h*]:	4	4	12 or 24	12	24	6	6
SRT [*days*]	20 measured	20 measured	20 measured	20	20 measured	20	20

Notes

4CP: 4-Chloro-Phenol

NA: not applicable

*The buffer capacity/COD ratio must be defined in the methodology

Then, the Cycle phases corresponding to the above experiment conditions are as follows:

	UNAM	UNAM	UU	UU	LBE	POLIMI
Fill	12 min	variable	30 min	30 min	10 min	13 min
anaerobic	0	0			3 h 40 min	2 h 17 min
aerobic	178 min	variable	10.5 h (or 22.5 h)	10.5 h	18 h	2.5 h
settling	30 min	30 min	40 min	40 min	2 h	37 min
draw	6 min	6 min	20 min	20 min	10 min	23 min
iddle	14 min	15 min	0	0	0	1 min
Total time	4 h	variable			24 h	6 h

The action variables that will be used in the above processes are:

- For the UNAM: influent flow rate,
- For the LBE: phase duration (as the principal action), then optionally there can be:
    - Influent flow rate,
    - Aeration flow rate,
    - Output sludge flow rate.
- For the UU:
    - Influent flow rate,
    - Sludge flow rate (purging),
    - Phase duration.
- For the POLIMI: phase duration (essentially), then there can be the same optionally options as the LBE.

3. WP2 – Model Selection and Parameter Identification

Rafael Canetti, the WP2 task leader, introduced Soledad Gutiérrez (UU) as the new person in charge on the experiments in the UU, Uruguay. Then, Rafael Canetti and Hadyan Fibrianto, Cesame – UCL (see (doc)) presented the WP2 mid-term report about the model selection.

Note that the data acquisition has to be adapted to the parameter identification of the model.

3.1. Modelling of the UNAM process

$$Cl \cdot Phenol + O_2 \rightarrow X_1 + CO_2 + (metabolite) \qquad \text{reaction (1)}$$

$$(O_2 + metabolite \rightarrow X_2 + CO_2) \qquad \text{reaction (2)}$$

with X_1 and X_2 the corresponding biomasses for both reactions, respectively.

First, it is about the metabolite. Indeed, the metabolite is only produced if there is inhibition; otherwise there is only weak quantity of metabolite. Moreover, it is not directly measurable. Usually, absorbance in several sequences is needed to enable its measurements.
Considering these difficulties, the metabolite study in modelling is optional; it will depend on the first experiments results.

On the other hand, there is a formulation problem of the biomass acclimation/ deacclimation in the physical point of view. Is it an enzymatic problem; is there any kinetics change? Several scenarios will be considered for the modelling.

3.2. Modelling of the other processes (with denitrification phase):

$$C + O_2 \rightarrow X_3 + CO_2 \qquad \text{reaction (3)}$$

$$NH_4^+ + O_2 \rightarrow X_4 + NO_3 \qquad \text{reaction (4)}$$

$$NO_3 + C \rightarrow X_3 + N_2 \qquad \text{reaction (5)}$$

+ endogenous respiration: $NO_3 + O_2 \rightarrow \ldots$ reaction (6)

+ mortality: $X_{total} \rightarrow X_d$ reaction (7)

Indeed, the reactions have to be reviewed, especially about the endogenous respiration such as:

$$C_X + NO_3 + O_2 \rightarrow \ldots \qquad \text{reaction (8)}$$

and the mortality corresponds to:

$$X_{total} \rightarrow X_d \rightarrow C_X \qquad \text{reaction (9)}$$

Also, we need to add one reaction representing the ammonification:

$$N \xrightarrow{r} NH_4^+ \qquad \text{reaction (10)}$$

with $r = k_0 N$

the reaction rate. The N measurement is equal to (TKN – NH_4^+).

One question is not clear for the moment: is there absorption?
The situation is as follows: there is a rapid disappearance of the substrate in the beginning of the process. Therefore, in the beginning of the process the reaction rate is different from that during the process.

If absorption is considered, the following expression can be considered:

$$r_a = k\,(C_s - C_l)$$

where C_s and C_l represent the substrate concentration in solid and that in liquid, respectively.

We need tests to validate the absorption. The UU and LBE are in charge for this task.

One other question concerns the Oxygen profile in the beginning of the process. From the first experiments (in Narbonne), it has been noted that O_2 is almost equal to zero in the beginning (quasi steady-state conditions). It does not mean that there is not reaction, but the biomass degradation capacity is very large such as we have this situation.
This phenomenon will be taken into account in the modelling.

4. WP3 – Hardware Sensor Development

The new task leader of WP3 is André Pauss, from Gradient/ UTC, Compiègne, France.

André Pauss and Thierry Ribeiro presented the implementability of the UV-spectrometer (ppt), which is developed by Gradient, to our wastewater treatment process.

After presenting the WP3 report of the Polimi (ppt), Nicola Fiocchi from Polimi talked about the use of a device called "Martina"(ppt) for measurements. This device uses the pH-DO titration technique.

It has been noted that the Gradient has to have the real wastewater of the partners. The Gradient will establish a protocol for this.

5. WP8 – Validation and integration

As Paolo Ratini, the WP8 responsible from the SPES, was not able to be there, he sent a text about the SPES proposition for the system integration. The SPES recommends the use of PLC. We were then discussing about 2 aspects of the system integration: one aspect concerns the technical part and the other one is about the financial part.

Technical aspect:

There are some points that have to be more clarified about the use of the "SPES system" (the solution developed by the SPES):

- More technical details of the proposed system are needed,
- Do we have to use only this system?
- If yes, according to what is described the Paolo text, an adapted slave board for sensors, which will be connected to the main board (developed by the SPES) has to be developed at each local experiment site. The UNAM will not able to do this.

The results of the discussion are as follows:

- The SPES solution will only be implemented at one site in this project.
- The main goal of the project is to obtain a common philosophy of control system, so each one does not have to apply exactly the same control system.

Financial aspect:

The question here is where the final integrated system will be implemented?

In the economic efficiency point pf view, the LBE of Narbonne in France is the best solution. But in the cooperation point of view, the UNAM of Mexico should be in priority.

After a discussion via Internet (doc), the SPES privileges the final system implementation in Narbonne for the financial reason. The SPES has also specified that they will provide one integrated system for one pilot plant using the EC fund (with free host costs).

6. Next meetings and reports

The next meeting will take place in Compiègne, France, instead of Milano, Italy. The scheduled dates are 15 – 17th October 2003. In this meeting, the annual report will be presented. The Cesame (UCL) will provide an example of a report. In September 2003, there will be a recall to all partners about the reports.

The future meetings are then:

- Louvain-la-Neuve, Belgium: mid-term review (about May 2004)
- Montevideo, Uruguay: annual report (about October 2004)
- Milano, Italy: last mid-term review (about May 2005)

Note that the scientific officer will be there in one meeting.

7. Others

The EOLI web-site is http://www.auto.ucl.ac.be/EOLI/. There will be a restricted area in the web-site for member only, which aims to allow the partners to exchange confidentially and easily documents and experiment data.

The European Commission
Community Research
Confirming the International Role of Community Research

Minutes of the First Annual Meeting

October 15-17, 2003, Compiègne – France

Available in http://www.auto.ucl.ac.be/EOLI/

Present:	Denis Dochain (Coordinator & WP4 leader)	CESAME – UCL, Belgium
	Hadyan Fibrianto	CESAME – UCL, Belgium
	André Pauss (WP3 leader)	Gradient – UTC, France
	Thierry Ribeiro	Gradient – UTC, France
	Olivier Schoefs	Gradient – UTC, France
	Meriem Bekri	Gradient – UTC, France
	Jérome Harmand (WP7 leader)	LBE – INRA, France
	Michel Torrijos	LBE – INRA, France
	Djalel Mazouni	LBE – INRA, France
	Germán Buitrón (WP1 leader)	UNAM, Mexico
	Jaime Moreno (WP5 leader)	UNAM, Mexico
	Manuel Betancur	UNAM, Mexico
	Dieter Wimberger	UNAM, Mexico
	Ivan Moreno Andrade	UNAM, Mexico
	Ana Maria Perez	IBTech, Mexico
	Rafael Canetti (WP2 leader)	UU, Uruguay
	Melga Galisteo	UU, Uruguay
	Roberto Canziani	POLIMI, Italy
	Nicola Fiocchi	POLIMI, Italy
	Paolo Ratini (WP8 leader)	SPES, Italy
	Federico Coppa	SPES, Italy
Excused:	Cristina Verde (WP6 leader)	UNAM, Mexico
	Soledad Gutiérrez	UU, Uruguay
	Elena Ficara	POLIMI, Italy

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1. Introduction

We began the meeting by introducing some new members of the project: Olivier Schoefs and Meriem Bekri from Gradient/UTC, Ana Maria Perez from IBTech, Melga Galisteo from UU, Roberto Canziani from Polimi and Federico Coppa from SPES.

The meeting was organized to discuss three main subjects: first the progress evaluation of the work carried out during the first 12-month-period of the project; second the future work; and third the administrative subjects.

In the beginning of the meeting we discussed about the results which have been achieved since the beginning of the contract. Three of four work packages dealing with the first year of the project were discussed on Wednesday 15th October: process experiments (WP1), hardware sensor (WP3) and validation/ integration (WP8). The progress of the model selection and parameter identification (WP2) was evaluated on the next day.

After the WP2 progress evaluation, Thursday 16th was dedicated to the discussions concerning the plans for the following year and how they relate to the overall objectives and planning of the contract. This implied all WPs. Tasks and deliverables of each WP to be provided in the second year of project were studied carefully.

Finally, Friday morning was reserved for administrative discussions. The first annual scientific and financial reports were the topics. In the afternoon, some individual discussions and lab-visit were organized.

2. Progress evaluation

As it is mentioned in introduction, only four work packages are involved in the first year of the project. These are process experiments (WP1), model selection and parameter identification (WP2), hardware sensor (WP3), and validation/ integration (WP8). The progress evaluation was then dedicated to these 4 WPs.

2.1. Process experiments (WP1)

Work package 1 results were presented by 5 partners, which are POLIMI, LBE, UNAM, UU and IBTech. German Buitrón (UNAM) as the task leader started the presentation by recalling the WP1 objectives in the first year period, and then he summarized the achieved results of all WP1 partners and compared them with the expected ones.

Following that, each partner presented the detailed works.

2.1.1. POLIMI results

Nicola Fiocchi presented the achieved results of POLIMI within the work package 1. He explained that in the Polimi case, the total wastewater treatment needed 5 hours; one hour was dedicated to the settling and drawing phases. Nevertheless 30 minutes were the needed time to settle the sludge.

2.1.2. LBE results

After that, Djalel Mazouni presented the achieved results of LBE. He showed that the NO_2/NO_3 transformation was very rapid. It has also been shown that there existed an absorption in Carbon degradation.

Roberto Canziani (Polimi) mentioned some references in the literature (works carried out in Rome, Italy) about this "absorption" problem that is also called "storage".

2.1.3. UNAM results

The next presentation was dedicated to the UNAM results and presented by Ivan Moreno Andrade. Acclimation and starvation cases were presented. It has been illustrated experiments with respect to 2 control strategies: optimal and even-driven controls.

We remarked that when oxygen concentration was low then the metabolite concentration was more important.

2.1.4. UU results

Then Melga Galisteo presented the UU results. She presented two reactors design existing in Uruguay (Manolo and Flora). Both were semi-automatic. There was also an installation adapted to any controller.

She presented CODs measurement methods (as it was asked in Mexico meeting). For the UU wastewater, the centrifuge method was recommended. More technical discussions were then envisaged between WP1 partners.

2.1.5. IBTech results

Ana Maria Perez presented the IBTech reactor design. It will be operational in June 2004 (see IBTech slides).

2.2. Hardware sensor development (WP3)

Work package 3 involves Gradient, Polimi and SPES contribution. André Pauss (Gradient) started the WP3 presentation by recalling the general objectives and mentioning the summary of the results. Then each partner presented its part.

2.2.1. Gradient/UTC

André Pauss presented the use of the UV-spectrometer for sampling substrates from a treated wastewater. He spoke also about the applicability of this method in the UNAM, POLIMI and LBE wastewaters.

The device allows to estimate suspended solids. For pure reference compounds, e.g. glycerine, NH_4Cl, urea, it is easier to apply the measuring method. In other cases (e.g. lysine) we can establish relations to enable the measurement.

For the absorption measurement in the LBE wastewater, relations can be made between influent and effluent wastewater.

Nevertheless, the limitation of the UV-spectrometer is when there are a lot of compounds in the wastewater (more spectrum make the measurement more difficult). For instance, a true municipal wastewater may give more then 50 spectrum (generally up to 100).

2.2.2. POLIMI

Roberto Canziani presented the pH-stat titration methodology. The titration can be used quite well in the SBR case. He illustrated the capacity of the method to measure (de)nitrification rate and endogenous rate.

However, there is a discrepancy between pH-titration and DO-titration. Please see Polimi slides for more details.

2.3. Integration (WP8)

Work package 8 results were presented by Paolo Ratini (SPES). He recalled the state of art of the most general interfaces between actuators and PC. There existed usual three interfaces: PLC, Field bus and SCADA system. However, they are usually only used in big plants.

SPES will design an embedded system allowing to integrate all the components of the monitoring and controlling system. The innovative aspects of the SPES system are all digital components and low noise signal.

The actual information about the cost of the SPES system is as follows: Slave boards cost about 300-500 euros, while main board costs about 1000-2000 euros. However, it is difficult to state a price until a business plan exists for these items.

It has been noted that the SPES system will be developed for and used in Narbonne. Any work from other work packages done for the reactor in Narbonne will have to be delivered in MATLAB.

Furthermore we agreed that in other locations a custom solution can be developed as well as reported. UNAM an UU will have such custom solutions. With regard to UNAM, there will be discussion with the WP8 leader (Paolo Ratini) about the UNAM contribution to WP8.

It has been also noted that there will be re-allocation of man-month for UU.

2.4. Model selection and parameter identification (WP2)

Rafael Canetti started the work package-2 evaluation by recalling the expected results in the first year. He presented then the summary of the achieved results. Following that Hadyan Fibrianto (Cesame/UCL) presented the modelling and parameter identification methodology.

It has been noted that during the anoxic phase, the denitrification rate was equal to $\mu_{denit}X_h$, with $$\mu^{o}{}_{denit} = \mu_{d\max}\frac{S_{NO}}{K_{NO}+S_{NO}}\frac{S_C}{K_C+S_C}\frac{K_O}{K_O+S_O}$$

where μ_{denit} is the specific growth rate of the anoxic heterotrophic bacteria X_h; S_{NO}, S_C and S_O represent the concentrations of nitrate (+nitrite), carbon (i.e. COD) and dissolved oxygen, respectively; K_{NO}, K_C and K_O are the constants of saturations corresponding to NO, carbon and dissolved oxygen, respectively. When S_O is low (usual case in anoxic phase), then the last term of μ_{denit} is approximately equal to 1. This led us to have:

$$\mu_{denit} = \mu_{d\max}\frac{S_{NO}}{K_{NO}+S_{NO}}\frac{S_C}{K_C+S_C}$$

We have noted according to LBE data the absorption phenomenon in C-removal. This led us to introduce two new variables in the model, S_{mes} and S_{abs}, which represent the carbon concentration that we measure in the liquid medium (corresponding to the obtained data) and the absorbed carbon concentration in the cell. The modelling idea can be illustrated by the following figure:

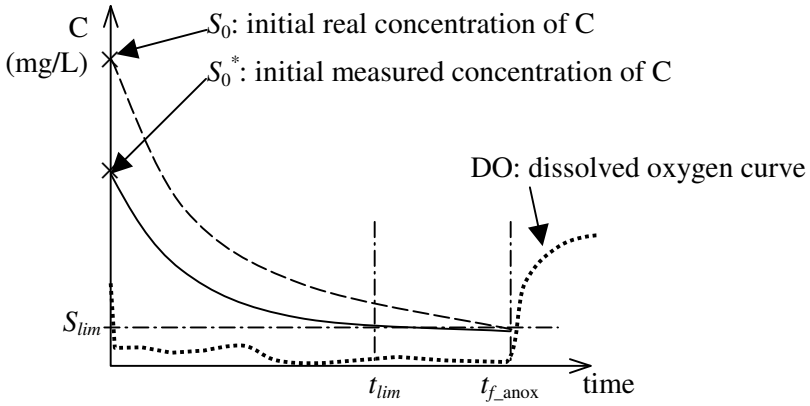

Figure 1. Illustration of absorption in C-removal

S_{lim} is the substrate concentration when S_{mes} is in steady state ($dS_{mes}/dt = 0$) with t_{lim} corresponding to the beginning instant of steady state. t_{f_anox} is the ending time of anoxic phase. The continuous line describes what we can measure (i.e. COD in the liquid medium), while the dashed line corresponds to the real evolution of C degradation, because a part of C is degraded inside the cell (due to absorption), such as $S_{mes} + S_{abs} = S_{real}$. Let us consider γ be the rate of apparent C degradation, we proposed then:

$$\frac{dS_{abs}}{dt} = -k_1 \mu X + \gamma (S_{mes} - S_{abs})$$
$$\frac{dS_{mes}}{dt} = -\gamma (S_{mes} - S_{abs})$$

or if we denote $S_{liq} = S_{mes} - S_{lim}$, then we can write

$$\frac{dS_{abs}}{dt} = -k_1 \mu X + \gamma S_{liq}$$
$$\frac{dS_{mes}}{dt} = -\gamma S_{liq}$$

Polimi data showed that the denitrification happened in 2 steps (NO_3 reduction into NO_2, then NO_2 reduction into N_2) and so did the nitrifying activities (NH_4 oxidation then NO_2 oxidation). The data are illustrated in the figure 2.

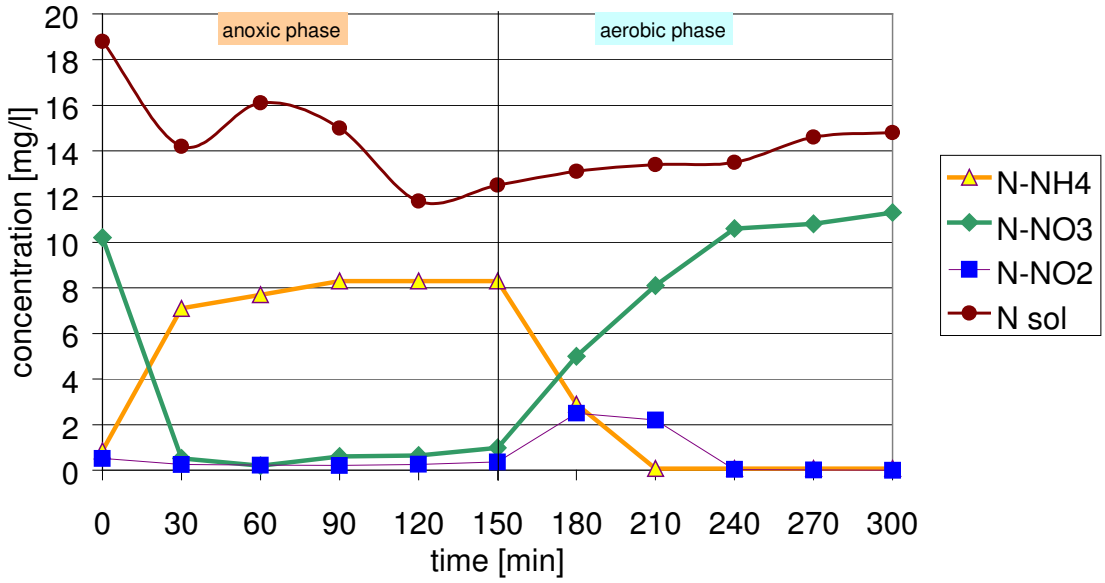

Figure 2. One example of POLIMI data

3. Future work

WP 1 – 8 were discussed respectively.

For WP1, the operating data will be sent at t0+14 and last data will have to be provided in last January 2004 (especially for POLIMI).

About WP2, the parameter identification will be continued and a model validation will be carried out. First complete model will be presented at the next meeting in Louvain-la-Neuve. In the last day, some agreements (about WP1 experiments for WP2) were made at the Compiegne meeting.

1) Methodology Summary

Germán Buitrón has already sent a detailed e-mail of the needed summary to send with the experiments.

2) Sampling period in anoxic phase

It was observed that particularly denitrifying activity has its main reaction during the first minutes of "anoxic phase", mainly during filling. With the used equally spaced sampling rate the reaction takes place mainly before the first measurement. This is both for LBE Narbonne and Polimi.

It was agreed to propose to change the timing of the off-line measurements.

POLIMI: it was proposed sampling at 0 (initial conditions), 10min, 20 min, 30 min, 60 min, 120 min (initial conditions for next phase).

3) Sampling period in aerobic phase

The areobic phase reactions are slower. Then there is no change with respect to the first protocol established in the beginning.

4) Sampling processing in anoxic phase

Another important issue is the sample processing. When a sample is taken, is first filtrated and then one can suppose that reaction is stopped as biomass is separated. But this takes few minutes.

The denitrification reaction is relatively fast, and during sample processing the reaction continues so the measured values do not correspond exactly to the time that the sample is taken.

There was no more specification for the WP3.

Concerning WP4, CESAME asked all partners to provide all potential measurements for their processes (t0+13).

Within the control design (WP5), Jaime Moreno asked the implication of other partners, i.e. LBE and UU. The control strategy that will be applied to their processes will be discussed in individual discussions.

In the discussion about the future work in WP6, Dieter Wimberger suggested to establish the standard operation regions for the treatment processes.

This proposal was opposed by Denis Dochain, who in his turn, suggested to start with collecting faults and problems from each partner. The majority agreed with his proposal and following items were collected:

Sensors:

DO, pH, ORP, Nitrate, T

Fault/Problem

1. Does not work
2. Drift

Actors:

Pumps, Aeration

Fault/Problem

1. Does not work

Process:

Fault/Problem

1. Settling
2. Foaming
3. Deacclimation (México)
4. Accumulation of intermediate products

It was observed that a lot of these problems are related to changes in the activity of the biomass.

In the line of the discussion it was also remarked that WP6 and WP7 are closely related and agreed that the two work package leaders will discuss and negotiate a close integration of their work.

As a first step, a questionnaire will be created and send to each partner as soon as possible. Its objective will be to collect a list of faults and problems, information about them, as well as to establish priorities.

It was observed that the first milestone at T0+6 in WP6 was most likely supposed to be T0+16, as the work package officially starts at T0+12. However, it was agreed that the involved partners would try produce and provide the milestone as soon as possible.

4. Administrative discussion

The first annual report and the form E-1 (financial report) were discussed. We have talked mainly about the format and contents of the annual report.

It has been agreed that the individual reports from partners would be sent in the week that follows this meeting.

PARTNERS' ANNEXES

November 2002 -October 2003

EOLI
Efficient Operation of Urban Wastewater Treatment Plants

Work Package 1
First Annual Report

ANNEX
WP1 - POLIMI - 1st year activities

November 2002 -October 2003

Contract Number ICA4-CT-2002-10012

SUMMARY

During the first year of experimentation the main objectives for POLIMI was the design and the construction of a laboratory scale Sequencing Batch Reactor, in order to perform the first experiments defined by the EOLI protocol and specified in the general meeting that has been held in Mexico City in May 2003. The SBR was instrumented to measure on-line: temperature, DO, air flow rate, redox potential and pH.

With reference to the objectives listed above, POLIMI has built an appropriately instrumented laboratory SBR which was started from a sludge inocolum drawn from a full scale SBR.
The laboratory SBR has been now operated for approximately 8 months, fed on synthetic urban wastewater; the main parameters were monitored periodically, as specified below.
Five of the experiments requested in the experimental plan (which we will call "cyclic studies" from now on) have been performed in June and July 2003. During August '03, due to the seasonal closure of POLIMI's laboratory, the SBR was emptied, and the mixed liquor was kept in a refrigerator for the whole month. At the beginning of September '03, the SBR was working again. The next cyclic studies will be performed on a weekly basis, on average, starting from September 24th, having reached a stable biomass concentration of 3 gSS/L in the SBR.

During the SBR working period, it was possible to check the proper operation of the on-line instrumentation.

We are at the moment considering the feasibility of conducting the experimentation also on a pilot SBR (0.4 m^3) which has recently been built by ENEA near Bologna (Italy). The design of this SBR was made by ENEA in collaboration with POLIMI, and the plant could be managed by these two partners. The feasibility of having ENEA as a subcontractor is going to be negotiated and will not imply any financial modification within the EOLI project.

Set up of a laboratory scale SBR

The SBR (see Figure 1) is a 30 L cylindrical tank with a working volume of 20 L (V_{MAX}). The SBR is equipped with: 1 peristaltic pump for feeding (PA); 1 peristaltic pump for effluent discharge (PS); 1 peristaltic pump for waste sludge discharge (PF); 1 aeration system (3 air compressors + multiple pipe diffusers) (SA); 1 variable speed mechanical mixing system (SM); 1 controlled heating system to maintain sludge temperature at 25 ^oC; 4 timers for activation/deactivation of PA, PS, SA e SM.
This SBR operates according to 4 cycles per day. Each cycle lasts t_C = 6h and includes the following phases:
ANOXIC FILL (F) - (PA: ON; PS: OFF; SA: OFF; SM: ON), duration: t_F = 10 min;
ANOXIC REACT (ANR) - (PA: OFF; PS: OFF; SA: OFF; SM: ON), duration t_{ANR} = 150 min;
AEROBIC REACT (AER) - (PA: OFF; PS: OFF; SA: ON; SM: ON); duration t_{AER} = 150 min;
SETTLE (S) - (PA: OFF; PS: OFF; SA: OFF; SM: OFF), duration t_S = 37 min;
DRAW (D) - (PA: OFF; PS: ON; SA: OFF; SM: OFF); duration t_D = 23 min;

The SBR is fed with a synthetic influent (modified from *OECD Guidelines for testing of chemicals*. 1993 - 209 'Activated sludge inhibition Test', OECD Paris) with the following composition:
peptone: 0.343 g/L;
meat extract: 0.236 g/L;
NaCl: 0.015 g/L;
$CaCl_2 \cdot 2H_2O$: 0.012 g/L;
$MgSO_4 \cdot 7H_2O$: 0.005 g/L,
K_2HPO_4: 0.06 g/L.

According to analytical analyses, this influent is characterised by:
COD = 600 mg/L ± 5%;
N = 75 mg N_{tot}/L ± 10%;
therefore the average COD/N ratio is 8.

At the beginning of each cycle, 4 L of the influent described above are loaded (ΔV). The resulting volumetric exchange ratio (VER), feeding rate (Q_{FEED}) and hydraulic retention time (HRT) are therefore:
$VER = \Delta V / V_{MAX} = 4\ L / 20\ L = 0.2$,
$Q_{FEED} = \Delta V / t_C = 4\ L / 6\ h = 0.66\ L / h$,
$HRT = V_{MAX} / Q_{FEED} = 20\ L / 0.66\ L / h = 30\ h$.

The sludge retention time (SRT) was fixed in 20 days at standard conditions.

An on-line acquisition system has been set up by using the prototype of MARTINA (Multiple Analyte Reprogrammable TItratioN Analyser) to monitor temperature, pH, ORP and DO signals.

The following probes are in use:

ORP - Mettler Toledo (Greifensee, Switzerland), InLab 501;
DO -Endress Hauser (Reinach, Switzerland), COS 3s;
pH - Mettler Toledo (Greifensee, Switzerland),InLab 412, temperature - IKD, (Varese, Italy), Pt100 TRM

Acquisition frequency can be defined by the operator (max: 1 data per second). During this first part of the experimentation, the acquisition frequency has been set at the value of 3 data/min.

The remaining acquisition channels of the MARTINA prototype (that are: 1 ORP, 1 pH and 1 DO channels) are used to perform pH-DO-stat titration tests. These tests were performed on sludge samples, (0.5-1 L) manually collected from the reactor, in order to evaluate biomass activity in the SBR.

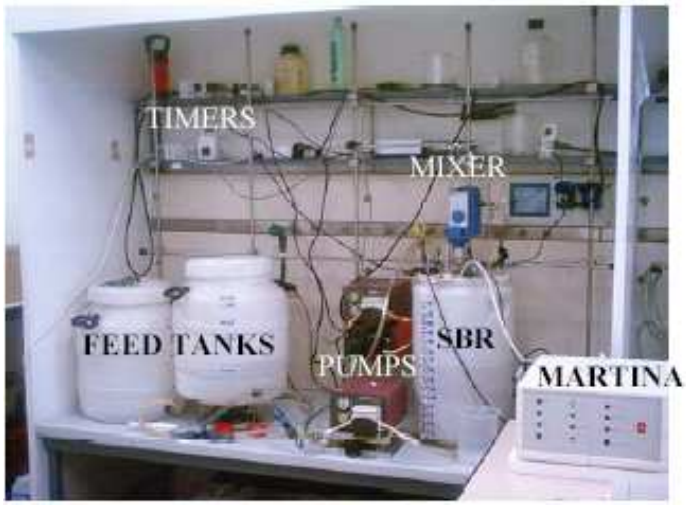

Figure 1 – SBR reactor and MARTINA unit

SBR start up

The SBR operation was started on the 15th January 2003 by inoculating activated sludge drawn from a full scale SBR (Funo, Bologna, Italy) treating urban wastewaters and serving about 7000 PE. Initially no waste sludge was discharged. The following analytical determinations were periodically performed in order to monitor the SBR performance: suspended total and volatile solids (TSS, VSS) - Figure 2; ammonia in the effluent - Figure 3; nitrate in the effluent - Figure 4; and COD in the effluent - Figure 5.

During the first 3 weeks the SBR was fed with standard OECD influent, at 800 mgCOD/L and 130 mgN/L. During this period, COD removal was always satisfactory, while the SBR nitrification capacity was insufficient to completely oxidise ammonium which built up in solution. Since the operating pH ranged between 7.9 and 8.3, high ammonium concentrations might have had an additional inhibitory effect on ammonium oxidisers; this effect is known to be greater and greater at increasing pH values, due to the increased free ammonia concentration.

From week 4 the SBR loading rate was halved by diluting the influent with tap water once a day. Moreover, during weeks 4 and 5, after the settling phase, the SBR supernatant was replaced by tap water until ammonium concentration was reduced to below 30 mg/L. At day 29, sludge from a fully nitrifying WWTP was inoculated (10% of the MLSS in the SBR) to enhance nitrification activity.

During the following weeks, the loading rate was kept at half the value that was set at the beginning of the experiment.

From day 49, when biomass concentration reached 1.6 gTSS/L sludge wastage was started at a rate of 1.6 L/d, with the aim of keeping a sludge age of around 20 days. However, solids concentration (both TSS and VSS) started decreasing and, within the following 2 weeks, they fell to values lower than 0.5 gTSS/L and remained constant. From day 75, sludge withdrawal was reduced to 0.5 L/d and an inoculum from a fully nitrifying WWTP was added, in order to enhance sludge re-growth.

From day 133 the influent composition was modified as described above (600 mgCOD/L and 75mgN/L). Then biomass rapidly grew up to 2 gVSS/L, and steady standard conditions were reached after three weeks.

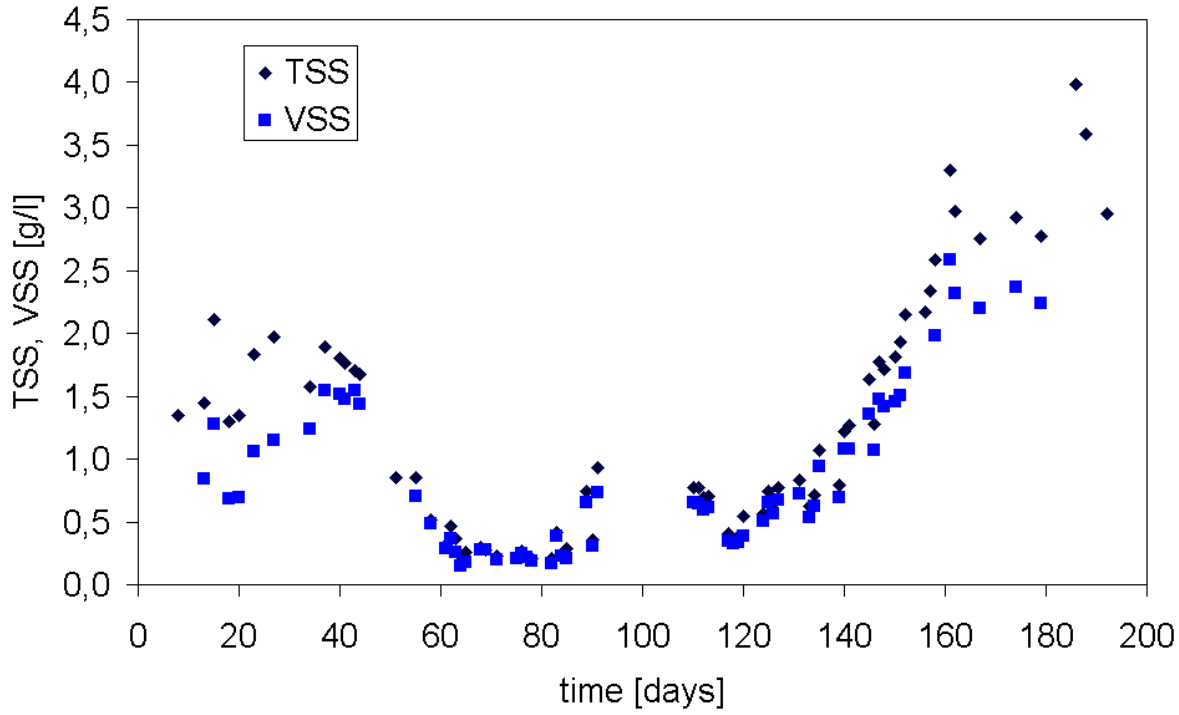

Figure 2 – Total and volatile suspended solids in the SBR reactor

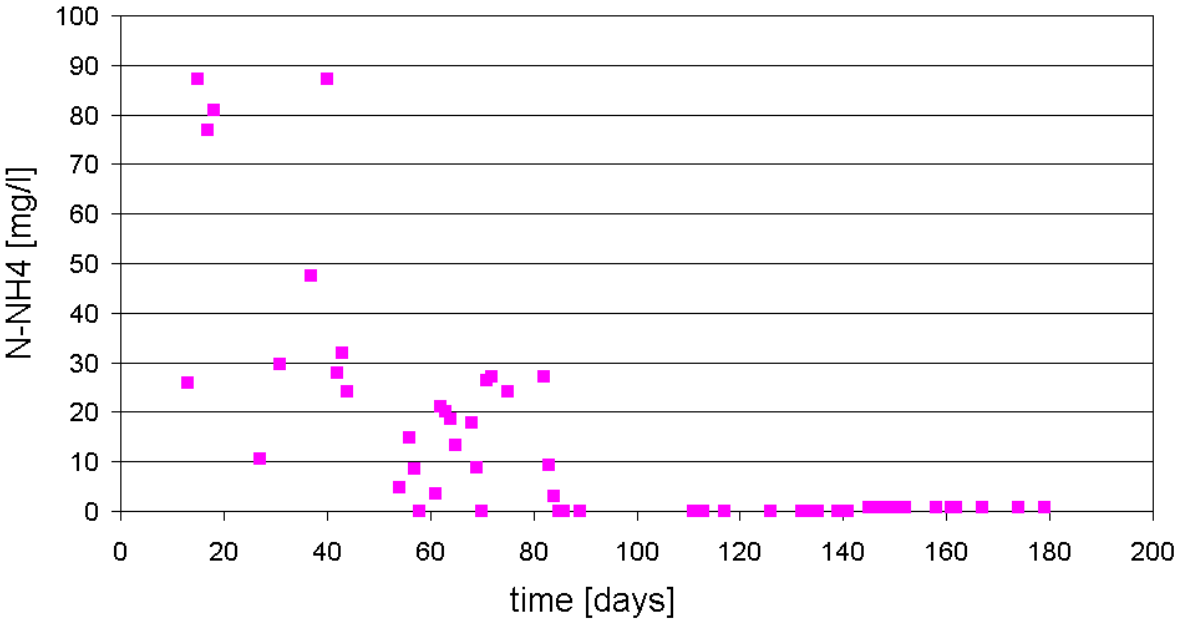

Figure 3 – Ammonia concentration in SBR's effluent

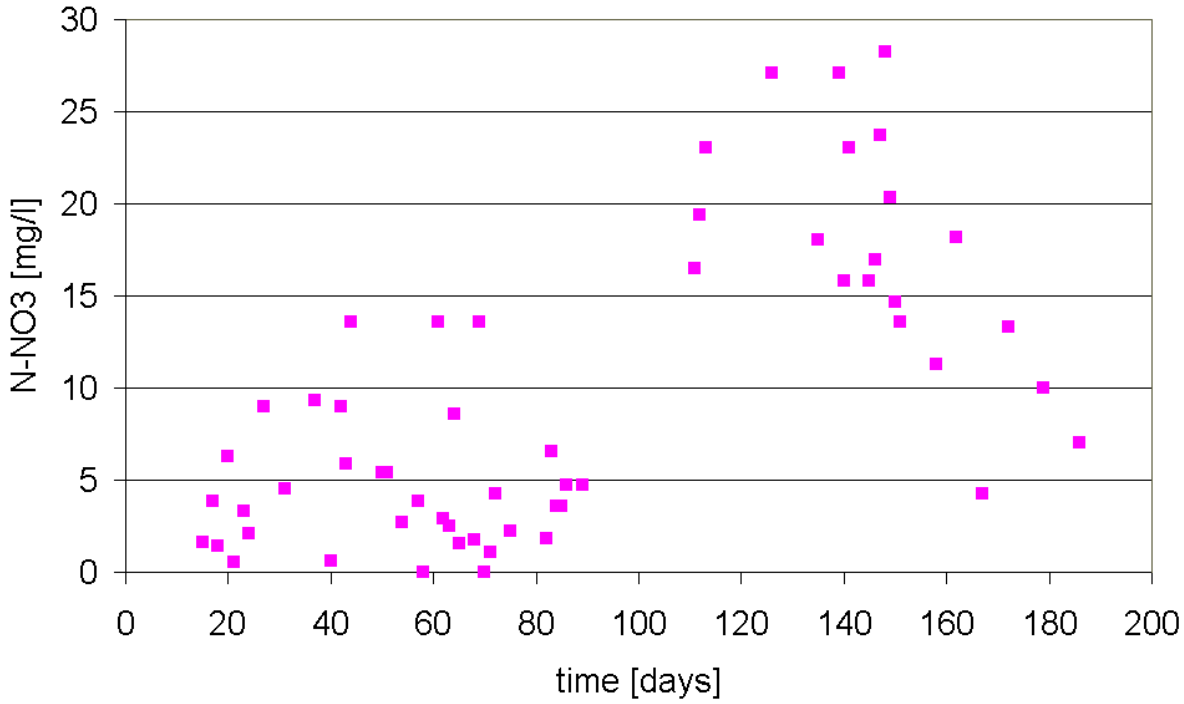

Figure 4 – Nitrate concentration in SBR's effluent

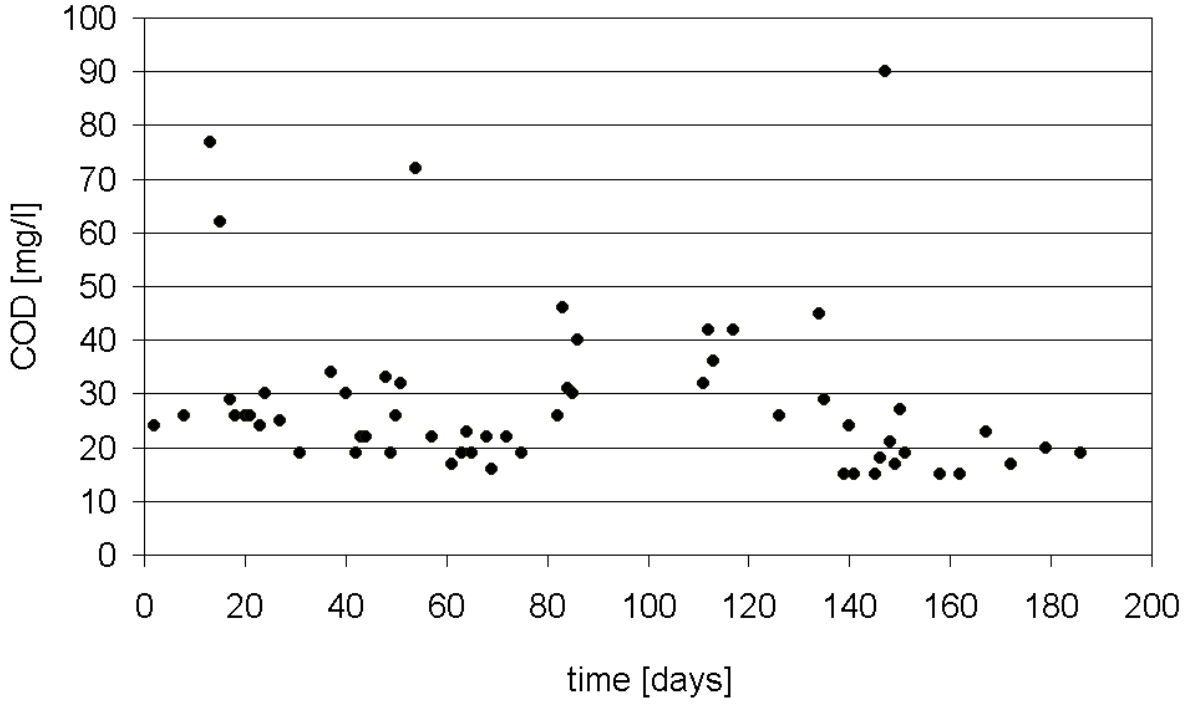

Figure 5 – COD concentration in SBR's effluent

Operation under standard conditions

Once the reactor reached standard conditions (see Table 3) DO, pH and ORP profiles showed the relevant points that indicate the transition between the main biological reactions.

The denitrification process is very fast and lasts no more than 30 minutes; the end-point of the reaction can be detected by
1) the “nitrate knee” in the ORP profile and
2) the “nitrate-apex” (i.e. the maximum), in the pH profile.

The nitrification process is completed within 60 minutes; the end point can be detected by observing:
1) the “ammonia valley” in the pH profile (Chang and Hao, 1996),
2) the bending point in the ORP profile (Plisson-Saune et al., 1996); and
3) the "DO flex" or "break-point" (Plisson-Saune et al., 1996; Andreottola et al., 2001), that is the typical change in the slope of DO profile.
Lab-analysis were made to confirm these end-points of the biological reactions.

In the figures 6 and 7 ORP, pH and DO profiles with the relevant points of the reactions can be observed; these data were collected during a “standard condition” cycle.

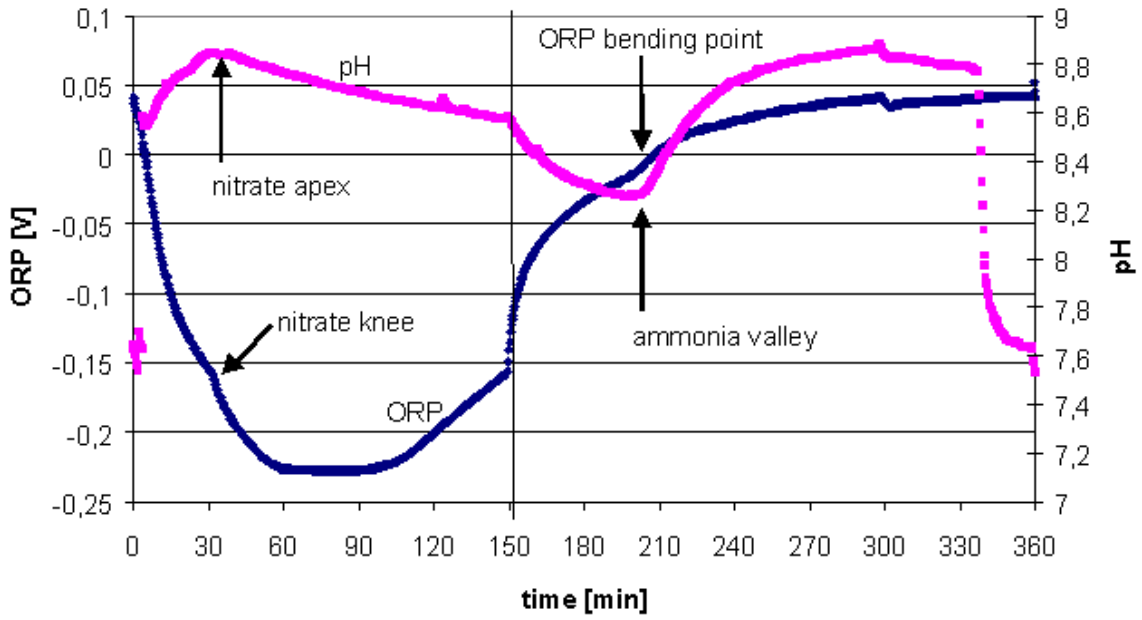

Figure 6 – ORP and pH profiles during a “standard conditions” cycle of SBR

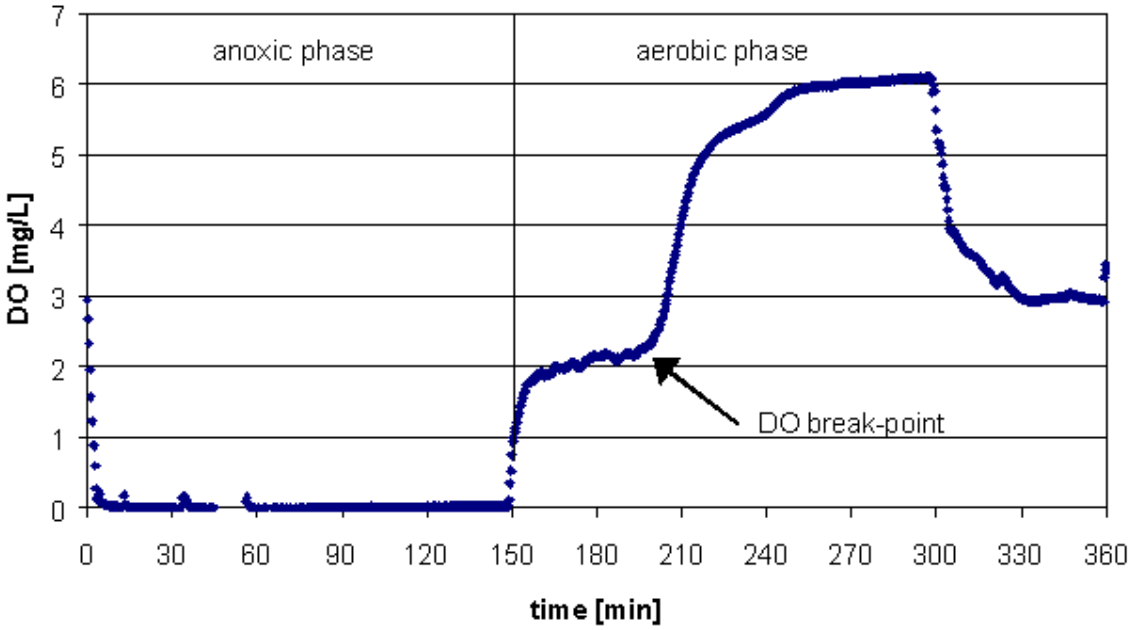

Figure 7 – DO profile during a “standard conditions” cycle of SBR

Experiments for evaluation of the mass balance model developed within the framework of EOLI

Plan of the experiments

The plan of the experiments was decided in the meeting held in Narbonne (November 2002) and included:
a) one standard experiment, that was aimed to monitor the SBR operating conditions and performance under standard operation;
b) a series of cyclic studies that were planned in order to monitor the effects of the variation of several parameters.
In Table 1 the final set of experiments is summarised, as it was defined during the meeting held in Mexico City (May 2003).

Table 1 – Plan of the experiments

different Carbon/Nitrogen ratios	[= 6 experiments]
acute toxicant (smaller size, same sludge)	[= 3 experiments]
different O_2/Carbon ratios	[= 2 experiments]
different C/X ratios (including overload condition)	[= 4 experiments]
standard conditions	[= 1 experiment]
Total	16 experiments + 4 replicates

Analytical methods

Analytical methods are described in Table 2.

Table 2 – Analytical methods

parameter	Analytical method	Principle
NO2-N	Photometric method (cuvette-test)	Nitrites react with primary aromatic amines in acidic solution to form diazonium salts. These combine with aromatic compounds that contain an amino group or a hydroxyl group to form intensively coloured azo dyes. Variability of data expressed as percentile: 5% Detection limit: 0.015 mg/L
NO3-N	Photometric method (cuvette-test)	Nitrate ions in solutions containing sulphuric and phosphoric acids react with 2.6-dimethylphenol to form 4-nitro-2.6-dimethylphenol. Variability of data expressed as percentile: 5% Detection limit: 0.2 mg/L
NH4-N	Photometric method (cuvette-test)	Ammonia compounds combine with chlorine to form monochloramine. These react with salycilate to form 5-aminosalycilate, that is oxidized in the presence of a sodium nitroprusside catalyst to form a blue-colores compound. Variability of data expressed as percentile: 10% (<2 mg/L), 5% (>2 mg/L) Detection limit: 0.2 mg/L (<2 mg/L), 2 mg/L (>2 mg/L).
N total	Photometric method (cuvette-test)	An alkaline persulfate digestion converts all forms of nitrogen to nitrate. Sodium bisulfite is added after digestion to eliminate halide interferences. The digested sample are analysed following the nitrate analytical method. Variability of data expressed as percentile: 10% Detection limit: 5 mg/L
COD	Photometric method (cuvette-test)	Water sample is heated for two hours with a strong oxidizing agent, potassium dichromate. Oxidable organic compounds react, reducing the yellow dichromate ion to green cromic ion. Variability of data expressed as percentile: 10% (<50 mg/L), 5% (>50 mg/L) Detection limit: 15 mg/L (<50 mg/L), 50 mg/L (>50 mg/L).
TOC	Instrumental analyzer	Total carbon is converted to CO2 by combustion in the presence of an oxidation catalyst. CO2 is detected in a non-dispersive infrared gas analyser (NDIR). Inorganic carbon is converted to CO2 acidification with phosphoric acid. CO2 is detected in a non-dispersive infrared gas analyser (NDIR). TOC carbon is obtained by subtracting the IC concentration from the TC concentration. Variability of data expressed as percentile: 5% Detection limit: 1 mg/L
SVI	Imhoff cone	One litre of mixed liquor is withdrawn at the end of the aerobic phase and it settles for 30 minutes inside an Imhoff cone. At the end of the settling the volume of sludge settled in the graduated container is read and SVI is calculated dividing this volume for the TSS concentration of the mixed liquor. SVI is expressed in ml/g.
TSS		20 ml of the sample are filtered with a GFC filter. Then the filter is kept at 105°C for 24 h. When the filter reaches again the ambient temperature (in a drier), it is weighted and it's calculated the concentration of TSS.
VSS		The filter used before to measure TSS is kept at 540°C for 2 h. When the filter reaches again the ambient temperature (in a drier), it is weighted and it's calculated the concentration of TSS.

The analytical protocol defined in WP2 sets that for each reaction phase of the SBR, at least five samples must be collected, so that a sample (50 ml approx.) is withdrawn from the SBR every 30 minutes and is immediately analysed according to the methods described in Table 2.
On-line acquisition of pH, DO, Temperature and ORP is provided by the MARTINA prototype with a frequency of 3 data/min. All experiments last a single cycle of the SBR.
Since the single cyclic studies are performed at one-week intervals, it is assumed that the perturbations that have been induced do not affect the following experiment.

Experiments performed in the first year

After the meeting in Mexico City, the following experiments were performed in June and July:

1. standard conditions - 26th June 2003
2. standard conditions replicate –14th July 2003
3. COD/N –50% - 9th July 2003
4. COD/N –35% - 2nd July 2003
5. COD/N +35% - 22nd July 2003

The COD/N ratio was reduced by adding ammonium chloride, and it was increased by adding sodium acetate.

Experiment 1 : Standard conditions

The aim of the experiment was to monitor the behaviour of the SBR in the standard conditions reported in the table below, according to the EOLI experimental protocol.

Table 3 – Standard conditions parameters

Parameters	Values
Filling/Reaction Ratio [%]	20 (*)
C_{in} [*mgCOD/L*] $C_{(t=0)}$	600
Type of compounds	Synthetic urban sewage
$X_{(t=0)}$ [*mg/L*]	> 2,000
Volume loading rate [*gCOD/L-d*]	0.48 (**)
Mass loading rate [*gCOD/gVSS-d*]	0.20 (***)
Total *N-TKN* [*mg/L*]	75
NH_4^+ [*mg/L*]	Approx 0
COD/N-NTK	8
O_2 [*L/min.*]	Not defined
pH	Around 7 (monitored but not controlled)
T [*°C*]	25
$V_{(t=0)}$ [*L*]	16
$V_{(t=tfin)}$ [*L*]	20
Total cycle time [*h*]:	6
SRT [*days*]	20

Notes:
(*) 20%: 4 L feed in 20 L reactor volume
(**) 0.6 g/L x 4 L/cycle x 4 cycle/d : 20 L = 0.48 *[gCOD/L-d]*
(***) 0.48 g/(L d) / 2.4 gVSS = 0.2 *[gVSS/L-d]*

During the test, the SBR provided good removal efficiencies both for soluble COD (88%) and soluble nitrogen (52%). Nitrate removal proved to be very fast in the anoxic phase (it lasted no longer than 30 minutes). On the contrary, ammonia oxidation is slower and lasts around 60 minutes (see Figure 8). Nitrite production is important (up to 2.5 mgN-NO_2^-/L), but removal is complete at the end of the aerobic phase.

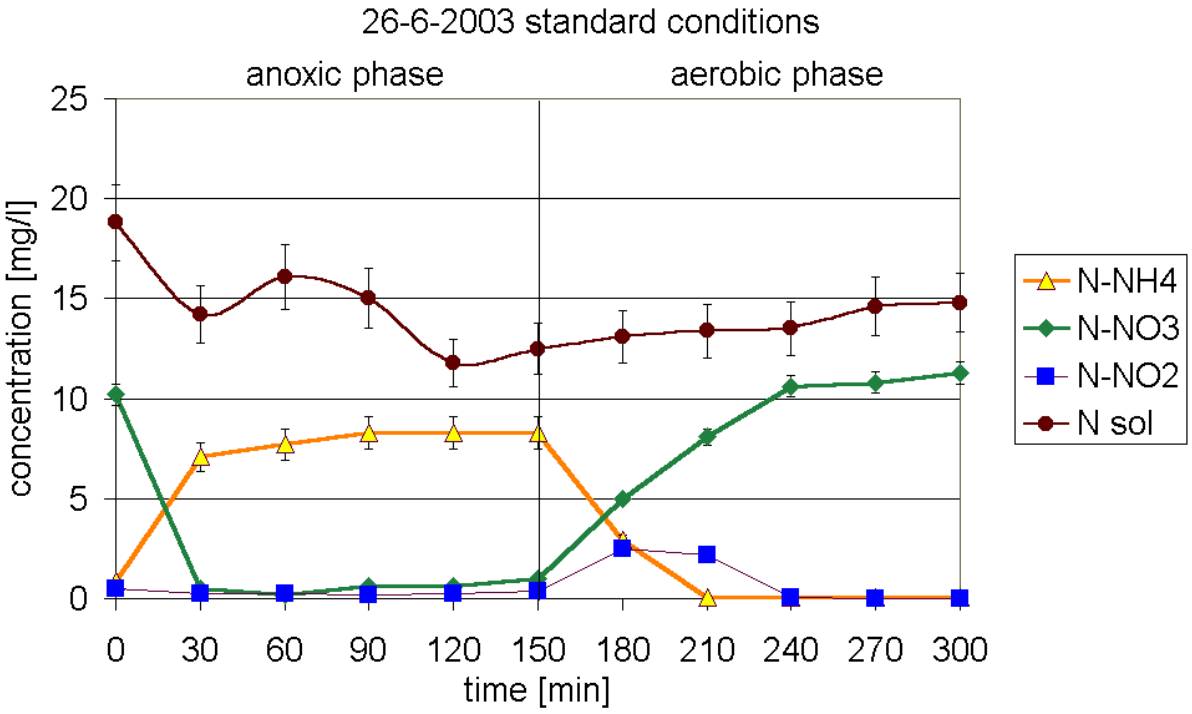

Figure 8 - Evolution of the N-forms during experiment 1

Experiment 2 : Standard conditions replicate

The SBR provided efficiencies as good as in the previous standard experiment (87% for soluble COD and 51% for soluble nitrogen).
However, it should be noticed that:

1) the amount of nitrate present in the SBR at the beginning of the experimental cycle was significantly higher (17.5 mgN- NO_3^-/L) than in the previous standard conditions test (10.2 mgN-NO_3^-/L); as a consequence, nitrate and nitrite removal in the anoxic phase was not complete, and higher residual nitrate could be measured in the effluent (see Figure 9).
2) although a possible error in the preparation of the influent caused higher COD and N concentrations (724 instead of 600 mgCOD/L and 92 instead of 75 mgN/L), the COD/N ratio remained equal to 8, as stated.

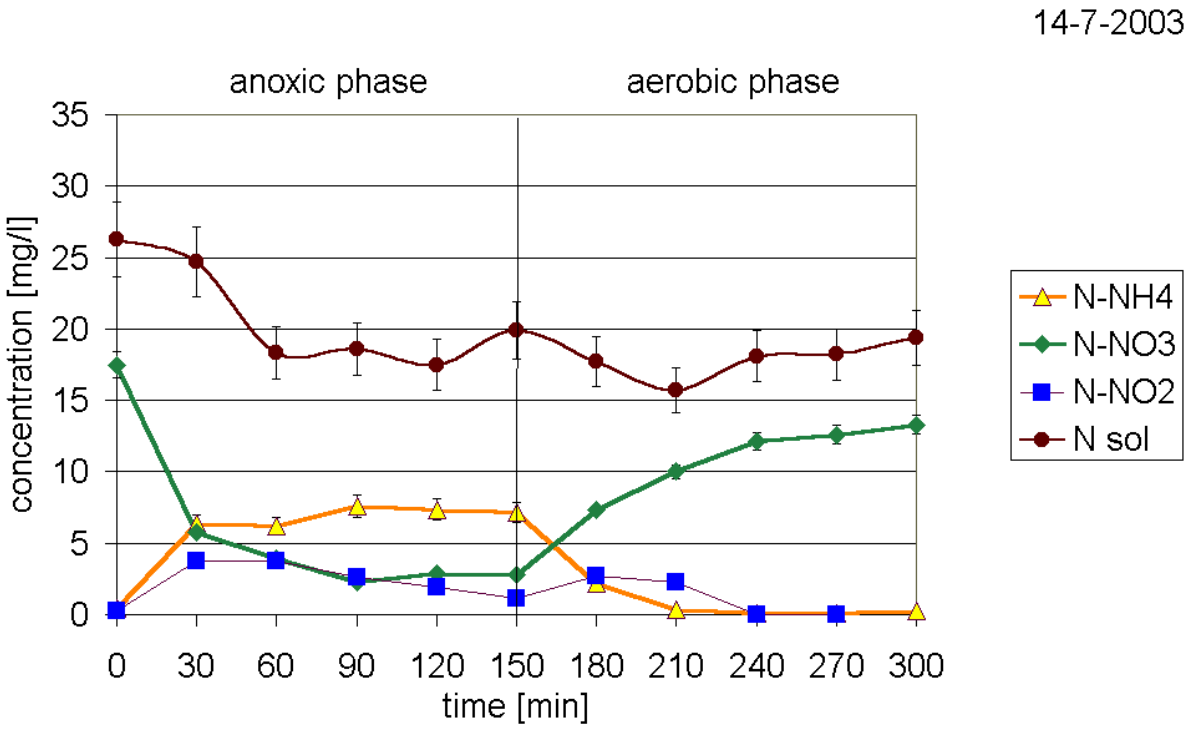

Figure 9 – Evolution of the N-forms during experiment 2

Experiments performed varying COD/N ratio in the influent

Experiment 3 : COD/N – 50%

The results of the test are shown in Figures 10 and 11.
It can be seen that removal efficiencies are slightly lower than those recorded in the standard condition tests (81% instead of 88% for soluble COD and 44% instead of 52% for soluble nitrogen. Denitrification doesn't allow the total removal of nitrate in the anoxic phase. Nitrite removal is not complete and a build up of 1.3 mg/L can be observed at the end of the aerobic phase.
This effect was partly enhanced by the considerable amount of nitrate that were present at the beginning of the cycle, almost twice the amount than in the standard conditions test (19 mgN-NO_3^-/L instead of 10.2 mgN- NO_3^-/L). Probably, excess nitrates after the previous test (Experiment n. 4, performed on the 2nd July) were not consumed during the week before the experiment. This may imply that a COD/N ratio of 8 does not provide organic carbon enough to cope with excess nitrogen loads.
As a matter of fact, soluble organic carbon was depleted almost completely before the first sampling (30 min) in the anoxic cycle (Fig. 11) while nitrate could not be depleted.

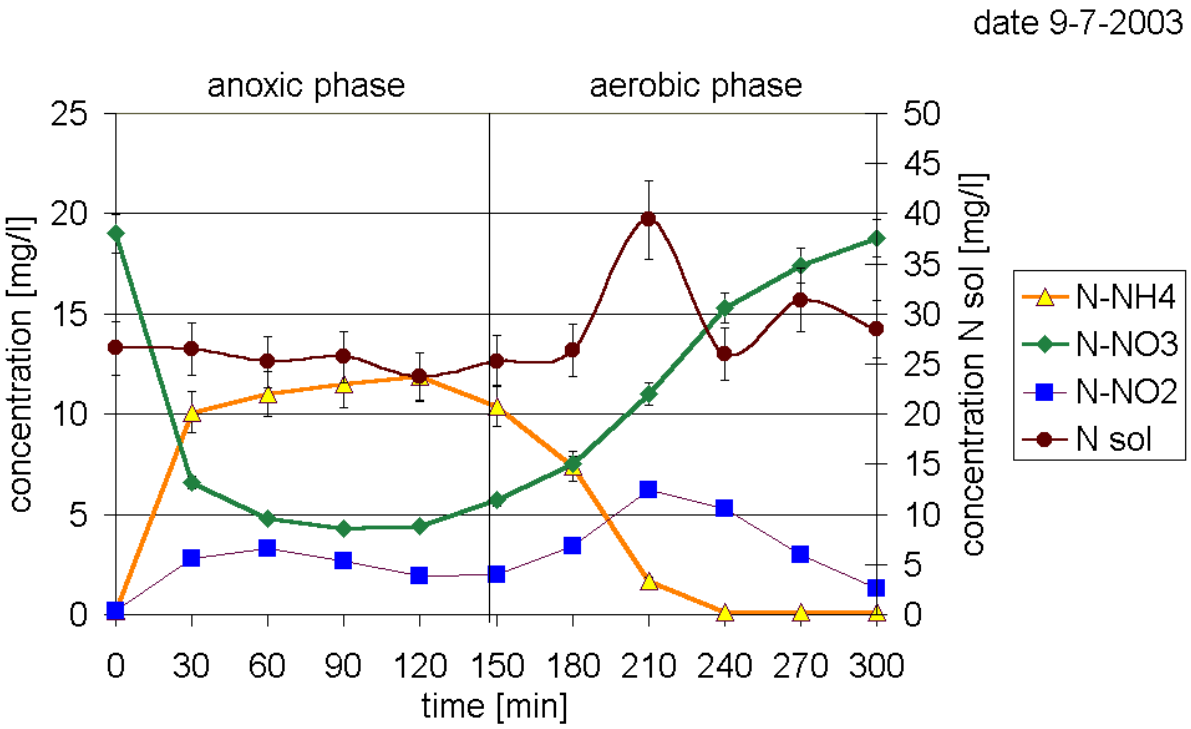

Figure 10 – Evolution of the N-forms during experiment 3

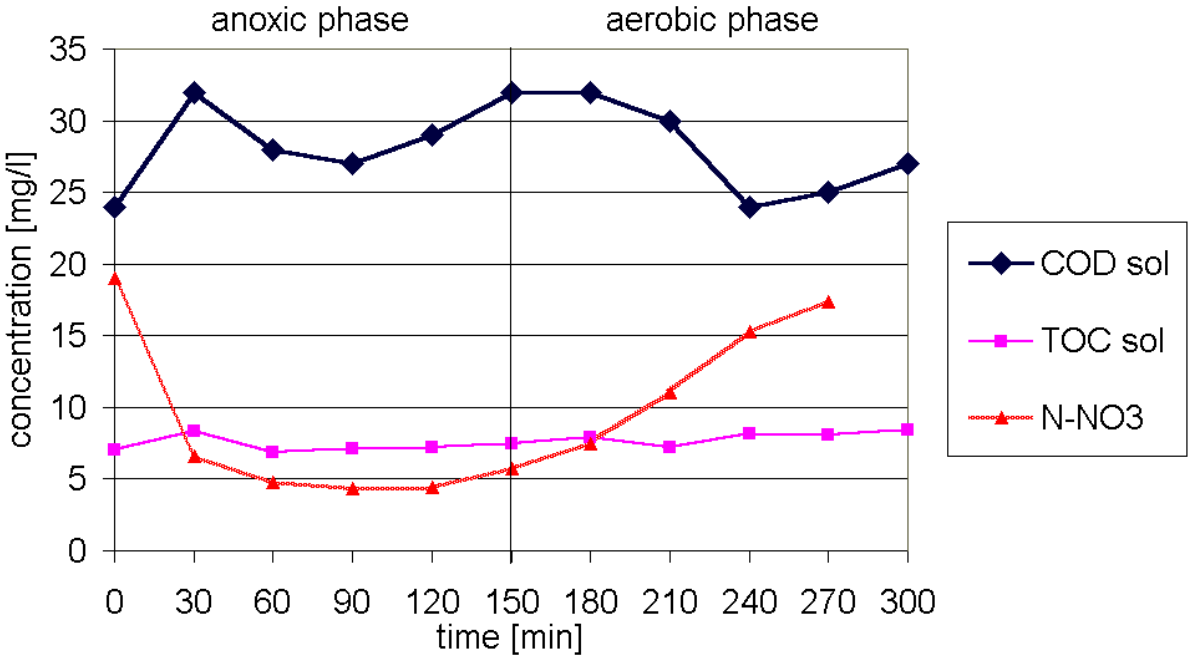

Figure 11 – Trend of COD, TOC and nitrates during experiment 3

Experiment 4 : COD/N – 35%

The results are shown in Figure 12.
Since this experiment was performed before experiment n. 3, the nitrate build up had not occurred yet and nitrates were depleted during the first 30 min of the anoxic phase. However, nitrates as high as 18 mgN- NO_3^-/L were detected at the end of the cycle.

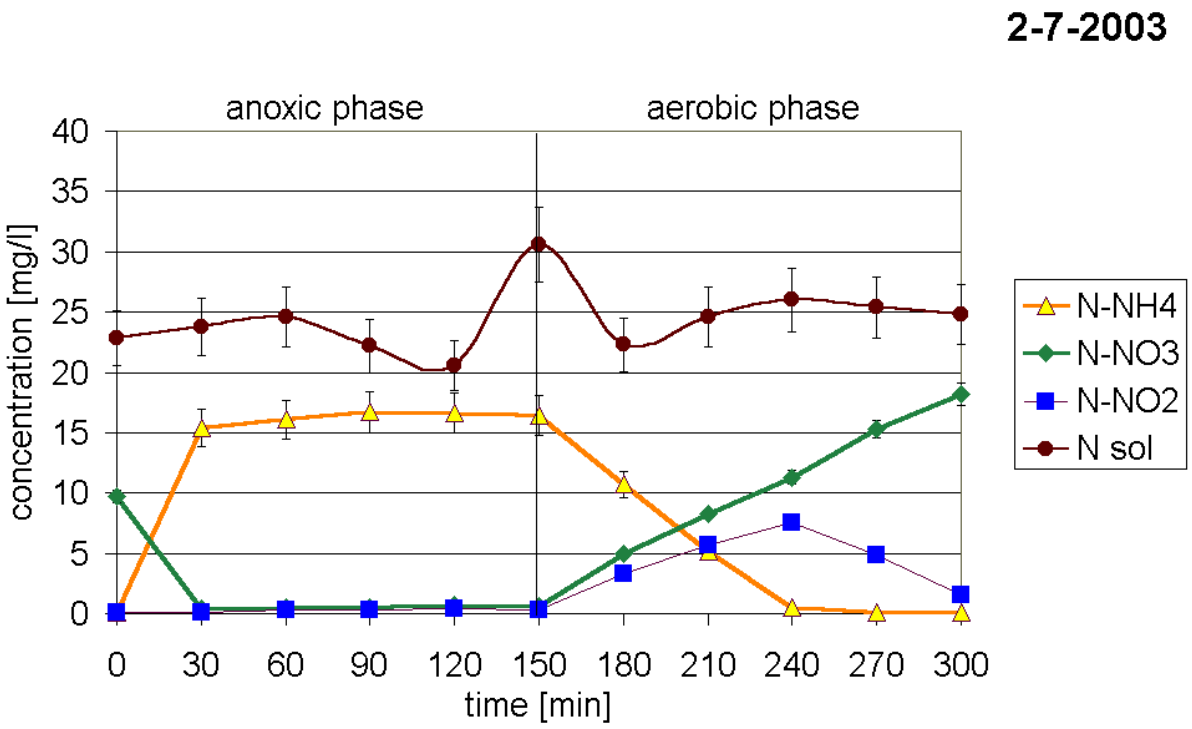

Figure 12 – Evolution of the N-forms during experiment 4

Experiment 5 : COD/N + 35%

Results of this test are shown in Figure 13.
While soluble COD and nitrogen removal efficiencies were very close to those observed during the standard condition tests, it looks like excess carbon helped in decreasing the nitrate build up. In fact the final nitrate concentration is lower than the concentration that was detected at the beginning of the cycle (10 instead of 12 mgN- NO_3^-/L).
Also, nitrite removal is complete.

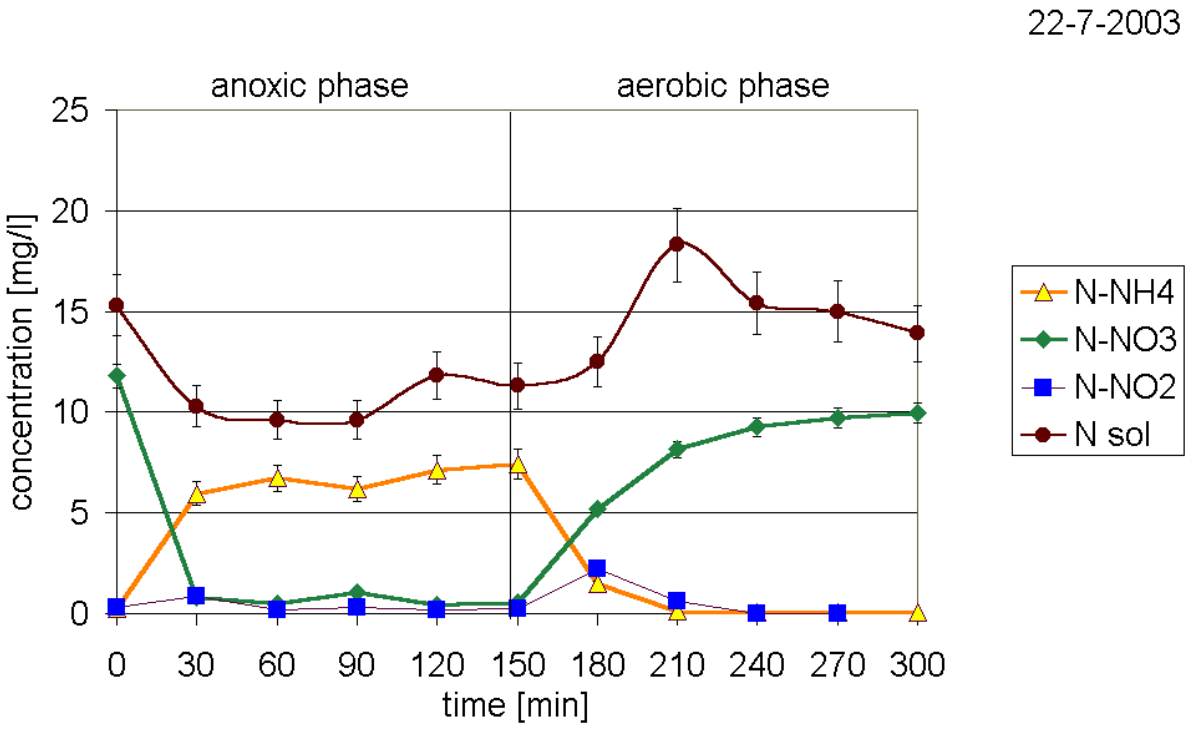

Figure 13 – Evolution of the N-forms during experiment 5

Planning of activities for the following year

Experiments planned, as agreed in Mexico City (with some slight changes), will be completed. Testing of the POLIMI hardware biosensor will be performed on the POLIMI lab-scale SBR, by using the modified OECD synthetic sewage and, subsequently, by using an artificial dairy sewage similar to that used at INRA, since the final integration of SBR control strategies and sensors will be performed at INRA.
Moreover, if the field scale SBR plant of ENEA will be available for the activities of EOLI project, an analytical campaign will be planned on real sewage. This campaign will be defined in details in order to test the performances of the prototype of the on-line automatic titration unit that POLIMI is developing in co-operation with SPES, within the activities concerning WP3 (Hardware sensor development).

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EOLI
Efficient Operation of Urban Wastewater Treatment Plants

ANNEX
WP1 - UNAM - 1st year activities

November 2002 -October 2003

Process Experiments
Partner 6, UNAM
First Annual Report

Contract Number ICA4-CT-2002-10012

Table of Contents

INTRODUCTION

This report presents the activities of the partner 6 (UNAM) concerning the WP1 of the EOLI project realized during the period November 2002-October 2003. In our case we investigate the biodegradation of a toxic compound by naturally occurring microorganisms. Concerning the experimental process activities, the experiments were designed, analytical methods were implemented, the reactor was assembled and experiments were conducted. The experiments conducted could be divided in two sets. In the first one, acclimation and deacclimation (by starvation) of the biomass to 4-chlorophnol was studied. In this part the Fixed Time Control (FTC) strategy was used. Later, the strategies utilized will be described in detail. The second part consist in a series of experiments conducted to calibrate and validated the model. In this case the Event Driven Time Optimal Control (ED-TOC) strategy was utilized to conduct the operation of the reactor.

MATERIAL AND METHODS

Reactor and Equipment

A pilot reactor of 10L (7L of working volume) was used. The reactor has a conical form to favor the settling of the sludge (Figure 1). The system of control was implemented using a personal computer and a data acquisition card (National instruments 6025E data acquisition card and the Labview package). An automatic temperature controller based on a recycle water pump was used to maintain a constant temperature of 20^{o}C inside the reactor. The input and output water flows were controlled by the computed system using two peristaltic pumps (Cole-Parmer model 7523, Masterflex series), respectively. The computer controls a mixer and a gas mass flow controller (Cole-Parmer E-33116-20) that turned on the aerator from the bottom of the reactor. The aeration flow was 1.5 L/min. The synthetic wastewater contained 4-chlorophenol (4-CP) as carbon source and complemented with nutrients the next composition per liter of water: KH_2PO_4 102 mg, K_2HPO_4 130 mg, $Na_2HPO4.H_2O$ 300 mg, NH_4Cl 30 mg, $MgSO_4.7H_2O$ 39 mg, $CaCl.2H_2O$ 63 mg, $Fe_2Cl_3.6H_2O$ 0.4 mg, $MnSO_4$-$2H_2O$ 0.003 mg, H_3BO_3 0.0057 mg, $ZnSO_4$-$7H_2O$ 0.0042 mg, $(NH_4)_6Mo_7O_{24}$ 0.0035, EDTA 0.0055 and $Fe_2(SO_4).6H_2O$ 0.0044 mg.

Details of the Experimental Protocol

In our case, some particular conditions will be studied in relationship with acclimatization/deacclimatization process. Thus, additional experiments were planned, giving a total number of 32 experiments. The results for each one of the experiments report the data in line (Temperature, DO, and the Influent_FR) and the data off line (Conc of 4CP, CODs, DOCs, MET, DO, VOLreact, InfluentFR, TSS, VSS, SVI, SV, 4CP_in, CODt_inf, CODs_inf, pH_inf, pH (in the reactor at the end of the reaction phase), AirFR_in, CODT_ef, CODS_ef, TSSef, Kla, SOUR (End,To 4CP, To acetate), rpm (mixer), Temp (in the reactor), InfluentFR_in, the phases duration (AWOF, FWA, Aeration, Settling, Draw and the Total time).

Two different control strategies were used: Fixed Time Control (FTC) and Event Driven Time Optimal Control (ED-TOC)

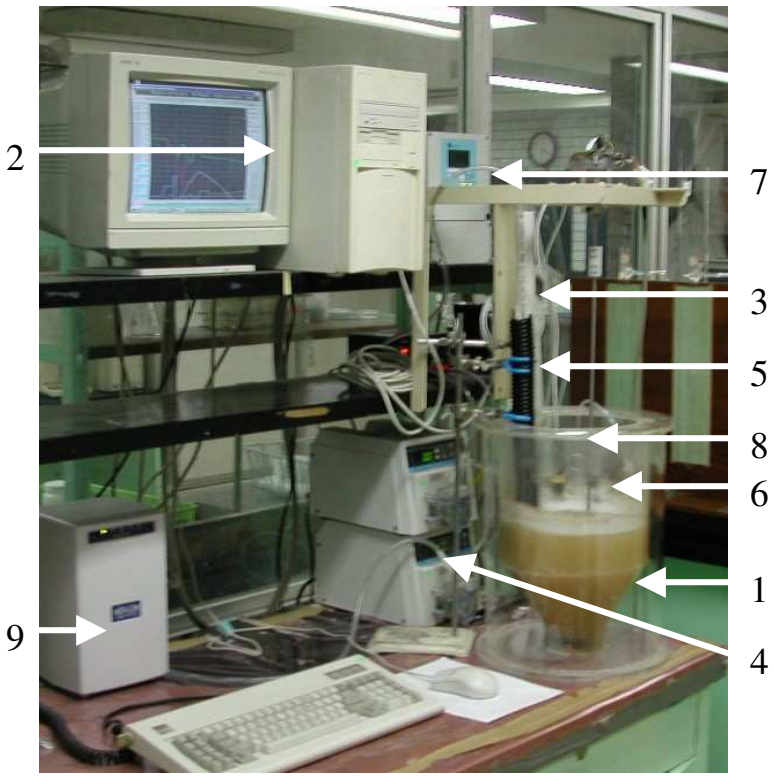

Figure 1. Pilot reactor utilized for the toxic compounds degradation. 1) Acrylic reactor with double wall and water recycling to maintain constant temperature at 20°C, 2) PC. 3) Acquisition card, 4) Peristaltic pumps (Master flex), 5) Temperature and Dissolved Oxygen Sensor (Endress + Hauser, COS4), 6) pH Sensor (Orion, model 720A), 7) Temperature and Dissolved Oxygen Transducers (Endress + Hauser, COM 223), 8) Level Sensor (Flow line LV10 series), 9) No break

Experiments Conducted

Experiment 1. Acclimation/Deacclimation

1.1. Acclimation/Deacclimation: New inoculum, 9 experiments. Strategy: FTC

1.1.1 Acclimation of the microorganism to degrade 50 mg4CP/L: 6 experiments

1.1.2Deaclimation with periods of starvation (8,12 and 24 h): 3 experiments

1.2. Acclimation/Deacclimation: New inoculum, 16 experiments. Strategy: FTC.

1.2.1 Acclimation of the microorganism to degrade 100 mg4CP/L (6 experiments)

1.2.2 Deacclimation with periods of starvation (12, 24 and 36 h)

1.2.2.1 Acclimation of the microorganism to degrade 200 mg4CP/L (4 experiments). Inoculum: sludge acclimated previously

1.2.2.2 Deacclimation with periods of starvation (12, 24 and 36 h)

Experiment 2. Standard conditions: 3 experiments (2 replicates)
Strategy: ED-TOC

Experiment 3. Variation of the relation carbon/biomass: 5 experiments (1 replicate)
Strategy: ED-TOC

Experiment 4. Variation of the relation oxygen/substrate: 3 experiments (1 replicate)
Strategy: ED-TOC

Phases of the SBR Control

Star-up and inoculation (acclimatization experiments)

The reactor was inoculated with activated sludge from a municipal wastewater treatment plant containing 2000 mgVSS/L. The acclimation was conducted operating the reactor with the following strategy: pre-aeration time (15 min) fill time (5 min), reaction time (variable depending on the necessary time to reach a removal efficiency of 4-CP of 99%), settle time (12 min) and draw time (1 min).

Fixed Time Control (FT)

When the reactor was acclimatized, the FTC strategy was used. Table 1 presents the conditions used for this strategy.

Event Driven Time Optimal Control (ED-TOC)

Moreno and Buitrón (1998) and Moreno (1999) proposed a control strategy to maintain the substrate removal rate at an optimum. The strategy called *Time Optimal Control Observed Based* (OB-TOC) tries to maintain the substrate concentration at S^*, by feeding the exact amount of dissolved substrate with the input water flow, for as long as the physical volume constraints of the reactor allow. After completely filling the reactor, one must only wait enough time as for the biomass to complete the degradation of the remaining substrate until its concentration is below a certain minimum. In synthesis, this control strategy determines the fill phase by controlling the input flow to the reactor and ends the reaction phase when almost all substrate has been degraded. Note that the optimal operation is fed-batch and not batch. This control law has a main problem: one *must continually measure* the biomass and substrate concentrations in order to implement it. This is either impossible or too expensive; therefore, other alternatives have been sought. One solution is to *estimate* asymptotically the unmeasured variables based on the mathematical model of the system and the measurement of other variables involved in the process; this constitutes a *state observer*. The drawback is that it needs to know exactly the inflow substrate concentration (S_{in}) and other critical SBR parameters as S^*. A slight mistake in estimating such parameters renders the observer useless. This makes the OB-TOC very difficult and unreliable to apply.

The *Event Driven Time Optimal Control* (ED)-TOC (Betancur *et al.*, 2004) (Figure 2) solves the problems by not looking at S, but instead finding a variable (named γ) related to the reaction's speed. Such γ can be estimated in real time by using O and V measures in equation (1). That is why it is feasible to control Q_{in} so that the reaction's speed stays inside the *fast zone* in Figure 2. Such zone is above a $P\%$ of the maximum speed. Associated with that there is a shaded rectangle to explain how controlling the speed indirectly keeps the unknown S oscillating in a gap between some S_{pl} (lower than S^*) and S_{ph} (higher) all the way trough the SBR filling. Every time S tries to leave this gap, an event is issued and the ED-TOC then switches Q_{in} on/off, to prevent it. This is why the volume-substrate plane trajectory zigzags inside the shaded envelope. As $P \rightarrow 100\%$ the zigzags will be finer and then the ED behavior will approach the theoretical TOC. This will work regardless of the S_{in} value and despite changes in most of the SBR parameters. Only $K_l a$ and O_s are needed to estimate γ and they do not even need to be known precisely. This makes the ED-TOC robust. In control terms, this means that increasing the error in obtaining those parameters

will only degrade the ED-TOC performance gradually. Even when those parameters are badly given, the ED-TOC will behave acceptably. This solution is therefore a good candidate for uses in real industrial environments. Table 1 shows the standard conditions used.

$$\gamma \overset{\Delta}{=} \frac{B}{Y_{X/O}}\mu + bB = K_l a(O_s - O)V - OQ_{in} + \frac{dO}{dt}V \qquad (1)$$

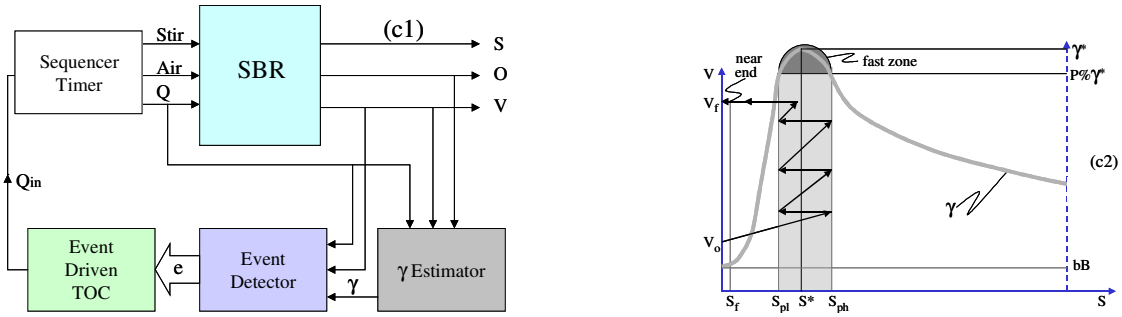

Figure 2. ED-TOC; 1) Control Layout, 2) V-S plane trajectory (VSpt); Secondary dashed line for μ or γ respectively. A dark area marks the speed related zone in which the process spends most of its time. Initial S=0 and V=V_o conditions are assumed.

Table 1. Standard conditions used for the strategies employed

	FTC	**ED-TOC**
Filling/Reaction Ratio, *%*	6.7 acclimation/ deacclimation	Aprox 100
C_{in} [*mg COD/l*] $C_{(t=0)}$	375 (350)$^{+}$· 214 (50 to 200) $^{+}$ $^{+}$as 4CP	375 (350)$^{+}$· 214 (200) $^{+}$ $^{+}$as 4CP
Type of compounds	Synthetic wastewater. 4-chlorophenol	Synthetic wastewater. 4-chlorophenol
$X_{(t=0)}$ [*mg/l*]	2,000	2,000
Volume loading rate, gCOD/L-d	2.25	2.25
Mass loading rate, gCOD/gVSS-d	1.12	1.12
O_2 [*l/min.*]	1.5	1.5
pH	7	7
T [°*C*]	20	20
$V_{(t=0)}$ [*l*]	3	3
$V_{(t=tfin)}$ [*l*]	7	7
Total cycle time [*h*]:	4	4
SRT [*days*]	20 measured	20 measured
Operational times		
Fill	12 min	variable
Aeróbic	178 min	variable
Settling	30 min	30 min
Draw	6 min	6 min
Iddle	14 min	15 min
Total time	4 h	variable

Control System

The system was developed to introduce the selected type of operation strategy for each of the realizing experiments.

Control window

In the manual control window of BIOREC, the user have the total control of the reactor functions, i.e. can determine the fill flow (1) and effluent flow (2), the settle time and draw time, mixer by a stirrer (3) and a valve that turned on the aerator (4) . The window shows the reactor volume (5) and the dissolved oxygen concentration (6).

Process register window

The process register window show the dissolved oxygen concentration (1), the reactor volume (2), the phase and the time elapsed of the phase (3), the file name (4), pH (5), temperature (6), estimated substrate (7), movements in the control register (8) and another parameters that are used in the control strategies (figure3).

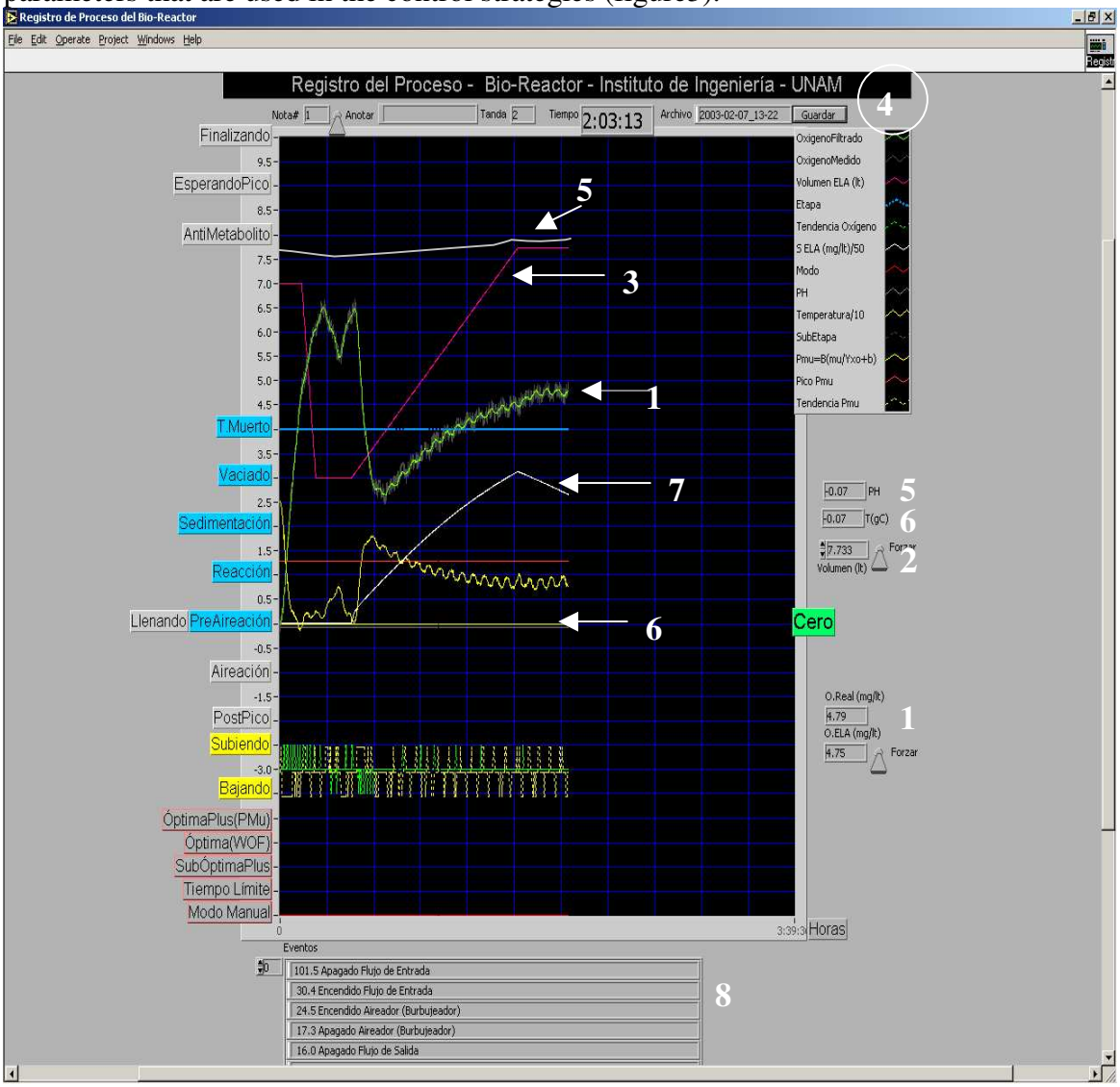

Figure 3. Process graphic register window

On Line Measurements

The on line measurements were obtained with the next devices:

- Dissolved Oxygen and Temperature sensor, Hendress+Hauser (Liquisys-M)
- Alimentation flow: Peristaltic pump Cole-Parmer model 7523- 50 (0-100 rpm), Masterflex series.
- Draw flow: Peristaltic pump Cole-Parmer model 7523- 40 (0-600 rpm), Masterflex series (The reactor volume evaluated integrating input ant output flows in time).

Off Line Measurements

Total phenols (4-CF), Chemical Oxygen Demand (COD), Dissolved Organic Carbon (DOC), Metabolite (5-chloro-2hydroxy-muconic acid semialdehyde), Volatile Solid Suspended (VSS) and Total Solid Suspended (TSS), Activity of microorganism, sludge volumetric index (SVI), settling velocity (SV).

Analitical Methods

Total phenols (4-CF)

Total phenols were determined using the 4-aminoantipyrine method (colorimetric method). The phenolic compounds have a reaction with the 4-aminoantipyrine at a pH of 7.9 +/- 0.1 in presence of alkaline medium for form a aminoantipyrine colored complex with color. This is read at 500 nm.

Chemical Oxygen Demand (COD)

The method used is according to HACH (method 420 COD Low Range). The sample was filtered with a glass microfibre GFA (Whatman).

Dissolved Organic Carbon (DOC)

The DOC is used in order to detect the degradation of 4-CP (organic compound) during the degradation kinetics. The sample was filtered with a glass microfibre filter GFA (Whatman), and the analysis were carried out with a Carbon Organic Total Analyzer (Shimatzu 5050)

Metabolite

The Metabolite 5-chloro-2hydroxy-muconic acid semialdehyde (Comandeur and Persons, 1990) is a compound formed by an alternate degradation route of 4-CP by the microorganisms, this can be inhibitory for the microorganisms. The compound is detected by spectrophotometric at 380 nm measured in a HACH spectrophotometer.

Volatile Solid Suspended (VSS) and Total Solid Suspended (TSS)

The VSS and TSS were done according to the S*tandard Methods* (APHA, 1992).

Activity of microorganism

The activity of the microorganisms was obtained by a respirometric method, following the next protocol:

Oxymeter calibration**.** A biological oxygen monitor (YSI Model 5300) with a 5357 micro oxygen probe was used. A solution of water saturated with oxygen was prepared during, at least, 2 hours before realizing the calibration. The calibration value was corrected by the effects of pressure (585 mmHg at Mexico City level) and temperature of the experiments (20 ºC). It was verified that the membrane of the oxymeter electrode was in good condition, in correct position and without any bubble of air in the reactor cell.

Determination of the activity. A reactor of a volume of 60 mL was used and placed in a container with water maintained at a constant temperature of 20°C. The nutrients solution was saturated with oxygen for a period of time of around one hour. The reactor was filled with the aerated nutrients solution and a magnetic bar, taking care to not produce any bubble of air. The electrode was introduced very slowly until the stopper of rubber closes. Then, a sample of 10 mL of activated sludge (2000 mgVSS/L), previously harvested from the reactor at the end of the reaction period, was introduced to the mini-reactor with a syringe. The oxygen consumption as function of time (approximately 20 min) was registered in a plotter. The reactor was mixed continuously. This experiment produces the endogenous respiration. The same procedure was conducted to obtain the activity against acetate (200 mg COD/L) and 4-CP (50 mg/L). For these cases, acetate and 4-CP solutions and nutrients were filled to the reactor.

Calculations. The VSS concentration was determine in the mini-reactor according to *Standard Methods* (APHA,1992). Maximal slope of the curve obtained from the plot of oxygen concentration vs. time was divided by the VSS giving the SOUR (specific oxygen uptake rate).

Units and Abbreviations

The abbreviations and units used in the tables of results and other reports are described in the table 2.

Table 2. Name of the measured variables and the abbreviations used in the results tables.

Name	Unit	Meaning
Temp	°C	Temperature inside the reactor
AirFR_in	L/h	input air flow rate
InfluentFR	L/h	Influent (liquid) flow rate
pH_inf	-	pH in the influent
PH	-	pH in the reactor
Rpm	rpm	mixer speed
SVI	mL/g	sludge volume index
VSS	mg/L	volatile suspended solid
TSS	mg/L	total suspended solid
TSSef	mg/L	total suspended solid in the effluent
SV	m/h	Settling velocity
DO	mg/L	dissolved oxygen
DOCs	mg/L	Soluble dissolved organic carbon
CODt	mg/L	total chemical oxygen demand
CODs	mg/L	soluble chemical oxygen demand
CODt_ef	mg/L	total chemical oxygen demand in the effluent
CODs_ef	mg/L	soluble chemical oxygen demand in the effluent
4CP	mg/L	4-chlorophenol
4CP_inf	mg/L	4-chlorophenol in the influent
MET	Absorbance	Metabolite (5-chloro-2hydroxy-muconique acid semialdehyde)
VOLreact	L	Reactor volume
SOUR	mgO_2/gSSV-h	Specific Oxygen Uptake Rate
End		Endogenous
AWOF		Aeration without fill
AWOF		Fill with aeration
FT		Fixed Time Control
ED-TOC		Event Driven Time Optimal Control
C	mg/L	Carbon
X	mgSSV/L	Initial biomass
Kla	h^{-1}	Mass transfer coefficient

EXPERIMENTAL RESULTS

Operation Data

The reactor was operated during 99 days. First 92 days under the FTC strategy and the rest under the EDTOC strategy (table 3).

Table 3. Summary of the experiments

Days of operation	Experiments	Control Strategy
0-8	Acclimation to 50mg4CP/L	FTC
17-26	Starvation (8,12,24 h)	FTC
36-41	Acclimation to 100mg4CP/L	FTC
42-52	Starvation (12,24 h)	FTC
60-62	Acclimation to 200mg4CP/L	FTC
83-92	Starvation (12, 36 h)	FTC
94-99	Several experiments	EDTOC

Evolution of the influent substrate.

Figures 4 to 10 resume the evolution of the influent substrate concentration (as 4CP and COD), suspended solids in the reactor, sludge volumetric index, settling velocity and specific oxygen uptake rate for the reactor operation under the experiments conducted. Note that the substrate variation is in the tank, before the reactor was fed and the dilution due to the volume exchange took place.

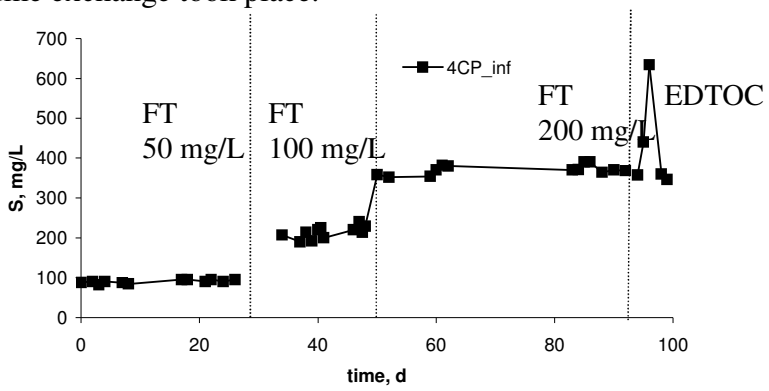

Figure 4. Evolution of the 4CP in the influent.

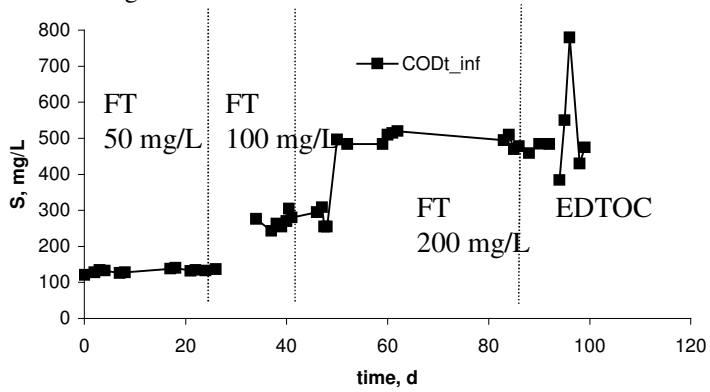

Figure 5. Evolution of the COD in the influent.

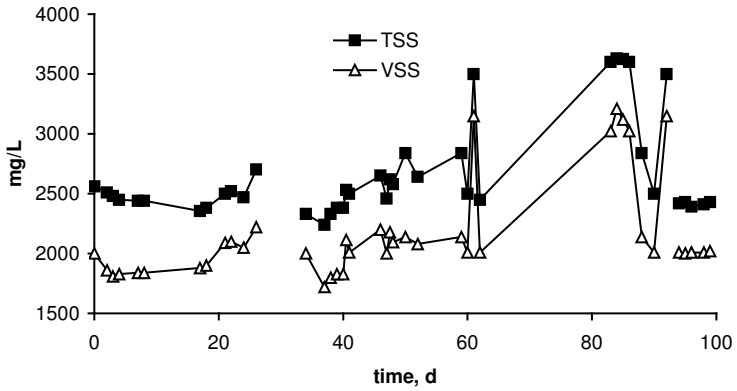

Figure 6. Evolution of the total and volatile suspended solids in the reactor

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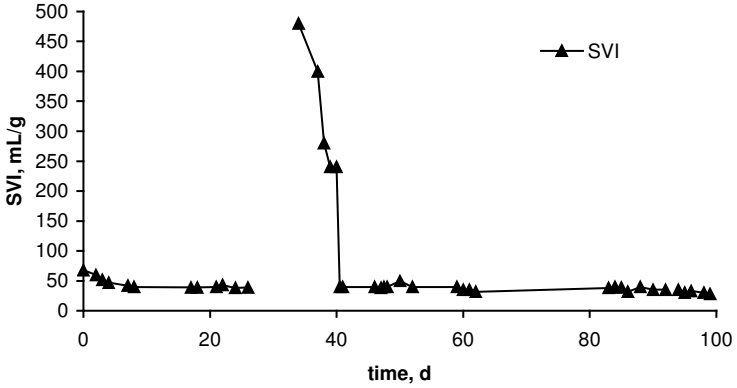

Figure 7. Evolution of the SVI. Note the rapid diminution of this parameter from 500 to around 50 for the case of the acclimation to 100 mg/L.

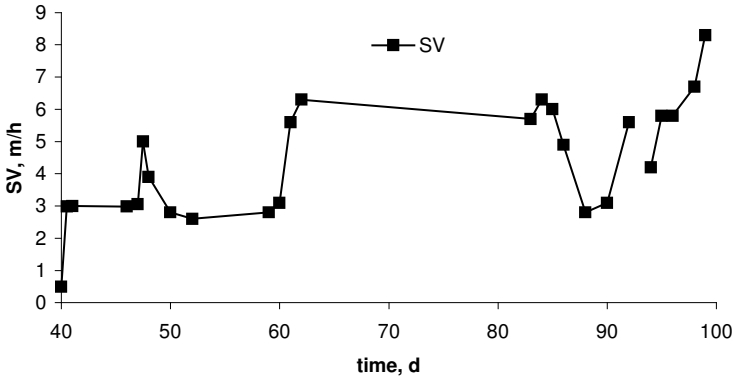

Figure 8. Evolution of the settling velocity

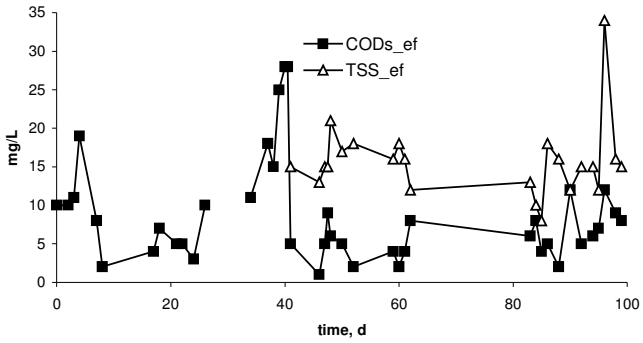

Figure 9. Evolution of the chemical oxygen demand and total suspended solids in the effluent.

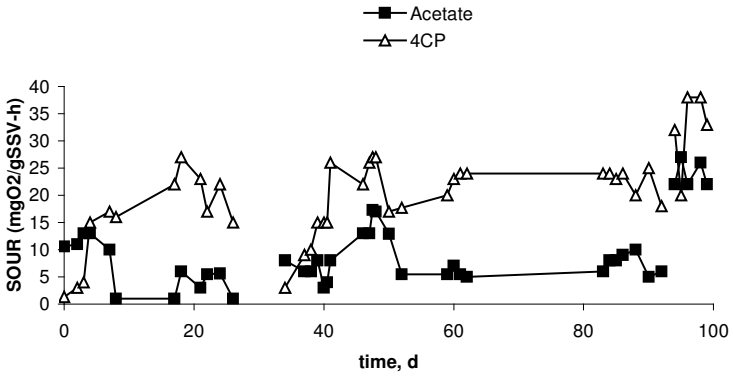

Figure 10. Evolution of the specific oxygen uptake rate

Acclimation

The degradation kinetics for the acclimation process was followed. For the initial concentrations of 4CP used, acclimation was obtained in 10 degradation cycles. During the acclimation, the 4CP was degraded with efficiencies higher than 99% as 4CP and 95% as DOC and COD. The results showed a reduction in the degradation time as the acclimation process occurred. In the case of 50 mg/L, degradation time was reduced from 40 h to 50 min, after 71 h (from cycle 1 to cycle 10)(Fig. 11) and from 52 to 1.16 h, after 105 h (Cycle 1 to 10) for 100 mg/L (Fig. 12). By comparing the necessary time to acclimate the consortia to 50 and 100 mg/L, it is noted that doubling in the initial concentration of the toxic only generates an increment of around 25% of acclimation period (71 vs 105 h).

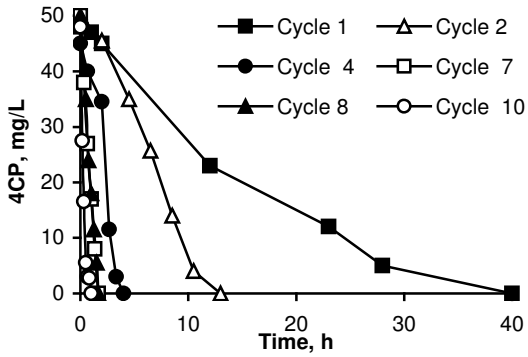

Figure 11. Degradation kinetics of 50 mg4CP/L during the acclimation process

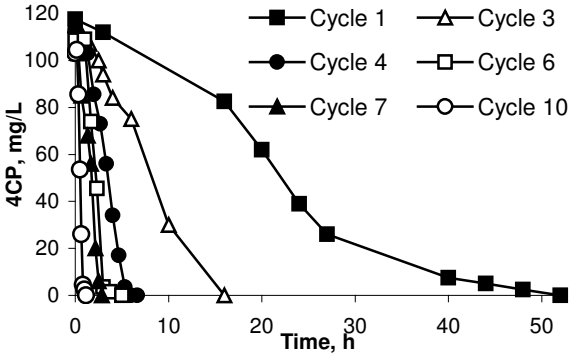

Figure 12. Degradation kinetics of 100 mg4CP/L during the acclimation process

When the pre-acclimated sludge to 100 mg/L was exposed to an increment of 100% of the initial concentration, degradation was only slightly affected. First degradation cycle for 200 mg/L took only 2.5 to remove 100% of the initial 4CP (Figure 13). After 5h, degradation times were reduced to 1.75 h (from cycle 1 to 6). This result indicated that during the 100 mg/L acclimation the required microorganisms reproduced and they also developed the necessary enzymatic activity. Doubling the initial concentration only generates an increment on the time to degrade a double quantity of 4CP. Nevertheless, care must be taken since an elevated concentration of the toxic compound may cause inhibition problems.

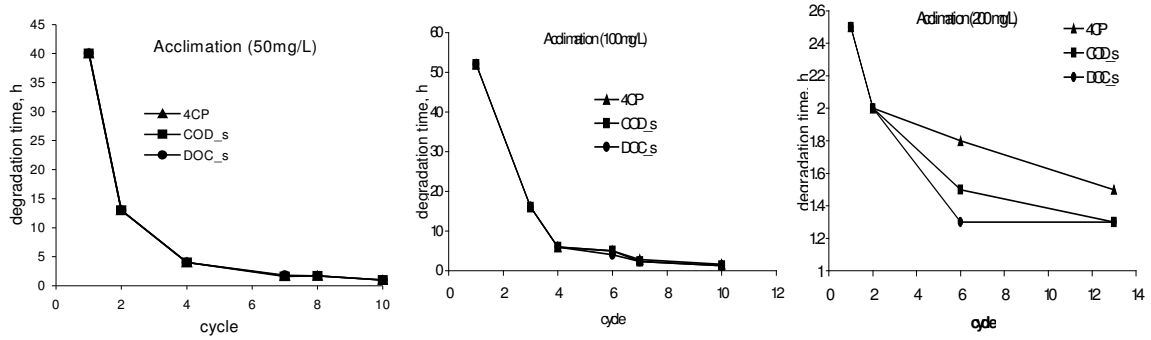

Figure13. Evolution of the degradation times during acclimation.

When the pre-acclimated sludge to 100 mg/L was exposed to an increment of 100% of the initial concentration, degradation was only slightly affected. First degradation cycle for 200 mg/L took only 2.5 to remove 100% of the initial 4CP (data not shown). After 5h, degradation times were reduced to 1.75 h (from cycle 1 to 6). This result indicated that during the 100 mg/L acclimation the required microorganisms reproduced and they also developed the necessary enzymatic activity. Doubling the initial concentration only generates an increment on the time to degrade a double quantity of 4CP. Nevertheless, care must be taken since an elevated concentration of the toxic compound may cause inhibition problems. Moreno and Buitrón (2003) observed that inhibition is not only function of the initial substrate concentration, but also of the initial biomass concentration. In general, a low biomass concentration will produce a greater inhibition. For this reason the acclimation of microorganisms is preferable to be done at lower initial substrate to microorganisms ratio. Once the microorganisms are acclimated, they can biodegrade concentrations of 4CP up to 1400 mg/L (Buitrón *et al.,* 2003).

Microorganism activity

Figure 14 presents the evolution of the SOUR computed during the acclimation of 4CP to microorganisms. Two parallel experiments were carried out. First, the SOUR was measured feeding the mini-reactor with an easy-to-biodegrade substrate, namely acetate. A second experiment was conducted using 4CP as substrate. The substrate for each case was the sole source of carbon and energy, and for both cases, endogenous respiration was evaluated and took into account for calculations. As acclimation took place, an increment in the SOUR against the 4CP was observed. On the contrary, a decrease on the SOUR occurred. In figure 3, a crossing point is observed around 60 h for both cases. We can consider that after this point affinity of the consortia is higher for the toxic compound than for an easy- to-

biodegrade substrate as the acetate. For the acclimation to 50 mg 4CP/L the crossing point was observed at 57h and 61 h for the case of the acclimation to 100 mg 4CP/L.

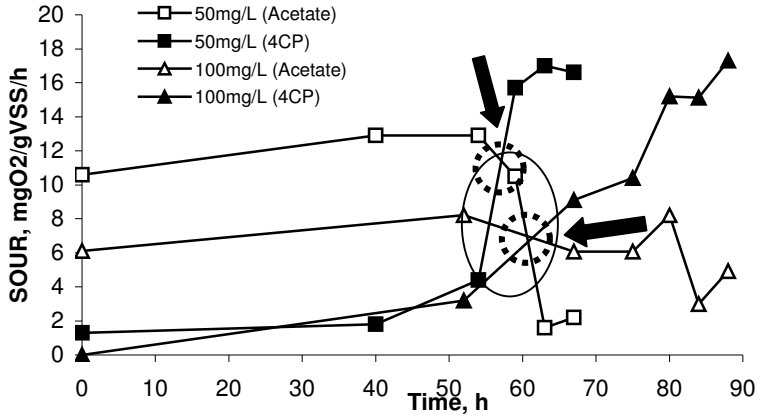

Figure 14. Evolution of the SOUR of the microorganisms acclimated to 4CP. Arrows indicate the crossing point when the activity to the consumption of 4CP is higher than the activity of acetate consumption.

Metabolite

The Metabolite 5-chloro-2hydroxy-muconic acid semialdehyde (Commandeur and Persons, 1990) is a compound formed by an alternate degradation route of 4-CP by the microorganisms, and this can be inhibitory. Table 4 shows the metabolite production during the acclimation experiments. To take in account the metabolite production, it was computed the absorbance generated during the degradation cycle, thus results are expressed as absorbance units multiply by hours. It is observed that higher quantities of metabolite were generated at the beginning of the acclimation. As the bacteria adapted, the toxic metabolite production diminished from 0.053 to 0.016 (for 50 mg/L) and from 0.110 to 0.018 absorbance units-hour. It has been observed that the apparition of this metabolite indicated an operation problem, thus a deacclimation of the microorganisms (Buitrón *et al.,* 2003).

Table 4 . Metabolite production during the acclimation process

Toxic concentration	Cycle number	Metabolite production (Abs*h)
50 mg/L	1	0.053
	2	0.020
	4	0.016
	7	0.016
	8	0.016
	10	0.016
100 mg/L	1	0.119
	3	0.026
	4	0.030
	6	0.016
	7	0.017
	10	0.018

Starvation

Many of the industrial processes generating wastewater containing toxic compounds are characterized by their variability. In the chemical, pharmaceutical, plastic and petrochemical industries, for some cases, production processes are in batch. Because of the high variations in flow and concentration of contaminants in industrial wastewater, treatment processes do not obtain satisfactory removal efficiencies. The first step to biodegrade toxic substances in a wastewater treatment plant is the acclimation of the microorganisms. Nevertheless, it has been shown that this acclimation is not permanent (Buitrón and Moreno, 2002). In effect, for instance, when the containers and reactors are cleaned, a peak in the concentration of toxic substances (shock load) is found in the wastewater treatment plant. After this sudden increase, there is a decrease of the toxic concentration. These variations of the toxic substrate or starvation in relation to the toxic compound have an important effect on the sludge activity. This is the case for intermittent industrial operation, which sometimes generates sudden increase of toxic substrate concentration (concentration peaks).

Table 5 and Figures 15 and 16 present the influence of starvation on the specific removal rate, qx and on the SOUR. As it is possible to note starvation generates a decrease on the microbial activity. In general, a decrement from 21 to 44 % was observed on qx due to the introduction of starvation periods, and from 26 to 35 % of activity lost measured as SOUR.

Table 5. Influence of starvation time on specific degradation rate and SOUR

	50 mg/L		100 mg/L		200 mg/L	
Starvation time, h	qx, mg 4CP/gVSS-h	SOUR, mg O_2/gVSS-h	qx, mg 4CP/gVSS-h	SOUR, mg O_2/gVSS-h	qx, mg 4CP/gVSS-h	SOUR, mg O_2/gVSS-h
0	29.7 ± 3.1	22.6 ± 0.6	52.1 ± 3.1	26.6 ± 0.6	42.9 ± 4.3	24.7 ± 2.1
8	22.5	17.7	--	--	--	--
12	19.2	17.6	57.2	22.4	33.9	22.9
24	15.6	15.9	41.0	--	37.3	21.1
36	--	--	--	17.2	28.4	18.2

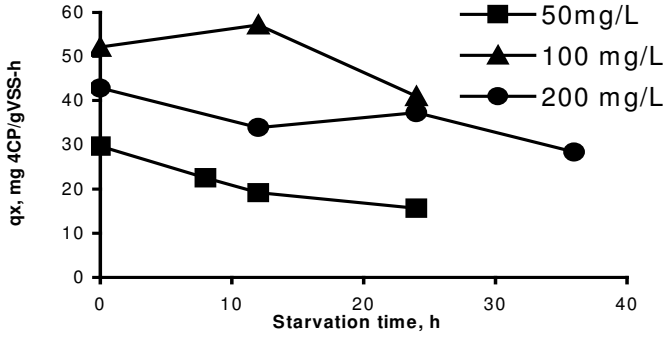

Figure 15. Influence of starvation time on the specific substrate removal rate. Results after starvation are compared with the initial condition before the perturbation.

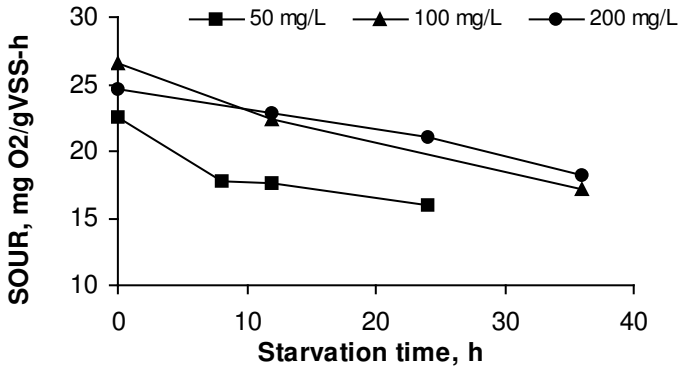

Figure 16. Influence of starvation time on the specific oxygen uptake rate. Results after starvation are compared with the initial condition before the perturbation.

ED-TOC kinetics

Standard Conditions

In order to obtain data to calibrate and validate the model, a series of experiments were conducted. First at all, the kinetics under the standard conditions was run (see table 1 for standard conditions). Figure 17 presents the behavior of the substrate concentration, measured as 4CP, COD, and DOC during a cycle. It is possible to distinguish how the control operates if the substrate evolution and the DO curve are followed. After the control algorithm found that a minimal DO concentration has passed, the feeding pump is switch on, and a new charge of substrate is fed to the reactor. In this kinetic it is possible to observe three times this behavior. As the cycle was finished the metabolite decreases, indicating a good operation of the system.

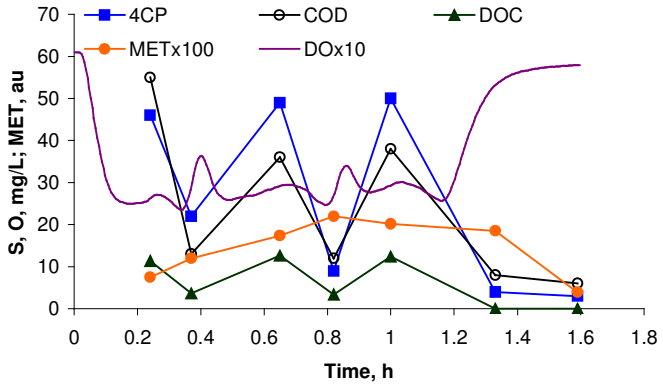

Figure 17. Kinetics under standard condition using the ED-TOC strategy.

Variation of C/X

Table 6 shows the values of the initial C/X ratio studied in this sets of experiments as well as the initial substrate concentration utilized. Figure 18 presents the behavior of the 4CP concentration during the kinetics. It was observed that an increase on the C/X ratio generates an increase of the degradation time. However, for all the cases the removal

efficiency of the toxic was superior to 95% as COD, and 99% as 4CP, indicating that a shock load of 613 mg/L had no influence on the performance of the reactor. Note that the maximal concentration in the reactor was around 50 mg/L irrespectively the initial concentration present in the feed. This indicates that S* is near to this value.

Table 6. Initial C/X ratio studied

Variation of C	C (mg4CP/L)	Relation C/X
STD	175	0.088
-25%	350	0.175
+25%	438	0.219
+50%	525	0.263
+75%	613	0.306

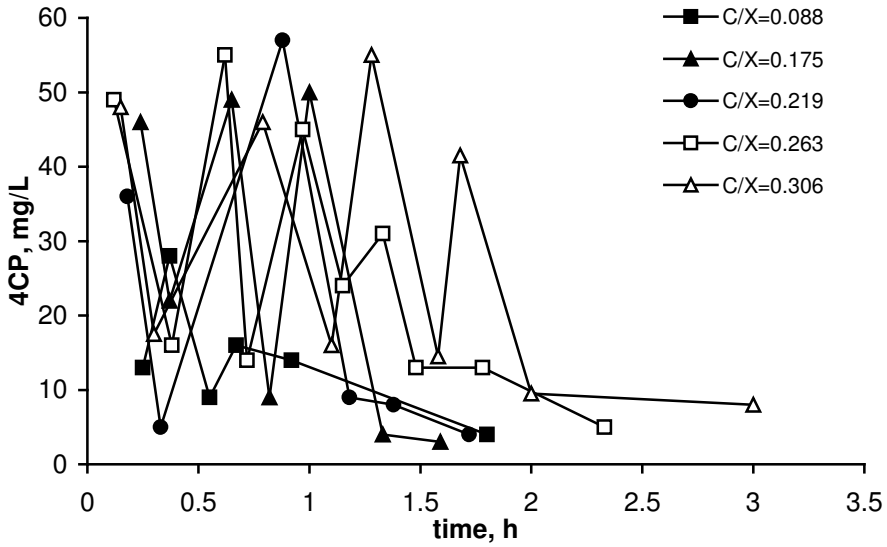

Figure 18. Degradation kinetics for different C/X ratio

Dissolved Oxygen Variation

Figure 19 presents the evolution of the dissolved oxygen during the variation of ± 50 of the air flow in respect to standard conditions. When a –50% condition was applied, DO in the tank was always superior to 2 mg/L. Thus it can be considered that no limitations for this element were present.

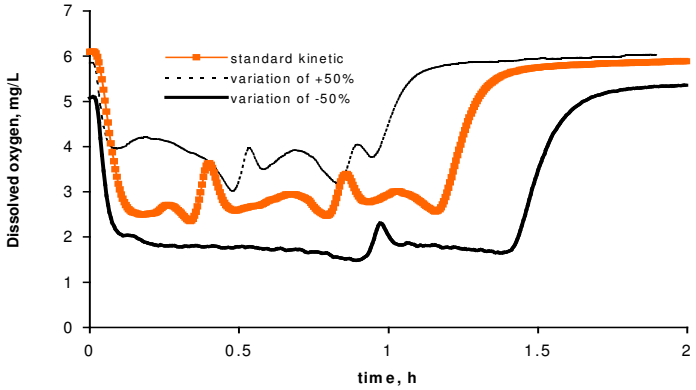

Figure 19. Evolution of the dissolved oxygen concentration as a function of time

Figures 20 and 21 showed the influence of the flow air variation on the substrate degradation and on the metabolite production. It is very interesting to note that in the case where the airflow was reduced by 50% there was an increase of the quantity of metabolite produced (figure 21). As a consequence the degradation time for this same condition increases (figure 20). Besides the great influence on the MET production, this toxic by-product was no removed after the degradation cycle, which may cause problems due to the accumulation in the next cycles.

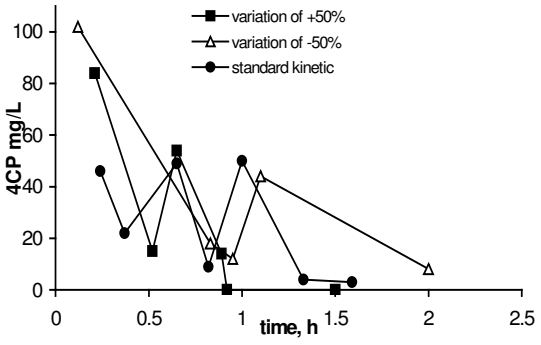

Figure 20. Evolution of the 4CP concentration for different airflow rates

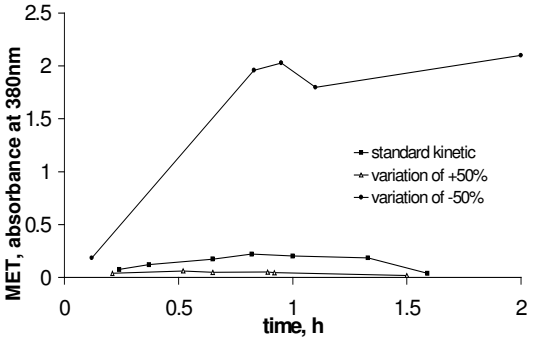

Figure 21. Evolution of the MET production for different airflow rates

Main Problems Encountered During Experimentation

In the biological process two problems were found and solved:

- An elevated concentration of 4CP in the fill in one cycle causing a lost of activity, which later recovered
- At the beginning of the acclimatization to 100mg/L, the inoculum used presented bulking as a consequence of elevated SVI present in the wastewater treatment plant. This problem was solved filling and settling manually the reactor. Decanting only as much as possible the supernatant. After one week, the problem disappears because the periodic process and the presence of the toxic compound inhibited the filamentous bacteria.

The errors that appeared with more frequency were errors and faults in the equipment.

CONCLUSIONS

During the first year the biodegradation of a toxic compound by naturally occurring microorganisms was studied. The experiments were designed, analytical methods were implemented, a pilot reactor (lab scale) was assembled and experiments were conducted. Two sets of experiments were studied with two control strategies: 1) Acclimation and deacclimation (by starvation) of the biomass to 4-chlorophnol using the Fixed Time Control strategy and 2) a series of experiments conducted to calibrate and validated the model using the Event Driven Time Optimal Control strategy.

The results showed a reduction in the degradation time as the acclimation process occurred. In the case of 50 mg 4CP/L, degradation time was reduced from 40 h to 50 min, after 71 h and from 52 to 1.16 h, after 105 h. By comparing the necessary time to acclimate the consortia to 50 and 100 mg/L, it is noted that doubling the initial concentration of the toxic only generates an increment of around 25% of acclimation period (71 vs 105 h). There exist a diminution on the toxic metabolite production as the bacteria adapted to the 4CP degradation. Acclimation to 4CP decreases the SVI

Starvation generates a decrease on the microbial activity. In general, a decrement from 21 to 44 % was observed on qx due to the introduction of starvation periods, and from 26 to 35 % of activity lost measured as SOUR.

Results obtained with the ED-TOC strategy indicated a good operation of the system under standard conditions. It was observed that an increase on the C/X ratio generates an increase of the degradation time. However, for all the cases the removal efficiency of the toxic was superior to 95% as COD, and 99% as 4CP, indicating that a shock load of 613 mg/L had no influence on the performance of the reactor. It was observed that in the case where the airflow was reduced by 50% there was an increase of the quantity of metabolite produced. As a consequence the degradation time for this same condition increases.

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EOLI
Efficient Operation of Urban Wastewater Treatment Plants

Work Package 1
First Annual Report

ANNEX
WP1 - UU - 1st year activities

November 2002 -October 2003

Contract Number ICA4-CT-2002-10012

Annex: REPORT OF THE ACTIVITIES AT THE ENVIRONMENTAL MICROBIOLOGY LABORATORY, Microbiology Department, School of Chemistry, since april 2003.

Objective 1: Potencial nitrifying activity measured using respirometric probe: Evaluation, optimization and application of the method to SBR sludges.

Based on the protocol proposed by EOLI we optimised the method to fit the condition of our laboratory. For this we used the sludge of the lab scale nitrifying reactor that we started in march. We proposed a protocol for respirometric assay of nitrifying activity

Results: for the sludge of the Reactors 1 and 2, the measured activities were:

Melga: aca queria poner solo los resultdos expresados por mgSSV, como estaban en la ppt, pero no los encontre asi.

Objective2: Fluorescence in situ Hybridization, molecular tool to quantify nitrifying community: optimisation and application.

Introduction

In situ hybridization techniques with whole cells using rRNA-targeted oligonucleotide probes (FISH) allow the enumeration and identification of bacteria in complex microbial communities. For this purpose the samples are treated with fixatives (paraformaldehyde or ethanol) to preserve cell morphology and allow the accessibility of oligonucleotide probes. Fixed samples are hybridized with fluorescently labelled probes, and visualised with an epifluorescence microscope. The specificity of the probes are adjusted to reveal different phylogenetic levels (e.g. domain, division, genus, species). For example the general probe Nso1225 detect most of the ammonia oxidizing beta Proteobacteria while a more specific probe like Nsv443 detect the species *Nitrosolobus multiformis*, *Nitrosospira briensis* and *Nitrosovibrio tenuis* within that group.

The use of specialised image acquisition software (e.g. Image ProPlus) is needed to quantify cells when they are clustered in dense aggregates. The software is also used when new probes are designed and evaluated. The evaluation of new probes requires the determination of optimal hybridization conditions with target and non-target organisms by measuring the signal intensity of cells with increasing formamide concentrations.

Results

We optimize the technique for quantification of cells by applying different ultrasonic treatments and solutions to achieve separation of most cells. We also used the software to measure the area of clusters of ammonia oxidizing bacteria.

EOLI
Efficient Operation of Urban Wastewater Treatment Plants

Work Package 2
First Annual Report

ANNEX
WP2 – CESAME – 1st year activities

November 2002 -October 2003

Contract Number ICA4-CT-2002-10012

WP2 - Model Selection and Parameter Identification
Model 2: WWTP with Nitrification/Denitrification

By Hadyan Fibrianto and Denis Dochain

Centre for Systems Engineering and Applied Mechanics (CESAME) – Université Catholique de Louvain, Belgium
Partner #1 of the EOLI project

1. Introduction

This document presents the process modelling of the WWT using nitrification and denitrification in the EOLI project (Model 2), after modifications in reaction scheme (proposed at the Mexico meeting, on May 7-9th, 2003). The partners involving in this process are the LBE (France), the UU (Uruguay) and the Polimi (Italy).

For all processes, we consider *stirred tank reactors* (STR) and use an *aerobic digestion*.

2. Reaction scheme

The aerobic phase is related to the reactions representing the nitrifying activity:

Reaction (2-1) $$C + O_2 \xrightarrow{\mu_{31} X_3} X_3 + CO_2 \qquad S_C + S_O \rightarrow X_3 + (CO_2)$$

Reaction (2-2) $$NH_4^+ + O_2 \xrightarrow{\mu_4 X_4} X_4 + NO_3 \qquad S_{NH} + S_O \rightarrow X_4 + S_{NO}$$

The anoxic phase involves the denitrification. The corresponding scheme is:

Reaction (2-3) $$NO_3 + C \xrightarrow{\mu_{32} X_3} X_3 + N_2 \qquad S_{NO} + S_C \rightarrow X_3 + (N_2)$$

Taking into account the ammonification, we have also:

Reaction (2-4) $$N \xrightarrow{r} NH_4^+ \qquad S_N \rightarrow S_{NH}$$

where N = TKN – NH_4^+, is the soluble organic nitrogen, and the reaction rate: $r = k_0 S_N$.

The endogenous respiration, with a reaction rate r_e, is related to the following reaction:

Reaction (2-5) $$C_X + NO_3 + O_2 \xrightarrow{r_e} \ldots \qquad C_X + S_{NO} + S_O \rightarrow \ldots$$

The biomass mortality is represented by the following scheme:

Reaction (2-6) $$X_{total} \xrightarrow{k_{d1} X_3 + k_{d2} X_4} X_d \xrightarrow{r_{XC}} C_X \qquad (X_3 + X_4) \rightarrow X_d \rightarrow C_X$$

where X_{total} is the total biomass (X_3 and X_4), and X_d is the dead biomass. C_X is the organic carbon issued from dead biomass. The previous reaction includes the mortality due to the presence of acute toxicant.

3. Modelling and notation

Let us denote S_C, S_{NH}, S_{NO}, S_O, X_3 and X_4, the biodegradable substrate concentration (carbon, mg COD/L), the ammonia nitrogen concentration (mg N/L), the nitrate (+nitrite) nitrogen concentration (mg N/L), the concentration of the dissolved oxygen (DO) in the water (mg/L) and the concentration of the digester biomasses (heterotrophs and autotrophs), respectively.

Remark.– Only the batch reactor configuration is considered here.

3.1. Anoxic Phase

The involved reactions in this phase are Reaction (2-3), Reaction (2-4) and Reaction (2-6), respectively:

$$S_{NO} + S_C \xrightarrow{\mu_{32} X_3} X_3 + (N_2)$$

$$S_N \xrightarrow{k_0 S_N} S_{NH}$$

$$(X_3 + X_4) \xrightarrow{k_{d1} X_3 + k_{d2} X_4} X_d \xrightarrow{r_{XC}} C_X$$

3.1.1. Mass balance of the substrates S_C, S_{NH}, S_{NO} and S_N

A mass balance on this phase leads to the following expressions: the time evolutions of the carbon, denoted S_C, and the ammonia, denoted S_{NH}, due to the ammonification, respectively are related to:

$$\frac{dS_C}{dt} = -k_{SX1} \mu_{32} X_3 \tag{2-1}$$

$$\frac{dS_{NH}}{dt} = k_{SN1} k_0 N \tag{2-2}$$

where k_{SX1} is the yield coefficient for the degradation of S_C by X_3 according to Reaction (2-3) with the reaction rate $\mu_{32}X_3$, k_{SN1} is the yield coefficient of the S_{NH} production by the ammonification in the anoxic phase and $k_0 S_N$ is its reaction rate. The ammonification is associated to the following equation:

$$\frac{dS_N}{dt} = -k_0 S_N \tag{2-3}$$

The nitrate time evolution corresponds to:

$$\frac{dS_{NO}}{dt} = -k_{SX2} \mu_{32} X_3 \tag{2-4}$$

where k_{SX2} is the yield coefficient for the degradation of S_{NO} by X_3 according to Reaction (2-3).

3.1.2. Mass balance of the biomasses:

The biomasses growths are as follows:

$$\frac{dX_3}{dt} = (\mu_{32} - k_{d1})X_3 \tag{2-5}$$

$$\frac{dX_4}{dt} = -k_{d2}X_4 \tag{2-6}$$

where k_{d1} and k_{d2} are the yield coefficients of the dead biomass X_d, from X_3 and X_4, respectively (see Reaction (2-6)), and the specific biomasses growth rate μ_{32} is given by:

$$\mu_{32} = \mu_{NO\max}\frac{S_{NO}}{K_{NO} + S_{NO}}\frac{S_C}{K_{C1} + S_C} \tag{2-7}$$

where $\mu_{NO\max}$, K_{NO} and K_{C1} are the maximum specific growth rate of X_3 associated with S_{NO}, the saturation constants associated with S_{NO} and S_C, respectively.

The time evolution of the dead biomass, denoted X_d, satisfies the following equation:

$$\frac{dX_d}{dt} = k_{d1}X_3 + k_{d2}X_4 - r_{XC} \tag{2-8}$$

with r_{XC} the reaction rate of the X_d /C_X transformation. The time variation of the C_x concentration is:

$$\frac{dC_X}{dt} = r_{XC} \tag{2-9}$$

3.2. Aerobic Phase

This phase involves Reaction (2-1), Reaction (2-2), Reaction (2-4), Reaction (2-5) and Reaction (2-6), respectively:

$$S_C + S_O \xrightarrow{\mu_{31}X_3} X_3$$

$$S_{NH} + S_O \xrightarrow{\mu_4 X_4} X_4 + S_3$$

$$S_N \xrightarrow{k_0 S_N} S_{NH}$$

$$C_X + S_{NO} + S_O \xrightarrow{r_e} \ldots$$

$$(X_3 + X_4) \xrightarrow{k_{d1}X_3 + k_{d2}X_4} X_d \xrightarrow{r_{XC}} C_X$$

3.2.1. Mass balance of S_C, S_{NH}, S_{NO}, S_O and S_N

In this phase, oxygen is needed for the degradation of the substrates S_C and S_{NH}. The time evolutions S_C and S_{NH} are related to the following expressions:

$$\frac{dS_C}{dt} = -k_{SX3}\mu_{31}X_3 \tag{2-10}$$

$$\frac{dS_{NH}}{dt} = -k_{SX4}\mu_4 X_4 + k_{SN2}k_0 N \tag{2-11}$$

where k_{SX3} and k_{SX4} are the yield coefficients for the degradation of S_C and S_{NH}, respectively, $\mu_{31}X_3$ and μ_4X_4 are the reaction rates of Reaction (2-1) and Reaction (2-2), respectively. k_{SN2} is the yield coefficient of the S_2 production by the ammonification in the aerobic phase.

The ammonification occurs also in this phase:

$$\frac{dS_N}{dt} = -k_0 S_N \tag{2-12}$$

The substrate S_{NO} (i.e. NO_3) is produced and also used to the endogenous respiration:

$$\frac{dS_{NO}}{dt} = k_{SX5}\mu_4 X_4 - k_r\, r_e \tag{2-13}$$

where k_{SX5} and k_r are the yield coefficients of the S_{NO} production and of the S_{NO} consummation for the endogenous respiration, respectively.

The dissolved oxygen variation in time is given by:

$$\frac{dS_O}{dt} = -k_{OX1}\mu_{31}X_3 - k_{OX2}\mu_4 X_4 - r_e + K_l a\left(S_{O,sat} - S_O\right) \tag{2-14}$$

where k_{OX1} and k_{OX2} are the oxygen yield coefficients associated with X_3 and X_4, respectively; r_e represents the endogenous respiration rate; K_la and $S_{O,sat}$ are the oxygen mass transfer coefficient and the saturation DO concentration in the liquid medium, respectively.

Endogenous respiration of the biomasses:

The endogenous respiration needs oxygen. Therefore this only occurs during the aerobic phase. The time variation of the C_x concentration is:

$$\frac{dC_X}{dt} = r_{XC} - r_e \tag{2-15}$$

with r_e the endogenous respiration rate.

3.2.2. Mass balance of the biomasses:

The biomasses kinetics can be written as follows:

$$\frac{dX_3}{dt} = (\mu_{31} - k_{d1})X_3 \tag{2-16}$$

$$\frac{dX_4}{dt} = (\mu_4 - k_{d2})X_4 \tag{2-17}$$

where k_{d1} and k_{d2} are the yield coefficients of the dead biomass X_d, from X_3 and X_4, respectively (see Reaction (2-6)), and the specific biomasses growth rates, μ_{31} and μ_4, are given by:

$$\mu_{31} = \mu_{CO\max} \frac{S_C}{K_{C2} + S_C} \frac{S_O}{K_O + S_O} \tag{2-18}$$

$$\mu_4 = \mu_{NH\max} \frac{S_{NH}}{K_{NH} + S_{NH}} \frac{S_O}{K_O + S_O} \tag{2-19}$$

where μ_{COmax}, μ_{NHmax}, K_{C2}, K_{NH} and K_O are the maximum specific growth rate of X_3 associated with S_{C} and that of X_4 associated with S_{NH}, the saturation constants associated with S_{C}, S_{NH} and S_O, respectively.

The time evolution of the dead biomass, denoted X_d, satisfies the following equation:

$$\frac{dX_d}{dt} = k_{d1}X_3 + k_{d2}X_4 - r_{XC} \tag{2-20}$$

with r_{XC} the reaction rate of the X_d /C_X transformation.

4. Basic Structural Form of the Dynamical Model

We can consider the general dynamical model form:

$$\frac{d\xi}{dt} = K\varphi(\xi, t) - Q(\xi) + \frac{F_{in}}{V}(\xi_{in} - \xi) \tag{2-21}$$

where K, φ, Q, ξ, ξ_{in} and F_{in} are the yield coefficients matrix, the reaction rates vector, the gaseous flow rate vector, the state variables vector, the input vector corresponding to the substrate feed rates and the influent flow rate. The term containing F_{in} is equal to zero in the batch case.

4.1. Anoxic phase

The involved reactions in this phase are Reaction (2-3), Reaction (2-4) and Reaction (2-6), respectively:

$$S_{NO} + S_C \xrightarrow{\mu_{32}X_3} X_3$$

$$S_N \xrightarrow{k_0 S_N} S_{NH}$$

$$(X_3 + X_4) \xrightarrow{k_{d1}X_3 + k_{d2}X_4} X_d \xrightarrow{r_{XC}} C_X$$

Therefore, the corresponding model to this phase is given by:

$$\frac{d}{dt}\begin{pmatrix} S_C \\ S_{NH} \\ S_{NO} \\ S_N \\ X_3 \\ X_4 \\ X_d \\ C_X \end{pmatrix} = \begin{pmatrix} -k_{SX1} & 0 & 0 & 0 & 0 \\ 0 & k_{SN1} & 0 & 0 & 0 \\ -k_{SX2} & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 1 & 1 & -1 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \mu_{32} X_3 \\ k_0 S_N \\ k_{d1} X_3 \\ k_{d2} X_4 \\ r_{XC} \end{pmatrix} \tag{2-22}$$

Now, let us focus on the sub-state variables $\xi_{sub1} = [S_1 \;\; S_2 \;\; S_3 \;\; N]^T$ corresponding to the measured state variables. We can therefore write the following sub-model:

$$\frac{d}{dt}\begin{pmatrix} S_C \\ S_{NH} \\ S_{NO} \\ S_N \end{pmatrix} = \begin{pmatrix} -k_{SX1} & 0 \\ 0 & k_{SN1} \\ -k_{SX2} & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} \mu_{32} X_3 \\ k_0 S_N \end{pmatrix} \tag{2-23}$$

Consider the following partition of the model (see [BAS 90]):

$$\xi_a{}^T = [S_{NO} \;\; S_N] \text{ and } \xi_b{}^T = [S_C \;\; S_{NH}]$$

such as:

$$\frac{d\xi_a}{dt} = K_a \varphi \tag{2-24}$$

$$\frac{d\xi_b}{dt} = K_b \varphi \tag{2-25}$$

with $\varphi^T = [\mu_{32} X_3 \;\; k_0 S_N]$ and

$$K_a = \begin{pmatrix} -k_{SX2} & 0 \\ 0 & -1 \end{pmatrix} \text{ and } K_b = \begin{pmatrix} -k_{SX1} & 0 \\ 0 & -k_{SN1} \end{pmatrix}$$

There exists a state transformation:

$$Z = A_0 \xi_a + \xi_b \tag{2-26}$$

where A_0 is the unique solution of the matrix equation:

$$A_0 K_a + K_b = 0 \tag{2-27}$$

Here, we have:

$$A_0 = \begin{pmatrix} -\frac{k_{SX1}}{k_{SX2}} & 0 \\ 0 & k_{SN1} \end{pmatrix}$$

hence, we can write:

$$\delta Z = A_0 \delta\xi_a + \delta\xi_b = \begin{pmatrix} -\frac{k_{SX1}}{k_{SX2}}\delta S_{NO} + \delta S_C \\ k_{SN1}\delta S_N + \delta S_{NH} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \tag{2-28}$$

The previous equation gives 2 expressions in the form of linear regression. They will allow the identification of the parameters k_{SN1} and k_{SX1}/k_{SX2}. However the knowledge of k_{SX1} and k_{SX2}, separately, is necessary. Therefore, supplementary equation(s) is (are) needed. Other partitions have been considered, but they all give the identical expressions.

4.1.1. The IWA Activated Sludge Model No. 1 in Denitrification (anoxic heterotrophic growth)

This model [HEN 87, VAN 99, DOC 01] considers one reaction involving the nitrate (+nitrite) nitrogen as follows:

Reaction (2- 7) $$\frac{1}{Y_h} S_C + \frac{1-Y_h}{2.86Y_h} S_{NO} + i_X S_{NH} \xrightarrow{r_{NO}} X_3 + (N_2)$$

with the corresponding reaction rate $r_{NO} = \mu_H^{\circ} X_3$ and the biomass growth rate is:

$$\mu_H^{\circ} = \mu_{H\max}\left(\frac{S_C}{K_C + S_C}\right)\left(\frac{S_{NO}}{K_{NO} + S_{NO}}\right)\left(\frac{K_{Oh}}{K_{Oh} + O}\right) \tag{2-29}$$

S_{NH} represents the ammonia-nitrogen concentration, which is associated to the yield coefficient i_X, the fraction of nitrogen in biomass (g N/g COD).

Taking into account the ammonification (Reaction (2-4)), we can establish the state model:

$$\frac{d}{dt}\begin{pmatrix} S_C \\ S_{NH} \\ S_{NO} \\ S_N \\ X_3 \end{pmatrix} = \begin{pmatrix} -\frac{1}{Y_h} & 0 & 0 \\ -i_X & k_{SN1} & 0 \\ -\frac{1-Y_h}{2.86Y_h} & 0 & 0 \\ 0 & -1 & 0 \\ 1 & 0 & -1 \end{pmatrix}\begin{pmatrix} \mu_H^{\circ} X_3 \\ k_0 S_N \\ k_{d1} X_3 \end{pmatrix} \tag{2-30}$$

If we focus on the sub-state variables $\xi_{sub2} = [S_C \;\; S_{NH} \;\; S_{NO} \;\; S_N]^T$, we will be able to identify Y_h by using the following linear regression:

$$-\frac{2.86}{1-Y_h}\delta S_{NO} + \delta S_C = 0 \tag{2-31}$$

Also, we will have the following expression:

$$-\frac{2.86\, i_X Y_h}{1-Y_h}\delta S_{NO} + k_{SN1}\delta S_N + \delta S_{NH} = 0 \tag{2-32}$$

From the previous expression, we can identify k_{SN1} and i_X. Note that if there is no nitrogen in the biomass ($i_X = 0$) then we will have the same linear regression as that described in equation (2-28).

4.1.2. Two-step denitrification model

In the literature [BOU 96, DOC 01] we can find a reaction scheme of denitrification in 2 steps:

1. *Reaction (2-8)*: NO_3 reduction,

$$\frac{1}{Y_{h1}}S_C + \frac{1}{\alpha_1}\frac{1-Y_{h1}}{Y_{h1}}S_{NO_3} \xrightarrow{r_I} X_3 + \frac{1}{\alpha_2}\frac{1-Y_{h2}}{Y_{h2}}S_{NO_2}$$

where r_I is its reaction rate, which is equal to $\mu_{NO3}X_3$ with

$$\mu_{NO3} = \mu_{NO3\max}\frac{S_C}{K_{C,h1}+S_C}\frac{S_{NO_3}}{K_{NO_3h}+S_{NO_3}} \tag{2-33}$$

2. *Reaction (2-9)*: NO_2 reduction,

$$\frac{1}{Y_{h2}}S_C + \frac{1}{\alpha_2}\frac{1-Y_{h2}}{Y_{h2}}S_{NO_2} \xrightarrow{r_{II}} X_3 + (N_2)$$

where r_{II} is its reaction rate, equal to $\mu_{NO2}X_3$

$$\mu_{NO2} = \mu_{NO2\max}\frac{S_C}{K_{C,h2}+S_C}\frac{S_{NO_2}}{K_{NO_2h}+S_{NO_2}} \tag{2-34}$$

Note that the values of α_1 and α_2 are known, equal to 1.17 and 1.71, respectively [BOU 96] while S_{NO2} and S_{NO3} are given in *mg* N/*L*. From the previous reactions, we can deduce the following model:

$$\frac{d}{dt}\begin{pmatrix} S_C \\ S_{NO_3} \\ S_{NO_2} \\ X_3 \end{pmatrix} = \begin{pmatrix} -\frac{1}{Y_{h1}} & -\frac{1}{Y_{h2}} & 0 \\ -\frac{1}{\alpha_1}\frac{1-Y_{h1}}{Y_{h1}} & 0 & 0 \\ \frac{1}{\alpha_2}\frac{1-Y_{h2}}{Y_{h2}} & -\frac{1}{\alpha_2}\frac{1-Y_{h2}}{Y_{h2}} & 0 \\ 1 & 1 & -1 \end{pmatrix} \begin{pmatrix} \mu_{NO3} X_3 \\ \mu_{NO2} X_3 \\ k_{d1} X_3 \end{pmatrix} \tag{2-35}$$

Let us focus on $\xi_{sub3} = [S_C \;\; S_{NO3} \;\; S_{NO2}]^T$ involving the following reaction rates $[\mu_{NO3} X_3, \mu_{NO2} X_3]$:

$$\frac{d}{dt}\begin{pmatrix} S_C \\ S_{NO_3} \\ S_{NO_2} \end{pmatrix} = \begin{pmatrix} -\frac{1}{Y_{h1}} & -\frac{1}{Y_{h2}} \\ -\frac{1}{\alpha_1}\frac{1-Y_{h1}}{Y_{h1}} & 0 \\ \frac{1}{\alpha_2}\frac{1-Y_{h2}}{Y_{h2}} & -\frac{1}{\alpha_2}\frac{1-Y_{h2}}{Y_{h2}} \end{pmatrix} \begin{pmatrix} \mu_{NO3} X_3 \\ \mu_{NO2} X_3 \end{pmatrix} \tag{2-36}$$

If we consider the partition of the model $\xi_a{}^T = [S_C \;\; S_{NO3}]$ and $\xi_b = [S_{NO2}]$, then we have:

$$K_a = \begin{pmatrix} -\frac{1}{Y_{h1}} & -\frac{1}{Y_{h2}} \\ -\frac{1}{\alpha_1}\frac{1-Y_{h1}}{Y_{h1}} & 0 \end{pmatrix} \text{ and } K_b = \frac{1}{\alpha_2}\frac{1-Y_{h2}}{Y_{h2}}\begin{bmatrix} 1 & -1 \end{bmatrix}$$

and the matrix A_0 is therefore given by:

$$A_0 = \begin{bmatrix} -\frac{1-Y_{h2}}{\alpha_2} & \frac{\alpha_1}{\alpha_2}\left(\frac{1-Y_{h2}}{1-Y_{h1}}\right)\left(\frac{Y_{h1}+Y_{h2}}{Y_{h2}}\right) \end{bmatrix}$$

Applying the state transformation $Z = A_0\, \xi_a + \xi_b$, described in (2-26), using the previous matrix, we will able to establish the following equation:

$$-\frac{1-Y_{h2}}{\alpha_2}\delta S_C + \frac{\alpha_1}{\alpha_2}\left(\frac{1-Y_{h2}}{1-Y_{h1}}\right)\left(\frac{Y_{h1}+Y_{h2}}{Y_{h2}}\right)\delta S_{NO_3} + \delta S_{NO_2} = 0 \tag{2-37}$$

4.2. Aerobic phase

This phase involves Reaction (2-1), Reaction (2-2), Reaction (2-4), Reaction (2-5) and Reaction (2-6), respectively:

$$S_C + S_O \xrightarrow{\mu_{31} X_3} X_3$$

$$S_{NH} + S_O \xrightarrow{\mu_4 X_4} X_4 + S_{NO}$$

$$S_N \xrightarrow{k_0 S_N} S_{NH}$$

$$C_X + S_{NO} + S_O \xrightarrow{r_e} \dots$$

The above reactions lead to the following model:

$$\frac{d}{dt}\begin{pmatrix} S_C \\ S_{NH} \\ S_{NO} \\ S_O \\ S_N \\ X_3 \\ X_4 \\ X_d \\ C_X \end{pmatrix} = \begin{pmatrix} -k_{SX3} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -k_{SX4} & k_{SN2} & 0 & 0 & 0 & 0 \\ 0 & k_{SX5} & 0 & -k_r & 0 & 0 & 0 \\ -k_{OX1} & -k_{OX2} & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & -1 \\ 0 & 0 & 0 & -1 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \mu_{31} X_3 \\ \mu_4 X_4 \\ k_0 S_N \\ r_e \\ k_{d1} X_3 \\ k_{d2} X_4 \\ r_{XC} \end{pmatrix} - \begin{pmatrix} 0 \\ 0 \\ 0 \\ -K_l a\left(S_{O,sat} - S_O\right) \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{2-38}$$

Consider only the sub-state variables: $\xi_{sub4} = [S_C, S_{NH}, S_{NO}, S_O, S_N]^T$ involving the reaction rates $\varphi = [\mu_{31} X_3, \mu_4 X_4, k_0 S_N, r_e]$, such as:

$$\frac{d}{dt}\begin{pmatrix} S_C \\ S_{NH} \\ S_{NO} \\ S_O \\ S_N \end{pmatrix} = \begin{pmatrix} -k_{SX3} & 0 & 0 & 0 \\ 0 & -k_{SX4} & k_{SN2} & 0 \\ 0 & k_{SX5} & 0 & -k_r \\ -k_{OX1} & -k_{OX2} & 0 & -1 \\ 0 & 0 & -1 & 0 \end{pmatrix} \begin{pmatrix} \mu_{31} X_3 \\ \mu_4 X_4 \\ k_0 S_N \\ r_e \end{pmatrix} - \begin{pmatrix} 0 \\ 0 \\ 0 \\ -K_l a\left(S_{O,sat} - S_O\right) \\ 0 \end{pmatrix} \tag{2-39}$$

Let us consider the following partition of the model:

$$\xi_a{}^T = [S_C \quad S_{NH} \quad S_{NO} \quad S_O] \text{ and } \xi_b = [S_N]$$

corresponding to:

$$\frac{d\xi_a}{dt} = K_a \varphi + Q_a \tag{2-40}$$

$$\frac{d\xi_b}{dt} = K_b \varphi \tag{2-41}$$

where

$$K_a = \begin{pmatrix} -k_{SX3} & 0 & 0 & 0 \\ 0 & -k_{SX4} & k_{SN2} & 0 \\ 0 & k_{SX5} & 0 & -k_r \\ -k_{OX1} & -k_{OX2} & 0 & -1 \end{pmatrix}, \quad K_b = \begin{bmatrix} 0 & 0 & -1 & 0 \end{bmatrix} \text{ and } Q_a = \begin{pmatrix} 0 \\ 0 \\ 0 \\ -K_l a\left(S_{O,sat} - S_O\right) \end{pmatrix}$$

Therefore, we can deduce $A_0 = -K_b\ K_a^{-1}$:

$$A_0 = \left[\frac{k_{OX1}k_{SX4}k_r}{k_{SX3}k_{SN2}\left(k_{SX5}+k_{OX2}k_r\right)} \quad \frac{1}{k_{SN2}} \quad \frac{k_{SX4}}{k_{SN2}\left(k_{SX5}+k_{OX2}k_r\right)} \quad \frac{-k_{SX4}k_r}{k_{SN2}\left(k_{SX5}+k_{OX2}k_r\right)} \right]$$

After the state transformation $Z = A_0\,\xi_a + \xi_b$, we will have:

$$Z = \frac{k_{OX1}k_{SX4}k_rS_C}{k_{SX3}k_{SN2}\left(k_{SX5}+k_{OX2}k_r\right)} + \frac{S_{NH}}{k_{SN2}} + \frac{k_{SX4}S_{NO}}{k_{SN2}\left(k_{SX5}+k_{OX2}k_r\right)} - \frac{k_{SX4}k_rS_O}{k_{SN2}\left(k_{SX5}+k_{OX2}k_r\right)} + S_N \tag{2-42}$$

Moreover we can write:

$$\frac{dZ}{dt} = -A_0Q_a = -\frac{k_{SX4}k_rK_la\left(S_{O,sat}-S_O\right)}{k_{SN2}\left(k_{SX5}+k_{OX2}k_r\right)} \tag{2-43}$$

Therefore, we can deduce the following expression:

$$\frac{k_{OX1}k_r}{k_{SX3}}\delta S_C + \frac{k_{SX5}+k_{OX2}k_r}{k_{SX4}}\delta S_{NH} + \delta S_{NO} - k_r\delta S_O + \frac{k_{SX5}+k_{OX2}k_r}{k_{SX4}/k_{SN2}}\delta S_N = -k_rK_la\left(S_{O,sat}-S_O\right)\delta t \tag{2-44}$$

By considering the partition: $\xi_a^T = [S_C \quad S_{NH} \quad S_{NO} \quad S_N]$ and $\xi_b = [S_O]$, corresponding to:

$$\frac{d\xi_a}{dt} = K_a\varphi \tag{2-45}$$

$$\frac{d\xi_b}{dt} = K_b\varphi + Q_b \tag{2-46}$$

where

$$K_a = \begin{pmatrix} -k_{SX3} & 0 & 0 & 0 \\ 0 & -k_{SX4} & k_{SN2} & 0 \\ 0 & k_{SX5} & 0 & -k_r \\ 0 & 0 & -1 & 0 \end{pmatrix},\ K_b = \begin{bmatrix} -k_{OX1} & -k_{OX2} & 0 & -1 \end{bmatrix} \text{ and } Q_b = -K_la\left(S_{O,sat}-S_O\right)$$

Therefore, $A_0 = -K_b\ K_a^{-1}$ is:

$$A_0 = \left[-\frac{k_{OX1}}{k_{SX3}} \quad -\frac{k_{SX5}+k_{OX2}k_r}{k_{SX4}k_r} \quad -\frac{1}{k_r} \quad -\frac{k_{SN2}\left(k_{SX5}+k_{OX2}k_r\right)}{k_{SX4}k_r} \right]$$

After the state transformation in Z, the same expression as previously will be obtained. The application of the other partitions gives always the same expression.

4.2.1. The IWA ASM1 in Nitrification (aerobic autotrophic growth)

The nitrification model according to [HEN 87, VAN 99, DOC 01] is as follows:

Reaction (2-10)
$$\left(\frac{1}{Y_a}+i_X\right)S_{NH}+\frac{4.57-Y_a}{Y_a}S_O \xrightarrow{r_{AA}} X_4+\frac{1}{Y_a}S_{NO}$$

with the corresponding reaction rate $r_{AA} = \mu_A X_4$ and the biomass growth rate is:

$$\mu_A = \mu_{A\max}\left(\frac{S_{NH}}{K_{NH}+S_{NH}}\right)\left(\frac{S_O}{K_{Oa}+S_O}\right) \tag{2-47}$$

Simultaneously with this reaction, there exists an aerobic heterotrophic growth, which is related to Reaction (2-1). The IWA ASM1 gives the following expression:

Reaction (2-11)
$$\frac{1}{Y_h}S_C+\frac{1-Y_h}{Y_h}S_O+i_X S_{NH} \xrightarrow{r_{AH}} X_3$$

with the reaction rate $r_{AH} = \mu_H X_3$ and the biomass growth rate is:

$$\mu_H = \mu_{H\max}\left(\frac{S_C}{K_C+S_C}\right)\left(\frac{S_O}{K_{Oh}+S_O}\right) \tag{2-48}$$

Remark.– The yield coefficient i_X is the fraction of nitrogen in biomass (g N/g COD)

Referring to Reaction (2-10) and Reaction (2-11), the model can be established in the following form:

$$\frac{d}{dt}\begin{pmatrix} S_C \\ S_{NH} \\ S_{NO} \\ S_O \end{pmatrix} = \begin{pmatrix} -\frac{1}{Y_h} & 0 \\ -\frac{1}{Y_a}-i_X & -i_X \\ \frac{1}{Y_a} & 0 \\ -\frac{4.57-Y_a}{Y_a} & -\frac{1-Y_h}{Y_h} \end{pmatrix}\begin{pmatrix} r_{AA} \\ r_{AH} \end{pmatrix} - \begin{pmatrix} 0 \\ 0 \\ 0 \\ -K_l a\left(S_{O,sat}-S_O\right) \end{pmatrix} \tag{2-49}$$

This model leads to the following regressions:

- By considering $\xi_a^T = [S_C \quad S_{NH}]$ and $\xi_b^T = [S_{NO} \quad S_O]$,

$$\begin{cases} \frac{Y_h}{Y_a}\delta S_C + \delta S_{NO} = 0 \\ \left(\frac{(1-Y_h)(1+i_X Y_a)}{i_X Y_a} - \frac{(4.57-Y_a)Y_h}{Y_a}\right)\delta S_C - \frac{1-Y_h}{i_X Y_h}\delta S_{NH} + \delta S_O = K_l a\left(S_{O,sat}-S_O\right)\delta t \end{cases} \tag{2-50}$$

- By considering $\xi_a^T = [S_{NH} \quad S_O]$ and $\xi_b^T = [S_C \quad S_{NO}]$,

$$\begin{cases} \left(\frac{Y_a}{Y_h} - Y_a\right)\delta S_{NH} - i_X Y_a \delta S_O + \delta S_C = -i_X Y_a K_l a\left(S_{O,sat} - S_O\right)\delta t \\ \left(Y_h - 1\right)\delta S_{NH} + i_X Y_h \delta S_O + \delta S_{NO} = i_X Y_h K_l a\left(S_{O,sat} - S_O\right)\delta t \end{cases} \tag{2-51}$$

Remark.– If we take into account the ammonification (with the reaction rate: $k_0 S_N$) according to the IWA ASM1, the model is given by:

$$\frac{d}{dt}\begin{pmatrix} S_C \\ S_{NH} \\ S_{NO} \\ S_O \\ S_N \end{pmatrix} = \begin{pmatrix} -\frac{1}{Y_h} & 0 & 0 \\ -\frac{1}{Y_a} - i_X & -i_X & 1 \\ \frac{1}{Y_a} & 0 & 0 \\ -\frac{4.57 - Y_a}{Y_a} & -\frac{1 - Y_h}{Y_h} & 0 \\ 0 & 0 & -1 \end{pmatrix}\begin{pmatrix} r_{AA} \\ r_{AH} \\ k_0 S_N \end{pmatrix} - \begin{pmatrix} 0 \\ 0 \\ 0 \\ -K_l a\left(S_{O,sat} - S_O\right) \\ 0 \end{pmatrix} \tag{2-52}$$

Note that the given model involves identification of the same parameters.

– If $i_X = 0$ (there is no nitrogen in biomass), then we will have the following regressions:

$$\begin{cases} \left(\frac{Y_a}{Y_h} - Y_a\right)\delta S_{NH} + \delta S_C = 0 \\ \left(Y_h - 1\right)\delta S_{NH} + \delta S_{NO} = 0 \end{cases} \tag{2-53}$$

Therefore, the parameters Y_a and Y_h are completely identifiable, each one.

4.2.2. Two-step nitrification model

We can find in the literature [PET 00, DOC 01] a two-step nitrification:

1. *Reaction (2-12)*: NH_4 oxidation to nitrite (NO_2), of which concentration is denoted S_{NO2} (*mg* N/*L*),

$$\left(\frac{1}{Y_{a1}} + i_X\right)S_{NH} + \frac{3.43 - Y_{a1}}{Y_{a1}} S_O \xrightarrow{r_{N1}} X_4 + \frac{1}{Y_{a1}} S_{NO_2}$$

2. *Reaction (2-13)*: NO_2 oxidation to nitrate (NO_3) with concentration S_{NO3} (*mg* N/*L*),

$$\frac{1}{Y_{a2}} S_{NO_2} + \frac{1.14 - Y_{a2}}{Y_{a2}} S_O \xrightarrow{r_{N2}} X_4 + \frac{1}{Y_{a2}} S_{NO_3}$$

where r_{N1} and r_{N2} are their respective reaction rates, with Monod or Double Monod kinetics models. In this case the COD degradation is given by:

Reaction (2-14)

$$\frac{1}{Y_h} S_C + \frac{1-Y_h}{Y_h} S_O + i_X S_{NH} \xrightarrow{\mu X_3} X_3$$

with μX_3 its reaction rate.

By neglecting the ammonification and the endogenous respiration, this two-step model can be rewritten in the form of the following state model:

$$\frac{d}{dt}\begin{pmatrix} S_C \\ S_{NH} \\ S_{NO_3} \\ S_{NO_2} \\ S_O \end{pmatrix} = \begin{pmatrix} -\frac{1}{Y_h} & 0 & 0 \\ -i_X & -\frac{1}{Y_{a1}} - i_X & 0 \\ 0 & 0 & \frac{1}{Y_{a2}} \\ 0 & \frac{1}{Y_{a1}} & -\frac{1}{Y_{a2}} \\ -\frac{1-Y_h}{Y_h} & -\frac{3.43-Y_{a1}}{Y_{a1}} & -\frac{1.14-Y_{a2}}{Y_{a2}} \end{pmatrix} \begin{pmatrix} \mu X_3 \\ r_{N1} \\ r_{N2} \end{pmatrix} - \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ -K_l a\left(S_{O,sat} - S_O\right) \end{pmatrix} \quad (2\text{-}54)$$

If we consider the following model partition:

$$\xi_a^T = [S_C \quad S_{NH} \quad S_{NO3}] \text{ and } \xi_b^T = [S_{NO2} \quad S_O]$$

involving:

$$K_a = \begin{pmatrix} -\frac{1}{Y_h} & 0 & 0 \\ -i_x & -\frac{1}{Y_{a1}} - i_x & 0 \\ 0 & 0 & \frac{1}{Y_{a2}} \end{pmatrix} ; \quad K_b = \begin{pmatrix} 0 & \frac{1}{Y_{a1}} & -\frac{1}{Y_{a2}} \\ -\frac{1-Y_h}{Y_h} & -\frac{3.43-Y_{a1}}{Y_{a1}} & -\frac{1.14-Y_{a2}}{Y_{a2}} \end{pmatrix}$$

therefore, we will obtain:

$$A_0 = \begin{pmatrix} \frac{-i_X Y_h}{1+i_X Y_{a1}} & \frac{1}{1+i_X Y_{a1}} & 1 \\ \frac{Y_h - 1 - i_X\left(3.43 Y_h - Y_{a1}\right)}{1+i_X Y_{a1}} & \frac{Y_{a1} - 3.43}{1+i_X Y_{a1}} & 1.14 - Y_{a2} \end{pmatrix}$$

After the state transformation, we can obtain:

$$\begin{cases} \dfrac{-i_X Y_h}{1+i_X Y_{a1}}\delta S_C + \dfrac{1}{1+i_X Y_{a1}}\delta S_{NH} + \delta S_{NO_3} + \delta S_{NO_2} = 0 \\ \dfrac{Y_h - 1 - i_X\left(3.43Y_h - Y_{a1}\right)}{1+i_X Y_{a1}}\delta S_C + \dfrac{Y_{a1}-3.43}{1+i_X Y_{a1}}\delta S_{NH} + \left(1.14 - Y_{a2}\right)\delta S_{NO_3} + \delta S_O = K_l a\left(S_{O,sat} - S_O\right)\delta t \end{cases} \quad (2\text{-}55)$$

If we consider the model partition:

$$\xi_a{}^T = [S_C \quad S_{NO2} \quad S_O] \text{ and } \xi_b{}^T = [S_{NH} \quad S_{NO3}]$$

which involves

$$K_a = \begin{pmatrix} -\dfrac{1}{Y_h} & 0 & 0 \\ 0 & \dfrac{1}{Y_{a1}} & -\dfrac{1}{Y_{a2}} \\ -\dfrac{1-Y_h}{Y_h} & -\dfrac{3.43-Y_{a1}}{Y_{a1}} & -\dfrac{1.14-Y_{a2}}{Y_{a2}} \end{pmatrix}; \; K_b = \begin{pmatrix} -i_X & -\dfrac{1}{Y_{a1}} - i_X & 0 \\ 0 & 0 & \dfrac{1}{Y_{a2}} \end{pmatrix}$$

then, after the state transformation, we will obtain:

$$\begin{cases} \left[(4.57-Y_{a2}-Y_{a1})i_X Y_h + (1+i_X Y_{a1})(Y_h - 1)\right]\delta S_C + (Y_{a2}-1.14)(1+i_X Y_{a1})\delta S_{NO_2} + (1+i_X Y_{a1})\delta S_O + \delta S_{NH} = -(4.57-Y_{a2}-Y_{a1})(1+i_X Y_{a1})K_l a\left(S_{O,sat}-S_O\right)\delta t \\ (1-Y_h)\delta S_C + (Y_{a1}-3.43)\delta S_{NO_2} - \delta S_O + \delta S_{NO_3} = (4.57-Y_{a2}-Y_{a1})K_l a\left(S_{O,sat}-S_O\right)\delta t \end{cases}$$

(2-56)

Remark.– If $i_X = 0$, then we will be able to establish the following regressions:

$$\begin{cases} \delta S_{NH} + \delta S_{NO_3} + \delta S_{NO_2} = 0 \\ (Y_h - 1)\delta S_C + (Y_{a1} - 3.43)\delta S_{NH} + (1.14 - Y_{a2})\delta S_{NO_3} + \delta S_O = K_l a\left(S_{O,sat} - S_O\right)\delta t \\ (Y_h - 1)\delta S_C + (Y_{a2} - 1.14)\delta S_{NO_2} + \delta S_O + \delta S_{NH} = -(4.57 - Y_{a2} - Y_{a1})K_l a\left(S_{O,sat} - S_O\right)\delta t \\ (1 - Y_h)\delta S_C + (Y_{a1} - 3.43)\delta S_{NO_2} - \delta S_O + \delta S_{NO_3} = (4.57 - Y_{a2} - Y_{a1})K_l a\left(S_{O,sat} - S_O\right)\delta t \end{cases} \quad (2\text{-}57)$$

5. Parameter identification

The parameter identification will be made in two parts: first part will be dedicated to identify the yield coefficients, and the second one deals with the kinetics parameters identification.

5.1. Yield coefficients identification

As two independents phases are considered, we will carry out the parameter identification for each phase separately.

5.1.1. Anoxic phase

We have seen in the previous section that in the anoxic phase we have essentially denitrification. In the literature, there exist two ways to consider this process: one-reaction denitrification according to the IWA ASM1 [HEN 87, VAN 99, DOC 01] or two-step denitrification [BOU 96, DOC 01].

5.1.1.1. The IWA Activated Sludge Model No. 1 in Denitrification (anoxic heterotrophic growth)

The first linear regression will allow to determine the parameter Y_h:

$$-\frac{2.86}{1-Y_h}\delta S_{NO} + \delta S_C = 0 \tag{2-58}$$

The experimental data will be fitted to "$y = a_{reg}\, x$". If we consider δS_C as y and δS_{NO} as x, therefore we can deduce:

$$Y_h = 1 - \frac{2.86}{a_{reg}} \tag{2-59}$$

If we consider δS_{NO} as y and δS_C as x, then we will have:

$$Y_h = 1 - 2.86\, a_{reg} \tag{2-60}$$

The second equation is:

$$-\frac{2.86\, i_X Y_h}{1-Y_h}\delta S_{NO} + k_{SN1}\delta S_N + \delta S_{NH} = 0 \tag{2-61}$$

As Y_h is already known, we will be able to identify k_{SN1} and i_{X3}. Let us assume $\delta S_{NO} \neq 0$ such as we can write the following regression:

$$\frac{\delta S_{NH}}{\delta S_{NO}} = -k_{SN1}\frac{\delta S_N}{\delta S_{NO}} + \frac{2.86\, i_X Y_h}{1-Y_h} \tag{2-62}$$

Using the experimental data we can establish a linear regression "$y=a_{reg}\,x+b_{reg}$", such as:

$$k_{SN1} = -a_{reg} \text{ and } i_X = b_{reg}\left(\frac{1-Y_h}{2.86\,Y_h}\right) \tag{2-63}$$

5.1.1.2. Identified parameters from the experimental data for the one-step model

From the POLIMI experiment carried out on 26th June 2003, which is related to the standard conditions, we have the following data for the anoxic phase:

Time (min)	CODs (mg/L)	N-NH4 (mg N/L)	N-NO3 (mg N/L)	N-NO2 (mg N/L)	Ns (mg N/L)
30	25	7.1	0.52	0.25	14.2
60	20	7.7	0.2	0.23	16.1
90	17	8.3	0.61	0.21	15
120	17	8.3	0.65	0.26	11.8
150	18	8.3	0.99	0.37	12.5

The data lead to have the following parameters:

Yield coefficient	Value
Y_h	0.96
k_{SN1}	0.2
i_X	0.006

LBE experiment (on 10th July 2003) related to the COD/X ratio equal to 75% of that in the standard conditions gives the following data:

Time (min)	CODs (mg/L)	N-NH4 (mg N/L)	N-NO2 (mg N/L)	N-NO3 (mg N/L)	Ns (mg N/L)
15	427.71	-	-	0.00	0.00
30	333.50	33.6	12.88	0.00	0.00
60	335.39	36.4	20.16	0.00	0.00
120	330.00	24.64	24.64	0.00	0.00

The identified yield parameters are as follows:

Yield coefficient	Value
Y_h	0.91
k_{SN1}	1.05
i_X	0.002

5.1.1.3. Two-step denitrification model

If we assume that $\delta S_{NO2} \neq 0$, then (2-37) can be rewritten, as follows:

$$\frac{\delta S_C}{\delta S_{NO_2}} = \frac{\alpha_1}{1-Y_{h1}}\left(\frac{Y_{h1}+Y_{h2}}{Y_{h2}}\right)\frac{\delta S_{NO_3}}{\delta S_{NO_2}} + \frac{\alpha_2}{1-Y_{h2}} \tag{2-64}$$

or
$$\frac{\delta S_{NO_3}}{\delta S_{NO_2}} = \frac{1-Y_{h1}}{\alpha_1}\left(\frac{Y_{h2}}{Y_{h1}+Y_{h2}}\right)\frac{\delta S_C}{\delta S_{NO_2}} + \frac{\alpha_2}{\alpha_1}\left(\frac{1-Y_{h1}}{1-Y_{h2}}\right)\left(\frac{Y_{h2}}{Y_{h1}+Y_{h2}}\right) \quad (2\text{-}65)$$

The two previous expressions deal with a linear regression in the form of $y = a_{reg}\, x + b_{reg}$, where a_{reg} and b_{reg} can be identified from the experimental data. This identification will lead us to deduce the parameters Y_{h1} and Y_{h2} from equations (2-64) and (2-65), respectively:

$$Y_{h1} = \frac{\alpha_1\alpha_2 - b_{reg}\alpha_1 - a_{reg}\alpha_2 + a_{reg}b_{reg}}{b_{reg}\alpha_1 - a_{reg}\alpha_2 + a_{reg}b_{reg}} \quad \text{and} \quad Y_{h2} = 1 - \frac{\alpha_2}{b_{reg}} \quad (2\text{-}66)$$

and
$$Y_{h1} = \frac{a_{reg}^2\alpha_1\alpha_2 - a_{reg}b_{reg}\alpha_1 - a_{reg}\alpha_2 + b_{reg}}{a_{reg}b_{reg}\alpha_1 - a_{reg}\alpha_2 + b_{reg}} \quad \text{and} \quad Y_{h2} = 1 - \frac{a_{reg}}{b_{reg}}\alpha_2 \quad (2\text{-}67)$$

By assuming that $\delta S_{NO3} \neq 0$, (2-37) can be rewritten:

$$\frac{\delta S_{NO_2}}{\delta S_{NO_3}} = \frac{1-Y_{h2}}{\alpha_2}\frac{\delta S_C}{\delta S_{NO_3}} - \frac{\alpha_1}{\alpha_2}\left(\frac{1-Y_{h2}}{1-Y_{h1}}\right)\left(\frac{Y_{h1}+Y_{h2}}{Y_{h2}}\right) \quad (2\text{-}68)$$

or
$$\frac{\delta S_C}{\delta S_{NO_3}} = \frac{\alpha_2}{1-Y_{h2}}\frac{\delta S_{NO_2}}{\delta S_{NO_3}} + \frac{\alpha_1}{1-Y_{h1}}\left(\frac{Y_{h1}+Y_{h2}}{Y_{h2}}\right) \quad (2\text{-}69)$$

They lead to have the parameters Y_{h1} and Y_{h2}, respectively:

$$Y_{h1} = \frac{a_{reg}^2\alpha_1\alpha_2 - a_{reg}\alpha_1 + a_{reg}b_{reg}\alpha_2 - b_{reg}}{a_{reg}\alpha_1 + a_{reg}b_{reg}\alpha_2 - b_{reg}} \quad \text{and} \quad Y_{h2} = 1 - a_{reg}\alpha_2 \quad (2\text{-}70)$$

and
$$Y_{h1} = \frac{\alpha_1\alpha_2 - a_{reg}\alpha_1 - b_{reg}\alpha_2 + a_{reg}b_{reg}}{a_{reg}\alpha_1 - b_{reg}\alpha_2 + a_{reg}b_{reg}} \quad \text{and} \quad Y_{h2} = 1 - \frac{\alpha_2}{a_{reg}} \quad (2\text{-}71)$$

If we assume that $\delta S_C \neq 0$, then (2-37) can be also rewritten, as follows:

$$\frac{\delta S_{NO_2}}{\delta S_C} = -\frac{\alpha_1}{\alpha_2}\left(\frac{1-Y_{h2}}{1-Y_{h1}}\right)\left(\frac{Y_{h1}+Y_{h2}}{Y_{h2}}\right)\frac{\delta S_{NO_3}}{\delta S_C} + \frac{1-Y_{h2}}{\alpha_2} \quad (2\text{-}72)$$

or
$$\frac{\delta S_{NO_3}}{\delta S_C} = -\frac{\alpha_2}{\alpha_1}\left(\frac{1-Y_{h1}}{1-Y_{h2}}\right)\left(\frac{Y_{h2}}{Y_{h1}+Y_{h2}}\right)\frac{\delta S_{NO_2}}{\delta S_C} + \frac{1-Y_{h1}}{\alpha_1}\left(\frac{Y_{h2}}{Y_{h1}+Y_{h2}}\right) \quad (2\text{-}73)$$

They lead to have the parameters Y_{h1} and Y_{h2}, respectively:

$$Y_{h1} = \frac{b_{reg}^2\alpha_1\alpha_2 - b_{reg}\alpha_1 + a_{reg}b_{reg}\alpha_2 - a_{reg}}{b_{reg}\alpha_1 + a_{reg}b_{reg}\alpha_2 - a_{reg}} \quad \text{and} \quad Y_{h2} = 1 - b_{reg}\alpha_2 \quad (2\text{-}74)$$

and $$Y_{h1} = \frac{-b_{reg}^2\alpha_1\alpha_2 - a_{reg}b_{reg}\alpha_1 + b_{reg}\alpha_2 + a_{reg}}{a_{reg}b_{reg}\alpha_1 + b_{reg}\alpha_2 + a_{reg}} \quad \text{and} \quad Y_{h2} = 1 + \frac{b_{reg}}{a_{reg}}\alpha_2 \tag{2-75}$$

5.1.1.4. Identified parameters from the experimental data for the two-step model

From the POLIMI data, the parameters in the two-step models are:

Yield coefficient	Value
Y_{h1}	0.82
Y_{h2}	1.01
k_{SN1}	1

LBE experiment does not allow to identify the parameters, because the values of the nitrate and nitrite in anoxic phase are equal to 0.

5.2. Aerobic phase

This phase involves the nitrification process. In the literature there are also two models: one-reaction nitrification according to the IWA ASM1 [HEN 87, VAN 99, DOC 01] or two-step nitrification [BOU 96, DOC 01].

Note here that the oxygen mass transfer coefficient, K_la, has already been identified experimentally. It is a known parameter.

5.2.1. The IWA ASM1 in Nitrification (aerobic autotrophic growth)

Assume that $\delta S_O \neq 0$. According to (2-50), we have the following regressions:

$$\delta S_{NO} = -\frac{Y_h}{Y_a}\delta S_C \tag{2-76}$$

$$\frac{\delta S_{NH}}{\delta S_O} = \left(\frac{1 + i_X Y_a}{Y_a}Y_h - \frac{4.57 - Y_a}{Y_a(1 - Y_h)}Y_h^2 i_X\right)\frac{\delta S_C}{\delta S_O} + \left(\frac{i_X Y_h}{1 - Y_h} - K_l a\frac{S_{O,sat} - S_O}{\delta S_O}\delta t\right) \tag{2-77}$$

By considering (2-51),

$$\frac{\delta S_C}{\delta S_O} = -\left(\frac{Y_a}{Y_h} - Y_a\right)\frac{\delta S_{NH}}{\delta S_O} + i_X Y_a\left(1 - K_l a\left(\frac{S_{O,sat} - S_O}{\delta S_O}\right)\delta t\right) \tag{2-78}$$

$$\frac{\delta S_{NO}}{\delta S_O} = -(Y_h - 1)\frac{\delta S_{NH}}{\delta S_O} - i_X Y_h\left(1 - K_l a\left(\frac{S_{O,sat} - S_O}{\delta S_O}\right)\delta t\right) \tag{2-79}$$

If we assume that there is no nitrogen in biomass ($i_X = 0$), then we will have the following regressions:

$$\left(\frac{Y_a}{Y_h} - Y_a\right)\delta S_{NH} + \delta S_C = 0 \tag{2-80}$$

$$(Y_h - 1)\delta S_{NH} + \delta S_{NO} = 0 \tag{2-81}$$

Using (2-81) we can identify Y_h, then (2-80) will allow to identify Y_a.

5.2.2. Two-step nitrification model

We have obtained from different partitions of the model:

$$\begin{cases} \dfrac{-i_X Y_h}{1+i_X Y_{a1}}\delta S_C + \dfrac{1}{1+i_X Y_{a1}}\delta S_{NH} + \delta S_{NO_3} + \delta S_{NO_2} = 0 \\ \dfrac{Y_h - 1 - i_X(3.43Y_h - Y_{a1})}{1+i_X Y_{a1}}\delta S_C + \dfrac{Y_{a1} - 3.43}{1+i_X Y_{a1}}\delta S_{NH} + (1.14 - Y_{a2})\delta S_{NO_3} + \delta S_O = K_l a(S_{O,sat} - S_O)\delta t \end{cases} \tag{2-82}$$

and:

$$\begin{cases} [(4.57 - Y_{a2} - Y_{a1})i_X Y_h + (1+i_X Y_{a1})(Y_h - 1)]\delta S_C + (Y_{a2} - 1.14)(1+i_X Y_{a1})\delta S_{NO_2} + (1+i_X Y_{a1})\delta S_O + \delta S_{NH} = -(4.57 - Y_{a2} - Y_{a1})(1+i_X Y_{a1})K_l a(S_{O,sat} - S_O)\delta t \\ (1-Y_h)\delta S_C + (Y_{a1} - 3.43)\delta S_{NO_2} - \delta S_O + \delta S_{NO_3} = (4.57 - Y_{a2} - Y_{a1})K_l a(S_{O,sat} - S_O)\delta t \end{cases} \tag{2-83}$$

When $i_X = 0$, the following regressions are obtained:

$$\begin{cases} \delta S_{NH} + \delta S_{NO_3} + \delta S_{NO_2} = 0 \\ (Y_h - 1)\delta S_C + (Y_{a1} - 3.43)\delta S_{NH} + (1.14 - Y_{a2})\delta S_{NO_3} + \delta S_O = K_l a(S_{O,sat} - S_O)\delta t \\ (Y_h - 1)\delta S_C + (Y_{a2} - 1.14)\delta S_{NO_2} + \delta S_O + \delta S_{NH} = -(4.57 - Y_{a2} - Y_{a1})K_l a(S_{O,sat} - S_O)\delta t \\ (1 - Y_h)\delta S_C + (Y_{a1} - 3.43)\delta S_{NO_2} - \delta S_O + \delta S_{NO_3} = (4.57 - Y_{a2} - Y_{a1})K_l a(S_{O,sat} - S_O)\delta t \end{cases} \tag{2-84}$$

5.3. Identification of the kinetics parameters

Once all the yield coefficients are known, we can start the identification of the kinetics parameters. In order to have a "better" identification of kinetics parameters, the knowledge of the biomass evolution in time is needed. The best way is then to measure it. Nevertheless, if the biomass measurement is not available, we can estimate it using the model.

Optimization methods in minimizing error such as Levenberg-Marquardt approach can be used to carry out the kinetics parameter identification.

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EOLI
Efficient Operation of Urban Wastewater Treatment Plants

Work Package 3
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ANNEX
WP3 – GRADIENT – 1st year activities

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Annex 1 Basics on the UV Spectral Analysis

- Direct spectral analysis (with deconvolution)

Let us consider that the experimental UV-spectrum to be analysed is a linear combination of elemental spectra (O. Thomas and co-workers Ecole des Mines d'Alès):

$$S = \sum_{i=1}^{p} a_i \cdot REF_i \pm r$$

where

S is the sample spectrum

a_i is the contribution coefficient of the ith reference spectrum REF_i

p is the number of reference spectra

r is the quadratic error

The development of the spectral UV analysis is based on the comparison between UV spectra of effluents and reference UV spectra of pure constituents (e.g. nitrate, detergent, and colloid) and/or measured global indicators (e.g. COD, TOC, BOD, TSS for WW). Typical UV spectra of some constituents or indicators are shown in Figure 1. Depending of the constituent or the global indicator, the development of a robust model may require the processing of more than 50 UV spectra. For wastewaters and because of their complex composition, it may be necessary to develop a specific model for each of them.

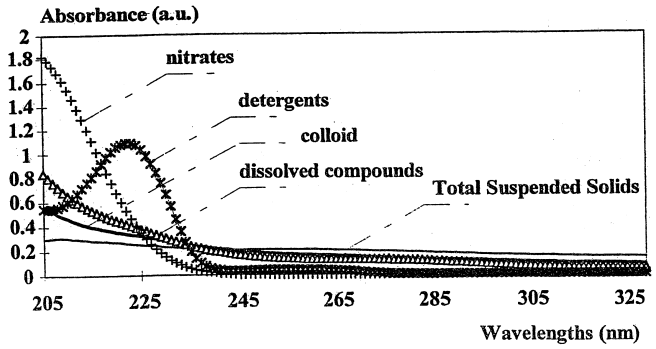

Figure 1. Typical UV spectra of some constituents and indicators.

- Spectral analysis (with deconvolution) after photochemical oxidation

As seen before, the spectral analysis can estimate the wastewater composition on the base of reference UV spectra. However some compounds do not exhibit UV signal, or the signal cannot be used efficiently. This is the case of nitrogenous organic compounds. One solution consists of oxidizing the molecules into other ones that exhibits UV signals. For example, total nitrogenous organic compounds can be quantified by oxidizing them into nitrates. Oxidation is performed using photochemical oxidation. In this project, photooxidation is performed using a Hg-lamp and the chemical oxidizing agent is sodium persulphate (Sigma Aldrich), at a

concentration equal to 25 mg /L in presence of a sodium tetraborate buffer at pH 9.0 (Sigma Aldrich).

The principle of the spectral analysis (direct and with photochemical oxidation) is illustrated in Figure 2.

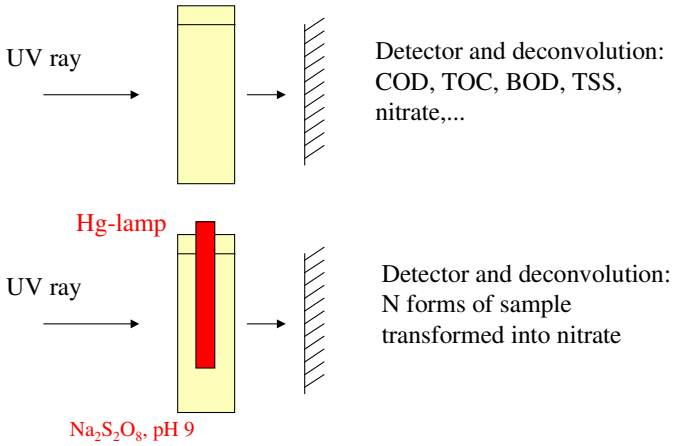

Figure 2. Schematic representation of the spectral analysis (direct and with photochemical oxidation).

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WP3 - POLIMI - 1st year activities

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SUMMARY

Within the EOLI project main objectives of POLIMI experimentation are:
- Evaluate the performance and usefulness of existing lab-scale titration (DO-stat and pH-stat) sensors to monitor the performance of SBRs.
- Develop an automated combined pH-DO stat titration unit to be used for on-line SBR monitoring.

To cope with the above listed objectives, the first year of Polimi activity included the following phases.
First an accurate review of literature data on the application of pH-DOstat technique to monitor biological processes, allowed to design an experimental protocol to apply this technique to monitor those bio-reactions typically taking place in an SBR reactor processing municipal wastewaters. Specifically, experiments were performed aimed at:
- the assessment of the biodegradable organic content of the SBR influent
- the determination of the maximum and real nitrification activity of the SBR sludge
- the feasibility to assess the end of the nitrification process during the aeration phase of the SBR cycle
- the assessment of the denitrification maximum activity of the SBR sludge

Then, Polimi constructed and put into operation a lab-scale SBR to provide the sludge required for testing the pH-DO stat technique. Technical details on the SBR can be found in the report related to WP1.

Laboratory prototypes of pH-stat and DO-stat titrators were initially used to assess the applicability of these techniques to monitor SBRs performance. Since interesting results were obtained a co-operation was started with SPES to design a prototype of an off-line combined pH-DO-stat titrator characterised by an increased software flexibility and by a new signals acquisition board developed to increase hardware reliability and to reduce components cost.

Then, this prototype was tested on SBR off-line monitoring. Details about this prototype are reported into the SPES-WP3 report.

LITERATURE APPLICATIONS OF DO-STAT AND PH-STAT TITRATION TECHNIQUES

An accurate literature review evaluated the existing hardware sensors for monitoring biological processes in SBR and the results are synthetically reported here below.

The following table and this paragraph constitute the contribution of POLIMI to the "Report on existing lab-scale hardware sensors to monitor SBR reactors", which is the first milestone requested within WP3 contract negotiation forms at T0+10.

The most promising hardware sensors in the field of upset early warning systems belong to the class of biosensors and bioassays and measure the interaction of pollutants with biological systems. They incorporate a biological component, which allows to obtain more complete information than conventional physico-chemical sensors, such as DO (dissolved oxygen), pH, ORP probes etc… and can be classified according to the measuring principle as reported in Table 1 (summarising Love and Both, 2000).

Table 1 - Review on existing biosensors for biological process control

Name	Measuring principle	References
pH-stat titration	It exploits the ability of some microorganisms to convert a neutral substrate into an acid or basic product, or to consume an acid or basic substrate to make a neutral product. These systems are potentially applicable to any pH affecting reaction in aerobic, anoxic or anaerobic conditions	Ramadori et al., 1980; Ficara et al., 2003.
Respirometry	It is the most broadly applied technology in WWTP biosensing. It is based on the measurement of oxygen uptake rate as an indicator of the biomass activity	Spaniers et al., 1998.
Microcalorimetry	It allows to evaluate the rate of a biochemical reaction by the assessment of the heat exchanged with the reaction environment	Beaubien and Jolicoeur, 1985. Aulenta et al., 2002.
Whole cell assays and biosensors	These techniques allow for the assessment of the metabolic state of a viable microorganism by means of a physico-chemical tranducer. The latter is located close to the biomass (bioassays) or on the support on which the biomass is fixed (biosensors). The most commonly applied bioassay is the Microtox®, which detects, via a luminimeter, the metabolic state of a naturally bioluminescent marine bacterium. Other widely applied amperometric transducers are dissolved oxygen probes. The biomass may be immobilized on the polyethylene membrane of the DO probe, typically by entrapping it in a polymeric matrix, which is then held in place by another appropriate membrane	Roger and Gerlach, 1996, 1999.

(Table 1 continues on next page)

(Table 1 - continued)

Name	Measuring principle	References
Molecular based biosensors	In these devices the biological component is a specific molecule (e.g. an enzyme, an antibody or a nucleic acid) which reacts with a specific substrate. This technology, initially applied in clinical and food processing fields, is at present being extended to environmental applications. Because of their specificity, these devices are generally devoted to the detection of a defined class of analytes of environmental concern. Based on their recognition element, molecular biosensors can be subdivided into two main groups: biocatalytic (enzimes) biosensors and bioaffinity (antibodies, receptors, DNA) biosensors. Current applications for these biosensors include the detection of pesticides (such as 2,4-D, carbamates, triazines), organic compounds (such as alcohols, sugar acids, benzo-a-pyrene, BTEX, cyanide, formaldehyde, organonitriles, phenol, BCP), metals (mercury, cadmium and zinc), potential carcinogens and endocrine dirsruptors	Roger and Gerlach, 1996, 1999.

Several experiences are already available in the literature demonstrating the feasibility of using pH and DO-stat titration to monitor biological processes used in environmental applications.

The pH-stat titration is a technique developed mainly during the nineties to monitor the activity of any bacterial consortium which converts a neutral substrate into an acidic or alkaline product or an acidic or alkaline substrate into a neutral product, thus affecting the pH of the suspension (Ficara et al., 2003). It consists in the controlled addition of dilute acidic or alkaline solutions to maintain a constant pH in systems where the pH affecting reaction is taking place. The titration rate is then proportional to the reaction rate. This methodology has been applied to monitor:

- nitrification (Ramadori et al, 1980; Massone et al., 1998, Gernaey et al., 1998; Ficara et al., 2000a, 2001);
- denitrification (Massone et al., 1996; Bogaert et al., 1997; Foxon et al., in press)
- acetoclastic methanogenesis (Rozzi et al., 2002)
- algal growth (Mezzanotte et al., 2002)

Moreover, pH-stat titration has been used to characterise wastewaters, specifically it was applied for:

- determination of the ammonium content of a wastewater (Massone et al., 1995),
- determination of the readily biodegradable organic load of a wastewater in term of BND (Biological Nitrate Demand) (Rozzi et al., 1997a)
- determination of the presence of volatile fatty acid in wastewaters (Rozzi et al., 1997b)
- determination of the organic content of a wastewater in term of carbon dioxide production (Ficara and Rozzi, 2002)

The DO-stat titration is a technique developed more recently, compared to the pH-stat, which makes possible to monitor aerobic reactions. It consists in the controlled addition of gaseous O_2 or of an oxygen-rich solution to maintain a constant DO concentration in systems where the DO affecting reaction is taking place. Under these conditions, the gas flow rate or the titration rate is again proportional to the reaction rate. Young et al. (2000) designed and patented a respirometer where a constant oxygen concentration is maintained in the gas phase, while Ficara et al. (2000b)

independently designed a DO-stat instrument where the dissolved oxygen concentration is maintained constant. The use of the DO-stat titration to measure Oxygen Uptake Rate (OUR) has been validated on nitrification monitoring (Ficara et al., 2000b) and on heterotrophic respiration assessment (Rozzi et al., 2003, Ficara and Rozzi, 2002).

PRELIMINARY EXPERIMENTAL RESULTS ON PH-DO-STAT TITRATION ON SBR SLUDGE

Some pH-DO stat titration tests were made on the sludge taken from the SBR reactor. The following solutions were used as titrants:

- NaOH 0.05 M
- H_2O_2 0.1-0.3 M

Set points values were:

- DO_{sp} = 8 mg/l for nitrification tests
- pH_{sp} = 8.3 for nitrification tests

Temperature was not controlled during these preliminary tests and was therefore close to ambient temperature (20-22.5 ^{o}C).

Assessment of the rapidly biodegradable organic content of the SBR influent

DO-stat tests were performed to determine the ratio between Rapidly Biodegradable COD (rbCOD) and total COD of the SBR influent. These tests were performed by adding a known volume of influent (30 ml) to a sample of washed sludge from the SBR (Figure 1). Titrations were performed until endogenous respiration was reached. Nitrification was inhibited by adding allylthiourea (ATU) in order to measure only the oxygen demand related to the heterotrophic degradation of the organic matter. The amount of oxygen furnished by H_2O_2 addition was used to estimate the amount of rbCOD.
The following data were obtained:

	rbCOD/totCOD
2/6/2003	60%
2/26/2003	50%

However, more investigation is required to ascertain the role of intracellular storage of organic bio-polymers (such as polyhydroxyalkanoates, PHA)

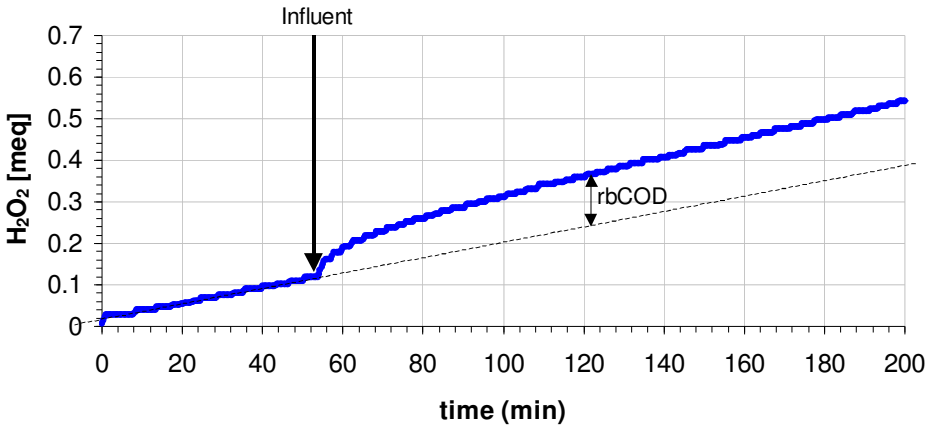

Figure 1: DO-stat titration to measure the influent rbCOD content.

Determination of the maximum and real nitrification activity of the SBR sludge

Two kinds of tests were performed:

- Tests on washed sludge in endogenous conditions: a sludge sample was collected from the SBR at the end on the aeration phase, washed by settling and re-suspension in tap water and aerated overnight. The day after, pH-DO-stat titration was activated and nitrification was started in the sludge sample by addition of known amounts of NH_4Cl (initial ammonium concentration of 5 mg N/L). The titration test was then performed until a knee in both titration curves (NaOH and H_2O_2 cumulated volumes versus time) was observed, indicating the end of the nitrification reaction and the complete consumption of ammonium. Titration was then continued during additional 1-2 h to evaluate the titration rate in endogenous respiration conditions (Figure 2). This test allowed assessing the maximum nitrification activity of the SBR sludge under controlled working conditions.
- tests on freshly collected sludge: a sludge sample was collected from the SBR reactor at the beginning of the aeration phase and pH-DO-stat titration was immediately started. In these tests, acidity production (and the corresponding NaOH titration rate) and oxygen consumption (and the corresponding H_2O_2 titration rate) are due to the simultaneous presence of two biological processes: nitrification and heterotrophic degradation of organic substrates. Therefore, allylthiourea (ATU, 10 mg/L) was used to distinguish between nitrification and heterotrophic respiration contributions. This test allowed assessing nitrification activity of the SBR sludge under real working conditions (Figure 3).

Results of nitrification tests on washed sludge are reported in the following Table 2:

Table 2 – Nitrification rates of SBR's sludge measured with NaOH and H_2O_2 as titrants

day	**Nitrification specific activity [mgN g^{-1}VSS h^{-1}]**	
	Titration with H_2O_2	Titration with NaOH
17	2.02	2.61
28	0.55	0.44
40	1.04	1.17

During the first days of the SBR operation, an unstable nitrification activity was observed which could be due to both ammonium accumulation in the SBR reactor, which reached 80 mg N/l during this start up period. For this reason SBR operating conditions were modified starting from day 24 (feed dilution plus supernatant decanting) in order to decrease ammonium concentration down to 10-20 mg N/l and to enhance the nitrification capacity. Further tests were performed on freshly collected sludge samples to monitor the real nitrification activity in the SBR working conditions.

Results of titration tests performed on freshly collected sludge samples are summarised in Figure 4. It can be observed that nitrification activity was found to vary between 2 and 6 mg N/(gVSS·h) due to unstable SBR operation as confirmed by the variability observed on the effluent ammonium concentration. However, a reasonable correspondence was found between nitrification activity and effluent ammonium concentration, which was found to increase when nitrification activity decreased. The observed difference between the nitrification activity assessed by pH-stat titration and by DO-stat titration (on average: 26%) may be due to both imprecise determination of titrants concentration and/or imprecise calibration of the microelectrovalves flow rate, used to determine dosed titrant volumes. Further research is needed to clearly identify the origin of this discrepancy.

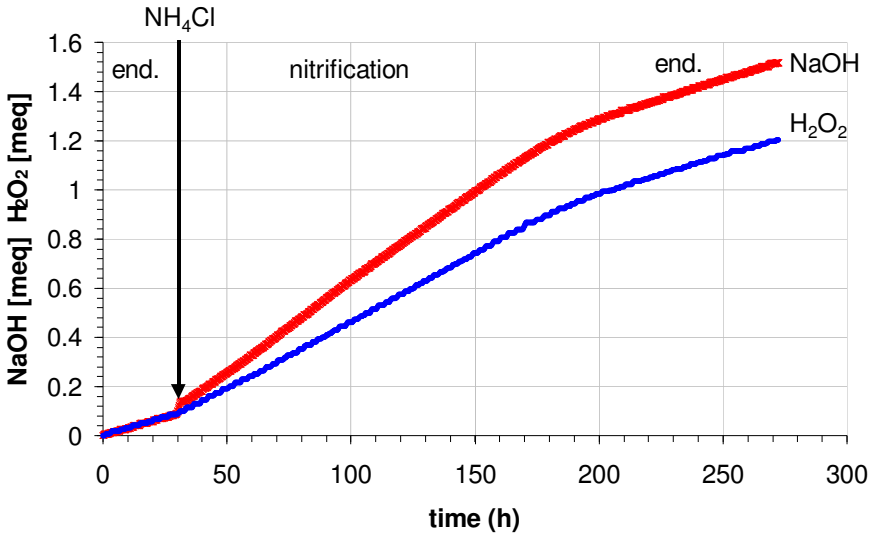

Figure 2: pH-DO-stat titration for nitrification activity assessment on washed sludge.

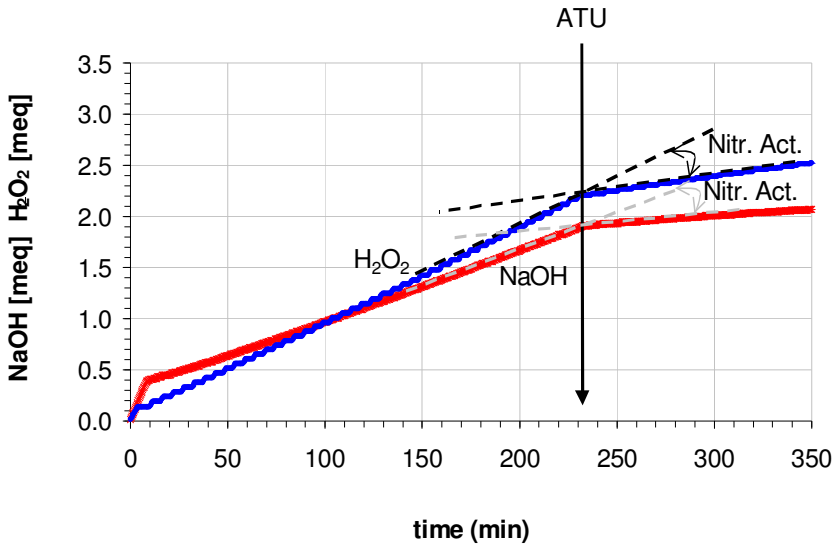

Figure 3: pH-DO-stat titration for nitrification activity assessment on freshly sampled sludge.

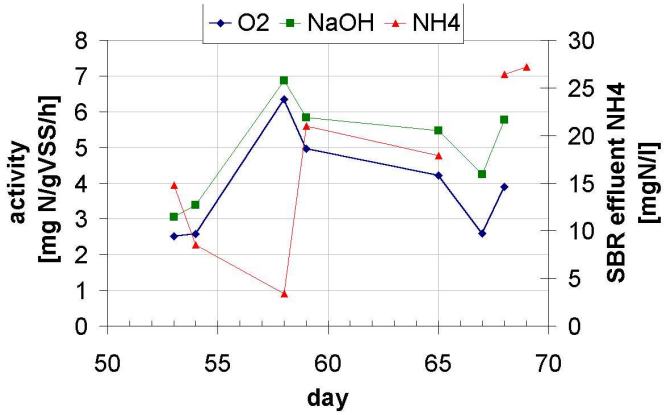

Figure 4: Nitrification activity measured on freshly collected SBR sludge samples and corresponding ammonium concentration in the SBR effluent.

Determination the nitrification endpoint during the aeration phase of the SBR cycle

This set of tests were aimed to verify the feasibility to perform pH-DO-stat titration tests on samples of SBR sludge to determine the end of the nitrification process in the SBR reactor. Since, during the start up period, nitrification was never completed within the scheduled time of the aeration cycle, the duration of this phase was prolonged until the 'ammonia valley point' could be observed in the pH trend.

Experiments were performed as follows: a sludge sample was drawn from the SBR at the beginning of the aerobic phase and placed in the pH-DO-stat titration unit. Titration curves were then collected during several hours in order to observe the end of the nitrification process indicated by the bending points in the titration curves. In parallel, SBR was monitored by collecting pH and ORP data.

Results of two of such experiments are reported in Figure 5. On the left hand side, titration curves and titration rates for both pH-stat and DO-stat titrations are plotted, while on right hand side, pH and ORP data measured in the SBR are depicted.

In the titration curve, the end of the nitrification process is indicated by the sharp decrease in the titration rate and by the corresponding knee on the curve reporting the total volume of titrant added.

According to titration data, during the first experiment (performed on day 74 from SBR start up) nitrification rate started decreasing significantly after 400 min, indicating substrate-limiting conditions and was negligible after approximately 480 min from the beginning of the aeration phase.
By looking at the pH trend in the SBR (graph on the right), a minimum can be observed after 400 min ('ammonia valley'), then, pH increases and an inflection point is observed at time t=480 min. Moreover, a maximum is observed in the ORP profile at this time. Therefore, an excellent correspondence was found in this experiment between titration data and on-line pH and ORP determinations.
This result allows concluding that differences in pH and DO working values between the two reactors (constant versus variable values) did not cause significant differences in the rate of the nitrification process.
Similar observations apply to the second experiment (performed on day 75 from SBR start up), however a difference of 3 ^{o}C in the working temperature in the pH-DO-stat reactor and in the SBR can be the origin of a delay of approximately 40 min in the duration of the nitrification process between the two reactors.
In conclusion, results of these experiments indicate that the fact that pH and DO keep constant in the pH-DO-stat titration unit (pH=8.3, DO=8.2), while they vary (pH = 7.6-8.0; DO=2-5 mg/l) within the optimal range for nitrifiers in the SBR, does not cause significant differences in the nitrification rate in the two reactors. On the contrary, attention should be paid to maintain the two reactors at the same working temperature.

Although pH-DO-stat titration gives similar indications as pH and ORP monitoring in the SBR reactor, the first technique allows to assess the nitrification rate (proportional to the titration rate) and the influent load (proportional to the volume of titrant added), as well as the end of the nitrification process.

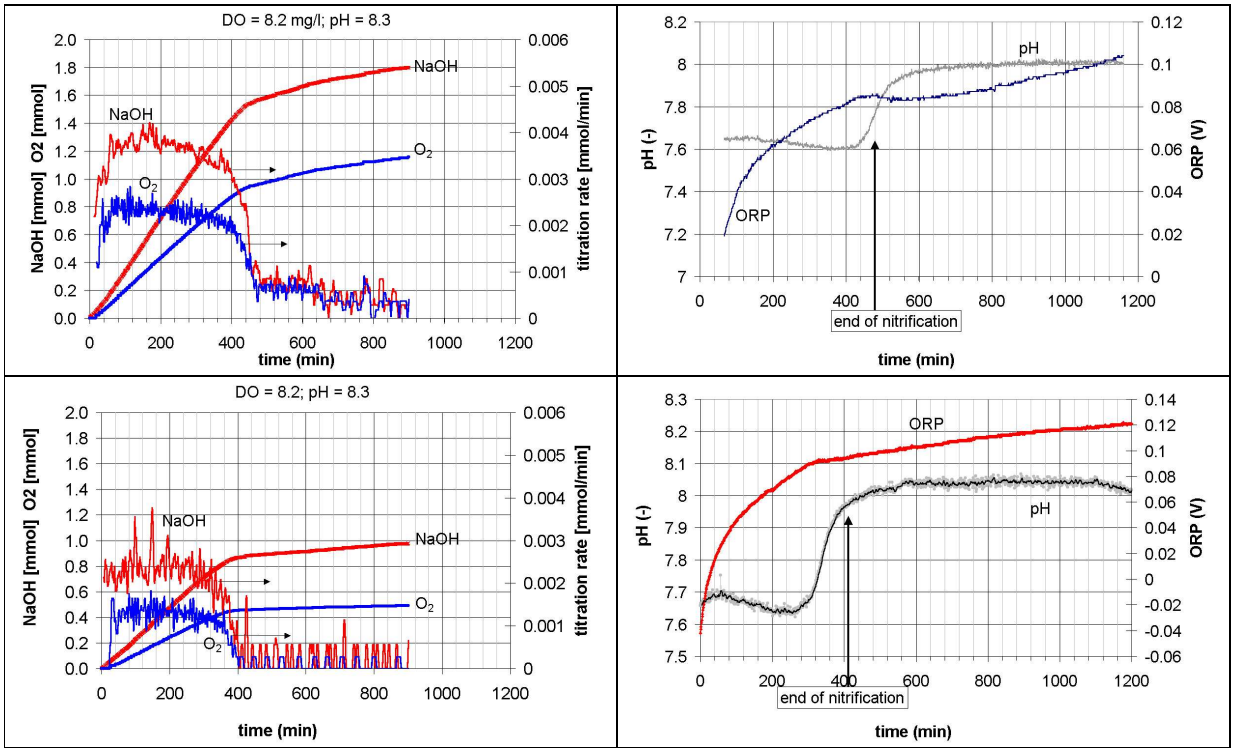

Figure 5: Comparing pH-DO-stat titration curves with ORP and pH trends in the SBR reactor.

DENITRIFICATION ACTIVITY TESTS WITH pH-STAT TITRATION MODEL

pH-stat theory

The pH-stat test is performed in a bioreactor, where the biomass is maintained at constant temperature and mixed at constant rate. According to the pH signal, measured by a pH-meter, the titration unit (MARTINA) activates the addition of an appropriate titrant (a diluted acid or alkaline solution) to maintain the pH constant at a pre-set value (pHstat). The system is, thus, a fed-batch reactor with liquid inflow (the titrant added) and no liquid outflow. A gas/liquid mass transfer may also be present, due to gas sparging or to gas production by the biomass. When gas sparging is present, the system will be defined as open, in contrast with a closed system, where no liquid/gas mass transfer takes place.
In the bioreactor, a generic reaction takes place which converts substrates (S_i, i = 1,n) into products P_j (j = 1, m; assumed not to affect the pH), with the concomitant production of protons, carbon dioxide, bicarbonate and carbonate, which affect the $CO_2/HCO_3^-/CO_3^=$ equilibrium and, thus, the suspension pH. This reaction is schematically described by the following stoichiometry (Ficara *et al.*, 2002):

$$\Sigma_i(s_i S_i) \rightarrow \Sigma_j(pP_j) + bHCO_3^- + cCO_2 + dCO_3^= + hH^+ \quad (1)$$

where the stoichiometric coefficients *b*, *c*, *d* and *h* are positive, when the corresponding chemical species is produced, or negative, when it is consumed, while the coefficient *s* for the substrate is always positive. It is very important, for a correct pH-stat operation and data interpretation, to determine the relationship between the reaction rate ($r_{p,i}$ = d[P_i]/dt, where [P_i] is the concentration of product P_i) and the pH-stat titration rate, r_t (moles of H^+, if $r_t > 0$, or moles of OH^-, if $r_t < 0$, added by the pH-stat unit per unit of time and per unit of suspension volume).
The titration rate (r_t) is the sum of two terms:

$$r_t = r_t\,(1) + r_t\,(2), \quad (2)$$

where:

$$r_t(1) = r_{p,i} \cdot \left[(b - h + 2\cdot d) - (b + c + d) \cdot \frac{10^{pH-pK_{A1}} \cdot (1 + 2\cdot 10^{pH-pK_{A2}})}{(1 + 10^{pH-pK_{A1}} \cdot (1 + 10^{pH-pK_{A2}}))} \cdot e^{-\alpha t} \right] \quad (3)$$

$$r_t(2) = \alpha \cdot 10^{pH-pK_{A1}} \cdot (1 + 2\cdot 10^{pH-pK_{A2}}) \cdot ([CO_2]_0 - [CO_2]_{eq}) \cdot \left(e^{-\alpha t}\right) \quad (4)$$

where:

$$\frac{[HCO_3^-]\cdot[H^+]}{[CO_2]} = K_{A1} \quad (5)$$

$$\frac{[CO_3^=]\cdot[H^+]}{[HCO_3^-]} = K_{A2} \quad (6)$$

$[CO_2]_{eq}$ is the $[CO_2]$ at equilibrium with the initial gas phase composition (defined by the Henry's law) and α is a constant parameter equal to:

$$\alpha = \frac{K_L a}{(1+10^{pH-pK_{A1}} \cdot (1+10^{pH-pK_{A2}}))} \quad (7)$$

where K_La is the CO_2 liquid/gas mass transfer coefficient.

The first term, $r_t(1)$, describes the pH-stat titration response to the production of protons, carbon dioxide, bicarbonate and carbonate due to the reaction in Eq. (1). The second term, $r_t(2)$, represents the response of the pH-stat unit to a CO_2 dissolving/stripping process originated by an initially unbalanced [CO_2]. It is relevant to observe that $r_t(2)$ is present only when liquid/gas exchange takes place, i.e. in open systems.

pH-stat tests

A series of tests were performed to establish the denitrifying potential of the sludge from the lab-scale SBR by means of the pH-stat technique. Sodium acetate (CH_3COONa) was used as carbon source, so that Equation (1) becomes:

$$PNO_3 + 0.625\ CH_3COONa \rightarrow 0.5\ N_2 + 1.25\ CO_2 + 0.125\ H_2O + 0.625\ NaOH + POH \quad (8)$$

where *P* is a cation (P^+) not influencing pH (i.e.: Na^+).

In order to balance the alkalinity produced by the denitrification reaction, nitric acid was used; by doing so, COD, not nitrate, was limiting the reaction.
Experiments were performed without any gas sparging to avoid liquid/gas mass transfer and simulate a closed system: therefore $r_t = r_t(1)$.
For each experiment, a sludge sample (0.7-0.8 L volume) was withdrawn from the SBR and kept under aeration for some hours to reach endogenous conditions. Moreover, at the beginning of the experiment, nitrate was dosed (as KNO_3) and 60 $mgNO_3^-/L$ was the initial concentration. Tests were performed at different pH constant values: the pH-stat ranged from 7.4 to 7.9 in the various tests, according to Ficara *et al.*, 2002.
Fig. 6 shows how the denitrification rate is calculated for the test performed at pHstat 7.4. After a transient period, which is necessary to reach the pH-stat value, the system measures the endogenous activity as mgN/(gVSS*h). Then, carbon is added to the mixed liquor, and the slope of the volume of titrant dosed over time increases sharply. Once COD has been consumed, the system turns again to endogenous conditions. Denitrifying activity is therefore calculated as the difference between the slopes that have been observed under exogenous and endogenous conditions (it's the angle β in Fig. 6). In Fig. 7 a test with four runs (four subsequent dosages of NaAc, test performed at pHstat 7.8) is represented.

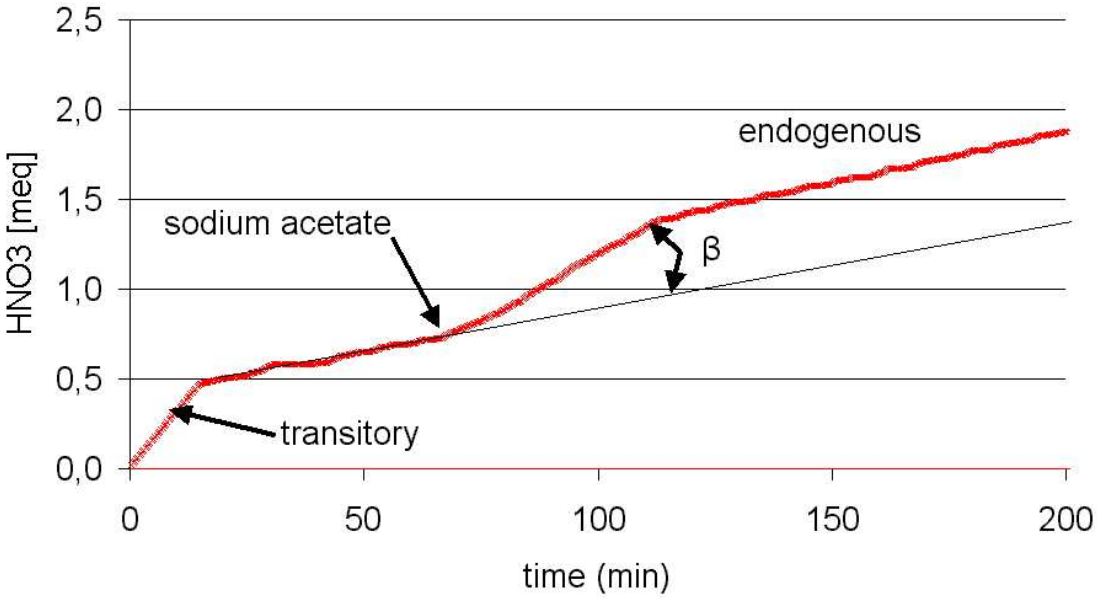

Figure 6 – Calculation of denitrification rate with sodium acetate as carbon source

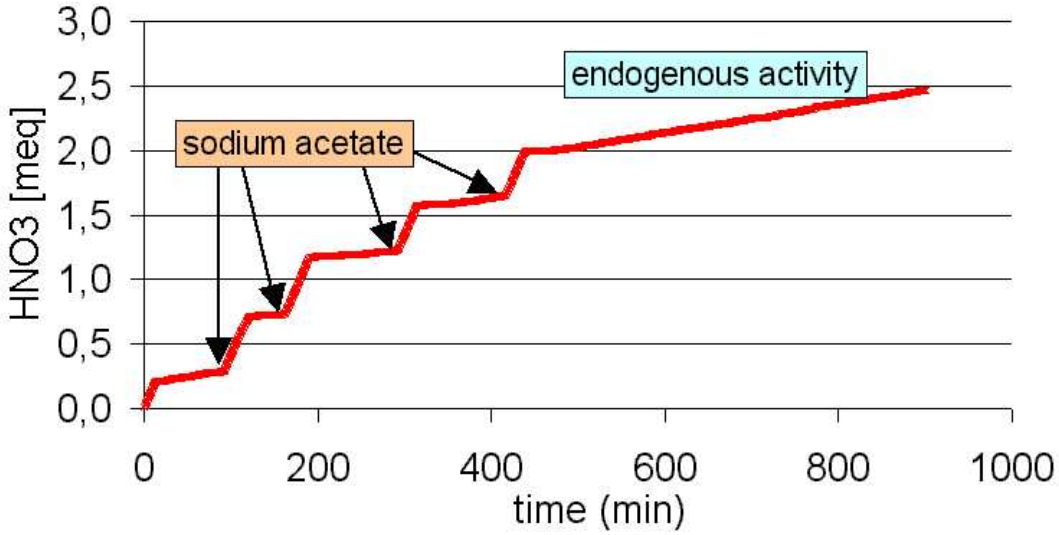

Figure 7- Denitrification test with sodium acetate as carbon source (4 runs)

In the following Table 3 and Figure 8 denitrification rates that have been calculated during eight runs, are reported. These rates compare well with those found in literature, as 20 mgN-NO_3/(gVSS*h) is the maximum value reported by Henze, 1991. The endogenous denitrification rate varied between 1.12 and 1.94 mgN-NO_3/(gVSS*h), comparable with values by Henze (0.2 - 0.5 mgN-NO_3/(gVSS*h); Henze, 1991) and Carucci (2.9 mgN-NO_3/(gVSS*h); Carucci *et al*., 1996). The overall observed biomass yield (Y) was calculated as follows:

Y = (CODr - CODox)/ CODr

where:
CODr = COD removed during the denitrification test
CODox = COD oxidised during the denitrification test

CODr was considered equal to the COD of the acetate dosed, since it disappeared completely before the end of the test; CODox was calculated by assuming the stoichiometric coefficient of 2,86 mgCODox/mgNO_3-Nrem and measuring nitrate removal by titration.

Values found for *Y* varied from 0.8 to 0.85 COD/COD, much higher than those found by some authors (0.65, Majone *et al.*, 2001; 0.66, Kubawa *et al*., 1999), but close to other's (0.79 ± 0.004; Ellis et al., 1996). This value is also very close to the yield that has been reported by Carucci et al. (2001) for PHB storage under aerobic conditions (0.76-0.82 COD/COD). It is known that substrate storage is an important occurrence in activated sludge systems especially for those in which biomass is exposed to a concentration gradient, typically SBR systems.

Denitrifying activity of SBR sludge increased with time, as confirmed by analytical trials (see Figure 8).
Tests that have been carried out with pH-stat technique appear to be repeatable and reliable, as it can be seen from Table 3 and Figure 8.

Table 3 – Denitrification rates for NaAc measured experimentally

Run n°	denitrification rate [mgN-NO_3/gVSS*h]
1	12.68
2	15.95
3	18.68
4	19.76
5	17.50
6	17.58
7	20.35
8	19.97
9	20.16

Within the framework of WP1 a series of tests was performed for monitoring the denitrification activity in the SBR, fed on synthetic sewage and the results have been also used for WP3 purposes.
The synthetic sewage is a modified formulation derived from OECD Guidelines for testing of chemicals, 1993 - 209 'Activated sludge inhibition Test' (OECD Paris) with the following composition:

peptone: 0.343 g/L;
meat extract: 0.236 g/L;
NaCl: 0.015 g/L;
$CaCl_2 \cdot 2H_2O$: 0.012 g/L;
$MgSO_4 \cdot 7H_2O$: 0.005 g/L,
K_2HPO_4: 0.06 g/L.
According to analytical analyses, this influent is characterised by:
COD = 600 mg/L ± 5%;
N = 75 mg Ntot/L ± 10%;

therefore the average COD/N ratio is 8.

The denitrifying reaction is very fast and efficient in the reactor, also because the rbCOD of the influent is 50% of the soluble COD. By observing the analytical profiles shown in Figure 9, it appears that COD removal during the anoxic phase is complete within half an hour from the beginning of the cycle.
Since the sample was collected at the end of the FILL phase (that lasts 10 minutes), the denitrification rate of the sludge fed on modified OECD influent could not be measured accurately. As a matter of fact, it is not possible to perform the pH-stat test within the FILL phase, because of the addition of influent affects pH and titration tests can give reliable results only if pH remains constant at a fixed value.
On the contrary, if denitrification took more time (e.g.: biomass inhibition or lack of carbon supply) this could be detected by the titration test.

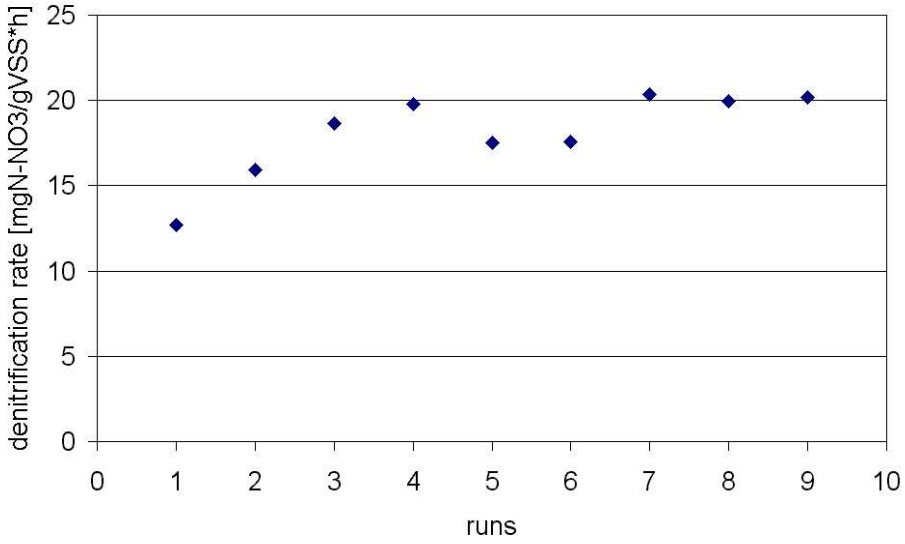

Figure 8 - Denitrification rates for NaAc measured experimentally

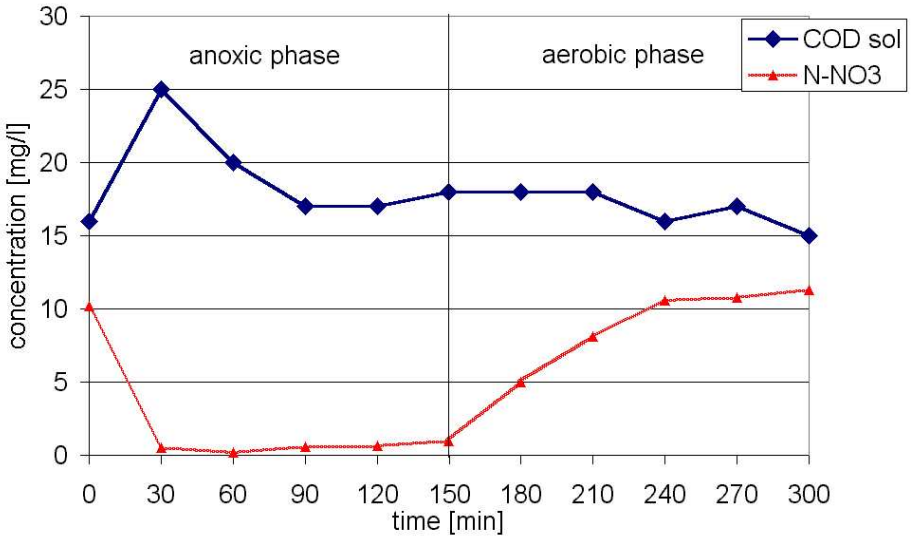

Figure 9 – Profiles of COD and N-NO_3 in the SBR during a standard cycle (date 26-06-2003)

At present, a new series of tests is in progress to measure the titration rate (r_t) when the carbon source is synthetic sewage (modified OECD formulation).

In this case it is not possible to calculate the actual COD oxidised, as it was done for NaAc, because is not known the elementary composition of the influent, as a consequence, and the stoichiometric ratio of the theoretical oxygen demand (ThOD) over NO_3-N is not known and has to be measured experimentally.
Once this is known, it will be possible to establish the denitrifying potential of the feed and to monitor the denitrifying activity of the SBR by running a pH-stat test.
The same obviously apply for real sewage, but the experimental determination of the COD/NO_3-N ratio has to be periodically checked.

SBR NITRIFICATION MONITORING BY PH-STAT TITRATION

The MARTINA prototype was applied to monitor nitrification activity and ammonium concentration during the aerobic phase of the SBR at various loading conditions. For this purpose, a sludge sample was drawn from the SBR at the beginning of the aerobic phase and transferred into the biomass beaker of MARTINA. A titration test was then started within few minutes from sludge withdrawal. The cumulated volume of NaOH dosed was used to estimate the nitrification rate and the ammonium concentration, according to the procedure previously described (paragraph "pH-stat theory").
DO-stat titrations were not performed since reliable DO readings by MARTINA could not yet be obtained.
In order to validate the estimates of ammonium concentrations by pH-stat titration, these were compared with analytical determinations and with pH, DO and ORP trends determined in the SBR.
It has to be reminded that titration curves refer to the MARTINA biomass beaker, while the concentration values are measured in samples taken from the SBR tank.

Estimation of the ammonium concentration by pH-stat titration

- *Standard loading conditions*

This test was performed under standard SBR loading conditions (i.e. COD = 600 mg/L; N = 75 mg Ntot/L as stated in the WP1 report). Figure 10 reports results of this test. A good correlation can be observed between titration and analytical results, although few data are available for comparison.
By observing trends of DO, pH and ORP signals in the SBR reactor, break-points described in the literature (DO break-point, pH ammonia valley, ORP bending point) can be detected. All three break-points take place almost simultaneously and approximately 20 min before the end of the nitrification phase, as determined from both analytical determinations and titration profile.

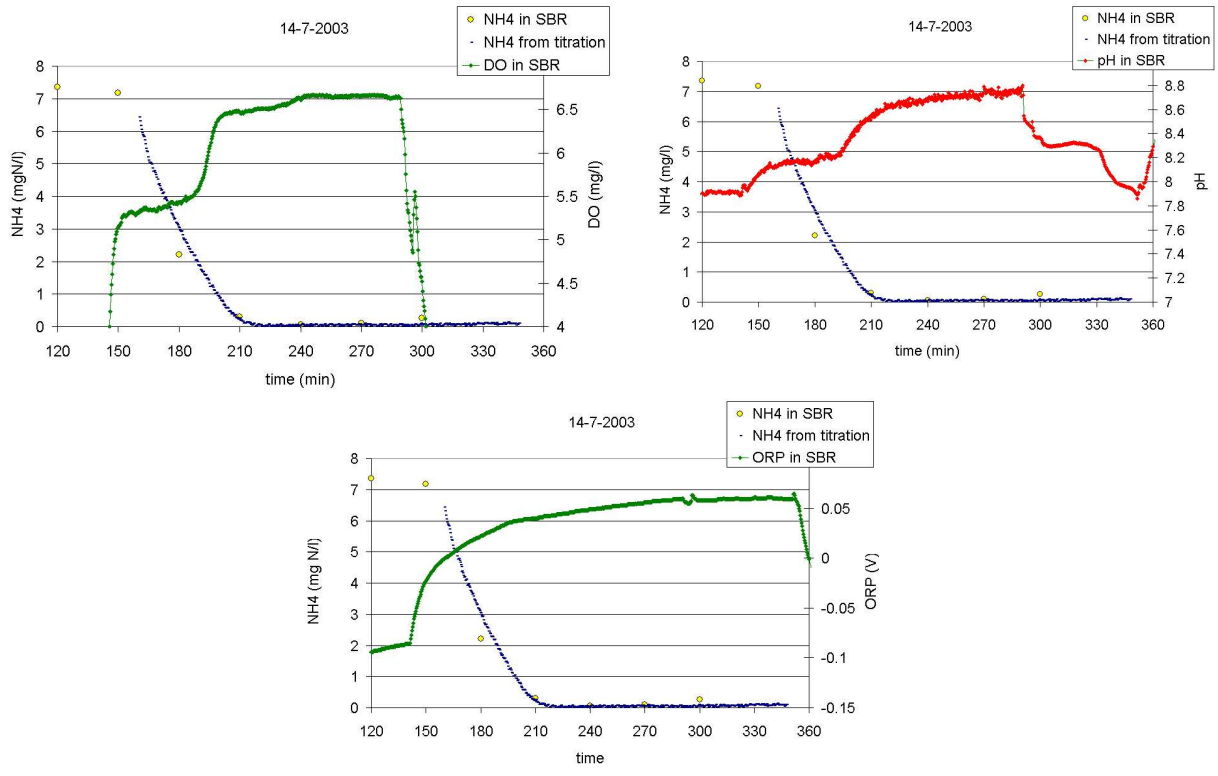

Figure 10: Results of the test performed under standard loading conditions

- *Increased ammonium load (-50% C/N)*

In this test, ammonium load was increased in order to obtain a 50% decrease in the C/N loading ratio.
In Figure 11, results of this test are reported.
Again, a good correlation can be observed between the ammonium profile estimated from pH-stat titration and the available analytical determinations. As soon as DO, pH and ORP trends are concerned, breakpoints can be observed as soon as the ammonium concentration, which has been estimated from both analytical determinations and pH-stat titration, approaches zero.
Therefore, in this test, all on-line determinations allow to detect the end of the nitrification phase.

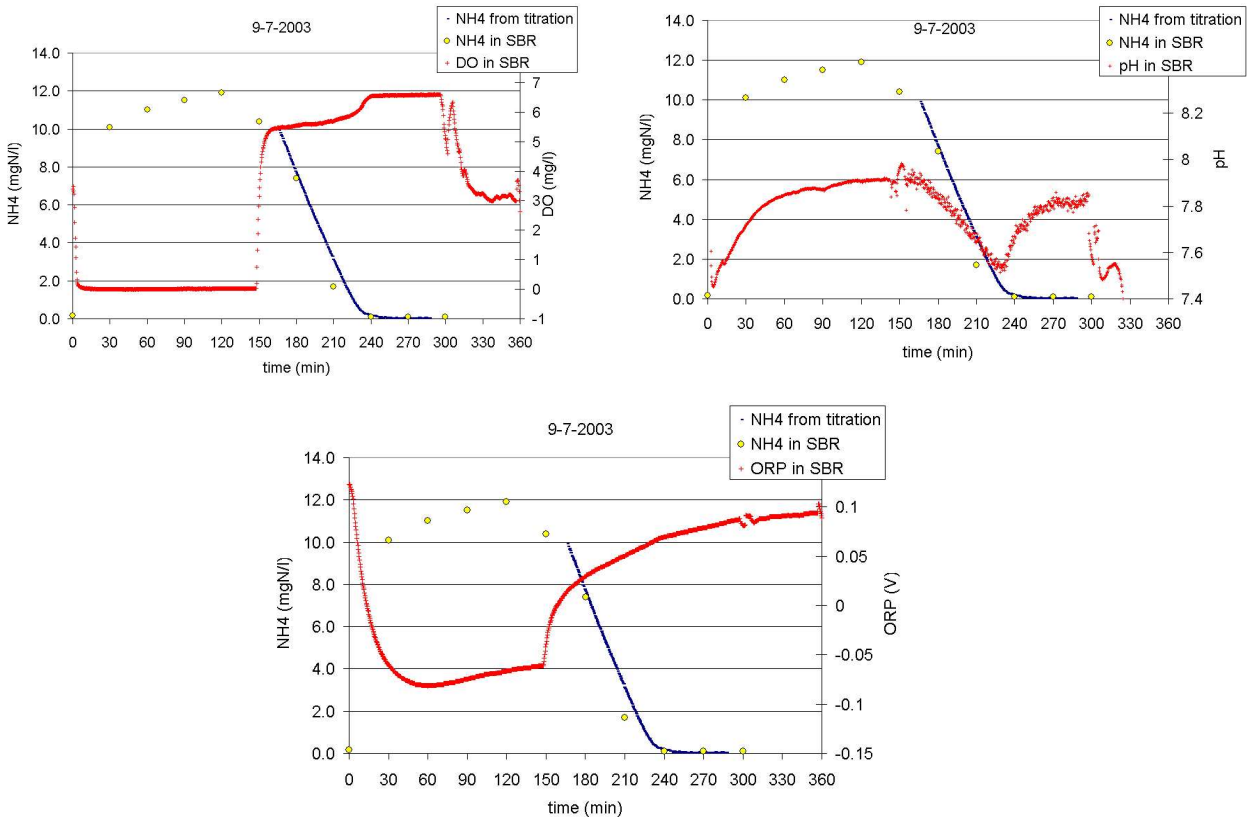

Figure 11: Results of the test performed under increased ammonia load

- *Increased organic load (+35% C/N)*

In this test, the COD load was increased in order to obtain a 35% increase in the C/N loading ratio.
In Figure 12, results of this test are reported.
In this test, pH-stat titration was started when more than 50% of the ammonium concentration present at the beginning of the aeration phase was already oxidised. Therefore, only two ammonium concentration data are available for comparison, and compare perfectly with pH-stat titration results.
Again, DO, pH and ORP breakpoints take place when ammonium concentration approaches zero.

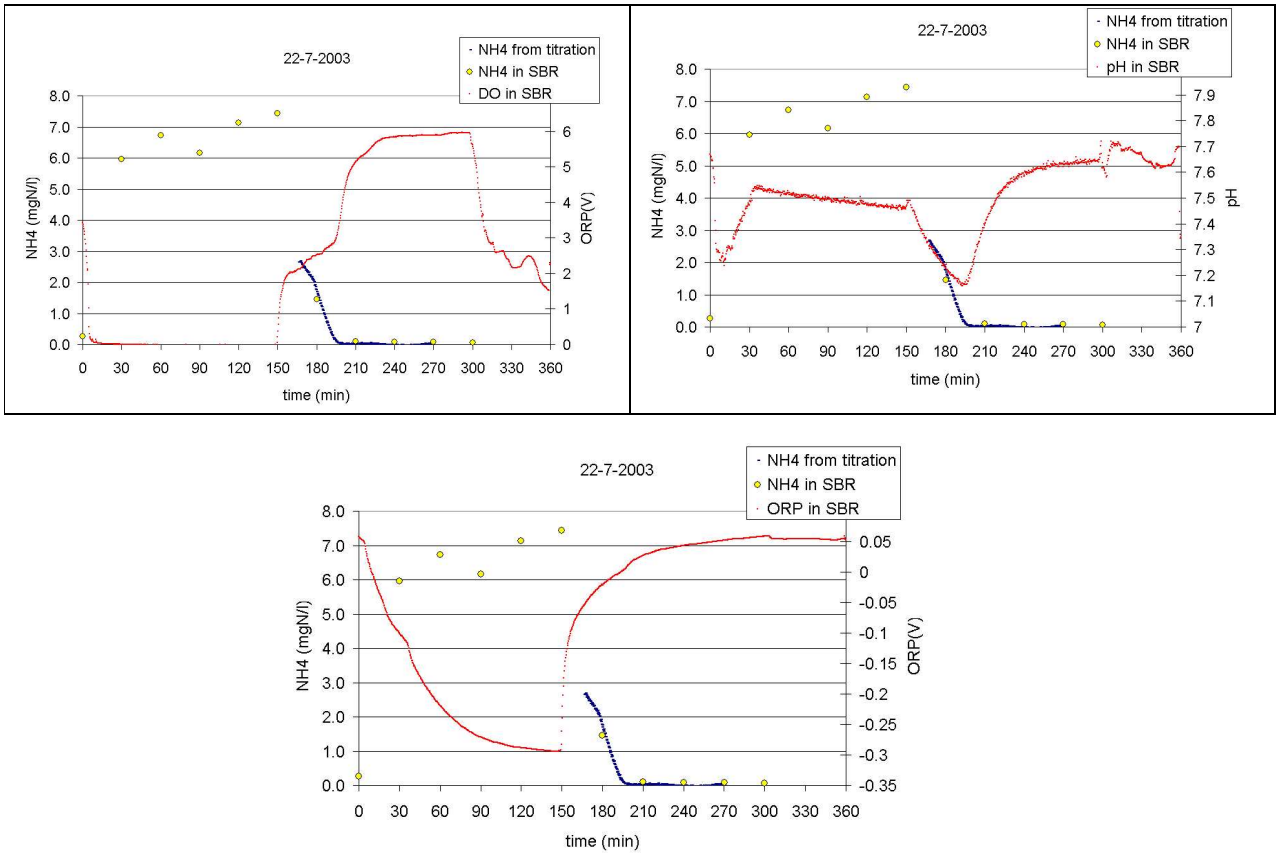

Figure 12: Results of the test performed under increased COD load

Estimation of the nitrification rate by pH-stat titration

The ammonium concentration profile obtained by pH-stat titration can be fitted to obtain the maximum specific nitrification rate, considered as the nitrification rate observed under non limiting substrate concentration (NH_4-N > 1-2 mg/l). Results related to different loading conditions are reported in Figure 13.

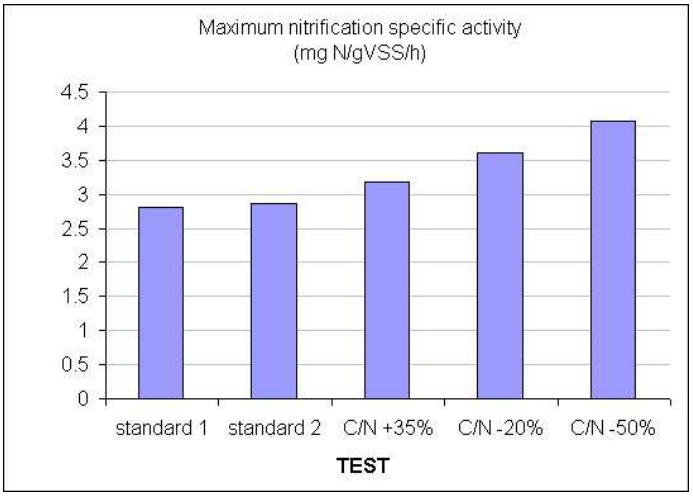

Figure 13: Maximum specific nitrification rates under various SBR loading conditions, as assessed by pH-stat titration

In the two tests performed under standard loading conditions, very similar nitrification activities were estimated (difference< 2%). This value falls within the usual range for activated sludge fed on urban wastewater (e.g.: Barnes and Bliss, 1983). A relevant increase in the sludge activity was observed under increased ammonium loading, especially in the –50%C/N test. This fact can be explained by the increased available substrate for ammonium oxidisers.

It is noteworthy the almost perfect correspondence between the results given by the titration unit and those that have been measured in the SBR tank.

DEVELOPMENT OF AN OFF-LINE PH-DOSTAT TITRATOR (MARTINA)

Preliminary titration tests on SBR sludge were performed with two existing instruments. The first was an existing pHstat laboratory prototype, developed according to the specifications of the ANITA (Ammonium NITrification Analyser) instrument (Massone et al., 1998). The latter was designed to measure activity of ammonium oxidisers and ammonium concentration in activated sludge samples. The second instrument was a DO-stat titrator that was developed in accordance with Ficara et al., 2000. This titrator was designed to measure the respirometric activity of aerobic activated sludge samples.
The experience gathered during this experimental campaign allowed to identify some limits of the existing titrators, which have been overcome by designing a new combined titrator to be applied to SBRs monitoring. The new instrument was named MARTINA (Multiple Analysis Reprogrammable TItration Analyser) and its main characteristics are described here below:

- it should be able to perform both pH-stat and DO-stat titrations on the same sludge sample,
- it should allow to perform titrations on two (or more) samples in parallel,
- it should be flexible in order to allow the implementation of all pH and DO-stat applications described in the literature,
- it should be reliable and affordable.

To meet with the above listed requirements, a co-operation was started between POLIMI and SPES. The former gave the main instruments specifications, while the latter developed both MARTINA's hardware and software. A strict co-operation was then required in order to debug the first instrument release, which was used in POLIMI's lab.

MARTINA's main specifications

As mentioned above, POLIMI efforts were aimed to define the main specifications of the MARTINA instrument.

In strict co-operation with SPES the minimum ***hardware*** requirements for the design and the development of the embedded electronic board used to control the instrument were defined as follows:

- Readings: 8 A/D channels,with signal amplification and noise reduction implemented on board, for the acquisition of:
  - 2 DO signals,
  - 4 pH or ORP signals,
  - 2 temperature signals (Pt100).
- Actuators: 12 ON/OFF switches for the actuation of:
  - 4 micro-solenoidvalves and 2 peristaltic pumps to control titrant dosage,
  - 2 aerators,

- 2 heaters,
- 2 mixers.

Compared to the previous available titrators, this new hardware configuration allows considerable costs reduction since the following commercially available components are no longer required:

- pH or ORP signal amplifiers
- DO signal amplifiers
- Pt100 signal amplifiers
- A/D converters
- ON/OFF switches

As soon as ***software*** requirements were concerned, the central idea was to maximise instrument flexibility by letting the user free to set the experimental configuration according to the variable to be measured.
Basically, the software should allow to perform, within a user-friendly frame, the following operations:

- calibration of all probes (pH, DO, ORP, Pt100);
- calibration of each titrant dosing line;
- experiment set up, including selection of:
  - number of beakers working in parallel; the hardware configuration allows to work with up to 2 fully instrumented beckers (equipped with 1 pH-probe, 1ORP-probe, 1 DO-probe, 1 temperature probe, 1 aerator, 1 mixer, 1 heater) or with several, partially instrumented, beckers in case not all signals or actuators need to be handled;
  - type of signals to be read in each beaker; for each beaker the user can define which signals should be read either to be monitored or controlled;
  - type of control to be performed on one or more the measured signals (up-bound, low bound, set-point);
  - definition of the experiment duration and data acquisition frequency;
- data logging on the PC hard disk;
- data plot of each signal and of the amount of titrant dosed during the course of the experiment;
- saving and re-loading of the experiment set-up.

Based on these specifications, SPES developed a first MARTINA prototype which was shipped to POLIMI for debugging. Debugging included the following activities:

- verification of the correct signal acquisition by comparison of pH, DO, ORP and temperature readings with those obtained with laboratory probes;
- verification of the correct calibration of the titrant dosing line by comparing the volume of titrant estimated by the instrument with that read in a cylinder.
- verification of the control routines by means of a-biotic pH-stat and DO-stat titration tests in which pH and DO were manually modified in a physico-chemical manner, i.e. by dosing acidic or alkaline solutions to modify the pH value, and aeration or sodium sulphite addition to modify the DO value.
- application of the instrument to typical biological tests to verify its performance in real conditions. Several of these tests were performed on activated sludge samples drawn from a full scale wastewater treatment plant to avoid excessive sludge withdrawal which would have affected reactor performance.

Major problems which were pointed-out and reported to SPES were:

- unreliable working of the DO acquisition channels,

- interferences between DO and pH readings (lack of proper electrical insulation between the two input channels),
- occasional malfunctioning of the opening/closing cycle of the microsolenoidvalves for titrant dosing,
- imprecise temperature reading.

On the basis of this first step of the test and debug activity, SPES designed and implemented a second version of the embedded board: the analog interface was completely re-designed to improve the efficiency and reliability of the galvanic insulation between the channels and the hardware filtering for noise reduction.

Also the firmware and the software were revised and the second release was delivered.

After this, most of the problems above have been already solved and the upgraded prototype is now available to POLIMI for further debugging.

DEFINITION OF THE SPECIFICATIONS FOR THE ON-LINE PH-DOSTAT TITRATOR

The off-line unit can be upgraded to be used as an on-line monitoring and controlling device to be applied to SBRs. In the following paragraph the various modes which can be applied by using the pH-DOstat unit to monitor SBRs are described.

Application of the pH-DOstat unit to monitor SBR processes

At present, the off-line unit (Martina) is equipped with two lines to perform activity tests on biomass. They can be used to collect data on the influent characteristics, which can be used for feed-forward control strategies; in particular, data can be obtained on:

- influent toxicity,
- influent N–content.

Alternatively, the Martina unit can be applied to get data for feedback control strategies by monitoring the status of the SBR system, in particular to:

- periodically assess the maximum nitrification capacity of the sludge,
- identify the end of the nitrification reaction during the aeration phase.

In Figure 14 the layout of a SBR plant (multiple-tank SBR) with a Martina unit is suggested.

Tank 1 is necessary to equalise the influent arriving from the sewer (retention time: 1-2 hours at least), and should be installed in every SBR plant, independently from the control strategy chosen. Tank 2 has almost the same retention time, or at least one hour; it is an ‘emergency storage volume’ where the influent is stored in case the monitoring system (Martina unit is its core) detects a serious toxic effect. Then, several strategies can be adopted to treat the toxic influent, e.g.: distributing the total volume in all the SBRs, or increasing feeding times, etc.
The maximum time required to complete a toxicity test by the Martina unit is estimated in 1 hour including sampling, testing, discharging and data analysis. Therefore, a retention time of 1 h at least for tank 1 is essential to store the influent during Martina toxicity determination.

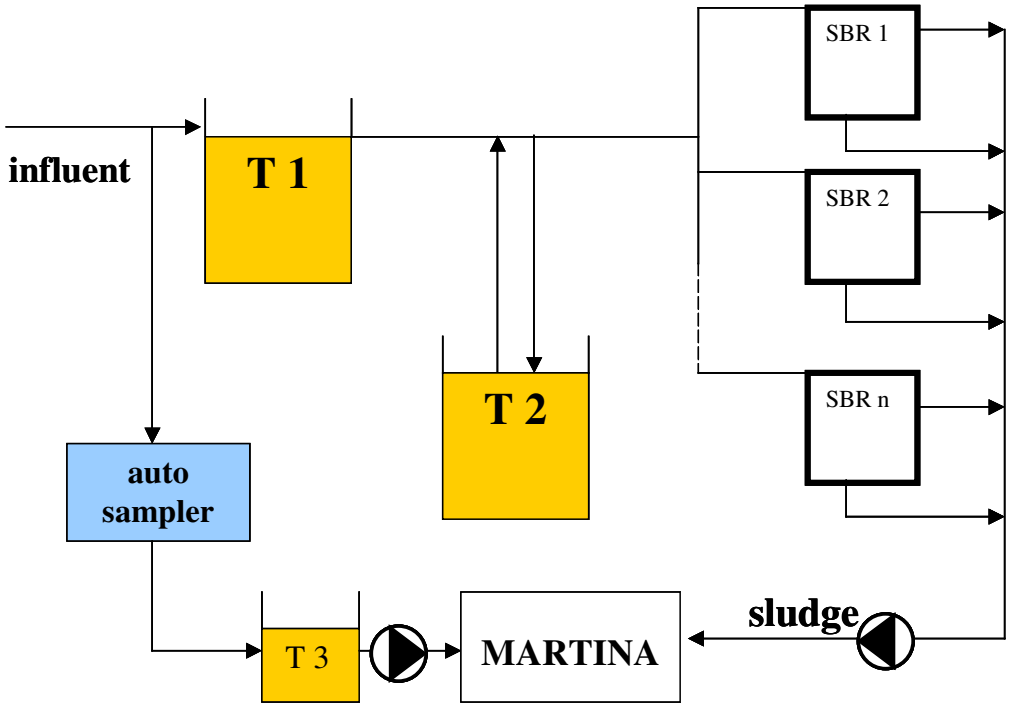

Figure 14 – Titration unit Martina to monitor a SBR plant

Mode 1: Determination of influent acute toxicity

- An automatic sampler collects the influent from the sewer during one hour (approximately) and stores it in T3 (volume stored 0.5 - 1 L). In this way the sample is representative of the average influent that reaches the plant in one hour;
- a sample of the mixed liquor is taken from the SBR at the end of the aeration phase in order to have it as close as possible to endogenous conditions at the beginning of the Martina test;
- sludge and influent samples are mixed in MARTINA's reactor in the same volumetric ratio as in the SBR reactor;
- a fixed amount of ammonia is added by a dosing system made of a peristaltic pump and by an electrically actuated valve, to ensure substrate non-limiting conditions for nitrifiers;
- a pH-DOstat test is performed until a sufficiently constant titration rate is observed;
- ATU is added to inhibit nitrifying activity;
- the pH-DOstat test is performed continuously to assess the titration rate due to processes other than nitrification;
- nitrifying activity is calculated by the Master computer connected to Martina, by calculating the difference in the titration rates (i.e. the slopes of titration curves) determined before and after the addition of ATU (Figure 15); a toxic event is indicated by a sudden reduction in the nitrification activity. In Figure 16, the case of an influent completely inhibiting nitrifiers is depicted.

Frequency: max 1 test per hour.

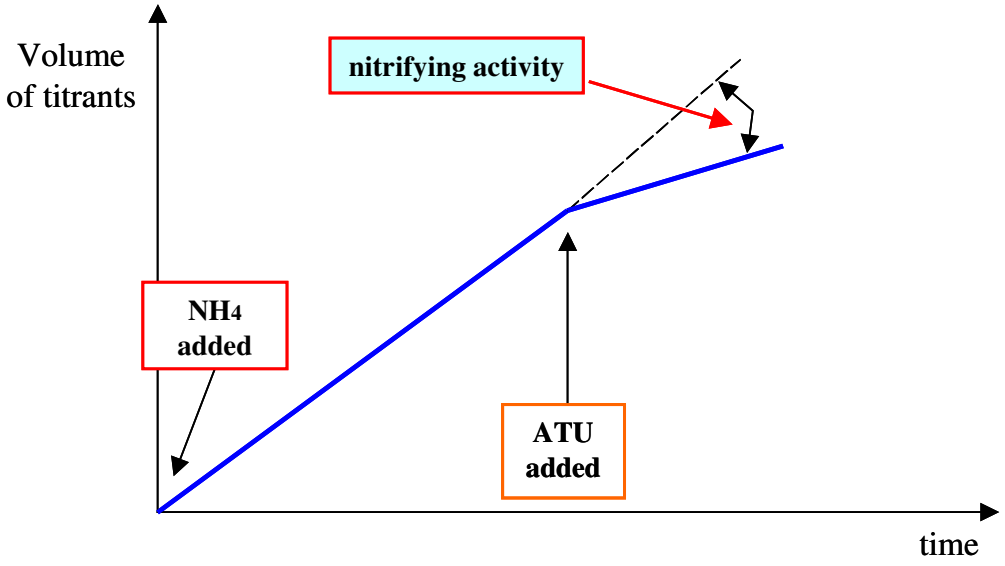

Figure 15 – Determination of nitrifying activity

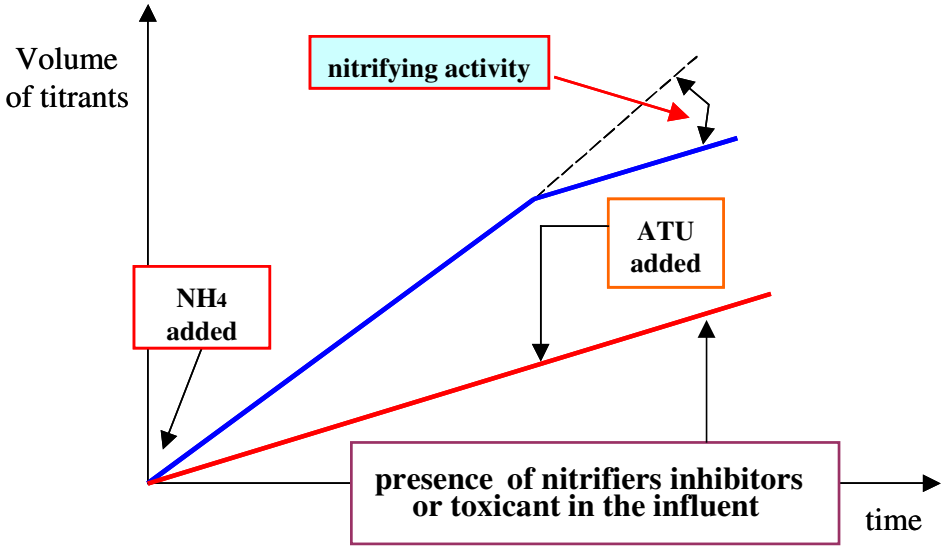

Figure 16 – Detection of an inhibitor and/or toxicant in the feed that totally inhibits nitrifying activity

Mode 2: Determination of ammonia - nitrogen load

To determine the ammonia-nitrogen load in the influent, the titration unit can be used to perform a pH-DOstat test (Figure 17). First of all, settled sludge is withdrawn from the bottom of one of the SBR tanks at the end of the sedimentation phase. Influent is then added to this sludge at a volumetric ratio lower than that used in the SBR. If compared with the previous test, sludge concentration is higher and the volumetric load is lower: in such a way the time required to complete the nitrification reaction is significantly lower than in the previous test. Therefore, the resulting titration curve (red line) is steeper than that obtained by using the mixed liquor (blue line). Moreover, the knee in the titration curve, which indicates the complete oxidation of ammonia nitrogen, appears earlier in the curve obtained on concentrated sludge ($t_{STOP1} < t_{STOP2}$). Therefore it is possible to have an estimation of the ammonia-N load in a shorter time than by following the same procedure that has been described for the previous test.

On the other hand, this procedure is less suitable to measure toxicity effects, since more biomass and less influent is used according to this procedure.

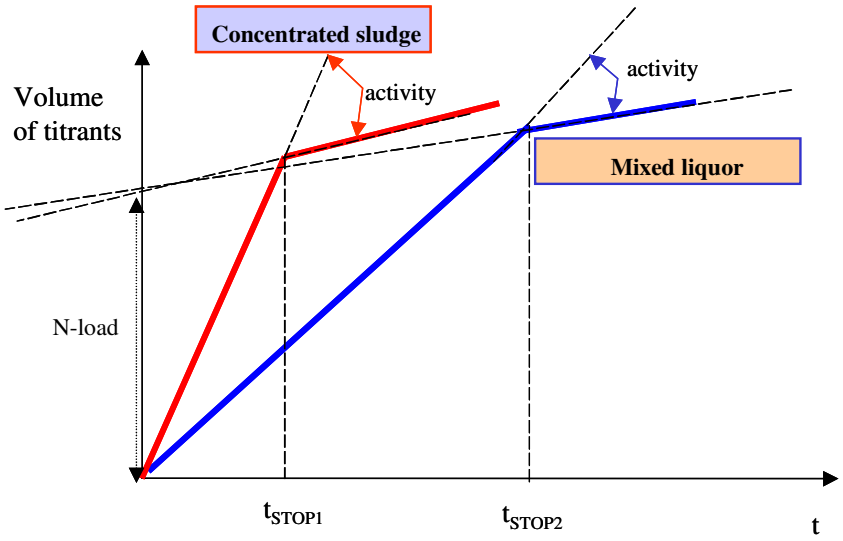

Figure 17 – Titration test to determine ammonia - nitrogen load

Mode 3: Monitoring SBR nitrification capacity

In this test, the sludge sample is withdrawn at the end of the aeration phase of the SBR tank and is kept under aeration also in the Martina's reactor, in order to ensure endogenous conditions. No influent is added to the sludge sample. The titration test is then performed according to the procedure described for Mode 1. This kind of test allows to assess the maximum nitrifying activity of the sludge and may be performed once per SBR cycle and on sludge samples collected alternatively from different SBR tanks. The resulting maximum nitrifying activity of the sludge is compared with historical data of the plant in order to highlight increasing or decreasing trends due to chronic toxicity, variations in influent load, operational conditions (pH, temperature, dissolved oxygen, …) or operational parameters (phase duration, loading strategy, …).

Mode 4: Identification of the end of the nitrification reaction during the SBR aeration phase

In this test, sludge is withdrawn from the SBR at the beginning of the aeration phase and pH-DOstat titration is immediately started. The nitrification process proceeds in the Martina reactor at the same rate as in the SBR, therefore, the knee observed in the titration curve indicates the end of the nitrification reaction in the SBR. This information can be used to optimize phases duration in the SBR.

Specifications to develop an on-line MARTINA unit

An instrument will be developed by SPES in co-operation with POLIMI and ENEA, that will be able to perform the following main tasks:

- F1: withdraw the sample to be analysed;
- F2: execute the titration experiment;
- F3: discharge the sample;
- F4: elaborate data collected during the experiment;
- F5: make elaborated data available for monitoring and control systems.

The instrument is made of two units communicating by radio signals (in the future a GSM system should be implemented):

FIELD UNIT: to be located on the plant, close to the sampling point, equipped with all that is necessary to execute phases F1, F2, and F3;

MASTER UNIT: operation and elaboration unit, that executes phases F4 and F5, to be located in the control room of the plant, connected to the PC by a serial link.

With GSM connection between the units, the control room could be very far from the plant and could be shared with several plants.

FIELD UNIT (Figure 18)

This unit is made of:

Automatic control board: allows to manage all operations required for calibration of probes and of the titrant dosing system and perform the experiment following the directions given by the MASTER UNIT.
The unit is equipped with a display and a keyboard to execute settings and for probes signal visualisation during experiment. It is possible to save data of probe signals and titrant volumes with a user-defined frequency. Once the maximum limit of storable data on the unit memory has been reached, these data will be transmitted to the MASTER UNIT and memory will be made available to store new data. Also the use of a Compact Flash Card is under investigation for data storage as a backup solution in case of failure of the radio link.
For every probe/solenoidvalve the control unit saves one datum every 10 seconds and saved data are transferred to MASTER UNIT at 10 minutes intervals (or other specified intervals).

Sampling piping circuits. Sampling occurs through two sampling circuits (Figure 18): one for sludge and the second for sewage sampling. Continuous circulation of the sample fluids (sludge and sewage) allows to take fresh samples and avoids unwanted settling/clogging or icing in the sampling piping.
A 15-cm wide grid-case (around 1-cm mesh width) is mounted at the inlet end of the sampling pipes, so that the inlet does not clog because of coarse solids.
Sludge sampling takes place from one SBR tank at two different levels: at the higher level it allows sampling MLSS; at the lower level it allows sampling settled sludge, when high-concentration sludge is required for testing ("mode 2", see previous paragraph).
3-way solenoidvalves (EV_{3cf}) are placed at each edge of the up-flow portion of the sludge sampling pipes, so that, when sampling occurs from one branch, the other branch can be emptied and no settling / drying / clogging nor icing occurs in the sampling pipe.
Sewage sampling takes place from the feed tank of the SBR plant and, again, a continuous-flow circuit is provided to take sewage to the inlet of the measuring / titration unit.
Both sampling circuits are equipped with pumps which allow a flow velocity of around 1 m s^{-1} in a 1/2"-diameter pipe.

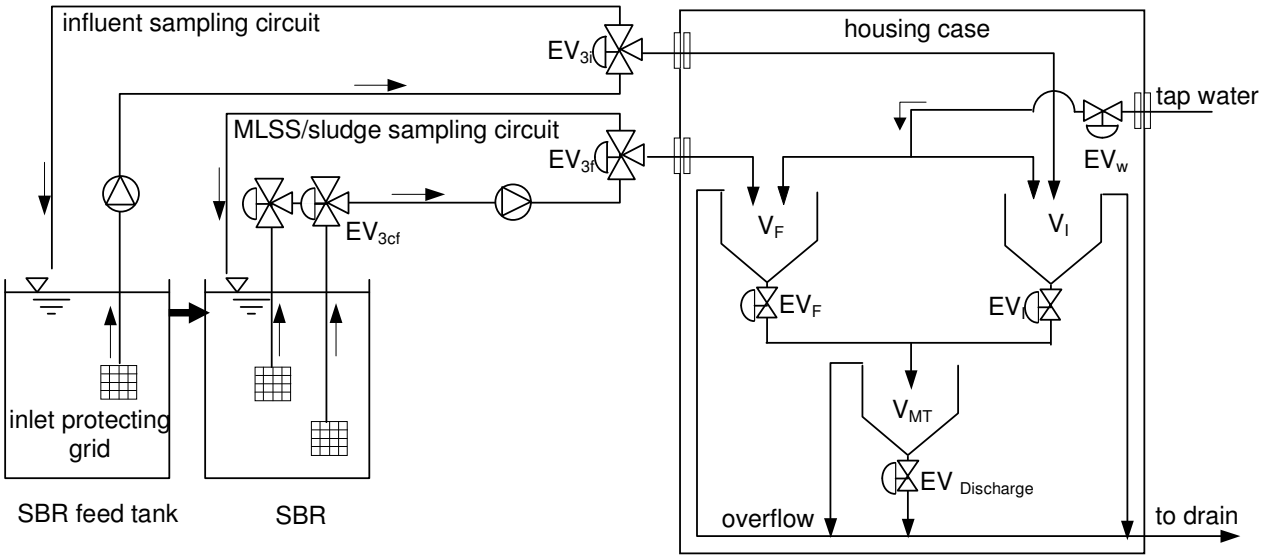

Figure 18: Overall outline of the FIELD UNIT (sampling circuits are included); V_F: sludge storage beaker; V_I: influent storage beaker; V_{MT}: measuring and titration beaker; EV_3: 3-way solenoidvalves; EV: actuated solenoidvalves.

Sampling/discharge unit of samples to be analysed. Three inlets are provided with a flange coupling on the FIELD UNIT, they can be coupled to pipes connected to n_1-1 sampling points on the plant (e.g.: influent inlet, equalisation tank, SBR tanks); an inlet is connected to tap water for cleaning purposes.
Each inlet (either of sludge or sewage) is open/closed by a 3-way solenoidvalve (EV_{3i}, EV_{3f}) and the sample is sent to a storage beaker (V_F, sludge; V_I, influent). The opening time of EV_{3i} and EV_{3f} will be long enough to collect excess sample volumes and discharge part of it through the overflow discharge ports, in order to ensure that the storage beakers will be full before the measuring session.
Each storage tank is equipped with an actuated solenoidvalve (EV_F, sludge; EV_I, influent) that allows the loading of the measuring/titration beaker (V_{MT}).
The control of sample volumes to be dosed in the measuring and titration unit is done through the opening time of the EV_I, EV_F actuated solenoidvalves.
It is under evaluation whether the control of sample volumes to be dosed in the beaker may also be done through level sensors. These should be positioned at defined levels (maximum, minimum) in the measuring and titration beaker and should also guarantee the diagnosis of malfunctioning on charge/discharge lines of the storage beakers (e.g.: clogging of solenoidvalves).
The volume of the sludge storage beaker (V_F) should be at least 1 L, but a bigger beaker (up to 2 L) can be placed if required. The volume of the influent storage beaker (V_I) should be about half of the sludge.
In fact, since the volume exchange ratio (volume of influent/ total volume) can vary from 0.2 to 0.5 (Wilderer et al., 2001), the influent dosed into the measuring/titration beaker can be varied accordingly, by acting on the opening time of the three-way solenoidvalves EV_F and EV_I.

Measuring and titration unit: this is made of:

- probes (DO, pH, T and ORP);
- 5 units, each one made of peristaltic pump + solenoidvalve to add titrants (H_2O_2, NaOH, HCl) and reagents (NH_4Cl, ATU);
- measuring beaker: cylindrical reactor with conic hopper on the bottom equipped with:
  - mechanical mixer,
  - aerator with porous stone,
  - submerged heater (or side surface heater),
  - removable cover for positioning of probes (DO, pH, T, ORP) and pipes to dispense titrants and reagents,
  - titrants and reagents tanks.

A 2-way solenoidvalve (EV_s) opens/closes a draining pipe placed on the bottom of the beaker. An overflow discharge port will ensure safe discharge of occasional unwanted excess filling of the beaker.
After each "measuring session" all beakers (storage and measuring/titration) are emptied and washed with tap-water.

Housing case: structure that contains the above described units, providing protection for instrumentation. It's equipped with: an plug for system's electric supply (220 or 380 V), flanged couplings to connect pipes for inlets and discharge, communication system to exchange data with the MASTER UNIT (initially by radio communication).

FIELD UNIT can be equipped to work on two sampling/discharging units and 2 measuring and titration units, while the control unit is unique and manages both lines.

Heating system and a refrigerating system for the measuring beaker and/or for reagents/titrants storing tanks have to be implemented and several options are currently under evaluation (Peltier system).

Reagent stability under field conditions will be tested during the operation of the prototype.
At the moment, sampling pump types, pump flow-rate, storing tank volumes, beaker volumes and geometry, pipe diameters, and other details are currently under evaluation.

MASTER UNIT

Basically it is the embedded electronic board, connected to the PC, that allows the setting of experiments, their management, data saving and analysis and the shipment of titration results to the plant integrated supervision system.

Experiments settings: this task will be accomplished by means of a software package structurally similar to the one developed for the laboratory version of MARTINA.
Additionally the software for the on-line version will also allow to set and manage sample collection and discharge.

Experiment management: routing have to be implemented for the identification of the different phases of the experiments and for the activation of the addition reagents at the appropriate time.

Data saving: data will be saved on logging files with the appropriate format to be read and elaborated.

Data analysis and results transmission: routines will be developed for the identification of knees in the titration curve and for the automatic identification of the end of the titration experiments. Biomass activity will then be calculated by moving window regression on titrated volumes. These data will be remotely sent to the plant integrated supervision system.

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EOLI
Efficient Operation of Urban Wastewater Treatment Plants

ANNEXES
WP1/WP8 - UU - 1st year activities

November 2002 -October 2003

Work Package 1 - Process experiments
Work Package 8 - Integration
First Annual Report

Contract Number ICA4-CT-2002-10012

Partner 7. UU
WP1 and WP8 Report Annex

Reactor's Automatic Control System

Objectives

The experimental set-up, consisting of two instrumented reactors will be operated in full automatic mode. The automatic operation of both reactors is performed by an "industrial control" system type. It was developed to accomplish several objectives:

- Robustness.
- Dependability.
- Flexibility of operation, especially for system start up.
- Easy operation.
- Ability to be used in future tasks. Eg.: control algorithms testing.
- Following industrial standards in order to be closer to a final application.

The system is intended to be used to perform tasks in WP1 (for the experiments needed in WP2 and WP5), and WP8 Work Packages. Most of the experiments in WP1 at this moment provide data for WP2 (see EOLI Experimental Protocol) and will be done under automatic operation. This operation should be reliable and follow the Protocol. This is related to the first four objectives.

When the Control Strategies developed in WP5 are finished, the system must be able to include them as part of its programming, in order to be tested. This will be done during year 2 of the project.

The system should be flexible enough to include some system integration tests at the year 3 of the project, and in this way contribute to WP8.

Architecture

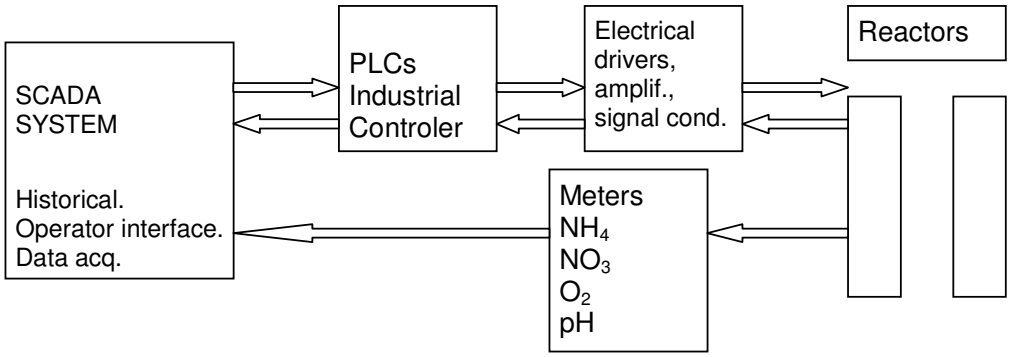

Figure 1. Control System general scheme.

Its general scheme is shown in Figure 1. The main functional parts are represented as blocks.

SCADA SYSTEM. The data acquisition, historical management, alarms, reports and operator interface is carried out by an SCADA system. It was implemented as an Intellution FIX ® application.
It runs on a dedicated PC (Pentium 4), which is connected through a serial port (RS 232-C) to the PLC. Is also connected through serial ports to the 8 meters that perform the main measurements (pH, NH_4, NO_3, DO) of the reactors' contents. Each meter interfaces it's electrode, performs signal conditioning and A/D conversion. The result is digitally transmitted to the PC.
Receives instrument data, and actuators and electrodes state from the PLC. Commands the PLC operation. Also receives analogic measurement of the electrodes' voltage and temperature (inside the reactors by Pt100). Performs all the database management for historical recording purposes.
The operator interface (local or remote) is described below.

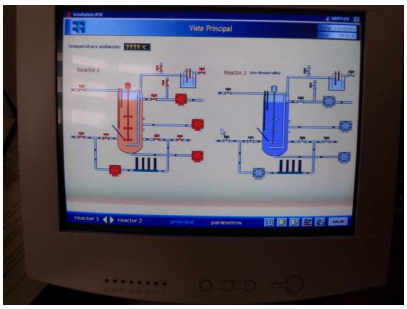

Fig.2. SCADA display

PLC. The real time process control is done by an ABB PLC based system. It performs data acquisition and actuators command, running a program that execute the reactors' cycle phases. The program is able to run stand-alone.
It receives analogic (electrochemical sensors, temperature) and makes its A/D conversion. Receives digital signals: emergency start-stop, reactors level electrodes, leaks electrodes. In the former cases, signal conditioning is needed.
Transmits this information and receive commands from the SCADA as described before. Commands are received as direct set of orders to actuators, or as operation parameters (timing for cycle phases).
Finally, the physical devices: pumps, valves, motors, etc. are driven by AC relays in order to buffer the PLC.

Fig. 3. PLC system

Operator Interface

Special attention was given to the operator interface. This interface must allow not only the normal cycle operation, but also special non pre-programmed operation.
The main operator screen (fig. 4) is a "general view" of both reactors. It shows by animated icons the actual state of sensors and actuators. From it one can "zoom in" to each reactor screen.
The reactor screen (fig.5) shows the detailed state of each element of the reactor, and permits the direct operation on it.

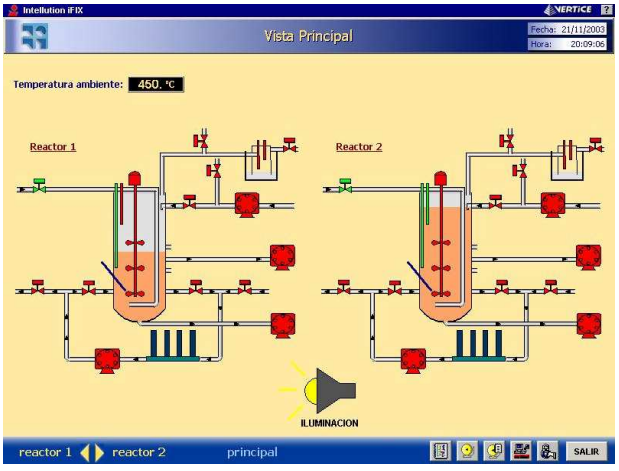

Fig. 4. General view (main)

On one hand, there is a programmed operation ("automatic" mode), programmed by stablishing the times associated to each phase of the cycles (see parameter configuration). On the other, the operator can override the automatic operation by manual operation of each actuator element in order to perform rutinary (and extraordinary) maintenance tasks, singular experiments, and corrective actions in case of failures.
Fig. 6 shows this screen indicating some key points as the soft buttons activated by a click of the mouse with the cursor pointing them.

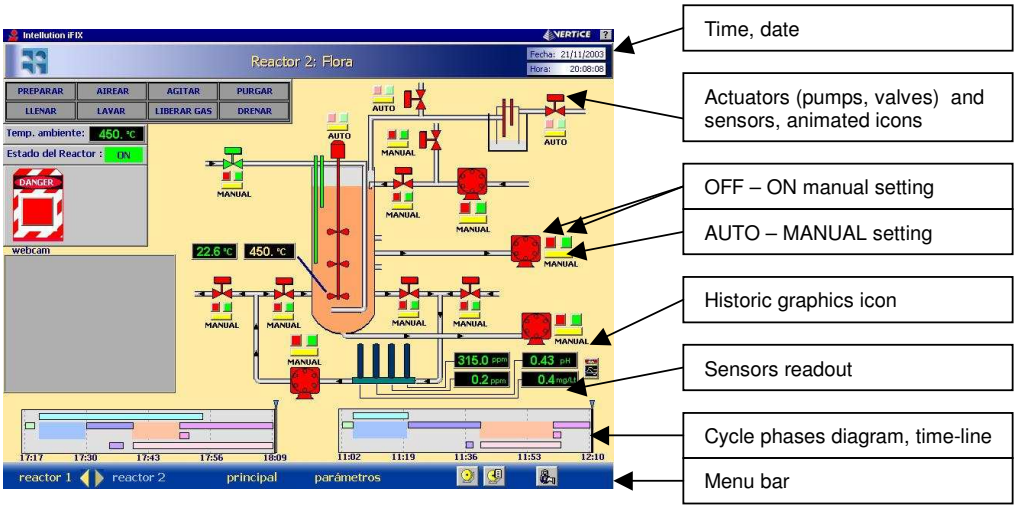

Fig. 5. Reactor screen

From this screen the operator can access also to the measures as a "zoom-in" to the sensors, seeing a historical graphic. (see fig. 6). In the same way he can display the history of pumps and valves operation.

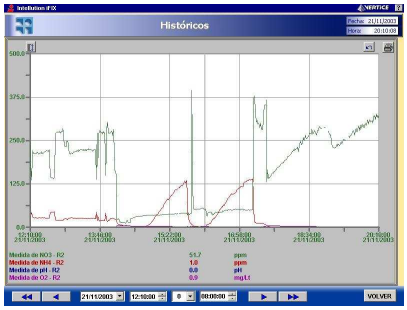

Fig. 6. Historical graphic.

The screen was designed to permit remote operation and monitoring of the system by ordinary PC's connected to Internet. This is helped by a web cam image displayed in the screen.
From the reactor screen, the operator can jump to the other reactor screen, the main screen, or the parameter screen (see fig. 7), where he can program the operation of each reactor by stablishing the beginning and ending of each phase of the reactor's operation cycle.

The parameters are organized as a table. The programmable parameters are operator modifiable entries. Besides the timing parameters, also the alarms and the electrodes cleaning periods are set in this way.

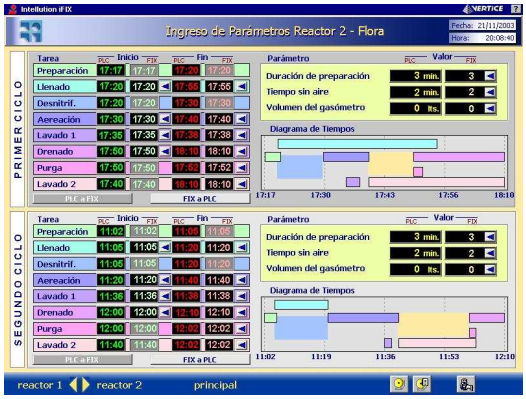

Fig. 7. Parameter screen.

EOLI
Efficient Operation of Urban Wastewater Treatment Plants

ANNEXES
IBTech - 1st year activities

November 2002 -October 2003

Contract Number ICA4-CT-2002-10012

	ANNEX CONTENTS BASIC ENGINEERING (REV. A)	DATE: 30/10/2003 BY: IBTech

NUMBER	DESCRIPTION	DOCUMENT
	SUMMARYS, INDEXES AND LISTS	
1	SUPPLYS CATALOG OF EQUIPMENT AND INSTRUMENTATION	IBT-WWT-EOLI-EC-001
2	ELECTRICAL EQUIPMENT	IBT-WWT-EOLI-LE-001
3	MOTORS AND PROCESS CONTROL	IBT-WWT-EOLI-CP-001
4	PROJECT PLANNING	IBT-WWT-EOLI-PPI-001
	DIAGRAMS AND DRAWINGS	
5	PIPING AND INSTRUMENTATION DIAGRAM	IBT-WWT-EOLI-PID-001
6	SYMBOLS DIAGRAM	IBT-WWT-EOLI-SD-001
7	PLOT PLANT	IBT-WWT-EOLI-PP-001
8	PLANT (ISOMETRIC VIEW)	IBT-WWT-EOLI-ISO-001
	DATA SHEETS (EQUIPMENT)	
9	MIXER, MA-01	HDE-001
10	PERISTALTIC PUMP, FP-02	HDE-002
11	CENTRIFUGAL PUMP, FP-01	HDE-003
12	AIR BLOWER, AB-01/02	HDE-004
13	WASTEWATER STORAGE TANK, ST-01	HDE-005
14	SEQUENCIAL BATCH REACTOR, SBR-01	HDE-006
15	AIR DIFFUSER	HDE-007
16	EFFLUENT PUMPING SYSTEM, EP-01	HDE-008
	DATA SHEETS (INSTRUMENTATION)	
17	HYDROSTATIC LEVEL MEASUREMENT, LE/LT-104	HDE-010
18	DISSOLVED OXYGEN MEASUREMENT, AE/AT O2-104	HDE-011
19	FLOWMETER / CONTROLLER, FITC-105	HDE-012
20	THERMOMETER, TE/TT-104	HDE-013
21	PH MEASUREMENT, AE/AT PH-104	HDE-014
22	ORP/REDOX MEASUREMENT, AE/AT ORP-104	HDE-015
23	PC CABINET, GAB-01	HDE-016
24	VALVE ON/OFF, FCV-01	HDE-017

SUPPLYS CATALOG OF EQUIPMENT AND INSTRUMENTATION

DATE:	19-Sep-03
DEPTO:	PROCESS
CLIENT: EOLI	
BY:	A.M.P.V.
REVISED:	J.E.L.H.
PROJECT: FILED-SCALE PILOT PLANT	
APROBE:	J.E.L.H.
PRIORITY: 1	
REVITION:	A
DEPARTAMENT: PROCESS	
Hoja: 1 de: 1	

ITEM	DESCRIPTION	UNIT	AMOUNT	SUPPLIER / TEL	CONTACT
EQUIPMENT					
MA-01	Mechanical Agitator, variable speed from 20 to 350 rpm, included 316 SS shaft, 316 SS A-310 impeller aun a drive quill with set screws, motor of 1/4 hp, type motor TENV, dimensions 20 1/2"-x 6-5/8", size impeller 7.6", Lightnin brand.	PIECE	1.0	EQUIPAR 54209901 ext. 206	Ing. Enrique Alvarez
FP-02	Feeding Pump, computer compatible/Programmable, speed control input 0 to 20 mA, 4 to 20 mA, or 0 to 10V, pumping direction/start/stop/purge, power 115 VAC, reversible 1/10 hp motor, Masterflex brand.	PIECE	1.0	EQUIPAR 54209901 ext. 207	Ing. Enrique Alvarez
FP-01	Feeding Pump, type horizontal centrifugal, motor TCCV of 1/4 hp, WEG brand.	PIECE	1.0	Casa Monroy 5578-9753	Sr. Victor Sotelo
EP-021	Effluent Pump, type submersible centrifugal, ON/FF control, 1/6 hp motor, Little Giant brand.	PIECE	1.0	IBTech	Ing. Jorge López
AB-01/02	Air Blower, motor of 1 hp, speed 1750 rpm, dimensions 16" x 6.5" x 9", GAST brand.	PIECE	2.0	Fabritanques S.A. de C.V. (664) 684-2122	Ing. Hugo Nieto
ST-01	Wastewater Storage Tank, HDPE material, 1100 liters of capacity, dimensions 43.3" x 54.72", Roplas brand.	PIECE	1.0	5586-0996 04455-59433293	Ing. Eduardo Martínez
SBR-01	Sequencing Batch Reactor, HDPE material, 1300 liters of capacity, dimensions 43.3" x 74.4", Rotoplas brand.	PIECE	1.0	5586-0996 04455-59433292	Ing. Eduardo Martínez
	Difuser system	PIECE	3.0	Blow Pressure 19977379	David Castillo
CCS-01	Computer Control System	PIECE	1.0	APC 5740-5197	Ing. Roberto Alvarez
GAB-01	PC Cabinet, for provide security from unauthorized access as well as protection from harsh enviroments.	PIECE	1.0	(1) APC 5740-5197	Ing. Roberto Alvarez
MCP-01	Motor Control Panel for harsh enviroments.	PIECE	1.0	(2) Sistemas de Control Industrial 55199112	Cesar Rodríguez
INSTRUMENTATION					
LE/LT-104	Pressure transmiter, gauge for hydrostatic level measurement flush mounted contite-sensor, certificate for non-hazardous areas, neck length (60-300 mm), process immersion length (75-3700mm). Endress + Hauser brand.	PIECE	1.0	Endress + Hauser 55682405	Eduardo Sequera
AE/ATO2-104	Amperometric dissolved oxygen sensor in SS 316L with PG 13.5 thread, membrane simple hygienic style. Includes dissolved oxygen transmitter panel mounted 96 x 96 mm, two lines display, meno in 6 languages.Endress + Hauser brand.	PIECE	1.0	Endress + Hauser 55682406	Eduardo Sequera
FICT-105	Gas Flow-Control System, flow range 0 to 500 lpm, pressure drop at maximum flow is 1.4 psi, max particulate size is 50 microns, conecctions 1/8" NPT(F), power 12 to 28 VCD, Cole Parmer brand.	PIECE	1.0	EQUIPAR 54209901 ext. 206	Ing. Enrique Alvarez
TE/TT-104	Thermometer with threaded proceess conection and neck. Temperature range -50 to 400ºC. Terminal head adjustable in operation. Pressure rating at 20ºC is at least 50 bar. Endress + Hauser brand.	PIECE	1.0	Endress + Hauser 55682405	Eduardo Sequera

	SUPPLY CATALOGUE OF EQUIPMENT AND INSTRUMENTATION	**DATE:** 19-Sep-03 **DEPTO:** PROCESS
	CLIENT: EOLI	**BY:** A.M.P.V. **REVISED:** J.E.L.H.
	PROJECT: FILED-SCALE PILOT PLANT **PRIORITY: 2**	**APROBE:** J.E.L.H. **REVITION:** A
	DEPARTAMENT: PROCESS	**Hoja: 1 de: 2**

ITEM	DESCRIPTION	UNIT	AMOUNT	SUPPLIER / TEL	CONTACT
	INSTRUMENTATION				
AE/ATO2-104	Amperometric dissolved oxygen sensor in SS 316L with PG 13.5 thread, membrane simple hygienic style. Includes dissolved oxygen transmitter panel mounted 96 x 96 mm, two lines display, meno in 6 languages.Endress + Hauser brand.	PIECE	1.0	Endress + Hauser 55682405	Eduardo Sequera
AE/ATpH-104	Manual retractable assembly for pH/ORP electrodes. For easy installation of gel filled electrodes with standard length 120 mm in tanks. Includes pH/ORP switchable transmitter, panel mounted 96 x 96 mm, two lines display, meno in 6 languages.Endress + Hauser brand.	PIECE	1.0	Endress + Hauser 55682406	Eduardo Sequera

	SUPPLY CATALOGUE OF EQUIPMENT AND INSTRUMENTATION	**DATE:** 19-Sep-03 **DEPTO:** PROCESS
	CLIENT: EOLI	**BY:** A.M.P.V. **REVISED:** J.E.L.H. **APROBE:** J.E.L.H. **REVITION:** A
	PROJECT: FILED-SCALE PILOT PLANT **P R I O R I T Y: 3**	
	DEPARTAMENT: PROCESS	**Hoja: 1 de: 3**

ITEM	D E S C R I P T I O N	UNIT	AMOUNT	SUPPLIER / TEL	CONTACT
	I N S T R U M E N T A T I O N				
AE/ATORP-104	Manual retractable assembly for pH/ORP electrodes. For easy installation of gel filled electrodes with standard length 120 mm in tanks. Includes pH/ORP switchable transmitter, panel mounted 96 x 96 mm, two lines display, meno in 6 languages.Endress + Hauser brand.	PIECE	1.0	Endress + Hauser 55682405	Eduardo Sequera

	CLIENT: EOLI PROJECT: FILED-SCALE PILOT PLANT DEPARTAMENT: PROCESS	DATE: **17-Sep-03**	SPECIFICATION:
		BY: **A.M.P.V.**	AREA: **BIOLOGICAL TREATMENT**
	ELECTRICAL EQUIPMENT	REVISED: **J.E.L.H.**	DEPTO. **PROCESS**
		APROBE:	SHEET: **1 DE 1**

ITEM	DESCRIPTION	CAPACITY	DIMENSIONS (long x wide x high)	VOLTS	RPM	FASES	CYCLES (Hz)	TYPE	AMOUNT	EQUIPMENT IN OPERATION (AMOUNT)	UNIT POWER (HP)	POWER TOTAL (HP)	POWER IN OPERATION (HP)	OPERATION
MA-01	MECHANICAL MIXER	1 m3	20 1/2" X 6 5/8"	110	20-350	1	60	VERTICAL MECHANICAL	1.00	1.00	**0.25**	**0.25**	**0.25**	INTERMITTENT
FP-02	FEEDING PUMP (PERISTALTIC)	0.6-8 l/min	16" X 9 1/2" X 9 5/16"	110	50-650	1	60	PERISTALTIC	1.00	1.00	**1/10**	**0.10**	**0.10**	INTERMITTENT
FP-01	BOMBA DE ALIMENTACIÓN RÁPIDA A REACTOR AEROBIO	64.90 l/min	CDT: 20.89 ft	110	*	1	60	HORIZONTAL	1.00	1.00	**0.25**	**0.25**	**0.25**	INTERMITTENT
EP-01	SUBMERSIBLE CENTRIFUGAL PUMP	1200 l/h	CDT: 35.94 ft	110	*	1	60	SUBMERSIBLE	1.00	1.00	**0.17**	**0.17**	**	INTERMITTENT
AB-01/02	AIR BLOWER	11.89 ft3/min	0.41mx0.16mx0.23m	110	1750	1	60	PALLETS	2.00	1.00	**1.00**	**2.00**	**1.00**	INTERMITTENT
										POWER TOTAL:		**2.77**	**1.60**	

*BY SUPPLIER

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IB Tech	CLIENT: EOLI PROJECT: FILED-SCALE PILOT PLANT DEPARTAMENT: PROCESS	DATE **26-Sep-03**	
		BY: **A.M.P.V.**	AREA: **BIOLOGICAL TREATMENT**
	MOTORS AND PROCESS CONTROL	REVISED: **J.E.L.H.**	DEPTO. **PROCESS**
		APROBE:	SHEET **1 DE 1**

ITEM	DESCRIPTION	SERVICE	VARIABLE	MAIN ELEMENTS	LOCATION		
					FILED	CONTROL PANEL	COMPUTER
MA-01	MECHANICAL MIXER	MIXER	SPEED	SWITCH ON/OFF		X	X
				DRIVE STATE INDICATOR		X	X
				SPEED CONTROL	X (note 1)		
FP-01	FEEDING PUMP (CENTRIFUGAL)	TO FED SBR REACTOR		SWITCH ON/OFF		X	X
				DRIVE STATE INDICATOR		X	X
FP-02	FEEDING PUMP (PERISTALTIC)	CONTROL OF INLET FLOW TO REACTOR	SPEED	SWITCH ON/OFF	X (note 2)	X	X
				SPEED CONTROL		X	X
				SPEED CONTROL	X (note 2)		X
EP-01	SUBMERSIBLE CENTRIFUGAL PUMP	EFFLUENTE PUMPING		SWITCH ON/OFF		X	X
				DRIVE STATE INDICATOR		X	X
AB-01/02	AIR BLOWER	TO PROVIDE THE AIRFLOW		SWITCH ON/OFF		X	X
				SPEED CONTROL		X	X
SBR-01	SEQUENCING BATCH REACTOR	BIOLOGICAL TRATMENT	LEVEL	SENSOR	X		
				TRANSMITTER		X	
				INDICATOR			X
				ALARMS			X
			TEMPERATURE	SENSOR	X		
				TRANSMITTER	X		
				INDICATOR			X
			O2	SENSOR	X		
				TRANSMITTER		X	
				INDICATOR		X	X
			PH	SENSOR	X		
				TRANSMITTER		X	
				INDICATOR		X	X
			REDOX	SENSOR	X		
				TRANSMITTER		X	
				INDICATOR		X	X
	AIR LINE	TO PROVIDE THE AIRFLOW	FLOW	SENSOR	X		
				INDICATOR	X (note 3)		X
				CONTROL	X (note 3)		

NOTES:

1. IN THE SAME EQUIPMENT.
2. IN THE SAME EQUIPMENT.
3. IN THE SAME LOCAL INSTRUMENT.

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PROJECT PLANNING
DESIGN AND CONSTRUCTION OF THE PILOT SCALE PLANT OF THE EOLI PROYECT

	ACTIVITIES	YEAR 1 MONTHS Nov-02	Dec-02	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	YEAR 2 MONTHS Nov-03	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04
1	**RECEPTION AND PREPARATION OF INFORMATION**																			
1.1	Reception of information from I de I																			
1.2	Information analysis																			
1.3	Work meetings (I de I-IBTech)																			
1.4	Design's basis																			
1.5	Design's basis review (I de I)																			
1.6	Field trips to two WWTP																			
2	**BASIC ENGINEERING**																			
2.1	Design and data sheets																			
2.2	Basic engineering's documents																			
2.3	Summarys, indexes and lists																			
2.4	**Work meeting (I de I-IBTech)**																			
2.5	Diagrams and drawings (PP, PID, etc.)																			
2.6	**I de I's review**																			
3	**DETAIL ENGINEERING**																			
3.1	Mechanical Project																			
3.2	Pipings Project																			
3.3	Electrical Project																			
3.4	Instrumentation Project																			
3.5	IBTech's basic review																			
3.6	**I de I's review**																			
3.8	IBTech's crossed review																			
4	**PROCUREMENT AND SUPPLIES (BY I. DE I.)**																			
4.1	Equipment																			
4.2	Instrumentation																			
4.3	Motor Control Panel (MCP) and Computer Control System (CCS)																			
5	**CONSTRUCTION OF FSPP MECHANICAL ESTRUCTURE (SUPERVISION)**																			
5.1	Mechanical support's FSPP																			
5.2	Materials transportation																			
5.3	Cut and Built skid for FSPP																			
5.4	Painting																			
6	**EQUIPMENT AND PIPING INSTALLATION**																			
6.1	Equipment																			
6.2	Supports and pipings																			
6.3	Hydraulics testing of pipings																			
7	**ELECTRICAL AND INSTRUMENTATION INSTALLATION**																			
7.1	Motor Control Panel (MCP)																			
7.2	Supports and conduit																			
7.3	Electrical wiring																			
7.4	Instruments wiring																			
7.5	**Work meeting (I de I-IBTech)**																			
7.6	Computer Control System Testing																			
8	**PRECOMISSIONING ACTIVITIES**																			
8.1	Hydraulics test of equipment																			
8.2	Equipment coupling																			
9	**COMISSIONING ACTIVITIES (START UP)**																			
9.1	Comissioning activities (start up) of SBR reactor																			
10	**DELIVERY OF THE FIELD-SCALE PILOT PLANT**																			
11	**PROYECT COORDINATION MEETINGS** (THE FIRST TUESDAY OF EACH MONTH)																			
12	**WORK PACKAGE**	WP1, WP3, WP8												WP1, WP3, WP5, WP7, WP8						
13	**DELIVERABLES TO EOLI**																			
13.3	D1.7																			
13.4	D5.2																			
13.5	D7.4																			
13.6	D8.4																			
	ANNUAL REPORT																			

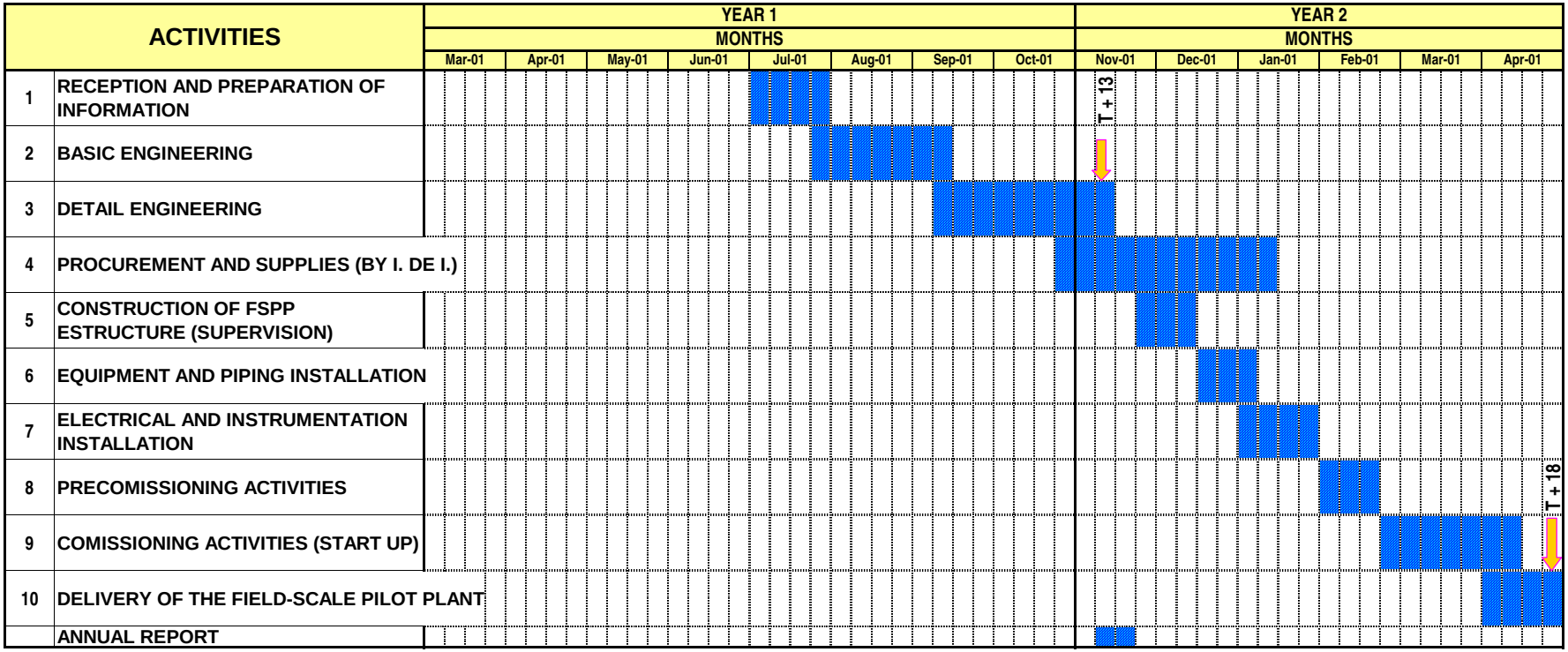
T + 13

T + 18

PREPARED BY: IBTECH, S.A. DE C.V.

	YEAR 3																	
	MONTHS																	
Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05		

WP1, WP3, WP5, WP7, WP8


ACTIVITIES
YEAR 1
MONTHS
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
YEAR 2
MONTHS
Nov-01
Dec-01
Jan-01
Feb-01
Mar-01
Apr-01
1 RECEPTION AND PREPARATION OF INFORMATION
2 BASIC ENGINEERING
3 DETAIL ENGINEERING
4 PROCUREMENT AND SUPPLIES (BY I. DE I.)
5 CONSTRUCTION OF FSPP ESTRUCTURE (SUPERVISION)
6 EQUIPMENT AND PIPING INSTALLATION
7 ELECTRICAL AND INSTRUMENTATION INSTALLATION
8 PRECOMISSIONING ACTIVITIES
9 COMISSIONING ACTIVITIES (START UP)
10 DELIVERY OF THE FIELD-SCALE PILOT PLANT
ANNUAL REPORT
T + 13
T + 18

CLIENT: **EOLI** PROJECT: **FIELD-SCALE PILOT PLANT**		DATE **29-Aug-03**	DEPTO. **PROCESS**
		BY **A.M.P.V.**	AREA: **BIOLOGICAL TREATMENT**
DATA SHEET **MIXERS** **HDE-001**		CHK'D **J.E.L.H.**	
		APPR. **J.E.L.H.**	SHEET **1 OF 2**

GENERAL

No.TAG.	**MA-01**	UNIT:	**PIECE**
SERVICE:	**TO MIX WATER**	AMOUNT:	**1**
SIZE:		MODEL:	**EW-50310-00**
TYPE:	**VARIABLE-SPEED**	MOUNTING:	**VERTICAL**
BRAND:	**LIGHTNI**	SUPPLIER:	**LIGHTNI**

OPERATION CONDITIONS

AGITATION ■ TO MIX ☐ DISOLUTION ☐ EMULSION ☐ INTERCHANGE HEAT

☐ ABSOR. OF GAS ☐ SUSPENSION ☐ OTHERS FLOCULATION

GRADO DE AGITACION ■ LIGHT ☐ MEDIUM ☐ STRONG

STRONG MIX: NOT

OPERATION ■ INTERMITTENT ☐ CONTINUOUS

OPERATION TIME: VARIABLE

WATER LEVEL: 0.95 m MAXIMUM LEVEL: 0.98 m MINIMUM LEVEL: 0.57 m

MIXER MATERIAL

COMPONENTES	VOLUME	DENSITY	VISCOSITY (CP)	TEMP. (°C)
WASTEWATER	1.0 m3	1.0	1.0	18.6

OPERATION: FILL: YES ■ NOT ☐

DECANTING: YES ■ NOT ☐

TANK DATA

TYPE:	**CILINDRIC TANK (SEE HDE-006)**
CAPACITY (LITERS):	**1000**
BOTTOM TYPE:	**CONICAL**
OPERATION PRESSURE:	**ATM**
MATERIAL:	**HDPE**
MOUNTING:	*

MECHANICAL DATA *

MOUNTING: ☐ CLAMP ☐ FLANGE ■ OTHER: WITH EXTERNAL SUPPORT

MIX SPEED	*				
IMPELLER	*	DIAMETER:	*	IMPELLERS No:	*
SHAFT:	*	DIAMETER	*	LENGHT:	*
COUPLE TYPE:	*	MOUNTING BY:	*		
GASKET:	*	MECHANICAL SEAL:	*		

REV.	DESCRIPTION	BY	CHK'D	APPR.	DATE
A	**Basic engineering**	**A.M.P.V.**	**J.E.L.H.**	**J.E.L.H.**	**29-Aug-03**

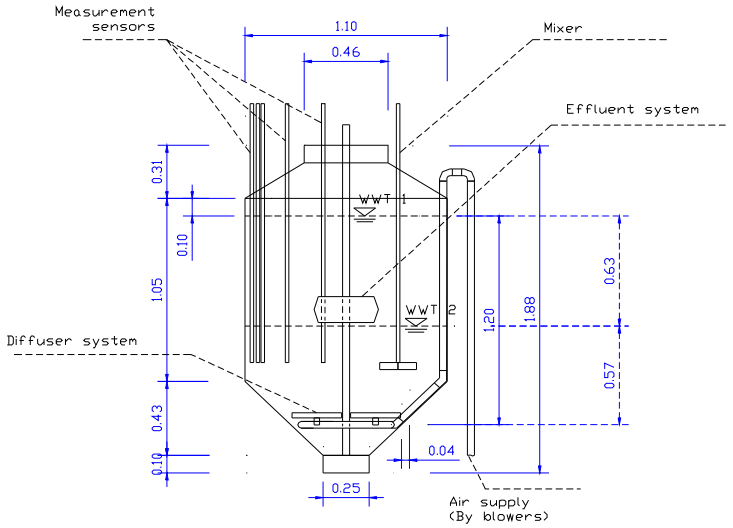
IB Tech	CLIENT: **EOLI** PROJECT: **FIELD- SCALE PILOT PLANT**	DATE **29-Aug-03** BY **A.M.P.V.**	AREA **BIOLOGICAL TREATMENT**
	DATA SHEET **MIXERS** **HDE-001**	CHK'D **J.E.L.H.** APPR.	DEPTO. **PROCESS** SHEET **2 OF 2**

SHAFT SEAL

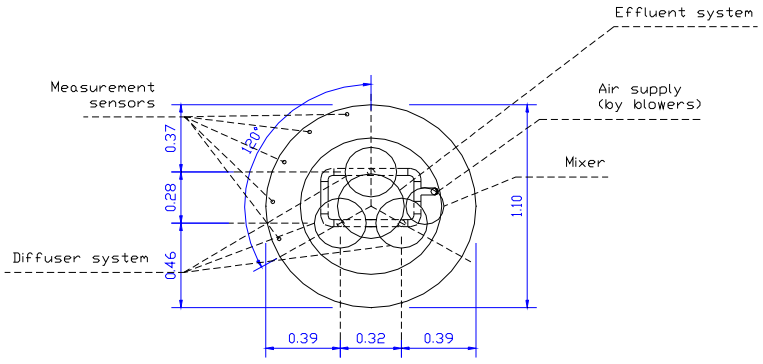
32	LUBRICATION:	*			PRESSURE:	*	
33	GASKET:	*	No RINGS:	*	MANUFACTURER:		
34	MECHANICAL SEAL:	*			MANUFACTURER:		
35	LUBRICATION LIQUID(GPM):		*				

	MATERIALS		MOTOR DATA			
36	IMPELLER:	*	MOTOR SUPPLIER:		MANUFACTURER:	*
37	SHAFT:	*	CLASS / DIVISION:	*	MOUNTING BY:	
38	COUPLE:	*	POWER: **1/4 HP**	RPM: **20-350**	ARMAZON:	*
39	MOUNTING NOZZLE:	*	FAB: *	TIPO: **TENV**	AISLAMIENTO:	**F**
40	ORINGS:	*	VOLTS / PHASES / HZ		110/1F/60Hz	
41	GASKET:	*	LUBRICATION:	*		
42	WEIGHT:	*	**DATA TRANSMISSION**			
43	MOTOR	*	CODE:	*		
44	TRANSSMISSION	*	MOUNTING BY: SUPPLIER			
45			FAB:	*		
46	OTHERS:	*	TYPE / MODEL:	*	AMOUNT:	*
47			AGMA CLASS:	*	SERVICE FACTOR:	**2**
48			HP AGMA:	*	RELATION:	*

49 **INSTALLATION DIAGRAM**



ELEVATION



PLAN

WWL: WASTEWATER LEVEL
DO NOT SCALE

NOTICES:

* BY SUPPLIER

THE MIXER HAVE TO A SPEED CONTROL.

REV.	DESCRIPTION	BY	CHK'D	APPR.	DATE
A	**Basic engineering**	**A.M.P.V.**	**J.E.L.H.**	**J.E.L.H.**	**29-Aug-03**

IB Tech	CLIENT: **EOLI** PROJECT: **FIELD-SCALE PILOT PLANT**		DATE **28-Aug-03**	SPECIFICATION **SPE-006**
			BY **A.M.P.V.**	AREA: **BIOLOGICAL TREATMENT**
	DATA SHEET PERISTALTIC PUMP HDE-002		CHK'D **J.E.L.H.**	DEPTO. **PROCESS**
			APPR. **J.E.L.H.**	SHEET **1 OF 2**

NOTICE: ❍ BY IBTECH / CLIENT ☐ BY SUPPLIER

FOR: ❍ TO QUOTE ● TO ORDER ❍ CONSTRUCTION

LOCATION:

SERVICE: **TO FEED TO SBR-01 REACTOR** MODEL: **U-07549-52 / 77601-10** UNITS: **1 PIECE**

MANUFACTURER: **MASTERFLEX** **I/P 73** SERIE:

DATOS GENERALES

No. DRIVE: * No. TAG. **FP-02**

MANUFACTURER: **MASTERFLEX**

● LIQUIDO

● FLUID: **WASTEWATER**

● TEMPERATURA DE BOMBEO (ºC)

NORMAL: **20º** **25ºC** MAX: **35ºC** MIN: **10ºC**

● SPECIFIC GRAVITY: **1.00**

● VAPOR PRESSURE (PSIA) @ PT: **0.55**

● OPERATING VISCOSITY (cP): **1.00**

● CORROSIVE FLUID: **NOT**

❍ CLORUROS CONCENTRATION (ppm)

❍ H2S CONCENTRATION (ppm) _____

FLUID: ○ TOXIC ○ INFLAMMABLE ○ EXPLOSIVE

● OPERATION CONDITIONS

● CAPACITY @ PT (LPM)

NORMAL: **0.6 TO 8**

● DISCHARGE PRESSURE (PSIG)

NORMAL: **30**

● POWER (HP) **1/4**

❍ SITE DATA

LOCALIZACIÓN ● INTERIOR ❍ EXTERIOR

❍ ELECT. AREA CLASS__**I**_____ GROUP_**A**____ DIV__**1**____

❍ PROTECTION

SITE DATA:

❍ OPERATION TEMPERATURE: (MIN / MAX) ___**10**___ / **30** **ºC**

CONDITIONS:

❍ DUST ❍ GAS ❍ SALINE ATMOSPHERE

❍ OTHER:

● SERVICE CONDITIONS:

	MOTOR	CONTROL	SHUTDOWN
VOLTAJE	110 V		
HERTZ	60		
PHASES	1		

❍ COOLING WATER: ENT._____ RET._____ DIS._____

❍ TEMPERATURE (ºC) MAX _____ MIN _____

❍ PRESSURE (PSIG) MAX _____ MIN _____

FUENTE _____

❍ AIR PRESSURE (PSIG) MAX: MIN:

☐ FUNCIONAMIENTO *

☐ No. PUMP HEADS: **1** NOMINAL CAP. (gph):

☐ NSPH REQUIRED (FT): ☐ PHID. TEST (psig):

☐ BHP NOMINAL: BHP ADJUSTABLE PRESSURE:

☐ DIAMETER (in): MAXIMUM PRESSURE. (psig):

☐ MOTOR SPEED (rpm): **50-650**

☐ PUMP HEAD:

☐ SPEED MAXIMUN (RPM) **650**

☐ SPEED MINIMUM (RPM) : **50**

☐ SPEED CONTROL: **+/- 0.25%**

FLOW RATE WITH I/P73 TUBING: **0.6 TO 8 LPM**

☐ CONSTRUCTION *

CONECTIONS	SIZE	ANSI CLASIF.	PHASE	POSITION
SUCTION				
DISCHARGE				
GLAND FLUSH				
DRAINS				
PURGE				

● PERISTALTIC

❍ JACKET REQ.

o MATERIALS

HEAD:

BODY:

ROTORES.:

TUBING:

OTHER:

CONTROL

FUENTE: +

❍ MANUAL ● REMOTE ❍ LOCAL

● AUTOMATIC ❍ LOCAL ❍ ELECTRONIC

CONTROL:

BY SPEED 50-650 RPM

ELECTRONIC (mA): **4-20mA**

REQUIREMENT OTHERS

❍ RELIEF VALVE

ADJUSTMENT PRESSURE: **30 psig**

TURNING DRIVE: **ON / OFF / REVERSE**

REV.	DESCRIPTION	BY	CHK'D	APPR.	DATE
REFERENCES					
A	**BASIC ENGINEERING**	**A.M.P.V.**	**J.E.L.H.**	**J.E.L.H.**	**28-Aug-03**

	CLIENT: **EOLI**		DATE **28-Aug-03**	SPECIFICATION **SPE-006**
	PROJECT: **FIELD-SCALE PILOT PLANT**		BY **A.M.P.V.**	AREA: **BIOLOGICAL TREATMENT**
	DATA SHEET PERISTALTIC PUMP HDE-002		CHK'D **J.E.L.H.**	DEPTO. **PROCESS**
			APPR. **J.E.L.H.**	SHEET **2 OF 2**

❍ MANOMETER
❍ CONTROL PANEL
LUBRICATING FLUID
☐ CARTER ☐ INTERMEDIATE ☐ LUBRICATING FLU

WEIGHT (kg) *

☐ HEAD ☐ TUE ☐ DRIVE

ACCESSORIES

❍ REDUCTOR MANUFACTURER
☐ INTEGRATE ❍ SEPARATE ☐ REDUCTION RELATION

NOTICES

TESTING

❍ MATERIALS ❍ DIMENSIONS
❍ NOT DESTRUCTIVE ❍ VERITICATION WITH INSPECTOR

TESTS	REQUIRED	TESTIFY	WITHOUT/TESTIFY
HIDROSTATIC	●	❍	❍
EXACTITUDE IN STABLE STATE	●	❍	❍
LINEARITY	●	❍	❍

MOTOR

❍ MOTOR: ● ELECTROMAGNETIC ❍ ELECTROMECHANICAL
☐ MANUFACTURER ☐ TYPE:
❍ CONSTANT SPEED (spm) ● VARIABLE SPEED
❍ VOLTS 110 ❍ HERTZ 60 m PHASE 1
❍ ENCAPSULAMIENTO ❍ OF GAS ❍ OF VAPOR ❍ OTHER

1. * BY SUPPLIER

2. THE SUPPLIER HAVE TO SUPPLY THE SYSTEM COMPLETE:

ELEMENT	MODEL
CONSOLE DRIVE	**U-07549-52**
PUMP HEAD	**77601-10**
TUBING	**I/P 73**
PHONE PLUG CONNECTOR, 1/4"	**A-07549-99**

REFERENCES					
A	**BASIC ENGINEERING**	**A.M.P.V.**	**J.E.L.H.**	**J.E.L.H.**	**28-Aug-03**
REV.	DESCRIPTION	BY	CHK'D	APPR.	DATE

	CLIENT: **EOLI**	DATE	SPECIFICATION
	PROJECT: **FIELD-SCALE PILOT PLANT**	**28-Aug-03**	**SPE-001**
		BY	AREA:
		A.M.P.V.	**BIOLOGICAL TREATMENT**
	DATA SHEET	CHK'D	DEPTO.
	CENTRIFUGAL PUMP	**J.E.L.H.**	**PROCESS**
	HDE-003	APPR.	SHEET
		J.E.L.H.	**1 DE 1**

GENERAL

1	No. TAG.	**FP-01**	4	UNIT:	**1**
2	SERVICE	**TO FEED THE SBR-01 REACTOR**	5	SITE PRESSURE (MM. HG.)	**750**
3	OPERATION	CONTINUOUS ☐ INTERMITTENT ■			

OPERATION CONDITIONS

6	LIQUID	**WASTEWATER**	12	CAPACITY	**10.3**	**G.P.M.**
7	TEMPERATURE	**18.6 ºC**	13	SUCTION PRESSURE	**1.28**	**FT H2O**
8	SPECIFIC GRAVITY	**1.00**	14	DISCHARGE PRESSURE	**22.17**	**FT H2O**
9	WASTEWATER VISCOSITY	**1.00**	15	CDT	**24.40**	**FT H2O**
10	VAPOR PRESSURE	**0.44 PSI**	16	N.P.S.H. DISP./REQ.	**28.38**	**FT H20**
11	pH	**7-7.5**				

PUMP SPECIFICATION

18	BRAND	**SIMENS OR WEG**	23	SUCTION: 1 1/4"	DISCHARGE: 1"	
19	TYPE	**HORIZONTAL CENTRIFUGAL**	24	SUC/DISCH DIAMETER:	*	
20	MODEL	*	25	IMPELLER:	**SEMI-OPEN**	
21	HYDRAULIC EFFICIENT:	*	26	ROTATION SPEED	*	**RPM**
22	SPHERE HOLE:	**0.5"**	27	POWER	(BY SUPPLIER 1/4 HP)	**BHP**

MOTOR

28	TYPE:	**TCCV**	32	POWER	(BY SUPPLIER 1/4 HP)	**H.P.**
29	CONSTRUCTION	*	33	VOLTS **127**	PHASE **1** CYCLES **60 Hz**	
30	TRANSMISSION ☐ DIRECT ■ REDUCTOR		34	ROTATION SPEED	*	**R.P.M.**
31	CLASS	**F**	35	BRAND	*	

MATERIALS			ACCESSORIES		
36	HOUSING	**CAST IRON**	44	ACOPLAMIENTO	**FLEXIBLE**
37	IMPELLER	**CAST IRON**	45	COUPLE	*
38	SHAFT	*	46	SELLO	*
39	SHAFT ACCESSORIES		47	REAR CASING:	*
40	ORING(S)		48	MANOMETER (S)	**BY INSTRUMENTATION**
41	GASKET	**N/A**			
42	MECHANICAL SEAL	*			
43	BASE	*			

NOTICES

* BY SUPPLIER.

REFERENCES					
A	**BASIC ENGINEERING**	**A.M.P.V**	**J.E.L.H.**	**J.E.L.H.**	**28-Aug-03**
REV.	DESCRIPTION	BY	CHK'D	APPR.	DATE

	CLIENT: **EOLI**	DATE **29-Aug-03**	SPECIFICATION
	PROJECT: **FIELD-SCALE PILOT PLANT**	BY **A.M.P.V.**	AREA: **BIOLOGICAL TREATMENT**
	DATA SHEET BLOWERS HDE-004	CHK'D **J.E.L.H.**	DEPTO. **PROCESS**
		APPR. **J.E.L.H.**	SHEET **1 OF 2**

GENERAL

1	No. TAG.	**AB-01/02**	5	AMOUNT	**2** (ONE IN OPERATION)
2	SERVICE	**AIR SUPPLY**	6	SITE PRESSURE (ATM)	**0.79**
3	OPERATION CONTINUOUS☐ INTERMITTENT ■		7	CLASIFICATION: **1**	GROUP: **A** DIV.: **1**
4	BRAN	**GAFT 1423**			

OPERATION CONDITIONS

8	FLUD	**CLEAN AIR**	12	MINIMUM TEMPERATURE	**10 ºC**
9	AVERAGE TEMPERATURE	**18.6 ºC**	13	MOLECULAR WEIGHT OF AIR	**29 kg/kgmol**
10	ALTITUDE	**2000 MSNM**	14	DISCHARGE PRESSURE (BLOWER)	**3.45 psig**
11	DENSITY@SITE COND.	**0.897 kg/m3**	15	POWER (BY SUPPLIER)	**1.0 bhp**

REQUIRED AIR @ SITE CONDITIONS

16	TEMPERATURE (ºC)	**18.6**
17	AIR TOTAL FLOW @ SITE COND. (cfm)	**11.89**

CONSTRUCTION *

	NOZZLE	DIAMETER	ANSI CLASIF.	MACHINATION	MUNTING
18	SUCTION	*	*	*	*
19	DISCHARGE	*	*	*	*

20	HOUSING MOUNTING :	□ CENTER	□ SUPPORT	□ VERTICAL (Type):	
21	ROTOR:	☐ LOBES	□ THREE-LOBES	□ RAD. TIPO VOLUTA	■ OTHER:
22	PRESSURE:	□ MAXIMUN	□ HIDROSTATIC TEST:		
23	CONNECTION:	■ VENTEO	□ DRAIN	■ MANOMETER	□ OTHER
24	MOUNTING:	□ SUSPENDED	□ GASKETS	■ OTHER:	□ CLOSED
25	BULLET TYPE :	□ RADIAL	□ PUSH	□ OF TIME	
26	LUBRICATION :	□ OIL	□ FLOOD	□ OIL MIST	■ WIHTOUT LUBRICATION
27	COUPLE	□ MANUFACTURER	□ MODEL		
28	MOTOR MOUNTING BY:	□ BLOWER MANUFACTURER		□ MOTOR SUPPLIER	■ CLIENT
29	GASKET	□ FAB. Y TIPO	□ SIZE / No. ORINGS		
30	MECHANICAL SEAL :	□ MANUFACTURER MODEL	□ CLASIF. API CODE		□ MANUFACTURER CODE

AUXILIARY PIPE

31	□ TUB. A.E.	□ C.U.	□ A.I.	□ TUBING	□ TUBE
32	□ TOTAL REQ. (COOLING WATER)		□ FLOW REQUIRED	VISUAL	
33	□ REQ. INYECTION ENF. AT GASKET		□ TOTAL GPM	□ PSIG	
34	□ PIPING PLAN (SEAL WASH) :	□ CAST IRON	□ STAINLESS STEEL	□ TUBING	□ TUBE
35	□ EXTERNAL WASH TO SEAL		□ GPM	□ PSIG	
36	□ SEAL AUXILIARY PLAN	□ CAST IRON	□ STAINLESS STEEL	□ TUBING	□ TUBE
37	□ FLUIDO DE ENF. SELLO AUXILIAR				

ACCESSORIES

38	□ PIPE FOR CONNECTION	44	■ EXPANSION JOINT (FLEXIBLE CONNECTION)
39	■ BASE FOR BLOWER AND MOTOR	45	■ FILTER AND SILENCER IN THE SUCTION
40	■ SILENCER IN TO DISCHARGE.		
41	■ ACCESSORIE FOR TRANSMISION.		
42	■ MANOMETER		
43	■ PRESSURE RELIEF VALVE		

REFERENCES

REV.	DESCRIPTION	BY	CHK'D	APPR.	DATE
A	**BASIC ENGINEERING**	**A.M.P.V.**	**J.E.L.H.**	**J.E.L.H.**	**29-Aug-03**

	CLIENT: EOLI PROJECT: FIELD-SCALE PILOT PLANT	DATE 29-Aug-03	SPECIFICATION
		BY A.M.P.V.	AREA: TREATMENT
	DATA SHEET BLOWERS HDE-004	CHK'D J.E.L.H.	DEPTO. PROCESS
		APPR. J.E.L.H.	SHEET 2 OF 2

MOTOR DATA

47	HP	1.0	RPM	1725		VOLT / PHASE / Hz	110 / 1 / 60
48	MANUFACTURER		BALEROS			LUBRICATION	SIN LUBRICACION
49	TYPE CLOSED WITH VENTILATING		INSULATE	F TYPE		AMP. TO TOTAL LOADING	
50	CAPACITY		INCREASES TEMPERATURE (ºC):			AMP. TO BLOCKADED ROTOR	
51	□ VHS		□ VSS			CAP. PUSH VERT, LB	
52	TRANSMISSION		■ DIRECT		□ BY "V"	□ OTHER:	

MATERIALS

53	HOUSING	ASTM 48X	BASE	ASTM 48X		
54	SHAFT	ASTM 48X	BODY	ASTM 48X	GASKET	*
55	SILENCER (SUCTION)	ASTM 48X			SEAL	*
56	SILENCER (DISCHARGE)	ASTM 48X				

MANUFACTURER TEST

57	■ COMPLETE / WITHOUT TESTIFY	□ COMPLETE / WITH TESTIFY
58	□ HIDROSTATIC/ WITHOUT TESTIFY	□ HIDROSTATIC/ WITH TESTIFY
59	□ MANUFACTURER WITHOUT INPECTOR	
60	□ OTHER :	

WEIGHT

61	BLOWER :	30 kg	BASE : *	DRIVE :	*	kg

62 NOTICES: * BY SUPPLIER.

THE SUPPLY AIR HAVE TO FEED FREE OF OIL.

SUCTION AND DISCHARGE: 3/8" NPT

THE SUPPLIER HAVE TO SUPPLY THE FOLLOWING ACCESSORIES:

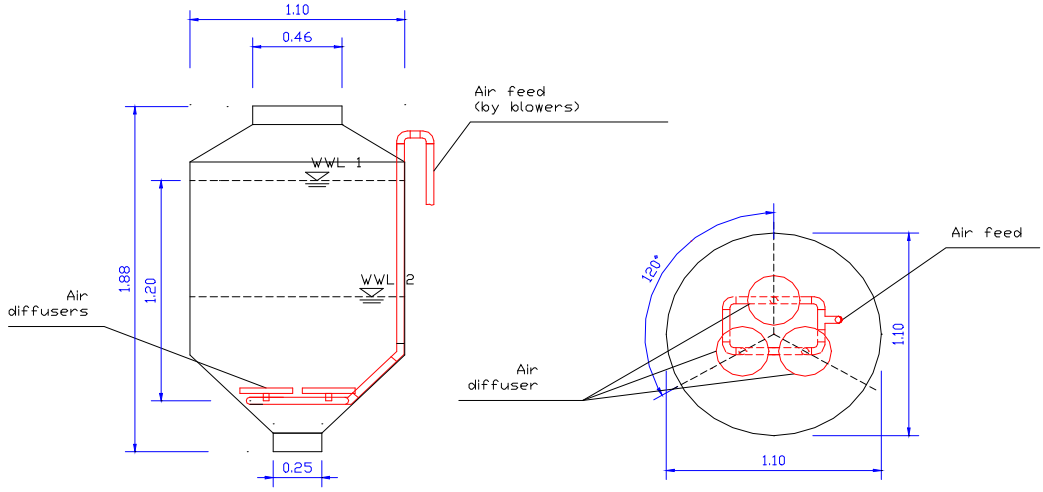
1. PRESSURE RELIEF VALVE
2. PRESSURE MANOMETER
3. FILTER AND SILENCER

REFERENCES

REV.	DESCRIPTION	BY	CHK'D	APPR.	DATE
A	**BASIC ENGINEERING**	**A.M.P.V.**	**J.E.L.H.**	**J.E.L.H.**	**29-Aug-03**

IB Tech	CLIENT: **EOLI** PROJECT: **FIELD-SCALE PILOT PLANT**		DATE **28-Aug-03**	SPECIFICATION
			BY **A.M.P.V.**	AREA: **BIOLOGICAL TREATMENT**
	DATA SHEET **AIR DIFFUSER** **HDE-007**		CHK'D **J.E.L.H.**	DEPTO. **PROCESS**
			APPR.	SHEET **1 OF 1**

	GENERAL				
1	TAG.	**DIFFUSERS**	4	TYPE	**9" DIAMETER FINE BUBBLE DIFFUSER UNIT**
2	SERVICIE	**AIR SUPPLY**	5	AMOUNT	**3** PICES
3	OPERATION: CONTINUOUS☐ INTERMITTENT ■		6	DFFUSER EFFICIENT:	**12 %**
	OPERATION CONDITIONS				
7	FLUID	**AIRE ATMOSFÉRICO**	15	REACTOR DIAMETER	**1.1 m**
8	WATER TEMPERATURE	**18.6 ºC**	16	TANK HEIGHT	**1.88 m**
9	ALTITUDE	**2000 MSNM**	17	WATER LEVEL	**1.2 m**
12	DENSITY @ OPERATON COND.	**0.897 kg/m3**	18	**AIR SUPPLY**	**1.43 cfm**
13	MOLECULAR WEIGHT OF AIR	**29 kg/kgmol**	19	**AIR SUPPLY FOR DIFFUSERS**	**11.89 cfm**
14	DISCHARGE PRESSURE (BLOWER)	**3.45 psig**	20	FLOW BY DIFFUSER:	**3.96 cfm**
			21	OPERATION TEMPERATURE (MAXIMUM)	**35 ºC**
	CONSTRUCTION AND MATERIALS *				
22	DIFFUSER DIAMETER (EXTERNAL)	**9 INCHES**			
23	MEMBRANE MATERIAL:	**EPDM**			
24	BODY MATERIAL:	**POLYPROPYLENE**			
25	OTHER:	**3 CONNECTORS 3/4"**			
	TESTS				
29	☐ TOTAL (WITHOUT TESTIFY)		☐ TOTAL (WITH TESTIFY)		
30	☐ HYDROSTATIC (WITHOUT TESTIFY)		☐ HYDROSTATIC (WITH TESTIFY)		
31	■ TESTIFY OF MANUFACTURER				
	WEIGHT *				
32	BODY WEIGHT:	**kg**			



Elevation, reactor

Plant, reactor

DO NOT SCALE

WWL: WASTEWATER LEVEL

NOTE: THE DIFFUSER SUPPLIER HAVE TO SUPPLY THE CONNECTOR.

REV.	DESCRIPTION	BY	CHK'D	APPR.	DATE
A	**BASIC ENGINEERING**	**A.M.P.V.**	**J.E.L.H.**	**J.E.L.H.**	**28-Aug-03**

REFERENCES

IB Tech	PLANT: **EOLI**	DATA SHEET **HDE-010**		REV. No. **A**	
	PROJECT: ICA4-CT-2002-10012	AREA Instrumentation INV.AUT.:		REF. DWG.: **IBT-WWT-EOLI-PID-001**	
	NAME: **HYDROSTATIC LEVEL MEASUREMENT**	BY: A.M.P.V. DATE: #######	CHK'D: J.E.L.H. DATE: #######	APPR. J.E.L.H. DATE: #######	SHEET 1 OF 1

	1	Instrument	HYDROSTATIC LEVEL MEASUREMENT	
	2	Service	LEVEL MEASUREMENT	
	3	Description	■ SENSOR	
GENERAL	4		☐ INDICATOR	
	5		■ BLIND	
	6		☐ CONTROLLER	
	7		■ TRANSMITTER	
	8	No. TAG.	LE/LT-104	
	9	Type	HYDROSTATIC LEVEL MEASUREMENT	
	10	Localization	SBR-01 REACTOR	
	11	Material	METALLIC MEASURING	
SENSOR	12	Enviroment	NOT CORROSIVE	
	13	Mounting	IN THE TOP OF TANK	
	14	Inclination	Vertical	
	15	Measurement range	0-400 mbar	
	16	Position	VERTICAL	
	17	Process connection	1-1/2" NPT	
	18	Brand	ENDRESS + HAUSER	
	19	Model	**DB51-AE12BB11EE20**	
	20	TAG. No.	LIT-101/102	
	21	Out put	☐ 0-10 Volts	
			■ 4-20 mA	
	22	Range	0-400 mbar	
	23	Material	KYNAR	
	24	Case color	STD./FAB.	
TRANSMITTER	25	Localization	INTEGRTED WITH THE SENSOR	
	26	Classification	NEMA 4X	
	27	Electrical supply	INTERNAL	
	28	Brand	ENDRESS + HAUSER	
	29	Model	**DB51-AE12BB11EE20**	
	30			
	31	TAG. No.	SBR-01	
	32	Type	CYLINDRICAL	
	33	Dimensions Long	SEE HDE-006	
	34	Wide	SEE HDE-006	
SBR-01	35	High	SEE HDE-006	
REACTOR	36	Mixer	YES	
	37	Air system	YES	
	38	Reactor material	HDPE	
	39	Supply	BY OTHERS	
	40			
	41	Fluid	Wastewater	
	42	Temperature ºC	18.60	
	43	Specific gravity	1.06	
FLUID				

NOTES:

1.- The supplier have to Supplys a identification plate of SS304, with the instrument service.

2.- The transmitter is integrated in the sensor.

HOJA DE DATOS

INSTRUM. ULTRASONICOS DE NIVEL

CLIENTE:	**BARCEL MEXICO, S.A. DE C.V.**
PLANTA:	**LAGUNA**
PROYECTO:	**PLANTA DE TRATAMIENTO DE AGUAS RESIDUALES**

DEPTO:	INSTRUMENTACION
FECHA:	3/4/2001
ELABORO:	J. C. T.
REVISÓ:	J. C. T.
APROBÓ:	M. A. R. T.

REVISION:	A
HOJA	2 DE 4

	1	No. de Identificación	LE-104	LE-112	LE-119
	2	Servicio	GRASAS SEPARADAS	LODO DE PROCESO	CLARIFICADO DEL
	3				TKC-01
	4	Tipo de sensor	ULTRASONICO	ULTRASONICO	ULTRASONICO
	5	Material	KYNAR	KYNAR	KYNAR
	6	Rango de medición	0 - 5 m	0 - 5 m	0 - 5 m
	7	Medio ambiente	NO CORROSIVO	NO CORROSIVO	NO CORROSIVO
SENSOR	8	Vibración	MEDIA	MEDIA	MEDIA
	9	Ruido	MEDIO	MEDIO	MEDIO
	10	Humedad	ALTA	ALTA	ALTA
	11	Clasificación eléctrica	NEMA 4	NEMA 4	NEMA 4
	12	Montaje	2" NPT	2" NPT	2" NPT
	13	Tamaño conduit	1/2"	1/2"	1/2"
	14	Marca			
	15	Modelo			
	16	No. de identificación	LT-104	LT-112	LT-119
	17	Funciones requeridas	SALIDA 4-20 mA	SALIDA 4-20 mA	SALIDA 4-20 mA
	18				
	19				
	20				
ELEMENTO	21	Material	KYNAR	KYNAR	KYNAR
	22				
RECEPTOR	23	Montaje	INTEGRADO CON SENSOR	INTEGRADO CON SENSOR	INTEGRADO CON SENSOR
	24	Clasificación eléctrica	NEMA 4	NEMA 4	NEMA 4
(MODULO	25	Suministro eléctrico	24 VCD	24 VCD	24 VCD
ELECTRONICO)	26	Tamaño conduit	VER SENSOR	VER SENSOR	VER SENSOR
	27	Opciones			
	28				
	29	Marca			
	30	Modelo			
	31	Identificación	TKC-01	TLC-01	TKC-01
	32	Tipo de recipiente	RECTANGULAR	RECTANGULAR	RECTANGULAR
	33	Dimensiones: Largo	4,26 m	2,50 m	1,10 m
RECIPIENTE	34	Ancho	1,67 m	2,50 m	0,90 m
	35	Alto	1,85 m	2,40 m	1,15 m
	36	Agitador	NO	NO	NO
	37	Bombas	SI	SI	NO
	38	Material	CONCRETO	CONCRETO	CONCRETO
	39	Proporcionado por:	OTROS	OTROS	OTROS
	40				
	41	Fluido	GRASAS SEPARADAS	LODO DE PROCESO	CLARIFICADO DEL
DATOS	42	Temperatura ºC	22.3	22.3	22.3
	43	Gravedad Específica	0.848	1.18	1.02
DEL	44				
	45				
	46				
FLUIDO	47				
	48				
	49				
	50				

NOTAS: 1.- Suministrar placa de acero inox. 304 con núm. de identificacion y servicio grabados en forma permanente y adherido al instrumento.

HOJA DE DATOS

INSTRUM. ULTRASONICOS DE NIVEL

CLIENTE:	**BARCEL MEXICO, S.A. DE C.V.**
PLANTA:	**LAGUNA**
PROYECTO:	**PLANTA DE TRATAMIENTO DE AGUAS RESIDUALES**

DEPTO:	INSTRUMENTACION
FECHA:	3/4/2001
ELABORO:	J. C. T.
REVISÓ:	J. C. T.
APROBÓ:	M. A. R. T.

REVISION:	A
HOJA	3 DE 4

	1	No. de Identificación	LE-113	LE-114	LE-115
	2	Servicio	FOSFATO DE AMONIO	CLORURO FERRICO	POLIMERO
	3				
	4	Tipo de sensor	ULTRASONICO	ULTRASONICO	ULTRASONICO
	5	Material	KYNAR	KYNAR	KYNAR
	6	Rango de medición	0 - 5 m	0 - 5 m	0 - 5 m
	7	Medio ambiente	NO CORROSIVO	NO CORROSIVO	NO CORROSIVO
SENSOR	8	Vibración	MEDIA	MEDIA	MEDIA
	9	Ruido	MEDIO	MEDIO	MEDIO
	10	Humedad	ALTA	ALTA	ALTA
	11	Clasificación eléctrica	NEMA 4	NEMA 4	NEMA 4
	12	Montaje	2" NPT	2" NPT	2" NPT
	13	Tamaño conduit	1/2"	1/2"	1/2"
	14	Marca			
	15	Modelo			
	16	No. de identificación	LT-113	LT-114	LT-115
	17	Funciones requeridas	SALIDA 4-20 mA	SALIDA 4-20 mA	SALIDA 4-20 mA
	18				
	19				
	20				
ELEMENTO	21	Material	KYNAR	KYNAR	KYNAR
	22				
RECEPTOR	23	Montaje	INTEGRADO CON SENSOR	INTEGRADO CON SENSOR	INTEGRADO CON SENSOR
	24	Clasificación eléctrica	NEMA 4	NEMA 4	NEMA 4
(MODULO	25	Suministro eléctrico	24 VCD	24 VCD	24 VCD
ELECTRONICO)	26	Tamaño conduit	VER SENSOR	VER SENSOR	VER SENSOR
	27	Opciones			
	28				
	29	Marca			
	30	Modelo			
	31	Identificación	TAA-01	TAA-02	TAA-03
	32	Tipo de recipiente	TANQUE VERTICAL	TANQUE VERTICAL	TANQUE VERTICAL
	33	Dimensiones: Diámetro	0,93 m	0,93 m	0,93 m
RECIPIENTE	34	Altura	1,30 m	1,30 m	1,30 m
	35				
	36	Agitador	NO	SI	NO
	37	Bombas	SI	SI	SI
	38	Material	CONCRETO	CONCRETO	CONCRETO
	39	Proporcionado por:	OTROS	OTROS	OTROS
	40				
	41	Fluido	FOSFATO DE AMONIO	CLORURO FERRICO	AGUA RESIDUAL
DATOS	42	Temperatura ºC	22.3	22.3	22.3
	43	Gravedad Específica	1.06	1.04	1,00
DEL	44				
	45				
	46				
FLUIDO	47				
	48				
	49				
	50				

NOTAS: 1.- Suministrar placa de acero inox. 304 con núm. de identificacion y servicio grabados en forma permanente y adherido al instrumento.

HOJA DE DATOS

INSTRUM. ULTRASONICOS DE NIVEL

CLIENTE:	**BARCEL MEXICO, S.A. DE C.V.**
PLANTA:	**LAGUNA**
PROYECTO:	**PLANTA DE TRATAMIENTO DE AGUAS RESIDUALES**

DEPTO:	INSTRUMENTACION
FECHA:	3/4/2001
ELABORO:	J. C. T.
REVISÓ:	J. C. T.
APROBÓ:	M. A. R. T.

REVISION:	A
HOJA	4 DE 4

	1	No. de Identificación	LE-116		
	2	Servicio	HIPOCLORITO DE SODIO		
	3				
	4	Tipo de sensor	ULTRASONICO		
	5	Material	KYNAR		
	6	Rango de medición	0 - 5 m		
	7	Medio ambiente	NO CORROSIVO		
SENSOR	8	Vibración	MEDIA		
	9	Ruido	MEDIO		
	10	Humedad	ALTA		
	11	Clasificación eléctrica	NEMA 4		
	12	Montaje	2" NPT		
	13	Tamaño conduit	1/2"		
	14	Marca			
	15	Modelo			
	16	No. de identificación	LT-113		
	17	Funciones requeridas	SALIDA 4-20 mA		
	18				
	19				
	20				
ELEMENTO	21	Material	KYNAR		
	22				
RECEPTOR	23	Montaje	INTEGRADO CON SENSOR		
	24	Clasificación eléctrica	NEMA 4		
(MODULO	25	Suministro eléctrico	24 VCD		
ELECTRONICO)	26	Tamaño conduit	VER SENSOR		
	27	Opciones			
	28				
	29	Marca			
	30	Modelo			
	31	Identificación	TAA-01		
	32	Tipo de recipiente	TANQUE VERTICAL		
	33	Dimensiones: Diámetro	0,93 m		
RECIPIENTE	34	Altura	1,30 m		
	35				
	36	Agitador	NO		
	37	Bombas	SI		
	38	Material	CONCRETO		
	39	Proporcionado por:	OTROS		
	40				
	41	Fluido	HIPOCLORITO DE SODIO		
DATOS	42	Temperatura ºC	22.3		
	43	Gravedad Específica	1.06		
DEL	44				
	45				
	46				
FLUIDO	47				
	48				
	49				
	50				

NOTAS: 1.- Suministrar placa de acero inox. 304 con núm. de identificacion y servicio grabados en forma permanente y adherido al instrumento.

IB Tech	CLIENT: **EOLI**	**HDE-011** DISSOLVED OXYGEN MEASUREMENT			REV. No. **A**	
	PROJECT: **ICA4-CT-2002-10012**	AREA INSTRUMENTATION INV.AUT.:			REF. DWG.: **IBT-WWT-EOLI-PID-001**	
	NAME: **DISSOLVED OXYGEN MEASUREMENT**	BY: **A.M.P.V.** DATE: **#######**	CHK'D: **J.E.L.H.** DATE: **8/28/2003**	APPR. **J.E.L.H.** DATE: **8/28/2003**	SHEET 1 OF 1	

GENERAL	1	No. TAG.	AE/AT O2-104
	2	Servicie	DISSOLVED OXYGEN MEASUREMENT
	3	Units	1 piece
	4	Measurement range	1- 10 mg/l
	5	Operation pressure	0.79 atm
		Operation pH	0 - 14
	6	Operation temperature	(-15ºC - 130ºC)
	7	Specific gravity	1
	8	No. DTI	IBT-WWT-EOLI-PID-001
	9	Components	Registrador ☐ Indicator ■ Transmitter ■ Blind ☐ Other ☐
	10	Case	Standard ■ Size: STD Color: Standard Other: Note 1
	11	Mounting	Surfase ☐ Al ras ☐ Yuke ☐ Other: Tube 1.5" diameter
	12	Electrical classification	Interior area ☐ Exterior area ■ Hazardous areas ☐ Class: Gruop: Division: For non-hazardous reas ☐
	13	Electrical feed	117V 60Hz Other: ca: 115 VAC
	14	Tamaño cenexión conduit	1/2" ■ 3/4"NPT ☐ Other:
	15	Chart range	Lineal ☐ 12" circular ☐ Other: Rango: No:
	16	Chart drive	Elec. ☐ Spring ☐ Other: 24Hr ☐ Other:
	17	Scale	Type: Range 1 2 3
	18	Calibration	Internal ☐ External ☐ Remote ☐ Other:
TRANSMISOR	19	Units Model	1 piece **COM223-DX1105**
	20	Transmitter type Case size	Neum. ☐ Elec. ☐ Intelligent electronic ☐ Other: Normal electronic 96 mm x 96 mm x 146 mm
	21	Comuniction protocol	Hart ☐ Fielbus ☐ Other:
	22	Output signal Notes	4-20 mA ■ 10-50 mA ☐ 3-15 psig ☐ Other:
CONTROL	23	Control type	P ☐ PI ☐ PD ☐ PID ☐ slow ☐ Quick ☐ Other:
	24	Action	Direct ☐ Back ☐ Other:
	25	Auto-manual swich	
	26	Ajuste Set Point	Manual External ☐ Remote ☐ Other:
	27	Manual regulation	
	28	Output signal	4-20 mA ☐ 10-50 mA ☐ 3-15 psig ☐ Other:
	29	Comuniction protocol	Hart ☐ Fielbus ☐ Other:
SENSOR	30	Type	Inserción ☐ Profundidad de insersión Inmersión ■ Other:
		Units	1 pza
		Model	**COS21-1K0**
	32	Enveloping material	Acero ☐ ■ SS 316L 316 L PG 13.5 thread
	34	Process connection	3/4" NPT ■ 1" NPT ☐
	35	Electrode material	Glass ■ Platino ☐ Other:
	36	Immersion length	120mm.
	37	Reference electrode	Required ■ Not required ☐
	38	Temperature compensation	Required ■ Not required ☐
ACCESSORIES	39	Accessories	Electrolyte for COS 21, 50 ml in single dispensing bottle. **51505873**
			Cable four-core, coaxial with standard ■ connector (10.0 meters) Other:
		Note	Model: **COK 21 51505868**

Note 1: The instrument have to has aplate identification.

Note 2: To chek the instrument aplication with supplier.

Note 3: Supplier: Endress + Hauser.

Note 4.- The sensor and transmitter wil be separates, for that reason the supplier have to eupply a cable for connection between they. This cable will be 10.0 meter of length.

CLIENT: **EOLI**	**HDE-012** FLOWMETER / CONTROLLER		SPEC. No.	REV. No. **A**	
PROJECT: **6100-27, DGO UNAM**	AREA No. **INSTRUMENTATION** INV.AUT.:		REF. DWG.: **IBT-WWT-EOLI-PID-001**	REV. No.	
NAME: **MEDICIÓN DE AIRE**	BY: **A.M.P.V.** DATE:	CHK'D: **J.E.L.H.** DATE: **8/28/2003**	APPR. **J.E.L.H.** DATE: **8/28/2003**	SHEET 1 OF 1	

GENERAL	1	No. TAG.	FITC-105	
	2	Servicie	AIR CONTROLLER	
	3	No. DTI	IBT-WWT-EOLI-PID-001	
SENSOR AND CONTROLLER	4	Size	1.5"	
	5	Connectios	SCREWED	
	6	Materials	STAINLESS STEEL AND VITON	
	7	Accuracy	+/- 2% FULL SCALE	
	8	Repeatability	+/- 2% FULL SCALE	
	9	Connectios	1/4" NPT	
	10	Operation flow	336.72 L/min	
	11	Flow range	0 - 500 L/min	
	12	Turndown ratio	50:1	
	13	Response time	2.0 seconds	
	14	Temperature range	-10 A 70℃	
	15	Density range	0 - 5 g /cc	
	16	Differential pressure	20% OF SUPPLY PRESSURE	
	17	Min DP	5 psi	
	18	Maximum pressure	200 psig	
	19	Analog setpoint	0-5 VCD	
TRANSMITTER	20	Type	ELECTRONIC	
	21	Case		
	22	Power		
	23	Voltege output	12 VCD (+/- 5%)	
	24	mA output	13 VCD (+/- 5%)	
	25	Current consumption	<250 mA DC	
	26	Accuracy	+/- 2% FULL SCALE	
	27	Repeatability	+/- 2% FULL SCALE	
	28	Analog setpoint	0-5 VCD	
DATA OPERATION	29	Fluid	AIRE ATMOSFÉRICO	
	30	Calibration range	*	
	31	Maximun speed	4000 ft/min	
	32	Flow	336.72 L/min	
	33	Operation pressure	2.4 psig	
	34	Temperature	18.6ºC	
	35	Site pressure	0.79 atm	
	36	Density, kg/m3	0.89 kg/m3	
	37	Compressibility factor	1	
	38	Manufacturer	OMEGA	
	39	Sensor model	FMA-78P2	
	40	Transmitter model	FMA-876A-V	
	41	Controller model	FMA-876A-V	
	42	Connection model (cable)	FMA-78C25	

NOTICES:

To chek the instrument aplication with supplier.
* By supplier.

IB Tech	PLANTA: **EOLI**	**HDE-013** THERMOMETER		SPEC. No.	REV. No. **A**
	PROJECT: **ICA4-CT-2002-10012**	AREA Instrumentation INV.AUT.:		REF. DWG.: **IBT-WWT-EOLI-PID-001**	
	NAME: **THERMOMETER**	BY: **A.M.P.V.** DATE: #######	CHK'D: **J.E.L.H.** DATE:	APPR. **J.E.L.H.** DATE: **8/28/2003**	SHEET 1 OF 1

	1	No. TAG.	TE/TT-104
	2	Servicie	MEDICIÓN DE TEMPERATURA
	3	Units	1 piece
	4	Tipe	Thermometer with threaded process connection and neck.
	5	Model	**TST10-CE2XCS2BA2R**
	6	Temperature range	-50ºC - 400ºC
	7	Operation pressure	0.79 atm
	8	Operation temperature	35ºC
	9	Specific gravity	1
	10	No. DTI	IBT-WWT-EOLI-PID-001
	11	Función	Sensor ■ Indicator ☐ Transmitter ■ Blind ■ Other ☐
	12	Case	Standar ■ Size: STD Color: Standar Other: Note 1
GENERAL	13	Mounting:	Surfase ☐ Yuke ☐ Other: Tube of 1.5"
	14	Classification:	Interior area ☐ Exterior area ■ Hazardous areas ☐ Class: Group: Division: For non-hazardous reas ☐
	15	Electrical feed	Other: Computer control ca:
	16	Connection size (conduit)	1/2" ■ 3/4"NPT ☐ Other:
	17	Chart range	Lineal ☐ 12" circular ☐ Other: Range: No:
	18	Chart drive	Elec. ☐ Spring ☐ Other: 24Hr ☐ Other:
	19	Scale	Type: Range 1 2 3
	20	Calibration	Internal ☐ External ☐ Remote ☐ Otrher:
	21	Transmitter type	Neum. ☐ Elec. ☐ Intelligent electronic ■ Other:
	22	Transmitter	**In the top of the tank**
	23	Units	1 piece
TRANSMITTER	24	Comunication protocol	Hart ■ Fielbus ☐ Other:
	25	Output signal	4-20 mA ■ 10-50 mA ☐ 3-15 psig ☐ Other:
	26	Notice	Terminal head adjust. In orientation
	27	Control type	P ☐ PI ☐ PD ☐ PID ☐ slow ☐ Quick ☐ Other:
	29	Action	Direct ☐ Back ☐ Other:
CONTROL	30	Manual swich	
	31	Set Point	Manual External ☐ Remote ☐ Other:
	32	Manual regulation	
	33	Output signal	4-20 mA ☐ 10-50 mA ☐ 3-15 psig ☐ Other:
	34	Comunication protocol	Hart ☐ Fielbus ☐ Other:
	35	Type	Insertion ☐ Profundidad de inserción Inmersion ■ Other:
	36	Assemble	**Integrated with sensor**
	37	Enveloping material	Steel ☐ SS316L Other:
	38	Process connection	3/4" NPT ■ 1" NPT ☐
SENSOR	39	Process immersion length	75-3700 mm
	40	Immersion length to espec.	100 mm
	41	Sensor material	Glass ☐ Platino ■ Other: Pt 100
	42	Electrode reference	Required ■ Not required ☐
	43	Temperature compensation	Required ■ Not required ☐
ACCESSORIES	44	Accessories	

Note 1: The instrument have to has aplate identification.

Note 2: To chek the instrument aplication with supplier.

Note 3: Supplier: Endress + Hauser.

Note 4.- The transmitter is intregrated with the sensor.

IB Tech	PLANTA: **EOLI**		**HDE-014** PH MEASUREMENT			SPEC. No.	REV. No. **A**
	PROJECT: **ICA4-CT-2002-10012**		AREA Instrumentation INV.AUT.:			REF. DWG.: **IBT-WWT-EOLI-PID-001**	
	NAME: **PH MEASUREMENT**		BY: **A.M.P.V.** DATE: **#######**	CHK'D: **J.E.L.H.** DATE:		APPR. **J.E.L.H.** DATE: **8/28/2003**	SHEET 1 OF 1

	1	No. TAG.	AE/AT PH-104
	2	Servicie	PH MEASUREMENT
	3	Units	1 sensor + 1 transmitter
	4	Measurement range	1-12 pH
	5	Operation pressure	0.79 atm
	6	Operation temperature	(-15ºC) - (80ºC)
	7	Specific gravity	1
	8	No. DTI	IBT-WWT-EOLI-PID-001
	9	Components	Sensor ☐ Indicator ■ Transmitter ■ Blind ☐ Other ☐
	11	Case	Standard ■ Tamaño: STD Color: Standard Other: Note 1
GENERAL	12	Sensor mounting	Surfase ☐ Yuke ☐ Other: Tube 1.5" diameter
		Transmitter mounting	In motor control panel
	14	Electrical classification	Interior area ☐ Exterior area ■ Hazardous areas ☐ Class: Gruop: Division: For non-hazardous reas ☐
	15	Electrical feed	117V 60Hz Other: ca: 115 VAC
	16	Connection size (conduit)	1/2" ■ 3/4"NPT ☐ Other:
	17	Chart range	Lineal ☐ 12" circular ☐ Other: Range: No:
	18	Chart drive	Elec. ☐ Spring ☐ Other: 24Hr ☐ Other:
	19	Scale	Tipo: Range 1 2 3
	20	Calibration	Internal ☐ External ☐ Remote ☐ Other:
	21	Transmitter type	Neum. ☐ Elec. ☐ Intelligent electronic ☐ Other: Normal electronic
	22	Units	1 piece
	23	Model	**CPM223-PR1105**
	24	Case suze	96 mm x 96 mm x 146 mm
	25	Power	115 VAC
TRANSMITTER	26	Comuniction protocol	Hart ☐ Fielbus ☐ Other:
	27	Output information	pH / ORP and temperature
	28	Output signal	4-20 mA ■ 10-50 mA ☐ 3-15 psig ☐ Other:
	29	Notes:	Sin relevador adicional
	30	Control mode	P ☐ PI ☐ PD ☐ PID ☐ slow ☐ Quick ☐ Other:
	31	Action	Direct ☐ Back ☐ Other:
CONTROL	32	Auto-manual swich	
	33	Set Point	Manual External ☐ Remote ☐ Other:
	34	Manual reguration	
	35	Output signal	4-20 mA ■ 10-50 mA ☐ 3-15 psig ☐ Other:
	36	Comuniction protocol	Hart ☐ Fielbus ☐ Other:
	37	Type	Insersion ☐ immersion ■ Other:
	38	Model	**CPS11-2AS2ESA**
	39	Enveloping material	pH combination electrode with PTFE ring diaphragm, Polytex-gel electrolyte.
SENSOR	40	Process connection	3/4" NPT ■ 1" NPT ☐
	41	Immersion length	120 mm
	42	Electrode material	Glass ☐ Platino ■ Other: With PT 100
	43	Reference electrode	Required ■ Not required ☐
	44	Temperature compensation	Required ■ Not required ☐
	45	Accessories	
ACCESSORIES	46		Measuring cable CPK 9 for sensor ■ 10 m cable Other: Model **CPK9-NBA3A**

Note 1: The instrument have to has aplate identification.

Note 2: To chek the instrument aplication with supplier.

Note 3: Supplier: Endress + Hauser.

Note 4.- The sensor and transmitter wil be separates, for that reason the supplier have to supply a cable for connection between they. This cable will be 10.0 meter of length.

IB Tech	CLIENT: **EOLI**	**HDE-015** ORP/ REDOX MEASUREMENT	SPEC. No.	REV. No. **A**
	PROJECT: **ICA4-CT-2002-10012**	AREA Instrumentación INV.AUT.:	REF. DWG.: **IBT-WWT-EOLI-PID-001**	
	NAME: **ORP MEASUREMENT**	BY: **A.M.P.V.** DATE: **#######** CHK'D: **J.E.L.H.** DATE:	APPR. **J.E.L.H.** DATE: **8/28/2003**	SHEET 1 OF 1

	1	No. TAG.	AE/AT ORP-104
	2	Servicie	ORP/Redox MEASUREMENT
	3	Units	1 sensor y 1 transmisor
	4	Measurement range	0-14 pH
	5	Operation pressure	0.79 atm
	6	Operation temperature	(-15ºC) - (130ºC)
	7	Specific gravity	1
	8	No. DTI	IBT-WWT-EOLI-PID-001
	9	Components	Sensor ☐ Indicator ☐ Transmitter ■ Blind ☐ Other ☐
	11	Case	Standard ■ Size: STD Color: Standard Other: Note 1
GENERAL	12	Montaje de sensor:	Surfase ☐ Back ☐ Yuke ☐ Other: Tube 1.5" diameter
		Montaje de transmisor:	In motor control panel
	14	Clasificación eléctrica	General ☐ Exterior area ■ Hazardous areas ☐ Clase: Grupo: División: For non-hazardous reas ☐
	15	Electrical feed	Other: CA: 115 VAC
	16	Connection size (conduit)	1/2" ■ 3/4"NPT ☐ Other:
	17	Chart range	Lineal ☐ 12" circular ☐ Other: Rango: No:
	18	Chart drive	Elec. ☐ Spring ☐ Otro: 24Hr ☐ Other:
	19	Scale	Tipo: Range 1 2 3
	20	Calibration	Internal ☐ External ☐ Remote ☐ Other:
	21	Transmitter type	Neum. ☐ Elec. ☐ Intelligent electronic ☐ Other: Normal electronic
	22	Units	1 pice
	23	Model	**CPM223-PR1005**
	24	Power	115 VAC
TRANSMITTER	25	Comuniction protocol	Hart ☐ Fielbus ☐ Other:
	26	Output information	pH / ORP
	27	Output signal	4-20 mA ■ 10-50 mA ☐ 3-15 psig ☐ Other:
	28	Case size	96 mm x 96 mm x 146 mm
	29	Notes:	
	30	Control mode	P ☐ PI ☐ PD ☐ PID ☐ slow ☐ Quick ☐ Other:
	31	Action	Direct ☐ Back ☐ Other:
CONTROL	32	Auto-manual swich	
	33	Set Point	Manual External ☐ Remote ☐ Other:
	34	Manual reguration	
	35	Output signal	4-20 mA ☐ 10-50 mA ☐ 3-15 psig ☐ Other:
	36	Comuniction protocol	Hart ☐ Fielbus ☐ Other:
	37	Type	Insersion ☐ Immersion ■ Other:
		Model	**CPS12-0PA2ESA**
	38	Enveloping material	Electrodo de PTFE, diafragma de Polytex-gel electrolítico y encapsulado.
	39	Process connection	3/4" NPT ■ 1" NPT ☐
	40	Immersion length	120 mm
SENSOR	41	Electrode material	Glass ☐ Platino ■ Other: PT 100
	42	Reference electrode	Required ■ Not required ☐
	43	Temperature compensation	Required ■ Not required ☐
	45		
ACCESSORIES		Accessories	Measuring cable CPK 9 for sensor ■ 10 m cable Other:
	46		Model **CPK9-NBA1A**

Note 1: The instrument have to has aplate identification.

Note 2: To chek the instrument aplication with supplier.

Note 3: Supplier: Endress + Hauser.

Note 4.- The sensor and transmitter wil be separates, for that reason the supplier have to supply a cable for connection between they. This cable will be 10.0 meter of length.

IB Tech	CLIENT: **EOLI** PROJECT: **FIELD-SCALE PILOT PLANT**	DATE **28-Sep-03**	SPECIFICATION	
		BY **A.M.P.V.**	AREA: **BIOLOGICAL TREATMENT**	
	DATA SHEET HDE-016 **PC CABINET** **GAB-01**	CHK'D **J.E.L.H.**	DEPTO. **PROCESOS**	
		APPR. **J.E.L.H.**	SHEET **1 OF 1**	

GENERAL

1	No. TG.	**PC CABINET**		
2	SERVICE	**TO PROTECT A PERSONAL COMPUTER.**		
3	LOCALIZATION	**EXTERIOR**		
4	BRANDS:	**HOFFMAN**		
		DERRANT		
		RITTAL		
		APC		
5	EQUIPMENT:	**1**	**MONITOR**	
		2	**CPU**	
		1	**KEYBOARD**	
			ACCESSORIES FOR CONTROL (TARGETS)	
6	EQUIPMENT DIMENSIONS:	**MONITOR:**	**17 inches**	
		CPU:	**15" X 7.5" X 18"**	
7	MOUNTING:	**ON A METALLIC PLATAFORM.**		
8	WEIGHT:	*	**kg**	

NOTICES

THE SUPPLIER HAVE TO GIBE THE DIAGRAMS BEFORE TO SUPPLY THE EQUIPMENT.

* BY SUPPLIER.

THE CABINET IF FOR EXTERNAL AREA.

THE SUPPLIER HAVE TO QUOTE ALL ACCESSORIES BY SEPARATED.

REFERENCES					
A	**BASIC ENGINEERING**	**A.M.P.V.**	**J.E.L.H.**	**J.E.L.H.**	**28-Sep-03**
REV.	DESCRIPTION	BY	CHK'D	APPR.	DATE

		PLANT: **EOLI**	**HDE-017** VALVE ON / OFF		REV. No. **A**	
		PROJECT: **ICA4-CT-2002-10012**	AREA Instrumentation INV.AUT.:		REF. DWG.: **IBT-EOLI-WWT-PID-001**	
		NAME: **MEDIDOR TRANSMISOR DE NIVEL**	BY: **A.M.P.V.** DATE: #######	CHK'D: **J.E.L.H.** DATE: #######	APPR. **J.E.L.H.** DATE: #######	SHEET 1 OF 1
GENERAL	1	No. TAG.	FCV-01			
	2	Servicie	Process sludge			
	3	Line No.	1.5"-PVC-SP-09			
	4	Line diameter	1.5"			
	5	Schedule and material line	PVC 40			
VALVE AND POSITIONER	6	Body type	BOLA			
	7	Body size	1.5"			
	8	Connection type	SCREWED			
	9	Body material	PVC			
	10	Seal material	TEFLON			
	11	Materials				
	12	Body	PVC			
	13	Plug & seat	PVC			
	14	Operation	Direct			
	15	No. de modelo y tamaño	*			
ACTUATOR	16	Actuator type	Elec.			
	17	Air fails valve	Close			
	18	Action	Open/close			
	19	Other	---			
	20	Encapsulado	NEMA 4			
	21	Volts	120 volts / 1 phase			
	22	Hertz	60			
	23	Spoll type	H			
	24	Spoll operation	EASY			
SERVICE	25	Fluid	Process sludge			
	26	Flow unit	l/min			
	27	Qty. Max.				
	28	Qty. Normal				
	29	Operation pressure	74.5" in H2O			
	30	Pressure maximum	74.5" in H2O			
	31	Operation temperature	18.6ºC			
	32	Specific gravity	1.06			
	33	Viscosity				
	34	Brand	*			
	35	Model	*			
	36	D.T.I.	IBT-WWT-EOLI-PID-001			

NOTES: 1.- * By supplier.

2.- The valve will can close or open in manual manner.

HOJA DE DATOS

INSTRUM. ULTRASONICOS DE NIVEL

CLIENTE:	**BARCEL MEXICO, S.A. DE C.V.**
PLANTA:	**LAGUNA**
PROYECTO:	**PLANTA DE TRATAMIENTO DE AGUAS RESIDUALES**

DEPTO:	INSTRUMENTACION
FECHA:	3/4/2001
ELABORO:	J. C. T.
REVISÓ:	J. C. T.
APROBÓ:	M. A. R. T.

REVISION:	A
HOJA	2 DE 4

	1	No. de Identificación	LE-104	LE-112	LE-119
	2	Servicio	GRASAS SEPARADAS	LODO DE PROCESO	CLARIFICADO DEL
	3				TKC-01
	4	Tipo de sensor	ULTRASONICO	ULTRASONICO	ULTRASONICO
	5	Material	KYNAR	KYNAR	KYNAR
	6	Rango de medición	0 - 5 m	0 - 5 m	0 - 5 m
	7	Medio ambiente	NO CORROSIVO	NO CORROSIVO	NO CORROSIVO
SENSOR	8	Vibración	MEDIA	MEDIA	MEDIA
	9	Ruido	MEDIO	MEDIO	MEDIO
	10	Humedad	ALTA	ALTA	ALTA
	11	Clasificación eléctrica	NEMA 4	NEMA 4	NEMA 4
	12	Montaje	2" NPT	2" NPT	2" NPT
	13	Tamaño conduit	1/2"	1/2"	1/2"
	14	Marca			
	15	Modelo			
	16	No. de identificación	LT-104	LT-112	LT-119
	17	Funciones requeridas	SALIDA 4-20 mA	SALIDA 4-20 mA	SALIDA 4-20 mA
	18				
	19				
	20				
ELEMENTO	21	Material	KYNAR	KYNAR	KYNAR
	22				
RECEPTOR	23	Montaje	INTEGRADO CON SENSOR	INTEGRADO CON SENSOR	INTEGRADO CON SENSOR
	24	Clasificación eléctrica	NEMA 4	NEMA 4	NEMA 4
(MODULO	25	Suministro eléctrico	24 VCD	24 VCD	24 VCD
ELECTRONICO)	26	Tamaño conduit	VER SENSOR	VER SENSOR	VER SENSOR
	27	Opciones			
	28				
	29	Marca			
	30	Modelo			
	31	Identificación	TKC-01	TLC-01	TKC-01
	32	Tipo de recipiente	RECTANGULAR	RECTANGULAR	RECTANGULAR
	33	Dimensiones: Largo	4,26 m	2,50 m	1,10 m
RECIPIENTE	34	Ancho	1,67 m	2,50 m	0,90 m
	35	Alto	1,85 m	2,40 m	1,15 m
	36	Agitador	NO	NO	NO
	37	Bombas	SI	SI	NO
	38	Material	CONCRETO	CONCRETO	CONCRETO
	39	Proporcionado por:	OTROS	OTROS	OTROS
	40				
	41	Fluido	GRASAS SEPARADAS	LODO DE PROCESO	CLARIFICADO DEL
DATOS	42	Temperatura ºC	22.3	22.3	22.3
	43	Gravedad Específica	0.848	1.18	1.02
DEL	44				
	45				
	46				
FLUIDO	47				
	48				
	49				
	50				

NOTAS: 1.- Suministrar placa de acero inox. 304 con núm. de identificacion y servicio grabados en forma permanente y adherido al instrumento.

HOJA DE DATOS

INSTRUM. ULTRASONICOS DE NIVEL

CLIENTE:	**BARCEL MEXICO, S.A. DE C.V.**
PLANTA:	**LAGUNA**
PROYECTO:	**PLANTA DE TRATAMIENTO DE AGUAS RESIDUALES**

DEPTO:	INSTRUMENTACION
FECHA:	3/4/2001
ELABORO:	J. C. T.
REVISÓ:	J. C. T.
APROBÓ:	M. A. R. T.

REVISION:	A
HOJA	3 DE 4

	1	No. de Identificación	LE-113	LE-114	LE-115
	2	Servicio	FOSFATO DE AMONIO	CLORURO FERRICO	POLIMERO
	3				
	4	Tipo de sensor	ULTRASONICO	ULTRASONICO	ULTRASONICO
	5	Material	KYNAR	KYNAR	KYNAR
	6	Rango de medición	0 - 5 m	0 - 5 m	0 - 5 m
	7	Medio ambiente	NO CORROSIVO	NO CORROSIVO	NO CORROSIVO
SENSOR	8	Vibración	MEDIA	MEDIA	MEDIA
	9	Ruido	MEDIO	MEDIO	MEDIO
	10	Humedad	ALTA	ALTA	ALTA
	11	Clasificación eléctrica	NEMA 4	NEMA 4	NEMA 4
	12	Montaje	2" NPT	2" NPT	2" NPT
	13	Tamaño conduit	1/2"	1/2"	1/2"
	14	Marca			
	15	Modelo			
	16	No. de identificación	LT-113	LT-114	LT-115
	17	Funciones requeridas	SALIDA 4-20 mA	SALIDA 4-20 mA	SALIDA 4-20 mA
	18				
	19				
	20				
ELEMENTO	21	Material	KYNAR	KYNAR	KYNAR
	22				
RECEPTOR	23	Montaje	INTEGRADO CON SENSOR	INTEGRADO CON SENSOR	INTEGRADO CON SENSOR
	24	Clasificación eléctrica	NEMA 4	NEMA 4	NEMA 4
(MODULO	25	Suministro eléctrico	24 VCD	24 VCD	24 VCD
ELECTRONICO)	26	Tamaño conduit	VER SENSOR	VER SENSOR	VER SENSOR
	27	Opciones			
	28				
	29	Marca			
	30	Modelo			
	31	Identificación	TAA-01	TAA-02	TAA-03
	32	Tipo de recipiente	TANQUE VERTICAL	TANQUE VERTICAL	TANQUE VERTICAL
	33	Dimensiones: Diámetro	0,93 m	0,93 m	0,93 m
RECIPIENTE	34	Altura	1,30 m	1,30 m	1,30 m
	35				
	36	Agitador	NO	SI	NO
	37	Bombas	SI	SI	SI
	38	Material	CONCRETO	CONCRETO	CONCRETO
	39	Proporcionado por:	OTROS	OTROS	OTROS
	40				
	41	Fluido	FOSFATO DE AMONIO	CLORURO FERRICO	AGUA RESIDUAL
DATOS	42	Temperatura ºC	22.3	22.3	22.3
	43	Gravedad Específica	1.06	1.04	1,00
DEL	44				
	45				
	46				
FLUIDO	47				
	48				
	49				
	50				

NOTAS: 1.- Suministrar placa de acero inox. 304 con núm. de identificacion y servicio grabados en forma permanente y adherido al instrumento.

HOJA DE DATOS

INSTRUM. ULTRASONICOS DE NIVEL

CLIENTE: BARCEL MEXICO, S.A. DE C.V.
PLANTA: LAGUNA
PROYECTO: PLANTA DE TRATAMIENTO DE AGUAS RESIDUALES

DEPTO:	INSTRUMENTACION
FECHA:	3/4/2001
ELABORO:	J. C. T.
REVISÓ:	J. C. T.
APROBÓ:	M. A. R. T.

REVISION:	A
HOJA	4 DE 4

	1	No. de Identificación	LE-116		
	2	Servicio	HIPOCLORITO DE SODIO		
	3				
	4	Tipo de sensor	ULTRASONICO		
	5	Material	KYNAR		
	6	Rango de medición	0 - 5 m		
	7	Medio ambiente	NO CORROSIVO		
SENSOR	8	Vibración	MEDIA		
	9	Ruido	MEDIO		
	10	Humedad	ALTA		
	11	Clasificación eléctrica	NEMA 4		
	12	Montaje	2" NPT		
	13	Tamaño conduit	1/2"		
	14	Marca			
	15	Modelo			
	16	No. de identificación	LT-113		
	17	Funciones requeridas	SALIDA 4-20 mA		
	18				
	19				
	20				
ELEMENTO	21	Material	KYNAR		
	22				
RECEPTOR	23	Montaje	INTEGRADO CON SENSOR		
	24	Clasificación eléctrica	NEMA 4		
(MODULO	25	Suministro eléctrico	24 VCD		
ELECTRONICO)	26	Tamaño conduit	VER SENSOR		
	27	Opciones			
	28				
	29	Marca			
	30	Modelo			
	31	Identificación	TAA-01		
	32	Tipo de recipiente	TANQUE VERTICAL		
	33	Dimensiones: Diámetro	0,93 m		
RECIPIENTE	34	Altura	1,30 m		
	35				
	36	Agitador	NO		
	37	Bombas	SI		
	38	Material	CONCRETO		
	39	Proporcionado por:	OTROS		
	40				
	41	Fluido	HIPOCLORITO DE SODIO		
DATOS	42	Temperatura ºC	22.3		
	43	Gravedad Específica	1.06		
DEL	44				
	45				
	46				
FLUIDO	47				
	48				
	49				
	50				

NOTAS: 1.- Suministrar placa de acero inox. 304 con núm. de identificacion y servicio grabados en forma permanente y adherido al instrumento.