Efficient Operation of Urban Wastewater Treatment Plant (EOLI)

2nd year annual meeting

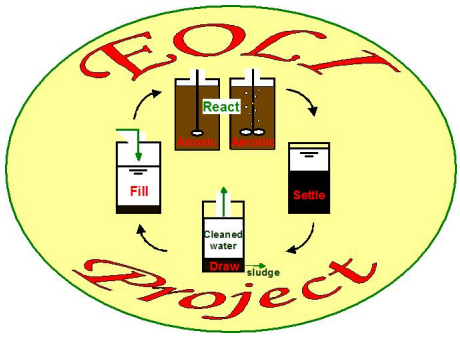
MINUTES

INCO: International Scientific Cooperation Projects (1998-2002)

Contract number: ICA4-CT-2002-10012

Project homepage: http://www.auto.ucl.ac.be/EOLI/

Keywords : wastewater treatment (WWT), aerobic digestion, sequencing batch reactor (SBR), monitoring, control system



Covering period from 1 November 2003 to 31 October 2004

Meeting held at POLIMI, Milano, Italy, 22 to 24 Nov 2004

Compiled by Manuel J. BETANCUR (Version 1.0). Corrections by

Denis DOCHAIN (V 1.1), Germán BUITRÓN (V 1.2), Nicola Fiocchi (V13)

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INTRODUCTION

The second year EOLI meeting was held at *Politecnico Di Milano, DIIAR, Sezione Ambientale, Piazza Leonardo da Vinci 32, 20133 Milano, ITALY*, December 22 to 24, 2004, under the local coordination of Prof. Roberto CANZIANI. The moderator was the project coordinator, Prof. Denis DOCHAIN. A full attendees list and their contact data are available in Annex 1.

During the meeting a general presentation of each WP has been done. Subsequent particular presentations were given by the respective partners involved in each WP. All presentations were electronically retrieved and are available in the EOLI webpage in PDF format. For this reason the minute's emphasis is put on summarizing the discussions made and the decisions taken around such presentations, not in explaining them. Each minute subsection is dedicated to an individual presentation. The presentations order is maintained in the minute sections order.

Important decisions and key remarks are embedded in a frame for easy visualization

Annex 2 lists the most common abbreviations used in this minute and in most of the presentation files.

1 WP1 *MONDAY 22, 2:08 PM*

1.1 Leader *G. Buitrón, file WP1__Leader_EOLI_2yp*

Tasks 1.2, 1.3, 1.4 and 1.5 are done ok. For task 1.6 the design is completed in Mexico and the field pilot SBR is now under construction. It was not possible to speed up the construction, so the original schedule is kept. Future work plans are presented. UU field SBR is not going to be ready on time. No other special problems are envisaged.

Looking at the deliverables list it seems that D1.3 is very similar to D2, and the situation may be generalized to other WP deliverables. The next question then arises:

How to integrate different WP deliverables?

The interest of each deliverable is different, thus each WP leader is responsible and autonomous; i.e. there is no need to coordinate with others. He may decide what is best for his WP and, if integrating with other WP is convenient, he may do so.

1.2 LBE-INRA *M. Torrijos, file WP1_LBE_EOLI_2yp*

Erratum: slide 5 should read in minutes, not hours; slide 11 in days.

CAC was discussed. Experimentally CAC was clearly observed. Unfortunately there are high differences for replicate experiments, but in the operation zone it is around 50%, more or less constant, almost linear. Comparatively, acetate was not adsorbed.

What is the difference in the biomass for the different experiment series? Not appreciable. Is it the same wastewater? Yes. Is the biomass kept the same, for example in holidays? Yes, at least in all measured parameters.

Acetate does not adsorb… it is interesting to note that the serum does. What is different? It must not be storage. Maybe is it some chemical reaction? It was not possible to check.

Was the history for the sludge the same? Yes. Was there starvation? No.

In Uruguay there is fat in the input. In the microscope it was not possible to detect adsorption. It seems not possible to do this by looking at the microscope.

Maybe it is important to look at the total suspended solids if it is a physical phenomenon, not the partial one.

The good news is that COD is not a problem, just look at the nitrates, if the cycle begins with an anoxic phase. But it is not always the case because sometimes it may be desirable to start with the aerobic phase, for optimal control purposes. Keep in mind that COD is not been removed… only adsorbed.

Is it a biomass surface related problem? Or is it a volume related problem? Do we need to understand this further? Is it necessary? To understand this at least one more year would be needed.

Sludge settling was also discussed. Increasing loading rate puts pressure on maintaining the sludge, but no special problems appear on settling even if the floc diameter changed. Next step is to go to microbial analysis. Ending spring all experiments will be completed. At the beginning of May sensors will be tested.

Project's second year was very active. Third year emphasis must be getting everything integrated. Be able to circulate results. Make sure everyone is ready to make the connection and integration. It is simple to say, but everybody must be aware of that.

1.3 POLIMI-ENEA *E. Ficara; file WP1_POLIMI_ENEA_EOLI_2yp*

The problem of losing biomass was accidental (Timer setting), not a problem of settling.

There were abnormal conditions: Nitration capacity loss. It was a no way back situation…. New sludge was required. Very bad situation…. It seems that pH and temperature (summer time is more difficult) do have a significant effect and DO also. Conclusion:

Avoid **long** anoxic periods in order to prevent irreversible nitration capacity loss. The reactor could be put in safe conditions by applying a long AERATION period, but this is not applicable in practice. It seems that when aerobic phase fails, it generates the problem.

A second abnormal condition was the loss of nitrification capacity.

Nicola presented the ENEA Pilot plant layout and changes in anoxic/aerobic times, but changes did not give the expected results. After another change with no results, the volumetric exchange ratio was changed. Looking at cycles 28-09-04 (slide 32) ORP trends showed some interesting patterns: after denitrification is completed, the negative slope of the ORP graph becomes steeper; on the contrary, when denitrification is not completed, the slope of the ORP graph does not change significantly.

Abnormal conditions: Incomplete denitrification in anoxic phase, and effluent nitrates build up.

An idea is to better understand nitrification buildup, because if the problem starts to happen; it seems to be irreversible.

1.4 UNAM *I. Moreno; file WP1_UNAM_EOLI_2yp*

A comparison among FTC and EDTOC was made. Problems in SBR operation were stated. The next recommendation was stated:

Be sure to integrate everything, as for example to analyze energy savings of EDOTC

How to integrate the spectrophotometer sensor to this work?

1.5 UU *S. Gutierrez; file WP1_UU_EOLI_2yp*

Lab reactors operation needs to be improved. Maybe aeration is too high. Removal efficiency is only 50% for NO3, and it builds up with aeration. Changes: Anoxic phase extended, mixing improved. It seems to be working. However activity seems to be very low. Maybe there is a sludge loss that explains maybe a short biomass life and a rapid parameters change.

Potential activity (With acetate instead of real WW) was used to compare both reactors (Manolo and Flora). Manolo presents comparable values but Flora is 40% better than the potential value. Not logical (?)

During the anoxic phase a mass balance showed there was adsorption.

The activity of the biomass decreases with time… no acclimation required, on the contrary…. de-adaptation happens spontaneously (?)

The control system will not be used for control purposes… as said in Mexico.

1.6 IBTECH *J.M. Morgan; file WP1_IBTECH_EOLI_2yp*

Finishing of the field SBR will be completed this year. Hydraulic tests are going to be made before delivering the plant in working conditions to UNAM, all within the year, for the first week of December.

After the presentations the project manager stresses out:

For INTEGRATION the bigger picture should be considered, not only the local case. Working SBRs are available in: Mexico, Montevideo, Narbonne, Milano and Bologna A good solution must be provided at the end of the project. The more the better, but time and resources are limited. It is therefore necessary to concentrate in certain process and establish priorities.

2 WP2 *TUESDAY 23, 9:08AM*

The WP leader presents, orally, a brief introduction. The general presentation follows.

2.1 CESAME *D. Dochain; file WP2_Cesame_EOLI_2yp*

Protocol was followed. Validation was made against available experimental data, so there remains an unanswered question about heterotrophic biomass values.

No sensitivity analysis was made for EM2, but it can be done if necessary. The question seems important to decide experiments for adsorption but, in view of data from WP1, there is no need. Not for EM2. Not for this project. Besides, if initial conditions for E2b are the ones for the filling phase, adsorption problem is reduced. It

is clear that the model does not explain everything: What happens with the substrate that gets out the liquid phase, inside the flocs? What are the effects for different combinations of substrates/biomasses?

The model should hold aerobic and anaerobic phases switching. There is no evidence against it. Once optimal control will be tested evidence will be available.

UU is going to send (this weekend) new sets of parameters for a new EM2 version, adapted to UU (With no adsorption dynamics, it is not finished yet).

For EM1 it was observed that different biomasses do have different Kinetic models, about 25% differences for the experiments at hand. If required better fitting, but more complex, EM1 versions are available.

WP6 insists in the need of a good model to produce usable results. The validation results are good compared to other projects, so the EMs are not perfect but are usable. Maybe more data, more experiments are needed, but that is what we have now. Be careful with the EM, it is a biological model. Complexification of the model often decreases reliability. Use it as it is and compromise with the results according to the parameters confidence intervals. Keep in mind that the idea of detecting faults is brought up just because the variability of the biological system. Conclusion:

We have now 3 good EOLI models, and all WPs can work with them as they are.

3 WP3 *TUESDAY 23, 10:15AM*

3.1 Leader *A.Pauss; file WP3__Leader_2yp*

Deliverables are on time. Hardware Sensors will be installed in Narbonne.

3.2 POLIMI-ENEA *E.Ficara; file WP3_POLIMI(Elena)_EOLI_2yp*

PH-stat denitrification tests were made to assess the relation between titration rate and denitrification rate. Useful information may be gathered i.e.: to assess the end of phase “a” (denitrification of rbCOD fraction); a constant slope in the titration means the denitrification keeps going; a plateau in the titration means there is no more denitrification. So it is possible to know that the SBR is working correctly.

Calibration must be repeated EVERY time, to guarantee the accuracy of the results. It is simple to do. More tests are in progress.

3.3 POLIMI-ENEA *N.Fiocchi; file WP3_ENEA(Nicola)_EOLI_2yp*

A description of TITAAN (TITrimetric Automated ANalizer) is done: fully interfaced and automated to take samples, elaborate data on real time and store data (Bologna). Five modes of operation are available: Influent toxicity assessment, nitrifiable nitrogen influent’s content assessment, maximum nitrification activity assessment, detecting the end of nitrification process (end of aerobic phase for SBRs), and residual nitrates assessment at the end of anoxic/aerobic phase.

3.4 SPES *P.Ratini; file WP3_SPES_EOLI_2yp*

Activities in cooperation with POLIMI ENEA, for the pilot plant in Bologna, were presented. Hardware characteristics were described. No problems were reported.

3.5 GRADIENT *M.Bekri; file WP3_GRADIENT_EOLI_2yp*

UV-spectrophotometric limitations of commercial available solutions were presented. Deconvolution techniques improvements are suggested. One of the second year activities was included also for the third year. New conditions for operating the SBR were implemented.

3.6 INRA-LBE *J.Harmand; file WP3_LBE_EOLI_2yp*

Preliminary results show some problems with robustness of calibration for UV-Visible spectrum use. Crossvalidation does not provide good results. By comparison results in the FTMIR spectra are promising even if cost is higher.

3.7 UNAM *G.Moreno; file WP3_UNAM_(Gloria)_EOLI_2yp*

Gloria MORENO presents her work in Compiegne. Results are good using the second peak in the UV spectra. It is possible to follow 4CP degradation using the UV spectra.

3.8 UU *A.Benítez; file WP3_UU_(Alejandra)_EOLI_2yp*

Alejandra BENITEZ presents her work in Compiegne. Reactor works OK after adding one hour to the standard condition. Anoxic phase presented good correlation with UV absorbance. Aerobic phase did not.

3.9 UNAM *J.Moreno; file WP3_UNAM_EOLI_2yp*

An idea to follow concentrations inside the reactor as reaction goes by is presented, assuming that *betas* are not constant against concentration. So nonlinear functions of concentration must be used, not a linear regression. Plausibility and pertinence of this non standard explanation is discussed.

After finishing WP presentations Fig. 1 is drawn to synthesize the future of the WP3

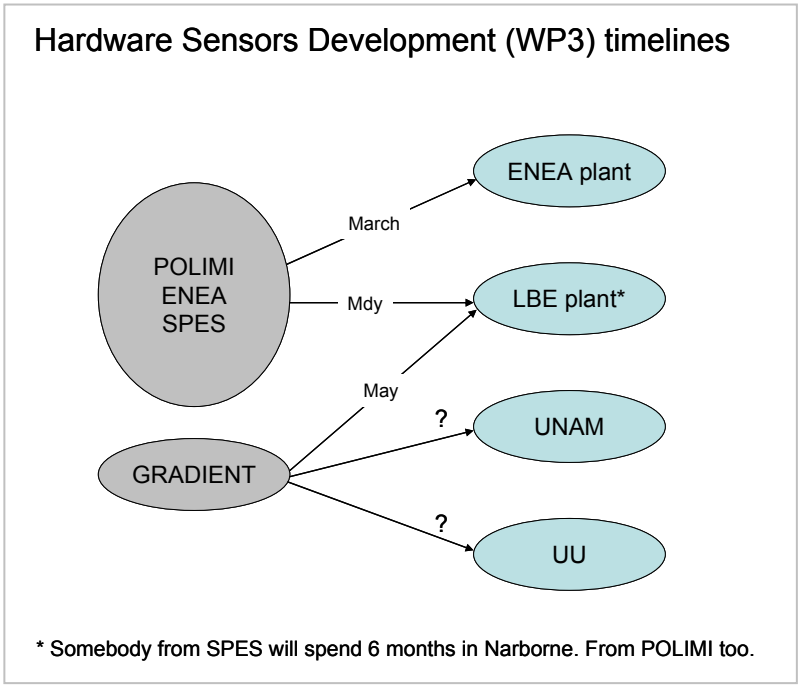

Figure 1. WP3 timelines

Additional discussions are held concluding that:

Titration Hardware sensors seems promising for estimating proton consuming/producing reactions, but for 4CP it seems UV is more promising. In Mexico it might be used directly, but for other WWs this is not true yet.

4 WP4 *TUESDAY 23, 3:15PM*

4.1 Leader *D.Dochain; file WP4_Cesame_EOLI_2yp*

Only WP6 asked for a new Software Sensor. The observer must converge inside the timescale of the batch process. Different observers and their characteristics were explained. For the Mexican case endogenous respiration poses a problem as convergence time gets big. If asymptotic plus adaptive solutions are used this may be corrected but then the observer gets highly sensitive to tuning. To increase robustness Extended Luenberger Observers might be explored, but only if there is clear need for that in some WP and if clear information on the processes is provided.

Software Sensors might be also useful for monitoring, not only for control.

5 WP5 *TUESDAY 23, 3:35PM*

5.1 Leader *J.Moreno; file WP5__Leader_EOLI_2yp*

The WP leader presents the WP synthesis. No problems are reported.

5.2 LBE-INRA *J.Harmand; file WP5_LBE_EOLI_2yp*

A sub-optimal control strategy is proposed using a simplified model and no limiting conditions for O_2 in aerobic phase. The idea is to have a cube as final target, and define the accessibility set as the initial conditions that have a path to that final target. Results show that at most two switches are necessary to reach the target, at least for initial conditions inside the reachability set. Maybe there is a faster solution using more switching but it is much more complex. One important result is that time can not be minimized in aerobic phase, only in anoxic phase.

Concerns arise about the biomass long term changes if reactions start aerobically. However the results are important and new, because there is no *feed-batch*, and for a control point of view this is very good.

5.3 UNAM *M.Betancur; file WP5_UNAM_EOLI_2yp*

Results about validation of the EDTOC (Event Driven Time Optimal Control) strategy are presented. In lab scale results are very good. Results are in advance to the original schedule. A list of 9 publications is presented, all of them in collaboration with other WPs. Next year main challenge is to start and test the EDTOC in the field scale reactor. Interesting problems are expected when using real wastewater.

After finishing WP5 presentations, the project manager asked to agree on:

Is it possible to use results from LBE-INRA or UNAM in UU or POLIMI?

POLIMI leader thinks it is not possible as it is… Nitrate excess is the problem. However some tests with Narbonne's solution, in open loop, may be done. Using the model and providing initial conditions, a Matlab module provided by Narbonne will specify the switching times. There are budget and timing limitations. "We can try", after March, in POLIMI, not in ENEA. Tests must not affect the controlled conditions needed to develop other instruments.

UU leader agreed to the possibility of using Mexican results in their reactor.

6 WP6 *TUESDAY 23, 5:22PM*

6.1 Leader *C.Verde; file WP6_Leader_UNAM_EOLI_2yp*

Main problems identified were described for sensors and actuators:

For the DO FD (Dissolved Oxygen sensor Fault detection) case the proposition is to change the conditions for the DO, during a non essential phase (as settling) of the reaction, to allow identification of time constants. The problem is how to change DO conditions as special hardware would be needed to do that in a real sensor. Or to have a sensor that allows doing that, disconnect it and reconnect it.

For the valves, it is a hot issue. Many important companies are researching ways to detect different problems in valves. Some of them assume the model is known. WP6 leader thinks this should not be assumed. Better to use the history of the valve to detect changes.

6.2 UNAM *D.Wimberger; file WP6_UNAM(Dieter)_EOLI_2yp*

Problems using WP2 results are described. Applicability is limited to reaction phases. The model is not valid in other phases that might be useful for FDI purposes. The behavior of the SBR was not reproducible with the model for FDI purposes. Variables as ORP or PH are not included in mass balance models, and now they seem important to predict events leading to problems. In order to study other alternatives D.Wimberger will stay some days at POLIMI.

As DO is the only online variable available and its model is well known, using it for online monitoring was suggested, as for looking patterns in the respiration rate. But warnings were expressed about that approach: it was tried in the 60s and 70s, but because real reactors do not have perfect mixing they need at least 6 sensors. Theoretically it is ok, but practically it is very difficult.

7 WP7 *WEDNESDAY 24, 9:24AM*

7.1 Leader *J.Harmand; file WP7_Leader_EOLI_2yp*

There are two partners integrating supervision systems: Mexico and Narbonne. For Narbonne algorithms depend on INRA, implementation on SPES. Data analyzing is missing and will be made in the next months. A solution with two parallel systems

is available. One based on WP2 models, the other, more industrial, is data based. They may be integrated later.

Model Based: The system have the model available at the beginning of SBR startup. Data is generated covering all operating conditions. Changing parameters, (in order to detect nitrite buildup, etc…) a very important set of data is generated. Six members are extracted from this data. Using this 6 parameters statistic approaches are used to classify problems. A data base with faulty situations exists. Then the closest case simulated must be found. Using key closeness neighbors method some abnormal situation might be found. If that is the case the plan is to shortcut the control algorithms. Inform operator and recommend Action to be taken (i.e. STOP and aerate)

It is easy to expand the system, i.e. more than 6 parameters, to include more variables. This is not yet done. Information must be fed to the system about what to recommend to the operator if an abnormal condition appears.

Francesco is trying to extend this work to POLIMI. Nicola is also involved.

8 WP8 *WEDNESDAY 24, 9:44AM*

8.1 Leader *P.Ratini; file WP8_Leader_2yp*

It is important to think on VALIDATION of all developed modules, Matlab, model, etc… as this is important for the evaluation of WP8.

There are two approaches to integration. One (UNAM, UU, IBTECH) uses commercially available Software and Hardware. The other one uses embedded electronics. For this a Modular architecture for the EOLI software is proposed, such that adding customized modules and upper level functions is allowed. XML files (text files in particular form) were chosen for several reasons: It is a standard de facto for communicating compiled modules; By using them some of the compiled modules may be run in different machines (reusability) as long as TCP connections are used; Remote links are possible to use it for real time interconnection if a reliable INTERNET connection is available (not in milliseconds, but in minutes time range).

An important plus is to be able to use a MATALB module, already tested in simulator or any other environment; with minor modifications (XML file interface should be added). MATLAB modules must be compiled, that is a standard procedure since MATALB 6.0 (Using the Matlab compiler that produces stand-alone code). This approach is a focus point. A final version is in progress for the formats (it is not ready yet. A slide about planning is shown in the presentation).

In February a document, including examples, will be delivered on how to generate customized EOLI software modules with XML interfaces.

The embedded system will replace the actual systems for VALIDATION with ENEA, even to integrate Hardware sensors, as TITAAN. For the other systems it is not so clear.

Putting the pilot system in the web was discussed as a way to let everybody know about the project results. For this a telemonitoring module should be added. The system might be open to any user in INTERNET, for demonstration purposes. Security is an issue. Absolute security is a dream. But a procedure based on

passwords is possible. Ownership of results is also a concern. No one from outside the group should be able to use this data. A suggestion is made about putting an EOLI mark in all visible data.

If everything goes OK, SPES agreed to do the INTERNET interface providing a "semiopen" online access (no permission to write or download anything, just to see)

The schedule was presented to install SPES embedded SYSTEM, and commission it, first in ENEA and then to replicate it in LBE.

Evaluation and validation, from IBTECH's and other systems, is important to show that this approach is usable not only with SPES embedded systems but also with general open systems. It is important to report this at least at the last deliverable. IBTECH agreed and asked how to do it. Paolo explained that the platform is different in each case. It is clear that IBTECH will not implement SPES systems, but will use high level modules that can be also used inside the SPES platform. The same is true for all validation of "own made" modules.

Software Modules to be validated in one of the two SPES provided systems have to be COMPILED and comply with the XML specifications (to be provided by SPES). It is not important if it is written in MATLAB or LABVIEW or else. But if a module is used exclusively only for other user, it is not necessary to provide SPES anything. Compatibility however is a must. It is important that EOLI philosophy could be demonstrated in all plants, especially if the final meeting is held in Mexico.

This is a change of what was decided last year, but the project coordinator believes that it is not a major change, and most probably the task will not be that heavy. The important thing to show is that a software module with the PARSER maybe used in the SPES platform and, without PARSER, can be used also outside SPES (as IBTECH) platform.

In the topic CONVERGING to INTEGRATION (WP1, 2, 3, 4) Paolo asked Jérôme to be the task leader for the Sensor's network.

Paolo compromised to send an email with schedules and then to check periodically that times are respected.

9 FINAL DISCUSSION *WEDNESDAY 24, 2:45PM*

Most of WPs will finish by year 2.5 except WP1 and the key WP8, dedicated to INTEGRATION. Everybody must take part in integration. Missing bricks should be filled in next six months. Integration is mainly for WP3, 4, 5, 6, 7. Remind there is interaction between EVERY WP.

It was agreed that diagrams in Figures 2 to 6 represent the interactions that should be explored between WPs from WP3 to WP7. For simplicity WP8 is not included in figures as it is too important and covers all other.

The arrows mean Commitment to work in that link, not necessarily to get results.

Every task leader should define DEADLINES for studying the interactions and follow what is going on periodically. The diagram must be put in their offices and looked at.

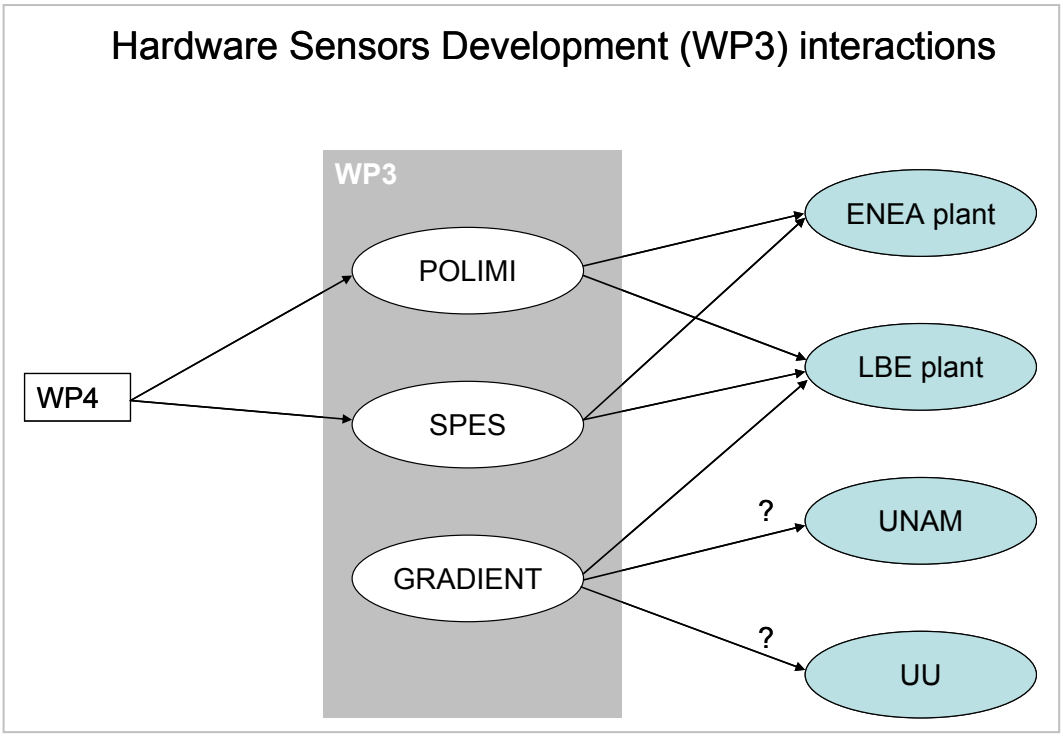

Figure 2. WP3 interactions

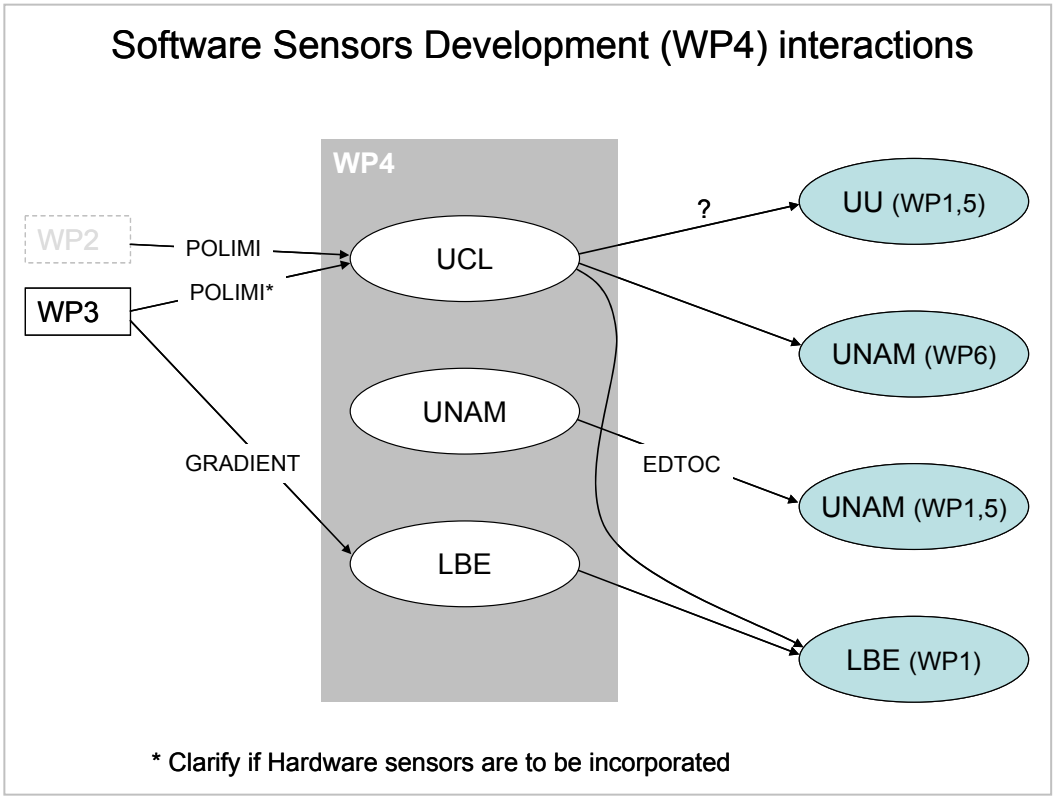

Figure 3. WP4 interactions

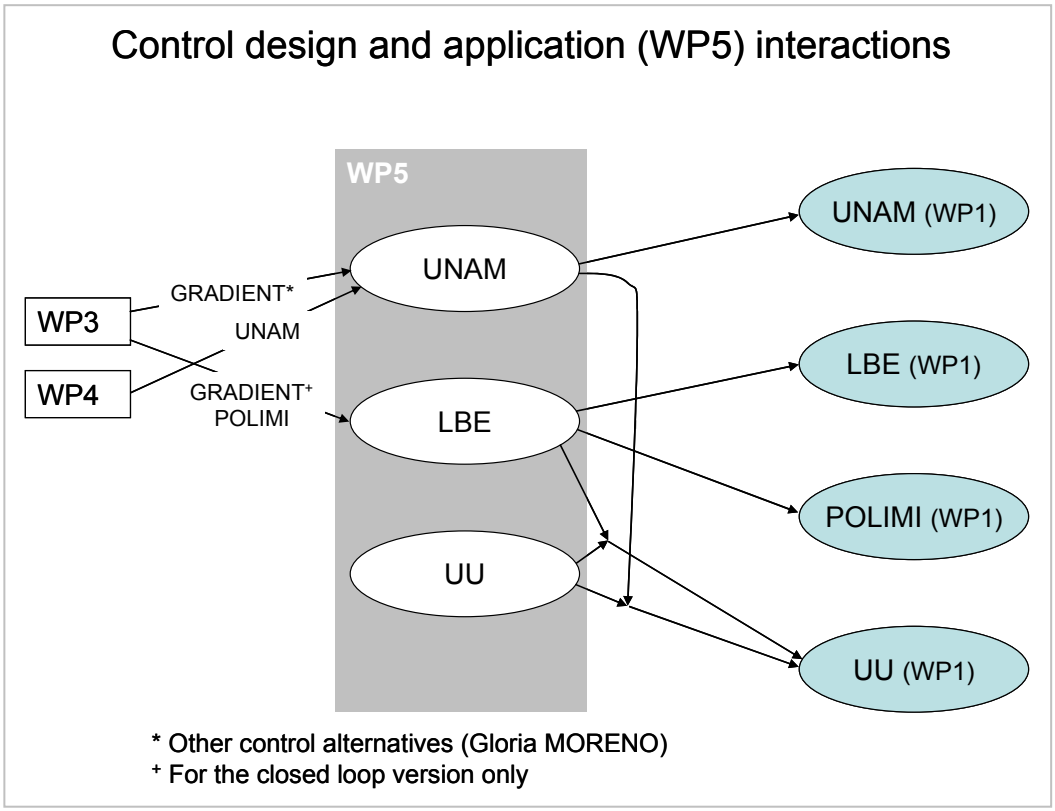

Figure 4. WP5 interactions

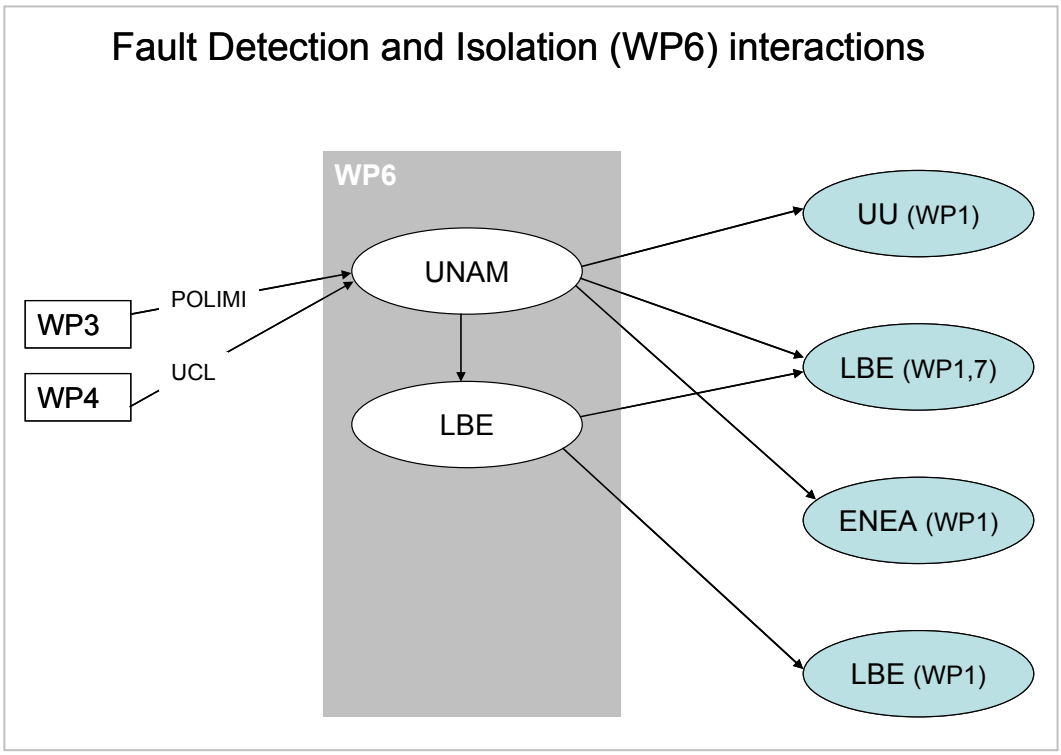

Figure 5. WP6 interactions

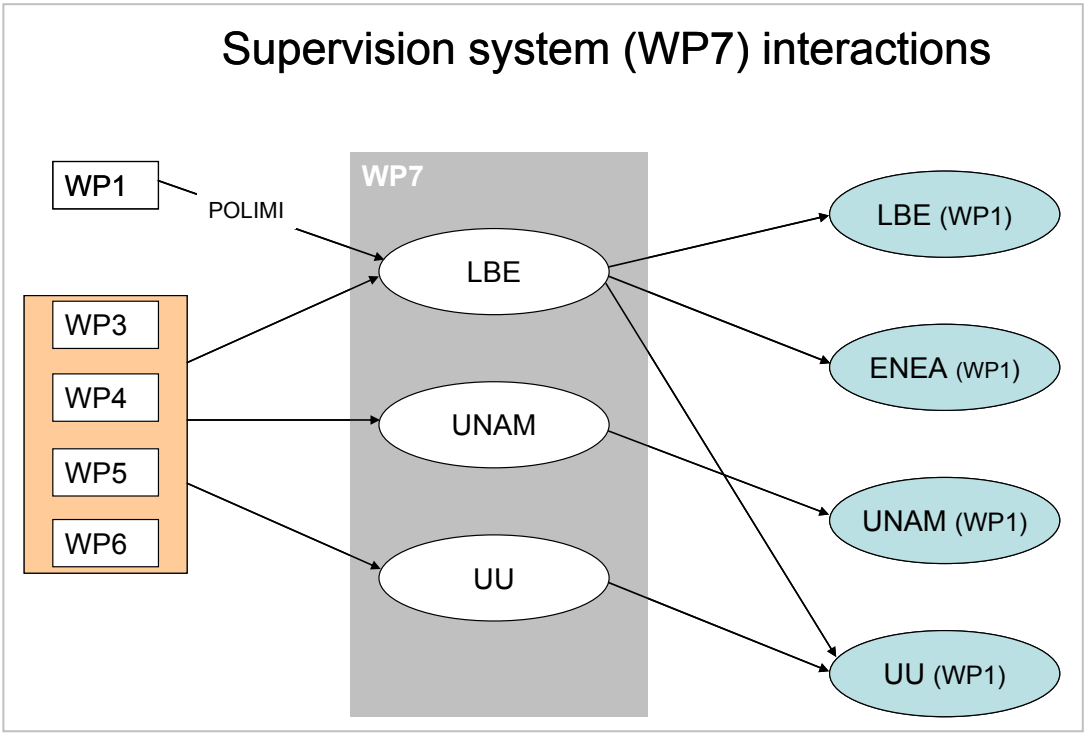

Figure 6. WP7 interactions

NEXT MEETING AND OTHER VARIOUS MATTERS:

The idea to switch meeting places was considered, but Mexico was decided long time ago, and if EC evaluators decide to attend the last meeting, it would be ideal to have them in Mexico.

Next meeting is going to be held in URUGUAY, May 9,10,11 (2005) (second option is May 2,3,4).

A workshop in NARBONNE (20 people from EOLI and 20 from outside) is proposed, after the end of EOLI. The presentation may include other presentations than EOLI's. The date will be fixed later, but after November 2005 (or beginning 2006, but no later than 6 months after finishing EOLI). Try to choose a date near other important events to take advantage of transportation.

The project leader will manage to re-put the webpage online, so please send all DELIVERABLES to put them on the webpage.

Monthly reports are still in order. The project coordinator will be more active in next months to be sure everything runs smoothly.

25 publications are OK, but it would be great to have MORE JOINT publications.

The meeting ends before 6:00pm.

ANNEX 1: LIST OF ATTENDEES AND CONTACT DATA

N°	Names	Contact/Relevant Data
1	***Université Catholique de Louvain UCL, Belgium*** DOCHAIN, Denis	***Project coordinator, modelling, identification and software sensors*** dochain@auto.ucl.ac.be
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6	***Universidad Nacional Autónoma de México UNAM, Mexico*** BETANCUR, Manuel BUITRÓN, Germán MORENO, Gloria MORENO, Iván MORENO, Jaime VERDE, Cristina WIMBERGER, Dieter	***Process experiments, fault diagnosis, process supervision and optimal control*** MBetancurb@iingen.unam.mx gbm@pumas.iingen.unam.mx gmro@pumas.iingen.unam.mx IMorenoA@iingen.unam.mx JMorenoP@iingen.unam.mx verde@servidor.unam.mx DWimbergerM@iingen.unam.mx
7	***Universidad de la República Oriental del Urugay UU, Uruguay*** BENÍTEZ, Alejandra CANETTI, Rafael GUTIÉRREZ, Soledad	***Process experiments, modelling, identification, optimal control and process supervision*** abenitez@fing.edu.uy canetti@fing.edu.uy soledadg@fing.edu.uy
8	***IBTech S.A. de C.V. IBTECH, Mexico*** MORGAN-SAGASTUME, Juan M.	***Design of a pilot plant and evaluation of tools*** jmms@pumas.iingen.unam.mx

ANNEX 2: LIST OF ABBREVIATIONS

4CP	4-Chloro-Phenol
ASM	Activated Sludge Model
CAC	COD adsorption capacity
CESAME	Centre for Systems Engineering and Applied Mechanics
D1.x – D9.x	Deliverables
DO	Dissolved Oxygen Concentration
DSS	Decision Support System
EC	European Commission
EDTOC	Event Driven Time Optimal Control
EM	EOLI Model
EOLI	Efficient Operation of Urban Wastewater Treatment Plant
FDI	Fault Detection and Isolation
FTC	Fixed Timing Control
GRADIENT	Groupe de Recherches et d'Animations pour le Développement, l'Innovation et l'Enseignement en Technologie
INCO	International Scientific Cooperation Projects
INRA	Institut National de la Recherche Agronomique
LBE	Laboratoire de Biotechnologie de l'Environnement
POLIMI	Politecnico di Milano
SBR	Sequencing Batch Reactor
SPES	Società di Progettazione Elettronica e Software
UCL	Université Catholique de Louvain
UNAM	Universidad Nacional Autónoma de México
UTC	Université Technologique de Compiègne
UU	Universidad de la República Oriental de Uruguay
WP	Work Package
WWTP	Wastewater Treatment Process