PROJECT FINAL REPORT

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4.1 Final publishable summary report

- **EXECUTIVE SUMMARY.**

Tougher effluent quality standards, increasing wastewater loads, and energy consumption and operation costs reduction requirements are nowadays forcing wastewater treatment plants (WWTP) to work under more and more stringent conditions. Many automatic control strategies have shown their usefulness at simulation scale, or even pilot plant scale for improving WWTP performance without structural changes in the plant. However, they are experiencing limited full-scale plant applicability mainly due to the still low reliability of the data provided by on-line sensors and analyzers and the ideal behaviour of sensors and actuators commonly assumed by existing WWTP-specific simulation platforms.

The ADD CONTROL project (www.addcontrol-fp7.eu) has addressed this problem and proposes an extension of the WWTP models and modelling architectures used in traditional WWTP simulation platforms considering next to the classical mass transformations (transport, physico-chemical phenomena, and biological reactions) all the instrumentation, actuation and automation & control components, where their real (not ideal) behaviour is modelled, including actuators power consumption. In this way, all aspects considerably influencing the real controllers' performance and strategy are accounted for.

Regarding mathematical modelling, a three-layer modelling architecture separating the mathematical models of the mass-flows derived from the water treatment process (tanks, reactors, settlers, hydraulic connections, hydraulic flows, etc.) from the virtualization of the data-flows associated with instrumentation, actuation and control devices has been implemented: (1) the treatment process or "mass" layer describing the biochemical, physico-chemical, equilibrium, liquid-gas transfer, hydraulic and other processes that take place in the different reactors of the plant, based on the Plant-Wide Modelling specification; (2) the "instrumentation & actuation" layer, describing sensors' and actuators' real behaviour, including signal delays, noise and failures and power consumption; (3) the "automation & control layer", describing automatic control devices (ON/OFF controllers, PID controllers, Fuzzy controllers,...) and some signal processing algorithms (sampling, filtering, A/D & D/A conversions,...). This architecture allows readily integrating the different mathematical models and replicating the classical control architecture of real plants.

Regarding SW development, a tool based on two well known and widely used modelling and simulation platforms has been developed: (a) the WEST®/TORNADO platform (mikebydhi.com), a water quality systems modelling and simulation SW platform, and (b) the MATLAB®/Simulink® platform (www.mathworks.com), a general purpose modelling and simulation SW tool. The (1) "mass" layer is implemented on WEST®/TORNADO using the MSL modelling language, whereas the (2) "instrumentation & actuation" layer and the (3) "automation & control" layer are implemented on WEST®/TORNADO using the MODELICA (www.modelica.org) modelling language on the one hand, and on MATLAB®/Simulink® on the other.

Regarding testing and validation, the developed SW tool has been used to design and test automatic controllers for: (a) a full-scale municipal WWTP and (b) a pilot-scale industrial WWTP, the controllers having been successfully implemented and validated. Thus, the final objective of this project, the development of a simulation tool to allow a rapid and reliable transition from the simulation of the controllers to their implementation in real plant, has been advantageously reached.

- **SUMMARY DESCRIPTION OF PROJECT CONTEXT AND OBJECTIVES.**

Introduction

In Europe, significant progress has been made in the last decade with respect to population connected to wastewater treatment facilities. In 2007, about 70% of the population was connected to any kind of urban wastewater treatment (EUROSTAT, 2011). Not only the quantity, but also the quality of wastewater treatment improved as the percentage of population connected to wastewater treatment facilities with tertiary treatment increased from 29% in 1997 to 48% in 2007 (EUROSTAT, 2011).

Nonetheless, many existing wastewater treatment plants (WWTPs) are being (or still need to be) upgraded with advanced treatment technologies to meet more stringent effluent criteria and standards for sludge disposal. In addition, many existing urban treatment plants are facing increasing wastewater loads that need to be treated. Similar tendencies are being observed for industrial wastewater treatment. Current regulations are forcing industries to install more and more wastewater treatment systems and to improve the effluent quality of their wastewaters before discharging into sewers or receiving waters.

Instrumentation, control, and automation (ICA) is a promising technology for improving treatment plant performance, and a valuable alternative to structural modifications of WWTPs, such as increasing reactor volumes. It has been shown, for example, that ICA may increase the capacity of biological nutrient removing WWTPs by 10 – 30% (Olsson et al., 2005). Furthermore, ICA can help to improve treatment plant performance in terms of process robustness, energy consumption, and operating costs while still ensuring the required effluent quality. Two examples from Olsson et al. (2005) are given below that demonstrate possible reductions in energy consumption and operating costs when implementing ICA:

1.- The dosage of chemicals for phosphorus precipitation can be reduced by 18% when using load proportional dosage of chemicals instead of constant dosage, and by 40% when implementing feedback control based on in-situ ortho-phosphate measurements.

2.- Aeration energy can be lowered by about 30% when implementing dissolved oxygen (DO) control with constant setpoint instead of applying a constant air flow. Implementation of DO control with variable setpoint can decrease the energy demand for aeration even further.

In the future, the issue of decreasing the energy consumption of a WWTP will gain importance, especially with rising energy prices. Designing control strategies for reducing operating costs and energy consumption of a treatment plant involves moving from the individual process level control to plant-wide control, considering different individual process levels together.

Nowadays, mathematical modelling and simulation have become essential tools for supporting not only the design and operation of wastewater treatment plants (WWTPs) but also the analysis and synthesis of control algorithms. The original Benchmark Simulation Model no. 1 (BSM1) protocol and its sequels, the Long-Term BSM1 (BSM1_LT) and the Benchmark Simulation Model nº 2 (BSM2), are three important simulation benchmarks aimed at providing researchers with standard methodologies for the objective comparison of control strategies (Copp et al., 2002). Since their publication, multiple automatic control approaches have been tested and verified by using these protocols: (1) conventional PID controllers (Yong et al., 2006a); fuzzy controllers (Yong et al., 2006b); model-based predictive controllers (Zarrad et al, 2004; Holenda et al., 2007); and feedback/feedforward controllers (Stare et al., 2007). However, the extensive work undertaken in the simulation domain has not been accompanied by the practical implementation of advanced

controllers in full-scale WWTPs. One reason for this is the fact that the design of good operational control systems requires working on more practical aspects than just the design of the control algorithms, i.e. the behaviour of sensors and actuators (Rosen et al., 2008), communication systems, databases and other technical aspects. Moreover, next to process stability and reliability, also final effluent quality and energy consumption gain importance in the design of a control strategy. Another reason is that existing WWTP-specific simulation frameworks have traditionally been intended for design and operation studies rather than for control law definition purposes. In practice, these software tools fail to allow a rapid transition from the simulation of the control strategy to its implementation in full-scale plants.

These existing WWTP-specific simulation packages (e.g. BioWin™, GPS-X™, SIMBA®, WEST®) typically provide some controller components to enable the implementation of simple control strategies in a WWTP model. The realized control strategies are, however, based on ideal behavior of sensors and actuators as signal noise and potential sensor and actuator failures are not considered. In order to design "practical control" products, real behaviour of sensors and actuators, communications between different hardware components, and data treatment need to be taken into account to ensure robust controller behaviour and adequate plant performance. Tools for control design and data treatment needed for designing practical control solutions are not available in WWTP-specific simulation packages, but in general-purpose simulation software packages (e.g. MATLAB®/Simulink®, SCILAB). General-purpose simulation software packages, on the other hand, lack model libraries of processes specific for wastewater treatment. Thus, neither existing WWTP-specific simulation packages nor general-purpose simulation software packages are suitable for designing, testing, and validating practical control solutions.

Therefore, this work proposes an extension of the traditional WWTP models and modelling architectures used in current WWTP-specific simulation tools, focusing on current needs for practical control. The proposed approach's principle is to simulate all the plant's components determining the final control solution: from biological tanks to instrumentation, actuation and automation systems. That is, the classical concept of WWTP simulation, in which the focus, hitherto, has been on the modelling of mass transformations (transport, physico-chemical phenomena, and biological reactions), is extended by a WWTP virtualization, where modelling covers all the components involved in the operation of a plant.

Objectives:

The **main objective** of the ADD CONTROL project is to **design, implement, and validate a new simulation tool for practical control in WWTP**s. In order for the general objective to be reached, the following partial goals have to be fulfilled:

1.- **Mathematical modelling of all those components that**, in general, **make up a WWTP**, considering components close to the treatment process (tanks, biological reactors, settlers, …) as well as components closer to the automation and control (sensors, actuators, PLCs, SCADAs …).

2.- **Interfacing components according to** a hierarchical architecture that emulates **the real architectures** for automation and control in full-scale WWTPs

3.- **Open environment to support the virtualization of different WWTP configurations and treatment technologies** (conventional activated sludge systems, membrane bioreactors, biofilm systems, anaerobic digesters, etc.).

4.- **Validation in real case-studies**. The performance of the software tool is assessed through two full-scale plant scenarios: (1) urban wastewater scenario; and (2) industrial wastewater scenario. In both cases, advanced controllers are designed and tested using the virtualization

software tool. Then, these controllers have been implemented and validated in their respective full-scale plant.

Structure

The ADD Control project is structured into six technical work packages. An additional WP deals with project management (WP1).

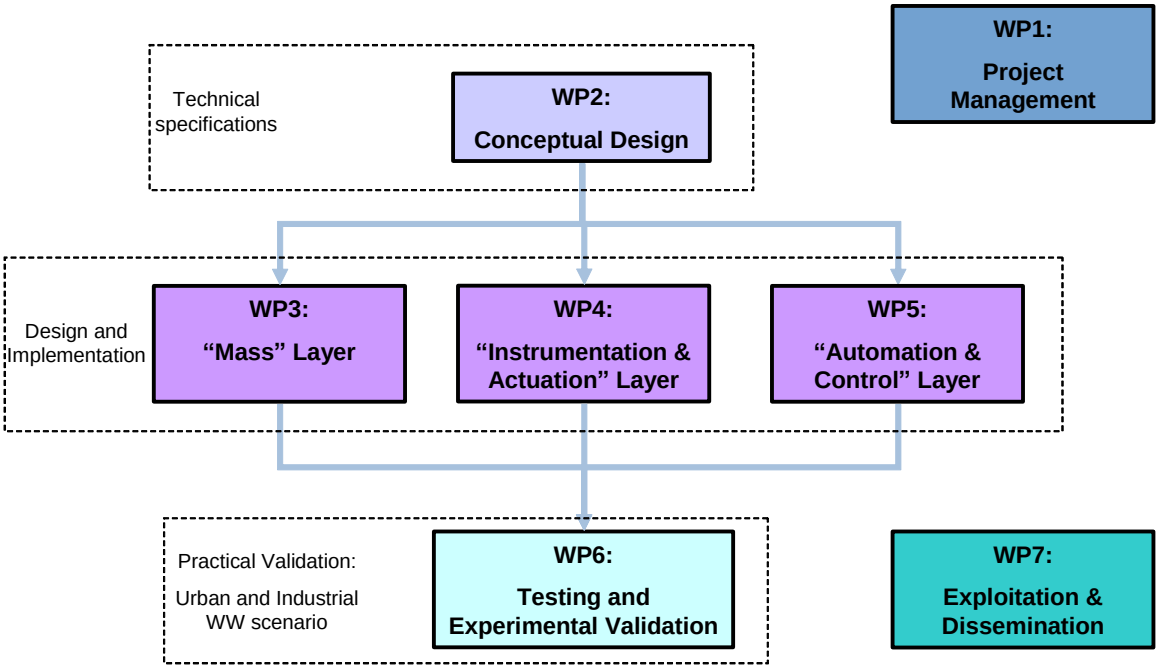
WP2 – WP7 are dedicated to:

WP2: Definition of technical specifications for the ADD CONTROL tool, including the software architecture and the software libraries to implement

WP3, WP4, WP5: Design, development and integration of the three software layers according to the technical specifications

WP6: Practical validation of ADD CONTROL in two full-scale plant scenarios (an urban and an industrial WWTP), in order to demonstrate the usefulness of the tool

WP7: Create the path for an effective exploitation of the project results and an effective dissemination, during and after the project life



- **MAIN S&T RESULTS/FOREGROUNDS**

Thank to the success of the project, the gathered knowledge will put Europe in pole position with respect to tackling optimisation of wastewater treatment processes in a sustainable way. In this sense, exploitable results can be commercialized together in a joined offer or as separate results. These are the exploitable results developed during the project:

1.- Software library models
2.- WWTP emulator software
3.- Advanced controllers
4.- Enhanced treatment technologies.

In overall, a new simulation SW platform, based on new process and system models, aimed at the design and implementation of new advanced controllers and already offering enhanced treatment technologies has been developed. Next, a description of these results is given:

1) SW LIBRARY MODELS

In this project an extension of the WWTP models and modelling architectures used in traditional WWTP simulation platforms has been implemented. Next to the classical mass transformations (transport, physico-chemical phenomena, and biological reactions), models for all the instrumentation, actuation and automation & control components have been developed, including their real behaviour (signal noise, signal delay, faults, drift, offset) and actuators' power consumption. That is, all aspects considerably influencing the real controllers' performance and strategy have been modelled.

Regarding modelling architecture, a three-layer modelling structure separating the mathematical models of the mass-flows derived from the water treatment process (tanks, reactors, settlers, hydraulic connections, hydraulic flows, etc.) from the virtualization of the data-flows associated with instrumentation, actuation and control devices has been implemented:

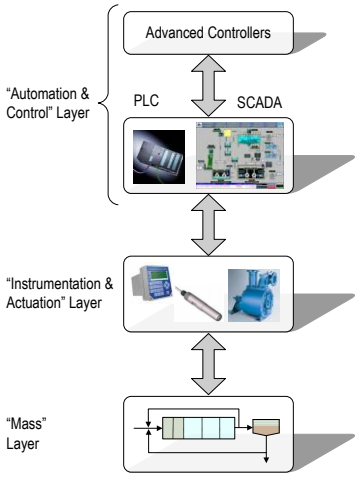


Figure 1 General schema of the implemented three-layer model-architecture.

1) The treatment process or "**mass layer"** describing the biochemical, physico-chemical, equilibrium, liquid-gas transfer, hydraulic and other processes that take place in the different reactors of the plant, based on the Plant-Wide Modelling specification;

2) The **"instrumentation & actuation layer"**, describing sensors' and actuators' real behaviour, including signal delays, noise and failures and power consumption;
3) The **"automation & control layer"**, describing automatic control devices (ON/OFF controllers, PID controllers, Fuzzy controllers,...) and some signal processing algorithms (sampling, filtering, A/D & D/A conversions,...). This architecture allows readily integrating the different mathematical models and replicating the classical control architecture of real plants.

Next, a description of each of these three layers is given:

The Mass layer

As mentioned above, the "mass" layer relates to the physical processes of a WWTP. This layer is represented and modelled in terms of Unit Processes (UP), where each UP represents a physical element of the plant. The UPs are modeled according to the Plant Wide Modelling (PWM) specification (Grau et al., 2007), based on the following two main features:

- A common state-vector is shared by all UPs.
- Conservation of mass and charge is considered in all the transformations.

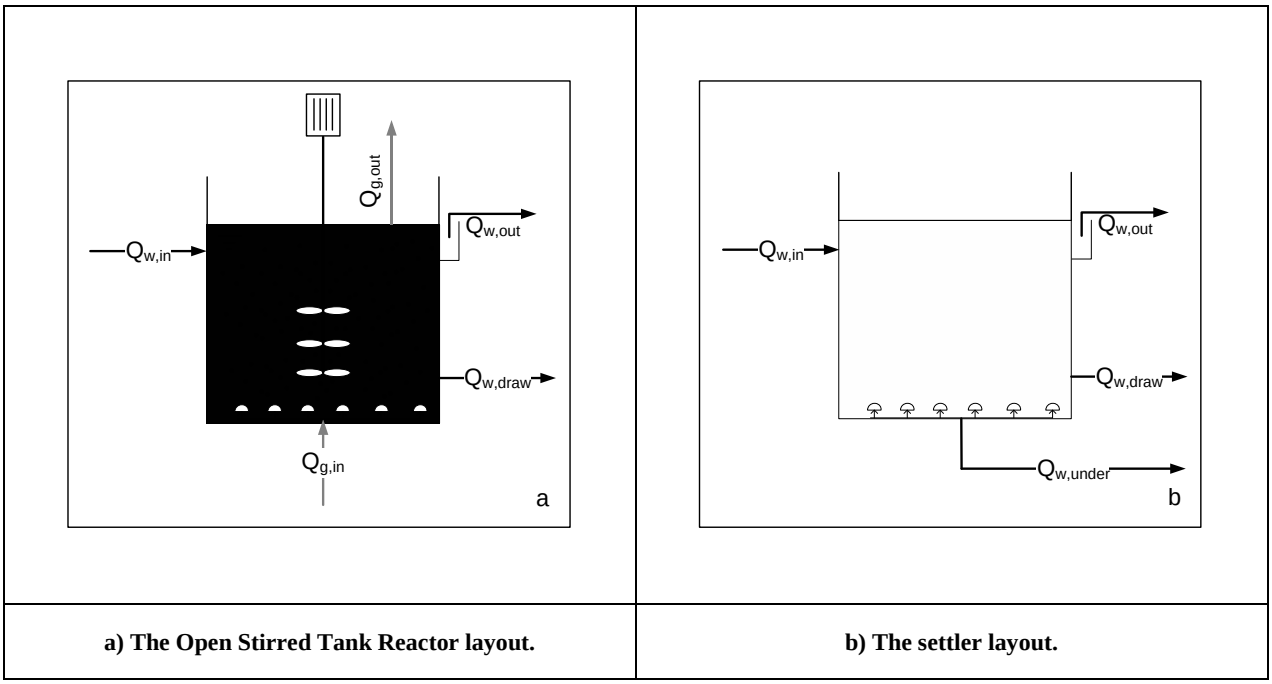
MSL (Model Specification Language) is the language chosen for modelling the UPs. Taking this into account, two PWM categories have been implemented:

- CN_AnD: Carbon, Nitrogen and Anaerobic Digestion. This category gathers all the components and transformations which dynamically describe aerobic, anoxic and anaerobic COD biodegradation and N removal.
- C2NP_AnD: Carbon, Nitrogen, Phosphorous and Anaerobic digestion. This category gathers all the components and transformations which dynamically describe aerobic, anoxic and anaerobic COD biodegradation, P biological removal, N removal in two steps ($NO_3^- \rightarrow NO_2^- \rightarrow N_2$) and anaerobic ammonia oxidation (the Anammox process).

Regarding the UPs of the "mass" layer, the main UPs by this work implemented are next listed:

- *Buffer Tank (Completely Stirred Tank - CST)*
- *Completely Stirred Open Tank Reactor (O-CSTR)*
- *Completely Stirred Closed Tank Reactor (C-CSTR)*
- *Intermittently Stirred Open Tank Reactor (O-ISTR)*
- *Settling Tank*

where the description of the internal transformations of those tanks considering biological reactions will depend on the PWM category selected. Next, the graphical layout of the O-ISTR tank reactor is shown by way of example:



a) The Open Stirred Tank Reactor layout. | **b) The settler layout.**

Figure 2. O- ISTR layout when operating as (a) O-CSTR, and (b) Settler.

The Instrumentation & Actuation layer

The "instrumentation & actuation" layer deals with the mathematical modeling of sensors and actuators with "real behaviour". For sensors, a "generic" sensor model has been built, no matter pH-probes, DO-sensors, flow rate sensors, temperature probes…are to be modelled. The idea is not to take an actual sample from a process unit such as an activated sludge tank, but to distort a perfect signal into a more realistic signal.

A virtual sensor gets its input (i.e. the ideal signal) from the "mass" layer and it outputs a mimicked real signal taking into account: 1) sensor dynamics (response time, delay and temporal resolution (sample-and-hold)), 2) signal noise and 3) sensor faults. The concept of the virtual sensor model is illustrated in Figure 3. Basically, it takes a signal input from the "mass" layer and produces a sensor signal and a sensor fault signal which are communicated to the "automation & control" layer.

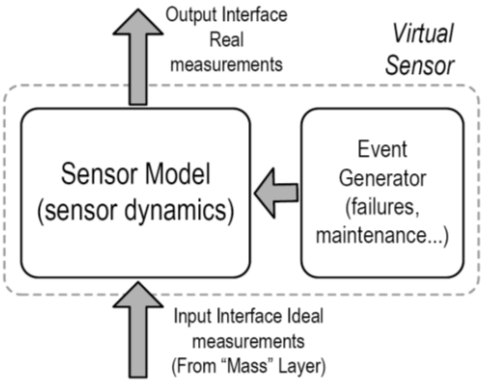


Figure 3. Illustration of the virtual sensor concept.

The implementation of the above "generic" virtual sensor, some of the associated sub-models and the fault model is partly based on the work of Alex et al. (2009), Corominas et al. (2010) and Rosen et al. (2008).

Concerning actuators, the modelling of pumps and aeration blowers has been addressed, since those are the most important energy consumers in wastewater treatment plants. An extensive literature review revealed that much knowledge is available on the theoretical functioning of pumps and blowers from a design point of view, but that no dynamic energy consumption models are readily available for implementation. Even though some commercial software packages for calculating and optimizing features for energy consumption of (mostly) pumps already exist, often these are static instead of dynamic. This research work proposes an approach to create dynamic models for the calculation of pumping and (bubble) aeration power, based on steady-state models and considering an ideal behaviour, and with the possibility to test different pump and blower types and different control mechanisms often used in practice.

Regarding pumps, centrifugal pumps and positive displacement pumps have been addressed. For these, generic models based on generic pump curves, generic systems curves and generic approaches to efficiency calculation have been developed. The general approach deals with delivering the required flow rate from a single pump. However, this would in most cases not be the situation in a real plant where the total flow rate between unit operations is the result of using two or more pumps in parallel. Thus, power consumption calculation for pump groups of different layouts (individual discharge pipes, one common discharge pipe) has also been implemented. The Markov chain concept followed by the fault modelling strategy used for sensors (Rosen et al., 2008) has also been applied to actuators by adapting the associated states and transition probabilities, both for the single pump model and the pump group model.

Regarding blowers, centrifugal blowers and positive displacement blowers have been addressed. Energy consumption for blowers, similar to that of pumps, is a function of air flow rate, efficiencies and discharge pressure. Thus, generic models based on generic blower curves, generic systems curves and generic approaches to efficiency calculation have also been developed here. However, significant differences and complexities are introduced to aeration blower applications due to the compressibility of air. Characteristics such as air density, relative humidity, altitude and temperature influence the required airflow to the system and therefore also the energy requirement of the blower. These aspects, together with the selected process control strategy, are the key issues that have been considered when evaluating the energy consumption of aeration systems.

All sensor and actuator models have been implemented in Modelica and in the Matlab/Simulink platform.

The Automation & Control layer

The “automation & control” layer deals with modelling approaches for controllers and signal processing. Controller models range from simple ON/OFF controllers and common PID controllers to advanced controllers, such as Fuzzy Logic Controllers and model based or adaptive controllers. The described modelling approaches for signal processing cover signal converters, signal analysis, digital filters, fault detection, data input and output as well as pseudo real-time simulation and OPC communication. Regarding fault detection, it is noted that a fault detection strategy based on receiving and processing fault signals sent from sensors and actuators and therefore, i.e. on the integration with the “instrumentation & actuation layer” has been implemented, where the fault signal sent by the sensors and actuators depends on the fault state of sensors/ actuators.

All the models have been implemented in the Matlab/Simulink platform. Parts of the models have also been implemented in Modelica.

2) WWTP EMULATOR SW

The developed simulation tool is based on the TORNADO framework for modeling and virtual experimentation (Claeys et al., 2006) and the WEST® product suite (Vanhooren et al., 2003). TORNADO supports simulation of complex systems and provides software interfaces to standard software platforms, such as MATLAB/Simulink (www.mathworks.com), .NET, and C++. WEST® is an environment for dynamic modeling and simulation of water quality systems, such as wastewater treatment plants, sewers, and urban catchments, and is built on top of TORNADO.

Typically, the wastewater treatment processes and, the instrumentation, actuation and control systems are modelled using domain specific software tools. WEST/Tornado (Claeys et al., 2006) and Matlab/Simulink (M/S; www.mathworks.com) are correspondingly two well known and widely used modelling and simulation platforms. This work considers two implementation architectures: (a) one platform-based implementation and; (b) two platforms-based hybrid implementation. Thus, the (1) "mass" layer is built within the WEST/Tornado platform, whereas the (2) "instrumentation & actuation" layer and the (3) "automation & control" layer are built in both the WEST/Tornado and the M/S platforms. Having the entire plant modelled in one platform makes the interfacing between different models easier, whereas using a hybrid solution allows exploiting the power of every specialized software platform at the expense of making the interfacing between different models more complicated.

A conceptual diagram of the above software architecture for the two platforms-based implementation is given in Figure 4. In this example, the "subsystem" functionality of M/S has been employed to embed the "instrumentation & actuation" and "automation & control" layers separately. A specific M/S block has been used to communicate these two M/S-based layers with the WEST/Tornado-based "mass" layer. Since both M/S and WEST/Tornado have their own numerical solvers to simulate their models, a synchronization mechanism has been required to ensure a unique simulation time in both platforms. Typically, models in the "mass" layer have to be simulated using "stiff" solvers; in contrast, fixed-step solvers seem to be appropriate for simulating the two other layers. This feature and the fact that the "mass" layer has been embedded into a specific M/S block leads to a hierarchical architecture where the M/S solver is on top of the WEST/Tornado solver.

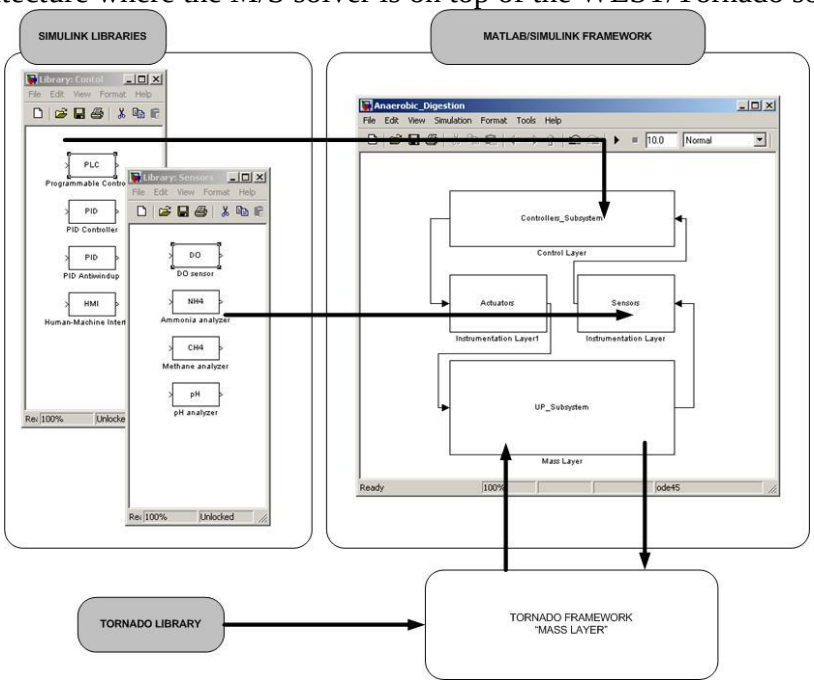


Figure 4. SW implementation of the proposed simulation software framework.

3) ADVANCED CONTROLLERS

Once the WWTP emulator software and the software library of models were available, the usefulness of the platform for the development of practical control solutions has been evaluated. Two different case studies have been analyzed by means of the proposed simulation framework:

(a) Full scale secondary treatment (water line) of the *Mekolalde* WWTP (Bergara, Spain).

(b) Pilot scale anaerobic digester located at INRA and fed by the industrial distillery wastewater of the distillery in Ornaisons, France (SCAD).

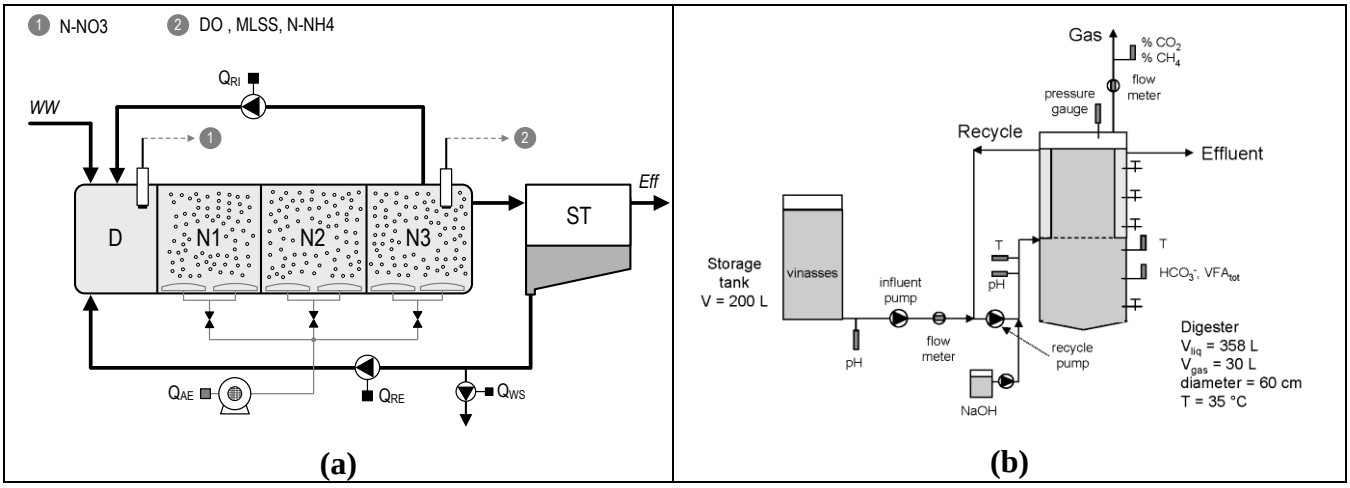


Figure 5. Validation case studies: (a) urban WWTP; (b) industrial anaerobic digester

Regarding the **secondary treatment** (water line) of the *Mekolalde* WWTP, once proven that the simulator for *Mekolalde* was fully operative for use, the next step was to explore its appropriateness to test and validate practical controllers before their implementation in a real control device. Taking into account that this plant must cope with nitrogen removal requirements, a decentralised control schema based on three non-interacting feedback controllers has been implemented, each of them devoted to control respectively (1) the **concentration of suspended solids** in the mixed liquor (MLSS); (2) the **ammonia concentration** in the last aerobic reactor; and (3), the **nitrates** in the first anoxic tank. Simulations carried out for testing the controllers showed their correct performance. By way of example, Figure 6 shows the shape of the DO reference trajectory which combines short-term (daily) and long-term (seasonal) variations in the wastewater. Lower and upper limits have also been considered (1 and 4 mg/L) in order to reproduce saturations in the control action of the outer loop.

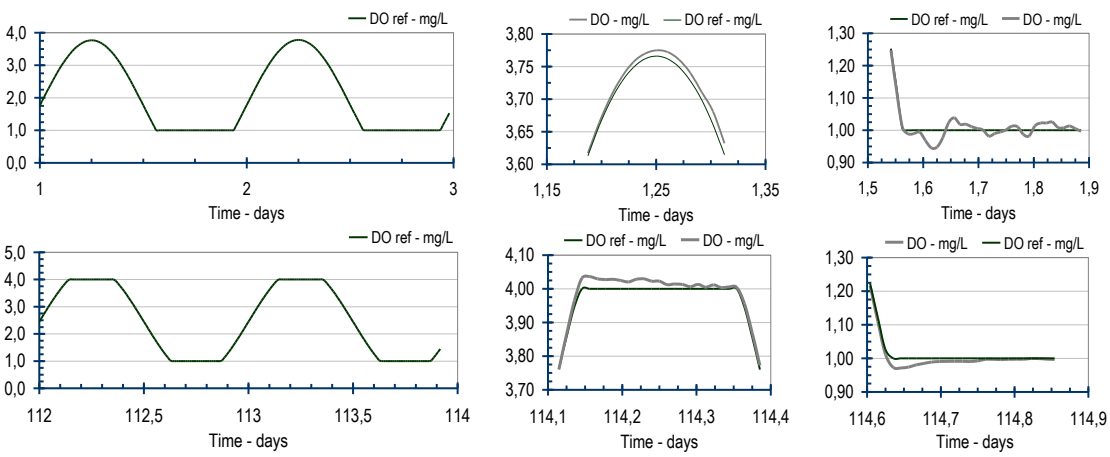


Figure 6. Performance results of the DO controller: tracking response.

Regarding the pilot scale **anaerobic digester**, **four different control strategies** have been designed and tested. Two of the controllers used PI controllers from the controller library of the "automation & control" layer. In addition, two model-based controllers, for total VFA control and methane gas flow rate control, have been developed and implemented in Matlab/Simulink. In all cases, aiming to mimic realistic conditions, signal noise has been activated at the "instrumentation & actuation layer". Simulations carried out for testing the controllers show that both conventional PI controllers and model-based controllers are able to keep the defined set-points despite variations in the influent COD concentration to the digester, and despite signal noise in the measurements.

These controllers have been validated in the real case-studies, obtaining positive results and validating the developed simulation software platform, models and advanced controllers.

4) ENHANCED TREATMENT TECHNOLOGIES

As previously mentioned, an urban WWTP and an industrial WWTP have been used as case-studies during the project. Thank to the advanced controllers develop using the ADD Control simulation software, the performance of the treatment technologies of these plants have been improved.

During the validation task of the project, it has been also validated that the developed "mass" layer is able to predict the behaviour of the real plants. This means that the ADD Control simulation software is appropriate for the design of both treatment technologies and advanced controllers.

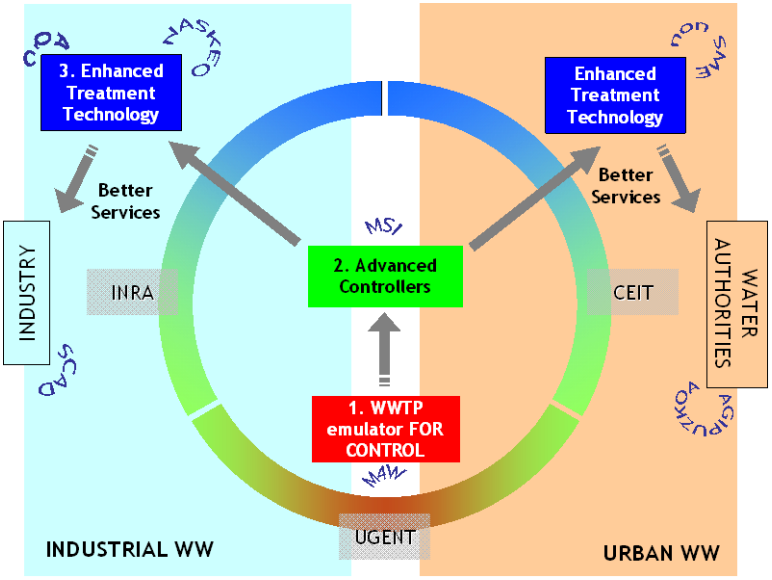
Regarding the secondary treatment (water line) of the *Mekolalde* WWTP, it corresponds to a **conventional pre-denitrifying activated sludge process** made up of four tanks arranged in series. The first tank operates under non aerated conditions, necessary to perform the denitrification of nitrates. On the other hand, a blower injects air into the other three reactors for supplying the oxygen required to keep the effluent ammonia concentrations below upper limits. After the implementation of the advanced controllers, the performance of the conventional activated sludge (without controllers) process was improved in terms of effluent quality and energy consumption. The enhanced activated sludge process is able to: (1) obtain the similar ammonia concentration in the effluent while reducing the nitrates concentration in the effluent; (2) reduce the power consumption of the biologic reactor by operating at lower oxygen concentrations and internal recirculation flow rates. Thanks to the positive results obtained in *Mekolalde*, it is convenient to analyse the implementation of the enhanced activated sludge process in existing or new urban WWTPs plants.

Regarding the **industrial anaerobic digester** treating distillery wastewater, although four advanced controllers were developed and analysed at simulation level, the following two control strategies were implemented and tested in the industrial anaerobic digester plant: 1) pH control using an incremental PI controller, and 2) linearizing control of the methane gas flow rate. Experimental results from the implementation of the pH control with an incremental PI controller show good results: the controller is able to keep the desired setpoint despite changes in COD influent concentration and load. Results obtained with the linearizing control of the methane flow rate are also promising. Thank to this enhanced industrial anaerobic digester, the operation of the digester is more stable (pH controller) and the biogas production is increased. In consequence the efficiency of the digester is improved.

Therefore, the real validations show that the simulation tool is useful to analyse the performance of the treatment technologies and improve their performance.

- **<u>THE POTENTIAL IMPACT</u>**

Following picture shows concept and different **possibilities of commercialization:**



As partners are completely complementary, there is need of distribution of market only between NASKEO and AQC. This is solved dividing European market, each in its local European area. AQC will exploit results from Germany (not including) to the East (including Norway, Sweden, Finland, Denmark, Easter countries and reaching the Mediterranean sea) and NASKEO the Western and South Europe (Belgium, Germany, Switzerland, Italy and the Western Europe)

In order to maximize the success of the commercial exploitation, the target group for dissemination and exploitation have been identified:

- **Control engineering companies**: Not only MSI will accede to WWTP emulator but also every control engineering company is a potential customer of this result. Thus, M4W will show via workshops and meetings the advantages of this solution. Firstly, to actual clients and then to potential users.
- **Environmental engineering companies**. MSI will commercialize advanced controllers to NASKEO and AQC covering both Industrial and Urban WWTP. Moreover, regarding Urban WW MSI will analyze environmental engineering companies with which solid commercial alliances will be established. MSI will contact to both end users and environmental companies in order to demonstrate the benefits of the project results.
- **End users**: Industry and Urban WWTP. Apart from actions to be done by MSI, NASKEO and AQC will exploit their current commercial routes in order to find potential end users of the developed solution. Initially, NASKEO will focus its commercial activities in Industry WWTP. However, it is planned that in a near future NASKEO may accede to Urban WWTP. AQC will focus its commercial activity in Industrial and Urban WWTP.

Dissemination activities:

There have been done different dissemination activities (publications in specialized and non specialized international journals, congresses, workshops and exhibitions and training activities to SMEs). All presentations and posters related with ADD CONTROL have showed the flag of the EU, the logo of the FP7 and the ADD CONTROL logo.

Exploitation of results:

Nowadays there are many planned to-do tasks but there are also some achievements. Most interest came from Environmental engineering companies related to Advanced controllers and Enhanced Treatment Technologies. At the moment exploitation of results could be summarized in the following way:

- Many visits and contacts have been done
- Industrial associations and their members were contacted through email and physically, taking advantage of meetings and congresses.
- Regarding end-users each SME is at the moment in contact with different plants. Not only European but also North-Africa and South America, where the implementation of enhanced treatment technologies and advanced controllers is being analysed.

Thus, the consortium started with the first exploitation activities during the project, which are still in process, and will focus in the exploitation of results after the end of the project.

- **The address of the project public website, if applicable as well as relevant contact details.**

http://www.addcontrol-fp7.eu/

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4.2 Use and dissemination of foreground

A plan for use and dissemination of foreground (including socio-economic impact and target groups for the results of the research) shall be established at the end of the project. It should, where appropriate, be an update of the initial plan in Annex I for use and dissemination of foreground and be consistent with the report on societal implications on the use and dissemination of foreground (section 4.3 – H).

The plan should consist of:

- Section A

  This section should describe the dissemination measures, including any scientific publications relating to foreground. **Its content will be made available in the public domain** thus demonstrating the added-value and positive impact of the project on the European Union.

- Section B

  This section should specify the exploitable foreground and provide the plans for exploitation. All these data can be public or confidential; the report must clearly mark non-publishable (confidential) parts that will be treated as such by the Commission. Information under Section B that is not marked as confidential **will be made available in the public domain** thus demonstrating the added-value and positive impact of the project on the European Union.

Section A (public)

This section includes two templates

- Template A1: List of all scientific (peer reviewed) publications relating to the foreground of the project.
- Template A2: List of all dissemination activities (publications, conferences, workshops, web sites/applications, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters).

These tables are cumulative, which means that they should always show all publications and activities from the beginning until after the end of the project. Updates are possible at any time.

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[2] (if available)	Is/Will open access[3] provided to this publication?
1	ADD CONTROL: Advanced control solutions for waste water treatment.	Brockmann, D., Steyer, J.-P., De Keyser, W., Nopens, I., Claeys, F., Urchegui, G. and Ayesa, E.	Reviews in Environmental Science and	Bio/Technology 10(1), 3-7. DOI 10.1007/s11157-011-9232-0.	Springer		2011			yes

[2] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).
[3] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

2	Development and evaluation of controllers for anaerobic digestion using a novel simulation tool	Brockmann, D., Steyer, J.-P., Latrille, E., Conte, T.,	Simulation and experimental results	In preparation	Process Biochemistry		2011			no
3	Realistic dynamic pumping energy models of wastewater applications	De Keyser, W.	Water research	In preparation	Elsevier		2011			no
4	Realistic and detailed dynamic modelling of a diffused aeration system´s energy consumption	Amerlinck, Y.	Water research	In preparation	Elsevier		2011			no

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date	Place	Type of audience[5]	Size of audience	Countries addressed
1	Conference	CEIT	10th IWA Conference on Instrumentation: Automation and Control (ICA2009)	June 2009	Cairns, Australia	Scientific Community (higher education, Research),		International ICA community from research and practice
2	Conference	CEIT	2nd IWA specialized conference on nutrient management in wastewater treatment processes	September 2009	Krakow, Poland	Scientific Community (higher education, Research), Industry		North American Water professionals
3	Conference	MSI, CEIT	Water platform conference: participation as listener to presentations related with simulation of WWTPs and Advanced controllers	Nov2009	Madrid, Spain	Scientific Community (higher education, Research), Industry		Spain
4	Conference	CEIT	Meta: Mesa española de Tratamiento de Aguas	2010	Bilbao, Spain	Scientific Community (higher education, Research), Industry		Spain
5	Conference	INRA, CEIT	2nd IWA/WEF Wastewater Treatment Modelling Seminar	March 28-30, 2010	Mont-Sainte-Anne, QC, Canada.	Scientific Community (higher education,	About 140 attendees	mainly european and north-american

[4] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[5] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias ('multiple choices' is possible.

			(WWTmod2010), International conference on modelling WWTPs			Research),		countries plus Mexico, India, Singapore, South Korea, Australia, New Zealand Attending plenary presentations on different aspects of modelling WWTPs, and active participation in conference workshops
6	Publications	INRA	12th IWA Specialist Conference on Anaerobic Digestion. International audience related to anaerobic digestion of organic substrates (both liquid and solid);	October 31 – November 4, 2010	Guadalajara, Mexico	Scientific Community (higher education, Research), Industry	About 700 attendees	mainly european, north- and latin-american countries plus Japan, China, Thailand, South Korea, Australia
7	Presentations	Ingmar Nopens (UGENT)	Kallisto	2 February 2011	Boxtel, The Netherlands	Industry, Policy makers	20	The Netherlands
8	Posters	INRA	Poster presenting project background, objectives, work plan, and partners involved in the project The poster is hanging	2011	Narbonne, France	Scientific Community (higher education, Research), Industry		National and international visitors to the laboratory of INRA

			in the hallway of INRA					
9	Conference	INRA	STIC & ENVIRONNEMENT 2011: About data acquisition, data treatment, modeling, and control;	May 11 – 13, 2011	Saint-Étienne, France	Scientific Community (higher education, Research), Industry		France
10	Conference	INRA	8th IWA Leading-Edge Conference on Water and Wastewater Technologies. Attendance as listeners	June 6 – 10, 2011	Amsterdam, The Netherlands	Scientific Community (higher education, Research), Industry		International Audience
11	Conference	ADD Control consortium	WATERMATEX 2011: "A MULTI-LAYER MODELLING SOFTWARE FRAMEWORK SUPPORTING THE DESIGN OF PRACTICAL CONTROL SOLUTIONS IN WWTPs"	20 June 2011	San Sebastian, Spain	Scientific Community (higher education, Research), Industry	150	World wide
12	Publications	CEIT, UGENT, INRA	WATERMATEX 2011: "A MULTI-LAYER MODELLING SOFTWARE FRAMEWORK SUPPORTING THE DESIGN OF PRACTICAL CONTROL SOLUTIONS IN	20 June 2011	San Sebastian, Spain	Scientific Community (higher education, Research), Industry	150	World wide

			WWTPs”					
13	Publications	CEIT	Autmonet 2011: “ADD CONTROL: PLANT VIRTUALIZATION FOR PRACTICAL CONTROL SOLUTIONS IN WWTP”	18 September 2011	Querétaro, Mexico	Scientific Community (higher education, Research), Industry	100	World wide
14	Presentation	CEIT	Autmonet 2011: “ADD CONTROL: PLANT VIRTUALIZATION FOR PRACTICAL CONTROL SOLUTIONS IN WWTP”	18 September 2011	Querétaro, Mexico	Scientific Community (higher education, Research), Industry	100	World wide
15	Conference	CEIT	World Water Congress & Exhibition	September 2012	Busan, Korea	Scientific Community (higher education, Research), Industry		World wide
16	Conference	CEIT, INRA, UGENT	11th IWA Conference on Instrumentation: Automation and Control (ICA2013) (organised by ADD CONTROL partner INRA)	2013	Narbonne, France	Scientific Community (higher education, Research),		International ICA community from research and practice

Section B (Confidential[6] or public: confidential information to be marked clearly)
Part B1

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

The list should, specify at least one unique identifier e.g. European Patent application reference. For patent applications, only if applicable, contributions to standards should be specified. This table is cumulative, which means that it should always show all applications from the beginning until after the end of the project.

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[7]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)

[6] Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.

[7] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2

Please complete the table hereafter:

Type of Exploitable Foreground[8]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[9]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	*Advanced controllers for biologic reactors of urban WWTPs and anaerobic digesters of industrial WWTPs*	*YES*		*Hardware / Software for implementation of controllers*	*Waste water treatment, urban and industrial*	2011/2012		*- MSI (Owner)*
Commercial exploitation of R&D results	*Enhanced Biologic reactor of urban WWTPs and Enhanced anaerobic digester of industrial WWTPs*	*YES*		*Hardware / Software for implementation of enhanced treatments*	*Waste water treatment, urban and industrial*	2011/2012		*- NASKEO / AQC (owners)*
Commercial exploitation of R&D results	*WWTP Emulation Software*	*YES*		*Software for the emulation of the WWTPs, based on use licences*	*Waste water treatment, urban and industrial*			
General advancement of knowledge	*Software library of models*	*YES*		*Library of the Mass, I&A and A&C layers*	*Waste water treatment, urban and*			*- MSI (co-owner)*

[19] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

[9] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Type of Exploitable Foreground[8]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[9]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
					industrial			

- Its purpose
- How the foreground might be exploited, when and by whom
- IPR exploitable measures taken or intended
- Further research necessary, if any
- Potential/expected impact (quantify where possible)

4.3 Report on societal implications

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	232302
Title of Project:	Advanced control solutions for waste water treatment
Name and Title of Coordinator:	Jose Maria Sagarna (R&D Manager)

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***NO***
2. Please indicate whether your project involved any of the following issues (tick box) :	***NO***
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	

• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	0 Yes 0 No
• Research having the potential for terrorist abuse	

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	1	6
Work package leaders	1	5
Experienced researchers (i.e. PhD holders)	2	10
PhD Students		
Other		

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**3**
Of which, indicate the number of men:	2

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?

○ Yes
X No

6. Which of the following actions did you carry out and how effective were they?

	Not at all effective				Very effective
❑ Design and implement an equal opportunity policy	○	○	○	○	○
❑ Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑ Organise conferences and workshops on gender	○	○	○	○	○
❑ Actions to improve work-life balance	○	○	○	○	○

○ Other:

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

X No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

X Yes- please specify: Watermatex 2011 Conference

○ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

○ Yes- please specify

X No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

X Main discipline[10]: 2.2

X Associated discipline[10]: 1.1

○ Associated discipline[10]:

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*

○ Yes
X No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

○ No

○ Yes- in determining what research should be performed

○ Yes - in implementing the research

○ Yes, in communicating /disseminating / using the results of the project

[10] Insert number from list below (Frascati Manual).

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ○ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture		Energy		Human rights	
Audiovisual and Media		Enlargement		Information Society	
Budget		Enterprise		Institutional affairs	
Competition		Environment		Internal Market	
Consumers		External Relations		Justice, freedom and security	
Culture		External Trade		Public Health	
Customs		Fisheries and Maritime Affairs		Regional Policy	
Development Economic and Monetary Affairs		Food Safety		Research and Innovation	
Education, Training, Youth		Foreign and Security Policy		Space	
Employment and Social Affairs		Fraud		Taxation	
		Humanitarian aid		Transport	

13c If Yes, at which level?

- ○ Local / regional levels
- ○ National level
- ○ European level
- ○ International level

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**4**
To how many of these is open access[11] provided?	**4**
How many of these are published in open access journals?	**1**
How many of these are published in open repositories?	**3**
To how many of these is open access not provided?	**0**
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[12]: ……	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		**0**
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**0**
	Registered design	**0**
	Other	
17. How many spin-off companies were created / are planned as a direct result of the project?		**0**
Indicate the approximate number of additional jobs in these companies:		

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

X	Increase in employment, or	X	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*

[11] Open Access is defined as free of charge access for anyone via Internet.
[12] For instance: classification for security project.

Difficult to estimate / not possible to quantify	X

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes X No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes X No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

❑	Press Release	X	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
X	Brochures /posters / flyers	X	Website for the general public / internet
❑	DVD /Film /Multimedia	X	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	X	English
❑	Other language(s)		

***Question F-10*:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as

geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]