Universitat de Girona

SUPERVISORY SYSTEMS IN WASTE WATER TREATMENT PLANTS: SISTEMATISE THEIR IMPLEMENTATION

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TESI DOCTORAL

Supervisory Systems in WasteWater Treatment Plants: Sistematise their Implementation

Memòria presentada per en Christian Cortés de la Fuente,
per optar al títol de Doctor Enginyer Industrial per la Universitat de Girona

Girona, Tardor de 2002

Als meus pares,
A la Marta

MANEL POCH ESPALLARGAS i JOAQUIM COMAS MATAS,
Pofessors d’Enginyeria Química de la Universitat de Girona,

CERTIFIQUEN:

Que el llicenciat Christian Cortés de la Fuente ha dut a terme, sota la seva direcció, el treball que, amb el títol *Supervisory Systems in WWTPs: Sistematise their Implementation,* presenta en aquesta memòria, la qual constitueix la seva Tesi per optar al Grau de Doctor Enginyer Industrial per la Universitat de Girona.

I perquè en prengueu coneixement i tingui els efectes que correspongui, presentem davant la Facultat de Ciències de la Universitat de Girona l’esmentada Tesi, signant aquesta certificació a

Girona, 8 d’Octubre del 2002

Manel Poch Espallargas Joaquim Comas Matas

Agraïments:

Haig d'agrair moltes coses i a molta gent, tantes coses i tanta gent que s'hem farà difícil recordar a tothom en aquestes línies. Per això demano disculpes a tot aquell que, per la meva mala memòria, nervis d'aquests dies, etc... no m'hagi recordat de ell o ella.

La defensa de la tesi, pel que m'han explicat, sempre ajuda a fer una parada en el camí i fer balanç de les coses que has fet, de les que no has fet, etc... dels últims anys i avaluar el teu propi creixement com a persona. Ara mateix em trobo en aquesta parada i al analitzar la meva vida en els últims quatre anys m'adono de que hi ha coses que he fet de les que estic molt content, d'altres de les que no i sempre queden coses que no es fan i es troben a faltar.

Una de les coses de les que estic més content es haver decidit, en el seu dia, prorrogar la meva educació. La continuació dels estudis universitaris mitjançant els estudis de doctorat m'ha fet créixer molt com a persona, m'ha permès ampliar els meus horitzons en tots els àmbits i m'ha permès conèixer molta gent molt maca. Aquestes oportunitats o fites que he assolit, ara mateix no tinc cap manera de saber si les hagués pogut aconseguir d'haver triat un altre camí en la meva vida, però sospito que no, si més no, no les mateixes.

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Vull acabar aquesta oratòria utilitzant les paraules que normalment sempre utilitzo per començar els meus discursos *Vull agrair, i agraeixo, la vostra assistència a aquest acte lúdico-festiu.*. espero que l'acte continuï durant molt de temps amb aquests actors i de nous.

Moltes gràcies a tothom!!

Resum

La implantació de Sistemes de Suport a la presa de Decisions (SSD) en Estacions Depuradores d'Aigües Residuals Urbanes (EDAR) facilita l'aplicació de tècniques més eficients basades en el coneixement per a la gestió del procés, assegurant la qualitat de l'aigua de sortida tot minimitzant el cost ambiental de la seva explotació. Els sistemes basats en el coneixement es caracteritzen per la seva capacitat de treballar amb dominis molt poc estructurats, i gran part de la informació rellevant de tipus qualitatiu i/o incerta. Precisament aquests són els trets característics que es poden trobar en els sistemes biològics de depuració, i en conseqüència en una EDAR. No obstant, l'elevada complexitat dels SSD fa molt costós el seu disseny, desenvolupament i aplicació en planta real, pel que resulta determinant la generació d'un protocol que faciliti la seva exportació a EDARs de tecnologia similar.

L'objectiu del present treball de Tesi és precisament el desenvolupament d'un **protocol que faciliti l'exportació sistemàtica de SSD** i l'aprofitament del coneixement del procés prèviament adquirit. El treball es desenvolupa en base al cas d'estudi resultant de l'exportació a l'EDAR Montornès del prototipus original de SSD implementat a l'EDAR Granollers. Aquest SSD integra dos tipus de sistemes basats en el coneixement, concretament els sistemes basats en regles (els quals són programes informàtics que emulen el raonament humà i la seva capacitat de solucionar problemes utilitzant les mateixes fonts d'informació) i els sistemes de raonament basats en casos (els quals són programes informàtics basats en el coneixement que volen solucionar les situacions anormals que pateix la planta en el moment actual mitjançant el record de l'acció efectuada en una situació passada similar).

El treball està estructurat en diferents capítols, en el primer dels quals, el lector s'introdueix en el món dels sistemes de suport a la decisió i en el domini de la depuració d'aigües. Seguidament es fixen els objectius i es descriuen els materials i mètodes utilitzats. A continuació es presenta el prototipus de SSD desenvolupat per la EDAR Granollers. Una vegada el prototipus ha estat presentat es descriu el primer protocol plantejat pel mateix autor de la Tesi en el seu Treball de Recerca. A continuació es presenten els resultats obtinguts en l'aplicació pràctica del protocol per generar un nou SSD, per una planta depuradora diferent, partint del prototipus. L'aplicació pràctica del protocol permet l'evolució del mateix cap a un millor pla d'exportació.

Finalment, es pot concloure que el nou protocol redueix el temps necessari per realitzar el procés d'exportació, tot i que el nombre de passos necessaris ha augmentat, la qual cosa significa que el nou protocol és més sistemàtic.

Abstract

The decision support systems (DSS) implemented in wastewater treatment plants (WWTP) make easier the application of better techniques based on the knowledge to manage the process, insuring the effluent quality and minimising the economical costs of its exploitation. The knowledge-based systems are characterised by its capability of working in ill structured domains, and with relevant information of type qualitative or uncertain. These are the characteristics that could be found in the biological systems treatments, and consequently in a wastewater treatment plant. However, the high complexity of the DSS makes very expensive their design, development and the application in a real WWTP, and because this reason it is very important the generation of a protocol that makes easier the exportation of the program to other similar plants.

The objective of the present document is the development of a protocol that makes easier the systematic exportation of DSS and the reuse of the process knowledge acquired previously. The document is developed in basis on the study case from the DSS exportation from the Granollers WWTP to Montornès WWTP. This knowledge-based system integrates two kinds of systems based on knowledge, concretely the rule-based systems (which are programs that simulate the human reasoning and its capability of problem solving using the same information sources) and the case-based reasoning systems (which are informatic programs based on knowledge that solve the current abnormal situations in the plant by means of retrieving the executed action in a similar past situation).

The document is structured in different chapters, in the first chapter; the lector is introduced in the DSS domain and in the wastewater treatment domain. Afterwards the objectives are defined and the materials and methods used are explained. Following, the Granollers DSS prototype is presented. Once, the prototype is explained, the first protocol made by the author in his research work is presented. Afterwards, the results obtained from the protocol application to export the DSS to other plant are presented. The real application of the protocol allows making better itself.

In conclusion, the new protocol reduces the needed time to make the exportation process, although the new protocol needs more steps to make the same work, this means that it is more systematic.

Abbreviations:

Acronyms	Means	Units
Ascent. vel.	Ascensional velocity	
BOD_5	Biological Oxygen Demand	mg O^2/l
CBRS	Case-Cased Reasoning System	
COD	Chemical Oxygen Demand	mg O^2/l
Cond	Conductivity	mS/cm
DO	Dissolved Oxygen	mg O^2/l
F/M ratio	Food to Microorganism ratio	kg BOD_5 /Kg MLSS·d
HMI	Human-Machine Interface	
HRT	Hydraulic Residence Time	$Days^{-1}$
KB	Knowledge Base	
KBS	Knowledge Based System	
KEMLG	Knowledge Engineering and Machine Learning Group	
LEQUIA	Laboratori d'Enginyeria Química i Ambiental	
MLSS	Mixed Liquor Suspended Solids	mg/l
MLVSS	Mixed Liquor Volatile Suspended Solids	mg/l
NH_4^+	Ammonia	mg N/l
NO_2^-	Nitrite	mg N/l
NO_3^-	Nitrate	mg N/l
P	Phosphorus	mg P/l
PLC	Programmable Logic Controller	
RAS flow rate	Return Activated Sludge flow rate	m^3/d
RBS	Rule-Based System	
RBS	Rule-Based System	
SCADA	Supervisory Control And Data Acquisition	
SRT	Sludge Residence Time	$Days^{-1}$
SS	Suspended Solids	mg/l
SVI	Sludge Volumetric Index	ml/g
T	Temperature	^oC
TKN	Total Kjeldhal Nitrogen	mg N/l
V30	Sedimentation test	mg/l
WAS flow rate	Waste Activated Sludge flow rate	m^3/d

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Chapter 1: Introduction

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1. Introduction

1.1. *Abstract*

This thesis is framed into a development process of an idea born in Lequia in the mid nineties. Since then, there has been an interaction between investigators from the Chemical Engineering Department at the University of Girona (Chemical and Environmental Engineering Laboratory, LEQUIA) and investigators from the Artificial Intelligence group at Universitat Politècnica de Catalunya (Knowledge Engineering and Machine Learning Group, KMSL). From this interaction was born the idea of unify both domains, the WasteWater Treatment Plant (WWTP) and the Artificial Intelligence (AI). This unification was intended to help the head of WWTPs to better control the treatment process, given that the conventional process control has many problems and errors.

At the end of the nineties, the second-generation EDSS prototype for a WWTP was created. This prototype was implemented in the Granollers WWTP, and that is where this thesis started.

During the period of the research work, we demonstrated that the prototype improved many aspects of the process control and won in reliability. The program was checked and it was proved that the head of the plant used the program like one more tool to control the process. These facts allowed considering the possibility of export the program to other WWTPs.

The main objective of a scientific discovery is for it to become valid for society; thus the discovery has to be useful, easy to use, and easy to implement. The prototype and the exportation protocol were made with these requirements in mind.

1.2. *The structure of the thesis*

The thesis objectives are explained in chapter 2. A set of studies, works, tests, and so on were performed to achieve these objectives. These efforts are collected, resumed and exposed in this document.

Each thesis chapter is structured, more or less, in the same way to facilitate the reading process and the comprehension of the ideas exposed. Chapters are usually divided into an abstract, where the main idea of the chapter is explained; an introduction, where one enters the subject more deeply; a core section, with detailed explanations; and a conclusions section, where the results of the chapter are presented and discussed.

- Chapter 1 is the thesis introduction. The main purpose in this chapter is that the reader becomes familiar with the thesis framework: the wastewater treatment process; the problematic points in the WWTP control, the main tools used to solve problems and how the marked objectives are achieved.

- Chapter 2 contains the thesis objectives.

- Chapter 3 consists of the materials and the methods used in this thesis development.
- Chapter 4 exposes the improvements made in the Granollers Environmental decision support system (EDSS) prototype.
- In chapter 5 the first approach to an exportation protocol is proposed. This protocol has to make able and easy the EDSS exportation to others WWTPs.
- Chapter 6 explains the exportation process made in Montornès WWTP, where the original protocol is applied.
- Chapter 7 describes the modified protocol to export the Prototype EDSS to other WWTP. The modifications are based on the experience acquired during design, development and implementation of the Montornès EDSS.
- Finally, chapter 8 exposes the conclusions that the PhD. Student found.
- In the Annex, the reader will find additional information referenced in the text.

The current chapter is structured as follows: the first part of the chapter tries to explain why wastewater treatment is necessary, as well as the legal framework. The second part explains the artificial intelligence tools used to help solve the problem of controlling these plants and the proposal that will be explained in the following chapters.

1.3. *Introduction*

Human activity generates residues that normally alter the health of the population as well as the ecosystem where they are evacuated or stored. These residues have increased enormously both in quantity and in levels of contamination throughout the time. Most of the environmental problems humans suffer at the present time are the consequence of the management of industrial residues for more than two centuries in a way that is now considered mistaken. Humans, as rational animals conscious of their acts, must maintaine and preserve the existing natural resources used for their survival, for the following generations, so that these can survive as well. This concept, known as sustainable development, allows humans to be able to develop themselves in a sustainable and rational way while preserving their environment

There is growing environmental concern in society, either in industries (e.g. the ISO 14001) or in politics (Kyoto's summit[1] or Rio de Janeiro's declaration[2]). In this frame, wastewater treatment is a hard-to-solve problem. The goal of Wastewater Treatment Plants (WWTP) is to provide a regulated outflow of water with a limited quantity of contaminants. These limits are established by governments in their efforts to ensure the environment quality of the receptor. Limits vary by country depending of the environmental commitment of their governments.

[1]http://www.panda.org/climate/summit/makebreakkyoto.rtf
[2]http://www.unep.org/Documents/Default.asp?DocumentID=78&ArticleID=1163

The Catalonia Generalitat **cleaning plan[3]**, based on council directive 91/271/CEE from the European Communities Official Diary, urges to treat the main urban wastewater contaminants that are poured in public river banks [Balaguer *et al*.1998]. The limits for the principal pollution indicators are the following:

Parameter	Concentration	Reduction percentage
BOD_5 (mg O_2/l)	25	70-90 %
COD (mg O_2/l)	125	75 %
SS (mg /l)	35	90 %
Total phosphorus (mg-P/l)	2 1 if > 100,000 inhabitant-eq	80%
Total nitrogen (mg-N/l)	15 10 if > 100,000 inhabitant-eq	70-80%

Table 1-1: Legal main parameters limits in Catalonia.

The Catalonia Generalitat **cleaning plan**, June 1996, defines the directives to water cleaning. These directives are orientated to:

- Preview the superficial, subterranean and marine waters contamination making special emphasis into the origin prevention.
- To return the potable and natural characteristics of subterranean and superficial waters.

The Catalonia Generalitat **cleaning plan** of June 1996 defines the directives for water cleaning. These directives are orientated to:

- Forecast the contamination of surficial, subterranean and marine waters, with special emphasis on prevention at origin.
- To return the potable and natural characteristics of subterranean and surface waters.

The main objective is to achieve a level of water quality that ensures the uses defined into the plan before 31/12/2005. Different development programs to achieve this objective compose the plan. Currently, the Urban Wastewater Cleaning Program 2002 (PSARUII) is running. The 91/271/CEE directive of urban wastewater cleaning and the frame directive about water policy 2000/60 frame this program, which intends to gives a solution to small population centres and reconsiders the treatment levels of WWTP proposed by PSARUI (increase the effluent quality). These improvements include the modification of actual WWTPs to allow higher quality levels at the WWTP outflows.

The PSARUI is the antecedent program; it basically focused on the wastewater treatment from large population centres, with more than 2000 inhabitants. Thus, the construction of aproximately 200 biological WWTPs was planed to achieve the water quality objectives.

In a biological wastewater treatment plant, the major challenge is to find out the current status of the process [Olsson and Newell. 1999]. A biological process is not known well enough and the head of the plant must treat a lot of information. Sometimes, he or she can not deal with all that information. Current developments in knowledge based systems offer opportunities for fault tolerance systems as well as the opportunity for dealing with complex systems in an integrated manner by considering qualitative and quantitative

[3] http://www.gencat.net/aca/cat/principal.htm

aspects simultaneously. Artificial Intelligence can help by providing efficient solutions to complex problems involving both quantitative and qualitative information as well as spatial and temporal aspects.

1.4. *Biological treatment systems*

The activated sludge process was initially developed by Fowler *et al*. [WEF, 1992] at the Manchester, England, wastewater treatment plant in the early 1900s [Operation of Municipal Wastewater Treatment Plants, volumeII]. Other bibliography locates the origin of wastewater treatment by means of activated sludge in Arden and Lockett in 1914 [Grady *et al*., 1999].

The activated sludge process is an aerobic, suspended growth, biological treatment method. This method uses the metabolic reactions of microorganisms to convert and remove the dissolved pollutants that have an oxygen demand in the wastewater. The microorganisms use the dissolved oxygen in water to consume the substrate (biodegradable organic molecules in wastewater). As a result of this consumption, the microorganisms obtain the necessary energy to maintain their vital functions, at the same time that new individuals are generated [WEF, 1996].

It is a flexible, reliable process capable of producing a high quality effluent. The main objective is organic matter removal. The activated sludge can also remove other kind of pollutants like nitrogen and phosphorus. The biological nutrient removal (BNR) processes are modifications of the activated sludge processes that incorporate anoxic and/or anaerobic zones to provide nitrogen and/or phosphorus removal [Grady *et al*., 1999].

The activated sludge process is perhaps the most widely-used process for the removal the pollutants in the wastewater. Because this reason the first EDSS prototype made was directed to a plant treatment process that uses this method to treat the wastewater.

There are many different process configurations, such as conventional activated sludge (CAS), step-feed activated sludge (SFAS), contact stabilization (CSAS), completely mixed (CMAS), extended aeration (EAAS), high-purity oxygen (HPOAS), selector (SAS) and sequencing batch reactor (SBRAS), plug flow, modified aeration, high-rate aeration, and oxidation ditch [Grady *et al*., 1999; Operation of Municipal Wastewater Treatment Plants, volumeII].

The activated sludge process is highly controllable, and its operation can be adjusted in response to a wide range of conditions [Grady *et al*., 1999]. The main problem consists of the difficult to control the process. The plant operations require qualified and experienced personnel 24 hours a day.

1.4.1. **Biological Treatment**

Diverse operations and processes are involved in the wastewater treatment. Different combinations of these systems, physical, chemical and biological, configure the WWTP process diagram.

Any biological WWTP configuration usually follows the same sequence with two lines. The water line consists of three major processes, a primary treatment, a secondary treatment and a tertiary treatment. The primary treatment makes a screening of solids from the water and afterwards the organic settleable matter is decanted. The secondary treatment consists in the biological process, where a multispecifical microbiological population degrades the dissolved organic matter in the water. Then, the secondary sedimentation separates the Mixed Liquor Suspended Solids (MLSS) to produce a clarified effluent. Both sedimentable phases generate solids that follow the sludge line. This usually consists of thickening, anaerobic treatment and drying processes.

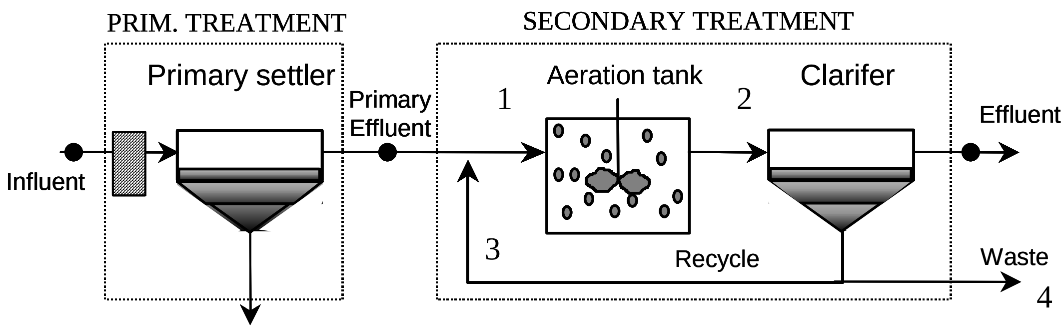

Figure 1-1: Typical configuration of activated sludge treatment plant.

The concentrated solids thickened in the secondary settler can be recycled via the Recycled Activated Sludge (RAS) stream back to the reactor or wasted out of the system by the Wasted Activated Sludge (WAS) stream. The concentrated biological solids are recycled back to the aeration tank to maintain a concentrated population of microorganisms to treat the wastewater. The continuous production of microorganisms generates an excess and the WAS is the way to put them out of the system. Four factors are common to all activated sludge systems [Grady *et al*. 1999]:

1. Flocculent slurry of microorganisms (mixed liquor suspended solids [MLSS]) is utilized to remove soluble and particulate organic matter from the influent waste stream.
2. Quiescent settling is used to remove the MLSS from the process flow stream, producing an effluent that is low in suspended solids.
3. Settled solids are recycled as a concentrated slurry from the clarifier back to the bioreactor.
4. Excess solids are wasted to control the Sludge residence time (SRT) to a desired value.

The bioreactor that contains the MLSS is also called aeration basin. This bioreactor is aerobic to facilitate the better conditions to oxide the organic matter and to facilitate the sludge mixing with the substrate. Three reactions are involved in the organic matter oxidation [Comas, 2000]:

$$\text{Energy: Organic matter} + O_2 \xrightarrow{\textit{microorganisms}} CO_2 + H_2O + \text{other products} + \text{energy}$$
$$\text{Synthesis: Organic matter} + O_2 + \text{energy} \xrightarrow{\textit{microorganisms}} \text{new cells}$$
$$\text{Decay: Microorganisms} + O_2 \rightarrow CO_2 + H_2O + \text{energy}$$

Figure 1-2: Main organic matter removal reactions within biological reactor.

Nitrification occurs during the aerobic growth of a class of organisms called authotrophs which convert ammonium compounds to nitrites/nitrates [Olsson and Newell, 1999].

The best WWTP is that which fulfils the standard of water quality and attains this standard in a sustainable way. The WWTP system has to be able to keep the outflow under environmental law limits, and minimize environmental effects [Miquel Sànchez *et al.*, 1996]. This way implies to achieve its objectives with the minimum environment impact and this concept includes since the WWTP is built to the water treated flow quality.

1.4.2. **Biological process control**

The complexity of the process – composed of several operational units – makes it difficult to implement an automatic process control over the wastewater treatment plant system [M. Sanchez-Marrè *et al*. 1996]. The internal process relationships between different system elements are not known sufficiently well and the information from the process is not structured, or is unclear, and sometimes the information does not even exist. This situation makes it difficult for the head plant to control the process.

One important point in the management of a wastewater treatment plant is the quality of the information collected by the head of the plant and the correct processing of this information. If the head of the plant has little data he cannot make a good follow-up of the process. On the other hand, when he has too much data, a saturation of information is made and the head of the plant also cannot make a good follow-up of the process.

One way to confront the complexity of activated sludge systems and accomplish the control of these systems, consist in instrument the WWTP with sensors. These allow uses to know the operation conditions in the process and therefore to increase the percentage of removal.

The following table illustrates the level of instrumentation in a medium-sized WWTP with activated sludge process, with an indication of the usage level of each sensor together with their main use. It can be foreseen that in the near future new and more reliable on-line sensors will become available to help the heads of WWTPs do their job.

Parameter	Usage	Used for
Temperature	+++	M
Conductivity	++	M
PH	+++	M
Redox Potential	++	M
Air Pressure	++	M
Water level	++	M
Water flow	+++	M, B, F
Air flow	+++	M, B
Dissolved oxygen	+++	M, B
Turbidity	+++	M
Total suspended Solids	++	M
Sludge Blanket level	+	M
BOD_5	+	M
COD	+	M
TOC	+	M
Ammonia	+	M
Nitrate	+	M
Total nitrogen		
Phosphate	+	M
Total phosphorus		
Respiration, activity	+	M
Toxicity	+	M
Sludge Volume index		

Table 1-2: Level of instrumentation at WWTPs (50.000 p.e.) in Spain and the main purpose of the measurements. +: seldom used; ++: frequently used; +++: normally used; M: Monitoring; B: Feedback control; F: Feed-forward control.;[U.Jeppsson *et al.*]

Sometimes airflow sensors, water sensors and dissolved oxygen sensors, can be used in the control of the process and in a common WWTP, the sensors can been used in many ways:

- **Monitoring:** where the sounding makes a continuous follow of the main variables of the process.
- **Feedback control:** this type makes a follow of different variables and makes an action over the variable to retrieve the process. This uses direct measurements of the controlled variables.
- **Anticipated control:** in this type of control the perturbation is analysed previous to the entrance to WWTP and makes an action is made in the process to minimize the effect of the perturbation.
- **Distributed control:** this kind of control can keep the plant running by a large number of local controllers for physical variables. The distributed control systems by PLCs, usually implemented as Supervisory Control and Data Acquisition (SCADA) systems provides a robust control over the process faults and enables system supervision [Comas, 2000].

Classical control methods have been used to improve and optimise WWTP operation. However, this classical approach, based on mathematical modelling, shows some limitations when trying to control the activated sludge process, mainly when the plant is not working in the ideal state [Miquel Sànchez-Marrè *et al.*, 1999]. Despite the quick advances in sensor technology, the amount of data collected this way is very reduced. Then the head of the plant has to make decisions about the process with the analytical data from the laboratory, with microbiological analysis and with qualitative observations of the process.

1.3.3. Management of biological processes

Environmental processes are complex systems, involving many interactions between physical, chemical and biological processes [Comas, 2000]. The successful management of environmental processes requires a multi-disciplinary approach and considerable expertise in diverse fields. Specifically, the biological process within a wastewater treatment plant cannot be well managed with a classical control only.

Control of the biological process is usually a set of routine actions over the control loops of the plant. But when the plant process is not running correctly, the head of the plant has to change the set-points of the control loops. Sometimes, these changes are not easy to detect and to modify.

When the WWTP does not run correctly, the head of the plant has to deal with a large amount of process data (on-line information, off-line information, qualitative information, engine failures, and so on) in trying to return the plant to a better process situation. Thus, the plant manager often encounters too many problems to manage correctly the biological process of the plant.

The biological process has many features that make it a very complex system without any pattern and the head of the plant has to manage the plant with the characteristics explained above. The head of the plant has access to several process control systems that facilitate this task. Usually, the head of the plant uses the following strategies to operate activated sludge processes that make the organic matter removal: i) aeration and dissolved oxygen control, ii) return activated-sludge control methods, and iii) waste activated-sludge control methods [Operation of Municipal Wastewater Treatment Plants, volume II]. Any change in one parameter can modify the others.

i) **Aeration and dissolved oxygen control** has two main objectives: keep the oxygen concentration within the appropriate limits to maintain the microorganisms active, and ensure that the tank contents are sufficiently well mixed to keep the solids in suspension and well-mixed with the wastewater. On the one hand, low dissolved oxygen concentration can limit the growth of microorganisms and induce the predominance of filamentous bacteria, with the subsequent deterioration of the effluent quality. On the other hand, high dissolved oxygen concentration represents a high-energy waste, generates excess turbulence, and may break up the biological floc resulting in poor settling characteristics and high concentration of solids in the effluent.

   Today, the dissolved oxygen concentration is well controlled in many WWTPs by means of current control loops. The dissolved oxygen concentration set-point can be changed in different reactor parts to make nutrient removal or other operations easier.

ii) **Return activated-sludge control methods** allow maintaining a suitable contraction of the mixed liquor, which keeps the activated-sludge process operating properly.

A percentage of the MLSS settled in the clarifier is returned back to the reactor as RAS. This action allows keeping the right concentration of microorganisms in the aeration tanks to biologically treat the wastewater. The return sludge flow rate has to be well calculated to avoid the different solids concentrations between operation units and other operational problems. There are three ways to return sludge to the reactor, by means of a constant rate, a constant percentage of secondary influent flow, and a varying rate to optimise the concentration and retention time of clarifier solids.

There are different RAS control techniques: direct sludge blanket level control, settleability, secondary clarifier mass balance, aeration tank mass balance, and sludge quality.

iii) **Waste activated-sludge control methods** are the most important techniques to control the solids inventory in the system. The wasting rate (WAS) is used to control the solids. The wasting of sludge affects the system more than any other process control adjustment. It can affect effluent quality, the microorganisms growth rate and types, oxygen consumption, mixed liquor settleability, nutrient quantities needed, the occurrence of foaming and the possibility of nitrification. There are four methods to effect WAS control: constant Sludge Residence Time (SRT), constant F:M ratio, constant MLSS, and sludge quality.

Environmental systems and WWTPs	General characteristtcs	✓	Dynamic.	Environmental systems evolve over time [Guariso and Werthner, 1989, Rizzoli and Young, 1997]. They are subject to continuous changes that can directly modify the performance of the process [Miquel Sànchez *et al.*,1996].
		✓	Spatial coverage.	Environmental systems involve physical processes which take place in a 2- or 3- dimensional space [Guariso and Werthner, 1989, Rizzoli and Young, 1997]
		✓	Randomness.	Many environmental processes are stochastic. In addition, the parameters of models representing such processes are usually uncertain, and their ranges are commonly known only approximately. These attributes call for techniques such as statistical analysis and qualitative analysis of model equations [Guariso and Werthner, 1989, Rizzoli and Young, 1997]
		✓	Periodicity.	Many environmental processes are periodic in time, which adds a degree of complexity to parameter calibration and validation [Guariso and Werthner, 1989, Rizzoli and Young, 1997].
		✓	Reliability:	Important maintenance efforts are necessary for the reliable functioning of the on-line analysers (for ammonia, nitrite, nitrate and dissolved oxygen) on which the data models are based [Ceccaroni, 2001].
		✓	Non-linearity	The reactions of the activated sludge process often reach pseudo-stability when substrates, nutrients or oxygen are limited [Comas 2000].
		✓	The WWTP domain ill-structure	Environmental systems are poor- or ill-structured domains [Comas 2000]. Mathematical models often are unable to represent biological processes because these do not follow a established pattern.
	Inflow	✓	Quality variability of inflow.	
		✓	Quantity variability of inflow.	Influent disturbances are enormous [Olsson and Newell, 1999].
		✓	Inflow is continuous and not controllable.	Inflow must be accepted and treated —the possibility of returning to the supplier does not exist [Olsson and Newell, 1999].
	Process	✓	Complex and dynamic process (physicochemical and biological interactions).	Environmental systems are complex, usually involve interactions between physicochemical and biological processes [Guariso and Werthner, 1989, Rizzoli and Young, 1997].
		✓	The population of microorganisms varies with time.	
		✓	The knowledge of the mechanisms of the process is limited.	
		✓	Few on-line reliable analysers and delay in analytical determinations.	
		✓	Incapacity of controllers to work with high number of symbolic variables.	
		✓	Incapacity to have an historic library of the plant historical situations.	
		✓	Low usage of experts' knowledge.	
		✓	Delays in data capture.	Information arrives at the control system with varying delays with respect to the sampling time [Ceccaroni, 2001].
		✓	The use of subjective information.	
		✓	Heterogeneity and Scale.	Processes in different media may have quite different characteristic time and space scales [Guariso and Werthner, 1989, Rizzoli and Young, 1997].
		✓	Lack of knowledge	Detailed knowledge of the treatment process is limited and theoretical understanding of biological phenomena such as bulking or foaming is still poor [Comas 2000].
		✓	Huge amounts of information and data.	The volume of data is so high that it is not an easy task for process experts to acquire, to integrate and to understand all this day-to-day increasing amount of information [Comas 2000].
		✓	Control objective	The control objective can change in some special conditions.
	Effluent	✓	Effluent limits	The legal regulations of the wastewater effluent have varied over time [Comas 2000].

Table 1-3: Characteristics of environmental systems and WWTP characteristics.

Successful operation in activated sludge treatment plants can be achieved only if each operator is able to recognize system changes and trends and make the proper decisions to successfully counteract potentially harmful changes [Operation of Municipal Wastewater Treatment Plants, volume II].

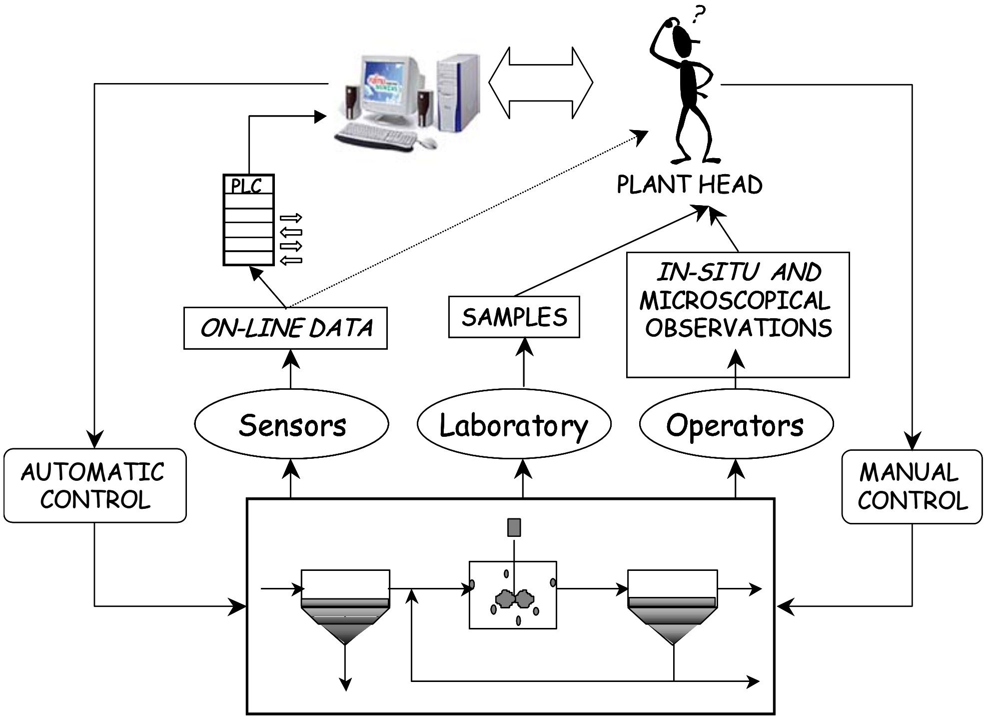

Figure 1-3: Data acquisition and current management in a WWTP.

Current management of WWTPs is summarized in the above diagram. The biological process generates a large amount of data from the operation of sensors, the analysis of samples and observations of operators. Thus, what is really important is to know how to interpret the signals provided by the sensors and the qualitative observations. Classical control systems cannot do this.

On-line information is collected by a set of Programmable Logic Controllers (PLCs) that transfers it to the Supervisory Control and Data Acquisition (SCADA) system. The latter can interact with the process by modifying automatically some parameters, or it can only show the information to the head of the plant. Off-line information is provided by the analysis of process samples. Qualitative observations provide valuable information on the current operating conditions in activated sludge systems, thereby helping operators to make decisions about alterations in process control parameters [Grady *et al*. 1999]. Microbiological information is used to know the condition of the microorganismal fauna.

The difficulty to manage correctly the operation of WWTPs has prompted the development of a number of tools that promise an advanced and efficient management of the process, especially when the process is far from the ideal situation. Supervision and control of activated sludge processes can only be treated in a multi-disciplinary way, which includes: monitoring, modelling, control, qualitative information, expert knowledge and experimental knowledge [Miquel Sànchez *et al*., 1996].

1.5. *Knowledge-Based Systems*

Wastewater treatment plants have many special features (see table 1-3) that make it difficult to represent the biological processes involved by means of mathematical models, and classical control systems cannot, by themselves, identify problem situations in activated sludge processes when detection requires on-line, off-line and heuristic information.

The proven insufficiency of chemical engineering classical control methods applied to WWTPs [M. Sanchez-Marrè *et al*. 1996] and the necessity to increase the control efficiency encourage the search for new methods that can use all the different types of knowledge available in a WWTP [Baeza, 1999]. A valuable alternative is found in the knowledge-based systems [Bañares, 1992]. KBSs are interesting because they can work with ill-structured domains, with qualitative and mixed, uncertain knowledge — the kind of knowledge typically available from biological systems [Hitzman, 1992; Knostantinov, 1992].

In this frame, AI can be very useful. Once problems in the WWTP process control are recognized, knowledge-based systems (KBS) can help in identifying them. The knowledge-based control attempts to incorporate the positive intelligence and creative attributes of human controllers, whilst avoiding the elements of inconsistency, unreliability, temporal instability, and fatigue associated with the human condition. [Olsson and Newell, 1999].

Knowledge-based systems (KBSs) are not only based on the control systems and mathematical models but on human behaviour and on computer science [Olsson and Newell, 1999]. KBSs are computational tools that enable the integration of numerical data and heuristic knowledge and mimic the human-decision making processes to solve complex problems. These systems are capable of using the knowledge of human experts, acquired through years of experience, to diagnose the state of a process, and to propose solutions to new problems [J. Comas *et al*. 2002]. These systems seek to enable a non-expert user to emulate the problem solving capability of an expert within some specialised domain of expertise [Olsson and Newell, 1999].

The potential use of KBSs to support the operation of WWTPs came into picture in the early 1980s. In the 1990s several interesting proposals were developed (*e.g.* Chan and Koe, 1991, Ladiges and Kayser, 1993, Ozgur and Stenstrom, 1994, and Bergh and Olsson, 1996). These applications never really succeeded because they were too complex, and the available knowledge could not be captured in reliable models and advisory systems [Olsson *et al.*, 1998]. In fact, a rigorous evaluation of these proposals could never be done since they were not installed in actual facilities, but performed under hypothetical simulated problem testing, presented as simplified case studies, or supervising specific experiments carried out in pilot plants.

The first generation of KBSs represented the first step in trying to help in biological processes control. Unfortunately, the programs developed in this decade, the 1990s, were designed to treat only off-line data, and a many of them were never implemented in a real system. Knowledge based technologies have been developed as off-line consultations for diagnosis, design, process optimisation, and so on [Miquel Sànchez *et al*. 1996]. These approaches only solve certain aspects of the problem.

Bergh and Olsson [Bergh and Olsson, 1996] created a knowledge-based system to diagnose solid-liquid separation problems in a WWTP. This system was tested with six-month data from a WWTP.

Ozgur and Stenstrom [Ozgur N.H. and Stenstrom M.K., 1994] presented a KBS for the control of the nitrification process in activated sludge systems. This program was not implemented in a real plant.

A new generation of KBS is being proposed recently. These are based on hybrid architectures that combine classical expert systems with soft computing (neural networks, fuzzy logic) and complementary knowledge-based techniques to deal with specific knowledge of the process (*e.g.* case-based reasoning). Some of these systems, which include real-time intelligent data interpretation and validation (also handling different scale qualitative information), have been successfully implemented and evaluated in real facilities (*e.g.*, Wen and Vassiliadis, 1998, Puñal *et al.*, 2001, Baeza *et al.*, 2002 and Rodríguez-Roda *et al.*, 2002).

The development of a KBS involves the crucial steps of knowledge acquisition, knowledge representation and knowledge implementation. The knowledge acquisition can easily become a bottleneck in building a good quality system. In order to build a complete knowledge base, several knowledge sources and methods can be used. Methods to identify and collect this information include those involving the human senses (*i.e.* carrying out interviews with the experts or reading specialized literature), and those involving the use of machines (automatic learning tools) to acquire knowledge from a database [Sànchez-Marrè *et al.*, 1997]. All the knowledge acquired during the knowledge acquisition process can be then synthesized in a suitable and understandable form of representation such as a decision tree. [J. Comas *et al*. 2002]

The expert knowledge can be implemented in two ways into a process control system. These are the direct expert control and the supervisory expert control [Knostantinov, 1993].

In the direct expert control, the knowledge modules are integrated in the control loop; fuzzy controls are belong to this kind of control. Fuzzy logic decreases the system's complexity by means of a representation of its structure in a linguistic form [Alsina, 1998]. The characteristics of fuzzy systems allow them to overcome the computational bottlenecks of expert systems Supervisory expert controls are hierarchically superior to the conventional process controls. In this case the knowledge is not integrated in the control loop. This control improves on the control system by incorporating the capability of making intelligent decisions based on the expert interpretation of the complex process behaviour [Baeza, 1999].

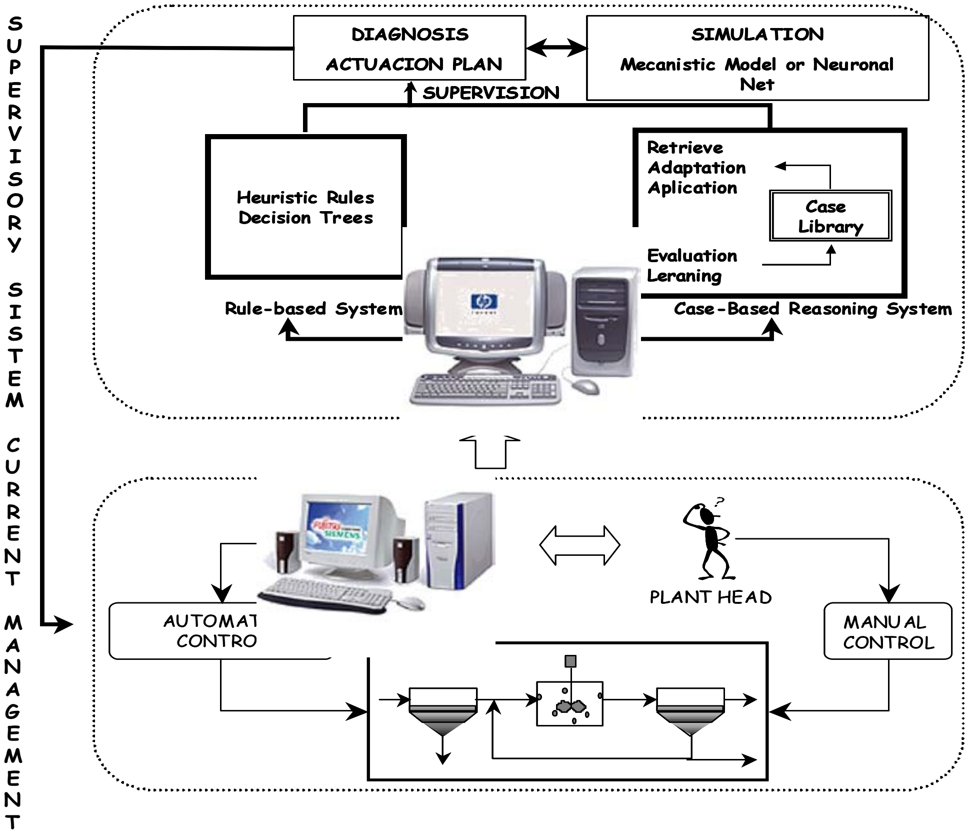

Figure 1-4: Hierarchical location of the KBS over the classical control.

The Granollers KBS uses two tools from the artificial intelligence: i) the Rule-Based Systems (also known as Expert systems) and ii) the case-based reasoning system. These tools are explained in the following sections.

1.5.1. KBS development process: AI Tools

The selection of an appropriate technique for the supervision and control of complex processes is crucial for achieving optimal results [Ignasi R-Roda *et al.*, 1999]. The knowledge-based system developed for Granollers uses two tools from the artificial intelligence domain.

The rule-based expert system.

In the late 1960s to early 1970s, expert systems emerged in the field of AI [Badiru, 1992]. Expert systems are the most successful demonstration of the capabilities of AI. The first truly commercial applications of AI are expert systems.

Rule-Based Expert Systems (RBESs) are advanced computer programs which emulate, or try to emulate, the human reasoning and problem-solving capabilities, by using the same sources of knowledge within a particular discipline. An ES is an interactive computer program that attempts to emulate the reasoning process of experts in a given domain over which the expert makes decisions [M.Poch *et al.*, 2000]. An ES operates as an interactive system that responds to questions, asks for clarification, makes recommendations and generally aids in the decision making process by using both facts and heuristics.

The structure of an ES presents two main independent modules: The knowledge base (KB) and the inference engine. While the KB contains the overall knowledge of the process, usually codified by means of heuristic rules, the inference engine is the software that controls the reasoning operations of the ES, chaining optimally these rules.

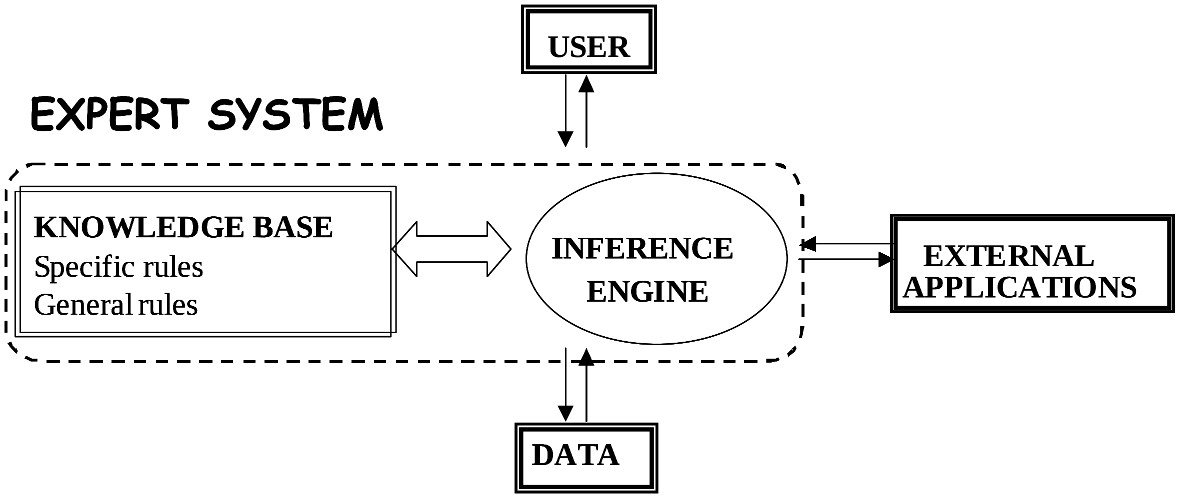

Figure 1-5: Rule-based expert system structure.

The knowledge acquisition for the knowledge base is difficult and, due to this reason, this task represents the main bottleneck in the ES design and development. There are several sources of information such as scientific literature searches, analysis of historical data from the plant and meetings with experts. The development of a specific knowledge is based in means of both meetings with the plant head and historical data study. On the other hand, this specific knowledge would be completed with general information about the troubleshooting at activated sludge treatment facilities compiled from specialised journals.

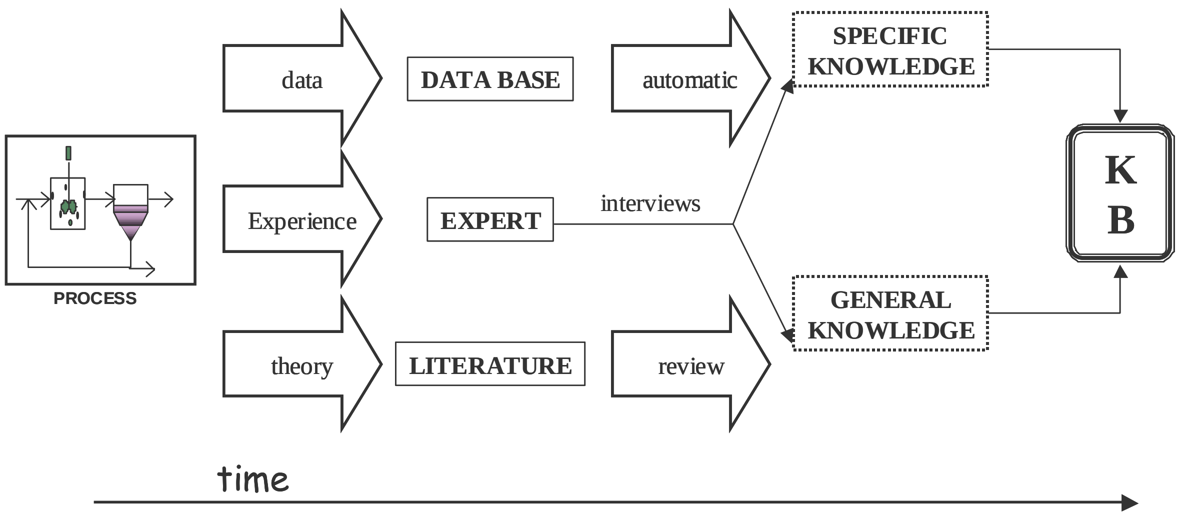

Figure 1-6: Knowledge sources for rule-based expert system knowledge base.

Interviews with plant managers are an important source of specific knowledge about the plant, although neither can achive a high level of concreteness, and the program is not concrete enough for a specific plant.

Once the knowledge has been collected, it is represented into decision trees. The goal is to structure the information. All symptoms, facts, procedures and relationships used for problem diagnosis [Poch *et al*., 2000] and problem solving can be included in these trees.

Next, the rules are made. These represent the knowledge included into the decision trees. ***If-then*** rules are used to develop the knowledge base. These rules contain premises or conditions in the ***if*** clauses, and conclusions in the ***then*** clauses [Badiru, 1992].

The inference engine can work in two ways: forward chaining or backward chaining [Mockler, 1992]. Forward chaining consists in the examination of the IF clauses and the search for a solution. When the answer to the entire IF clause is found in a rule containing a goal word in its THEN clause, the program gives the user its recommended solution. Forward chaining can expand very rapidly, since a virtually unlimited number of rules may be examined.

Backward chaining starts with one or more possible goals. The inference engine tests every goal to see whether or not the IF clauses in the rule containing every possible goal are all true.

The benefits of expert systems are:

- ESs increase the probability and frequency of making consistently good decisions.
- ESs help distributed human expertise.
- ESs afcilitate the inclusion and retention of heuristic knowledge from experts.
- ESs allow the processing of qualitative information.
- Knowledge is represented in an easily understandable form (rules).
- Large general knowledge base, with flexible use for any WWTP management.

Problems:

- The Rule-based systems are typically very domain-specific.
- Knowledge is general.
- Lack of specificity in the actions proposed.
- Knowledge base is static.

[Poch *et al*., 2000].

Case-based reasoning systems

The foundations case-based reasoning systems (CBRS) rely on the early work done by Schank and Abelson [Miquel Sànchez-Marrè *et al*., 1997]. Case-based reasoning systems are knowledge-based computer programs that attempt to solve current abnormal situations in any domain by remembering what was done in a similar historic case.

CBRS is the second artificial intelligence tool chosen because it provides an adequate framework to cope with continuous domains, where a great amount of new valuable experiences are continually [Miquel Sànchez-Marrè *et al.*, 1999] and because it provides specific knowledge. For these reasons, the CBRS was chosen to complement the rule-based expert system in the WWTP domain.

The CBRS can also increase its knowledge base, the case library, by learning about new situations in the WWTP. This case library started wit a set of cases obtained from historical data for our study plant. Afterwards, the library was increased with new plant situations.

The CBRS proceeds through four steps to achieve its objective: i) retrieving the most similar case, ii) adapting or re-using the information, iii) evaluating the proposed solution, and iv) learning [Miquel Sànchez-Marrè *et al.*, 1997].

i) **Retrieving the most similar case** is accomplished by selecting the best case by means of a case-ranking process through a similarity or distance function. The selection of the best case available from the retrieved cases is based on a quantitative similarity criterion. In the present work, the distance called *L'Eixample* [Sànchez-Marrè *et al.*, 1998], which is a normalised exponential weight-sensitive distance function, was applied.

The *Eixample* distance is defined as:

$$d(C_i, C_j) = \frac{\sum_{k=1}^{n} e^{w_k} \times d(A_{ki}, A_{kj})}{\sum_{k=1}^{n} e^{w_k}}$$

where

$$d(A_{ki}, A_{kj}) = \begin{cases} \dfrac{|\,quantval(A_{ki}) - quantval(A_{kj})\,|}{upperval(A_k) - lowerval(A_k)} & \text{if } A_k \text{ is an ordered attribute and } w_k \le \alpha \\[2ex] \dfrac{|\,qualval(A_{ki}) - qualval(A_{kj})\,|}{\#\mathrm{mod}(A_k) - 1} & \text{if } A_k \text{ is an ordered attribute and } w_k > \alpha \\[2ex] 1 - \delta_{qualval(A_{ki}),qualval(A_{kj})} & \text{if } A_k \text{ is a non-ordered attribute} \end{cases}$$

and,

C_i is case i; C_j is case j; W_k is the weight of variable k; A_{ki} is the value of variable k in case i; A_{kj} is the value of variable k in case j; qtv(A_{ki}) is the quantitative value of A_{ki}; qtv(A_{kj}) is the quantitative value of A_{kj}; A_k is the variable k; upperval(A_k) is the upper quantitative value of A_k; lowerval(A_k) is the lower quantitative value of A_k; α is a cut point on the weight of the variables; qlv(A_{ki}) is the qualitative value of A_{ki}; qlv(A_{kj}) is the qualitative value of A_{kj}; #mod(A_k) is the number of modalities (categories) of A_k; and $\delta_{qlv(Aki),qlv(Akj)}$ is the δ of Kronecker [Comas, 2000].

ii) Adapting or reusing the information and knowledge from the previous case to solve the new case. The selected best case has to be adapted to the characteristics of the new situation in the plant.

iii) **Evaluating the proposed solution** is made by the plant head, who evaluates whether the proposed solution executed was good or wrong. Both types of information are useful for future similar situations.

iv) **Learning** the parts of this experience likely to be useful for future problem solving.

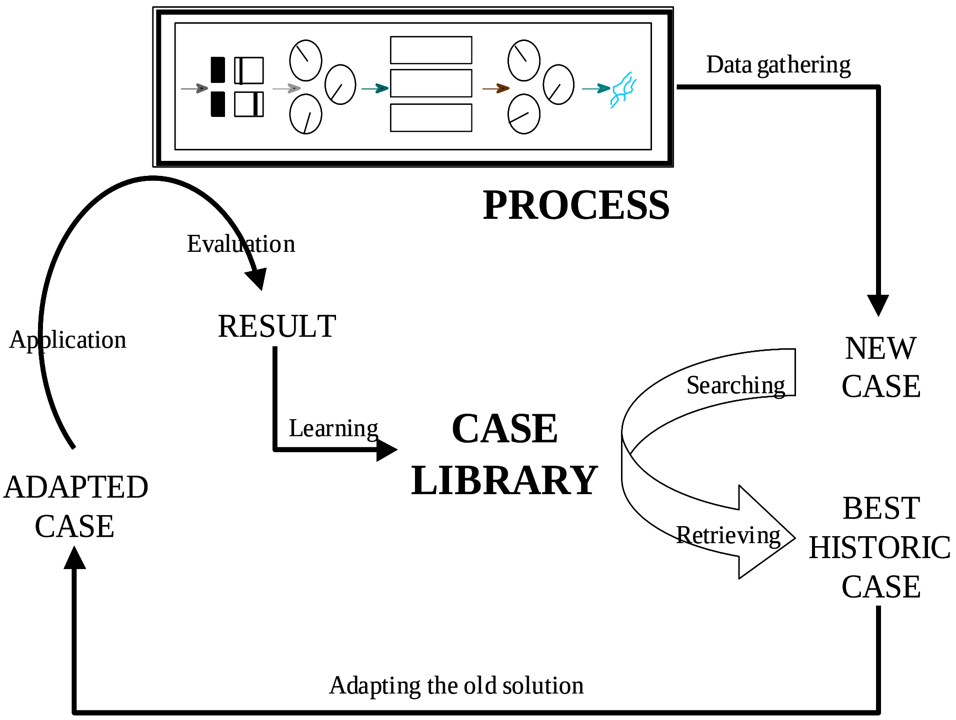

Figure 1-7: CBRS structure.

The cases stored in the case library are real WWTP operating experiences that have been captured and learned in such a way that they can be reused to solve future problems. [Sànchez-Marrè *et al.*, 1997]. Every case is structured in the same way; it has an identifier, the distance-to-case, the situation description by means of information in data form, the situation diagnosis, the additional comments for the diagnosis, the action made in the before case, and its evaluation.

It is difficult to define which parameters or variables from the process constitute the best situation description for a given case. Variables can be proposed as a result of the historical data study, but the plant head has to validate these proposed variables.

The case library is structured in a lineal way. Our experience with the Granollers CBRS shows that the number of stored cases is generally not large. This is due to the learning process, where any new case has to be different from the rest of the cases by a certain distance for it to be stored. A relatively low number of stored cases allows the computer to retrieve the three most similar cases in little time. In contrast, **Flat memories** consist simply of a database with all the historical cases. Flat memories have the advantage that they always retrieve the set of cases with the best match with the actual case. Moreover, adding new cases to the library is cheap. On the other hand, they have a major disadvantage: the retrieval time is very time-consuming (and so, expensive) since every case in the memory has to be matched against the current case, using a Nearest Neighbour (NN) algorithm [Comas, 2000]

The clustering process[4] applied to the historical data allows defining the original case library, which is afterwards validated by the expert opinion of the plant head.

1.5.2. EDSS: Integration of AI tools, data acquisition tools and interface tools.

Due to the complexity inherent to the control of wastewater treatment processes, even the most advanced conventional hard control systems have encountered limitations when dealing with problem situations that require qualitative information and heuristic reasoning for their resolution [Olsson, 1998]. These problems can be solved with the aid of knowledge-based systems, which can deal with data with uncertainty, with qualitative data and with incomplete information. However, KBS systems can solve only certain especific problems of WWTPs. Therefore, rule-based knowledge-based systems (KBSs) are not the definitive solution to the treatment problem as a whole [Ceccaroni, 2001]. When dealing with complex environmental problems, with managers who may not have sufficient knowledge of environmental issues, or with environmental processes that are not easily modelled because our knowledge is still incomplete and uncertain [Cortés *et al*. 2001], EDSSs can be useful [Ceccaroni, 2001].

An EDSS is the integration of KBSs, applied to an environmental issue, that potentially reduces the time in which decisions are made and improves the consistency and quality of those decisions [Guariso and Werthner, 1989]. A potentially important component of such systems is continuous improvement, of which optimisation is an instance. Continuous improvement allows the DSS to take a more proactive role in the supervisory process by generating low cost alternatives that meet user-defined goals and objectives [Ceccaroni, 2001].

An EDSS is an intelligence information system that ameliorates the time in which decisions can be made as well as the consistency and the quality of the decisions [Cortés, 2000]. It can manage and propose solutions to the manager. It integrates a coordinated set of knowledge-based processes, the so-called agents, that interact either by cooperation, by coexistence, or by competition to reach common objectives. An EDSS can be defined as a multi-layered system connecting the user with an environmental system or process [Cortés, 2000]. An EDSS is designed to help decision makers, managers, and advisors locate relevant information and carry out optimal solutions to problems using special tools and knowledge [Booty *et al*. 2001].

The decision support systems are designed and implemented into an integrated architecture that has different tools and programs to manage a big amount of information to help the manager make a decision. The decision support system described here was developed for the WWTP domain, and thus qualifies as an Environmental Decision Support System.

[4] See chapter 3, section 3.4.4.

The Montornès EDSS architecture is structured in five layers. The first layer contains the knowledge acquisition module. Here, the EDSS encompasses the tasks involved in data gathering and registration in databases [Poch *et al.*, 2002].

The second architecture layer which contains computer programs based on knowledge that attempt to identify to which class of operational situation the current Environmental systems situation belongs, is a key element to build a successful EDSSs [Nuñez *et al*. 2002; Poch *et al*., 2002].

The third layer corresponds to the supervisory task that entails gathering and merging the conclusions derived from knowledge based and numerical techniques. This layer also contains communication modules that inform the user about the plant situation by means of an interactive, graphical user-machine interface.

The fourth layer consists in the plan creation step. In this layer, plans are formulated and presented to managers as a list of general actions suggested to solve a specific problem.

The fifth layer applies the proposed plan using a set of suggested actions. The fifth layer can propose not only a action, or a sequence of actions (plan), but a value that has to be accepted by the plant head.

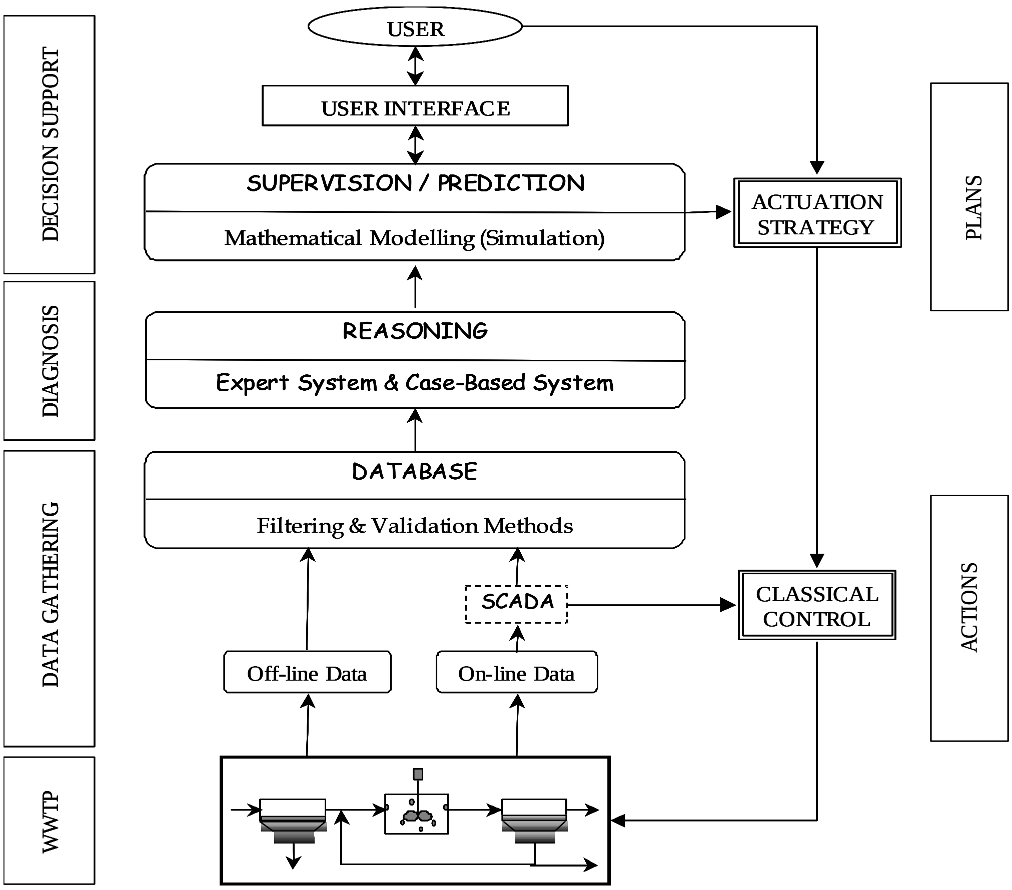

Figure 1-8: Montornès EDSS architecture.

An EDSS has to accomplish the user necessities, and allow the user to access and understand the collected plant information and the generated information. Because of this reason, a team work approach is suggested by which the user becomes involved in the design of the software as early as possible [David Lam and David Swayne, 2001].

The role of the user in EDSS development is usually poorly defined [Poch *et al*., 2002], but the paper of the user is very important for the EDSS operation. The user is the decision-maker that has to validate the EDSS proposals, that evaluates whether the proposed action is good or not, and so on. Users must be involved in the whole EDSS design and development process to ensure that the final EDSS will be useful for their purposes. One of the main interests of users is to obtain easily access to understandable information. The user-machine interface is the main way to access the information and it is responsible of the transfer of knowledge. The public user interface is windows-based for less technical users, but provides sufficient access to information and system manipulation in a simple and easy manner [Lam and Swayne, 2001]. The careful consideration of the needs of the end user is very important in designing the contents of the user interface.

The management of programs is generally performed by a person and it relies on a large amount of knowledge [Moisan, 2002]. Thus, it is necessary to keep this knowledge in an understandable and possibly operational form for future programs. The protocol explained in following chapters was developed this aim in mind. The knowledge to use and re-use the program in different situations, to document it and to help to maintain it, has to be saved.

Prototype re-use

In designing the Montornès EDSS we tried to re-use as much information as possible from the prototype. We wanted to capitalise on the time and human effort invested in the development of the prototype EDSS for the Granollers WWTP. The new EDSS development derived from the first program allows us to establish a set of steps to improve future EDSS versions. This set of steps is collected and summarised in an exportation protocol, which is explained in chapters five and seven of this document.

A number of approaches can be used for the development and delivery of EDSSs. These can be generalised into the three broad categories below, according to the main tools and techniques employed in the development [Guariso and Werthner, 1989; Rizzoli and Young, 1997]:

- Using programming languages;
- Using modelling and simulation software tools;
- Using model integration and reuse techniques.

In the case of the Granollers EDSS, development was made using the first category. A programming language was used to design, develop and implement the Granollers prototype. This approach requires substantial amounts of time, financial and human resources [Guariso and Werthner, 1989; Rizzoli and Young, 1997].

On the other hand, the Montornès EDSS was developed using the latter category. The model integration and reuse techniques are usually more efficient. Their use is recommended for the development of problem specific domain; in this case, the Wastewater Treatment Plants.

A software framework for model integration and reuse allows to prototype several different EDSSs, while tapping into a wider set of software resources to satisfy the requirements of each EDSS, thus providing an advantage over the standard tools for modelling and simulation [Guariso and Werthner, 1989; Rizzoli and Young, 1997]. Solutions for sharing knowledge in environmental processes are far from being fully developed, but one has to consider the great variety of data, and the strong dependencies of environmental processes to local constrains, such as weather conditions, climatic aspects, geographical positions, environmental or health law regulations, and so on. If specific models are to be developed for environmental problems, greater generality, precision (when possible) and realism will be required [Poch *et al*., 2002].

1.6. *Research group Antecedents in both Environmental and Artificial intelligence domains.*

In the middle of the nineties an interaction developed between investigators from from the Chemical Engineering Department at the University of Girona (Chemical and Environmental Engineering Laboratory, LEQUIA) and investigators from the Artificial Intelligence group at Universitat Politècnica de Catalunya (Knowledge Engineering and Machine Learning Group, KMSL). From this interaction the idea was born to unify both domains, the WasteWater Treatment Plant domain and the Artificial Intelligence domain. This unification was intended to help the head of a WWTP plant to control the treatment process, after agreeing that the conventional process control was plagued with problems and errors.

The second generation of EDSSs developed by our research group appeared at the end of the nineties. The new program consisted in an EDSS designed to help in a WWTP management. This prototype was implemented in the Granollers WWTP and works with real-time data. A prototype redesign was made in the beginnings of 2001. This new version integrated the experience acquired during the meetings with the plant head.

During 2001 and 2002, a new EDSS version from the prototype was developed to be implemented in the Montornès WWTP. The goal of this new EDSS was to achieve the user needs and try to detect the plant situation by making a heavier use of on-line data.

Currently, many solutions for sharing knowledge in environmental processes have been studied. This project includes an exportation protocol designed to share the knowledge acquired during these years and to reuse it in similar WWTPs.

1.7. *Thesis development process*

The main objective of this thesis is to develop a normalised exportation protocol to develop new EDSSs derived from a prototype. Once a prototype is developed, the main bottleneck is the implementation step within the EDSS redesign process. This project's goal is to facilitate and normalise this exportation task. .

The procedure followed to develop this exportation protocol begins with the prototype learning process. First of all, we needed to learn computer programming languages and learn about the Granollers EDSS. Once this task, which demanded a large time investment was finished, the next task was to plan the exportation process.

Then, the planed protocol was applied to a new WWTP. This selected facility was also based on an activated sludge process, but with a different configuration and a different level of process information than the Granollers WWTP. The new EDSS application allowed acquiring new knowledge that was included into the protocol 1.0, which, finally, became the protocol 2.0., it was based both on theoretical ideas and on the practical implementation.

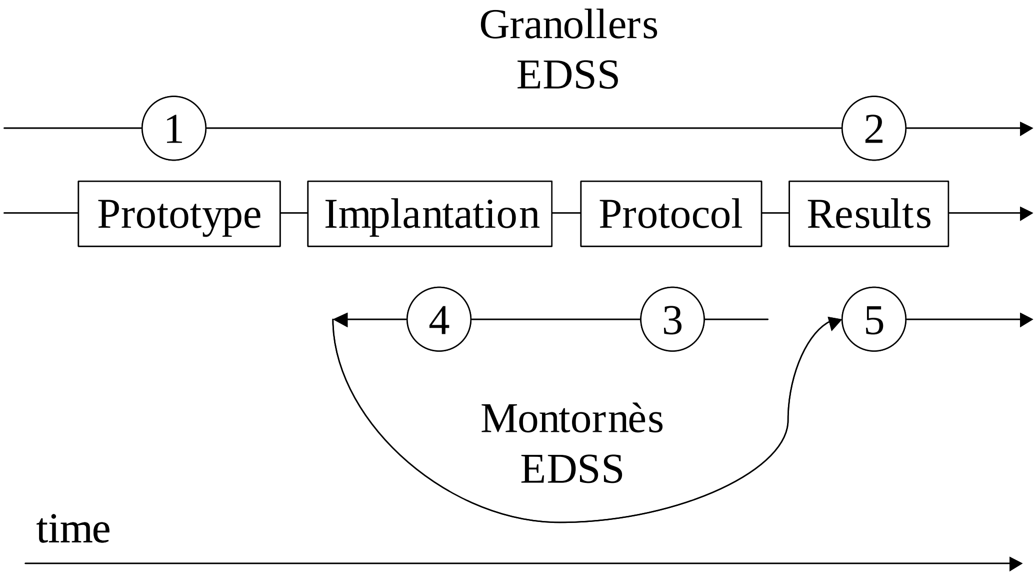

Figure 1-9: Thesis development process.

The main lines of the project can be summarised in the following points:

- √ Investigation and development of the AI techniques.
- √ Study phase.
- √ Prototype improved and checked.
- √ Creation and implementation of the exportation protocol.
- √ Discussion.

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Chapter 2: Objectives

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2. Objectives

2.1. *Objectives*

The objectives are divided into two groups: the main objectives and the secondary objectives.

2.1.1. Main objectives

- **To define, to apply and to validate** a protocol for DSS development and transferability it to biological treatment gestion of any WWTP. The Granollers EDSS is taken as a basis of this study, and as an exportation case study, it is taken the Montornès WWTP.

2.1.2. Secondary objectives

For the develop process, it will need the following:

- To review the biological process in wastewater treatment, the control and artificial intelligence tools, and the different EDSS modules architecture.

To the esportation process, it will need the following:

- EDSS Granollers study. The review includes the general maintenance, the results validation, and the knowledge bases (generals and specifics) study.
- Montornès WWTP study, of its biological treatment, its process characteristics, the available information and the existed operation protocols.
- EDSS evolution by means of the improvements in the data and knowledge acquisition, the communication bridges, and the user interface.

Based on the partials conclusionds obtained, it will be defined a protocol to the development and exportation process of the EDSS prototype, and its function cycle will be validated. Finally, the first version protocol (1.0) will be checked to allow generaliting its application in any WWTP with similar characteristics.

Chapter 3: Materials and Methods

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3. Materials and Methods

3.1. *Abstract*

The main purpose of this chapter is to describe the elements used to develop a new EDSS from the prototype. The elements used go from analytical tools to software tools, going through databases and a shell. This chapter describes all the material used.

3.2. *Introduction*

The materials and set of actions used to develop a new version, 1.0, from the prototype, beta version, are described in this chapter, which is structured in several parts. Firstly, a description of the informatics elements used is presented. Secondly, there is the description of the analytical, the database and knowledge acquisition systems.

3.3. *Materials and methods*

The materials and methods used to re-design the program and used to execute the program are described.

3.4.1. **Computer technical characteristics.**

The minimum computer requirements needed for the G2 environment to run correctly are:

REQUIREMENTS		**Personal computer used**
Hardware		
Pentium processor	☑	Pentium III/ CPU: x86 Family 6 Model 8 Stepping 3 Genuinelntel- 730 Mhz
128 MB RAM memory	☑	128 Kb RAM
200 MB free disk space without online documentation	☑	
CD-ROM	☑	
Display with resolution of 1024 x 768, 256 colours, and 2 MB of video RAM	☑	
Software:		
Microsoft Windows NT 4.0/2000	☑	Windows 2000
Microsoft Windows 98/Me (supported for desktop, off-line use only)		
Recommended		
850 MHz Pentium III processor or faster		
384 MB memory or more		
1000 MB free disk space for full installation		

Table 3-1: Personal computer requirements.

3.4.2. **The G2 shell.**

A shell is a domain-independent expert system framework but without any domain-specific knowledge. This means that it is a computer program that provides a user interface, an empty knowledge base and an inference engine [Olsson and Newell, 1999]. Shells contain such components as inference engine programs, programmed control mechanisms, programmed external software interface routines, and capabilities for storing and editing knowledge bases [Mockler, 1992].

In this case, the shell chosen is the G2 Development package developed by Gensym Corporation [Gensym, 2000].

G2 is a comprehensive, object-oriented environment to quickly build and deploy real-time expert system applications. Gensym's G2 is designed to bring complexity under control through expert operations management. It enables the knowledge engineer to capture the knowledge of the best operations experts, and to intelligently combine that knowledge with real-time data, archival information and even business policies. Powerful reasoning engines analyse all of these inputs in real time to develop the best possible operating decisions, either as operator recommendations or as automated actions.

G2 applications maximize operational performance by:
Transforming complex real-time data into useful information through knowledge-based reasoning and analysis
Monitoring for potential problems before they adversely impact operations
Diagnosing root causes of time-critical problems to speed-up resolution
Recommending or taking corrective actions to help ensure successful recovery
Coordinating activities and information to optimise operational processes

Table 3-2: G2 possibilities.

This informatics environment has been chosen for its characteristics. These characteristics allow anyone who does not have an informatics degree to program easily.

Feature	Benefit
Object-oriented modeling of connected objects	Enables rapid and realistic modelling of real-time process knowledge from which decisions can be driven that optimise operating efficiencies. For example, an object-oriented model of connected equipment within a production process can be the basis of "what-if" analysis for supporting both design and operational decisions that optimise material flows.
Rule-based reasoning engine	Provides advice and implements actions so that the availability of critical operational assets and services are maximized. Rule and procedural based knowledge contained within applications continuously monitor for situations that can adversely affect operations, and then quickly diagnose problems.
Real-time design and operation	Facilitates better management of complex, time-critical operations. G2 has the ability to include data histories and concurrently execute multiple lines of reasoning to support real-time decision-making.
Seamless integration of real-time expert system technologies	Allows developers to build and deploy operations management applications dramatically faster than traditional programming methods. G2's comprehensive platform provides an intuitive environment that seamlessly combines objects, natural language rules and procedures, real-time execution, interactive graphics, and connectivity.

Table 3-3: Benefits of G2.

G2 Technical Specifications, Platform Specifications

Object Representation
Hierarchical object classes
Graphical representation of objects
Multiple inheritances
Object attributes and methods
Cloning and connecting of objects
Generic rules and procedures capture object behaviours
Dynamic models associated with objects
Definable relationships among objects
Real-time Capabilities
Concurrent execution of rules, procedures, methods, and models with priorities
Sub-second scheduling of executable events
Histories and time-stamping of data
Validity intervals for variables
Rules, procedures, methods, and models that reason about time-based events and histories
Snapshot and warmboot facilities
Rules
Generic rules
Rules activated in many ways, including focusing, forward chaining, backward chaining, and scanning.
Watch for events and take actions by calling procedures and methods
Sub-second polling and timing waits
Procedures and Methods
Wait states
Parallel execution threads
Hierarchical structures for methods
Linkage of procedures to objects with methods
Modeling and Simulation
Built-in simulation capabilities
Concurrent operation of simulations with real operations
Formulas
Connectable objects
Development Environment
Modular development
Interactive, structured natural language editor with parse and error detection
Symbolic variables
Hierarchical workspaces
Lists and arrays with mixed element types
Incremental compile
Inspection facility
Debugging and tracing facilities
Revision management
Performance meters
Team development with Telewindows
User Interface
Telewindows2 Toolkit components for building Java-based end-user interfaces
Built-in graphs, charts, read-out tables, dials, and meters
Animation
Importable bitmap backgrounds and icons
Multi-layered icons with dynamic control of the layer colors and shapes
Icon editor
Configurable colors
Configurable and scalable workspaces

Scalable and rotatable icons
Built-in action buttons, radio buttons, check boxes, edit boxes, and sliders
Deployment Environment
Portable and interoperable across operating systems including Windows 98/Me, Windows NT/2000, Sun Solaris, IBM UNIX, HP UNIX, and Linux (scheduled for 2001)
Controlled authorized access of each user
Concurrent sharing of applications among users with Telewindows and Telewindows2 Toolkit
Remote application modifications with non-stop operation
International languages
Text-stripping option
Proprietary workspaces and applications
Deployment run-time licenses
Out-of-the Box Connectivity
G2 Oracle bridge
G2 Sybase bridge
G2 ODBC bridge
G2 OPCLink for access to plant data via OLE for Process Control
G2 CORBALink for CORBA-based connectivity solutions
Other bridges to plant control systems available from Gensym and its Solution Partners
G2 Gateway Standard Interface (GSI) toolkit for C/C+ connectivity solutions
G2 ActiveXLink for ActiveX connectivity solutions
G2 JavaLink for Java connectivity solutions
G2 WebLink for Web browser based interfaces
Connectivity Tools and Capabilities
TCP/IP protocols
Protocol handling
Buffering
Hand shaking
Restore after break
Sleep until awaken
Time stamping of data
Gateway design for concurrent communication among multiple data sources
Distributed Client/Server Networking
G2-to-G2 communications between G2 applications
Sharing of applications with Telewindows and Telewindows2 Toolkit
GSI processes running on independent platforms
Passing of objects and arrays between G2 applications and other systems
Synchronous and asynchronous Remote Procedure Calls

Table 3-4: G2 Technical Specifications, Source www.gensym.com.

G2 is designed to connect real-time data, off-line data and other programs. Gensym offers off-the-shelf bridges for bi-directional links to many commercial systems including databases, control systems, supervisory systems, network management platforms, and GUI packages.

In situations where a bridge does not exist, G2 has several interfaces that allow building bi-directional links to external data sources. They are easy to configure and, since they work automatically while an application runs, easy to use. The G2 Gateway standard interface (GSI) is the most commonly used interface for data connectivity.

GSI is a high-performance data server product to build and deliver real-time interfaces between the G2 and external processes and systems. It is a separate product that works with the G2. It can be used to develop interfaces to data acquisition systems, external simulations, remote databases, non-G2 end-user displays, and other programs. The off-the-shelf bridges available from Gensym are all built using GSI. GSI allows G2 to do the following:

- Obtain values from external sources.
- Set values in external systems.
- Send text messages and receive acknowledgments.
- Receive unsolicited input from external data servers.
- Make remote procedure calls (RPCs) in either direction.

GSI is designed to handle real-time issues and simultaneous access with multiple sources of data. For example, GSI takes care of protocol handling (TCP/IP); buffering; hand shaking; restore after break; and interruptible sleep. Moreover, GSI runs concurrently with G2, so that reasoning in G2 may continue while real-time data is being used.

The GSI data server, called G2 gateway later on, was used in the prototype. With the G2 Gateway two-way communication bridges between G2 applications and dynamic external systems such as database management systems, C/C++ programs, and external simulation software can be developed. The G2 Gateway gives a G2 application the real-time data it needs, and the ability to update the state of external systems.

The program also uses ActiveX bridges. G2 ActiveXLink enables the establishment of communications between the G2 and a COM-compliant application running under Windows. This product is designed for ActiveX connectivity solutions. The G2 is assumed to be running in the same system as the example programs at TCP/IP port 1111.

3.4.3. **Databases**

Plant and laboratory operators carry out a daily characterisation of the water and sludge quality and process state variables, including both quantitative and qualitative information, at different sample points. Quantitative data is provided by on-line sensors (flow rates, pH, dissolved oxygen, and so on) and by analysis of samples collected daily at the plant (for determinations of organic matter, nutrients, suspended solids, turbidity, conductivity, and biomass). Every plant process requires the analysis of a characteristic set of parameters. Some global parameters like SRT (Sludge Retention time), SVI (Sludge Volumetric Index) or F/M (Food to Micro-organism) are calculated whenever needed.

Qualitative data is usually measured once a day but some qualitative parameters can be measured many times a day. This kind of data includes microscopic determinations of the biomass like floc characterisation, microfauna identification and counting, and filamentous bacteria identification and counting. Other process qualitative observations (like presence and colour of foam and sludge, or appearance of the settler supernatant and effluent) are also determined.

Source	Variable	Sampling location	Frequency
Analytical	COD, BOD, TSS, $NH4^+$, TKN, NO_2^-, NO_3^-, Cl^-, P, MLSS, MLVSS and V30	Influent, primary effluent, and effluent Aeration tank and recycle	Daily
Sensors	pH, Cond	**Influent and effluent**	Online
	DO	Aeration tank	
	Flow rates	Influent, primary effluent, effluent, recycle, internal recycle, and waste.	
Global	SRT, SVI, and F/M		Daily
Microbiological	Protozoa, filamentous bacteria	Aeration tank	Weekly
Qualitative	Floc characterisation, odours, colours, sludge levels in tank and settler	Aeration tank Settlers	Daily (Many times a day)

Table 3-5: Variables usually used for classical process control.

The program uses two kinds of databases; one database with on-line information and another database with off-line information. The latter includes analytical, microbiological and qualitative information. For an on-line database, an excel spreadsheet is used where the online information that the SCADA receives is updated (Figure 3-1).

On-line data

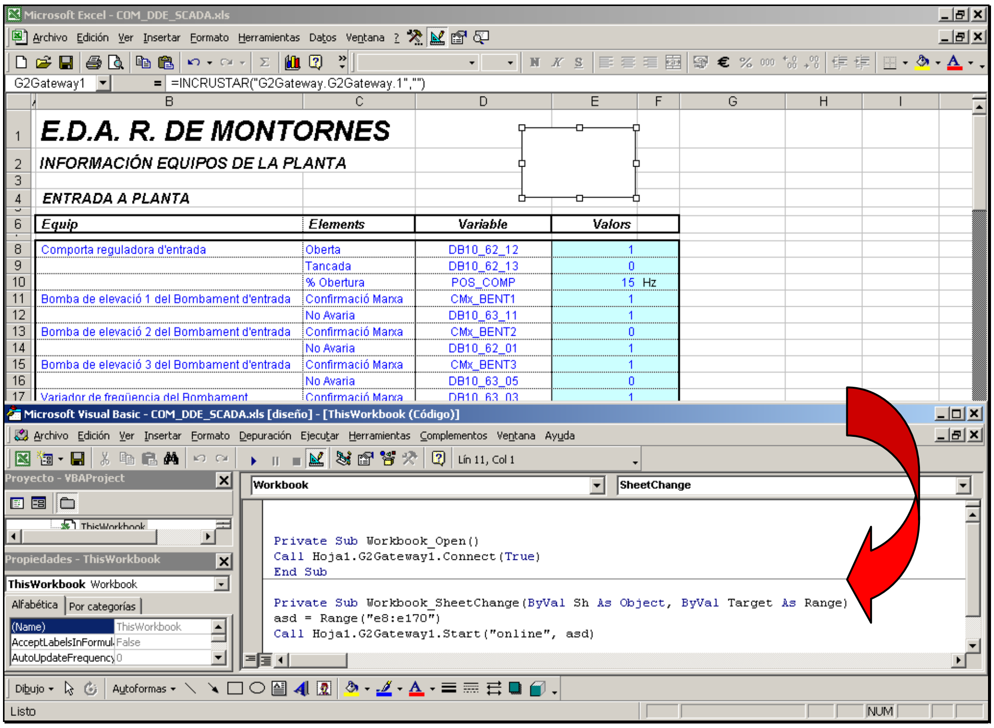
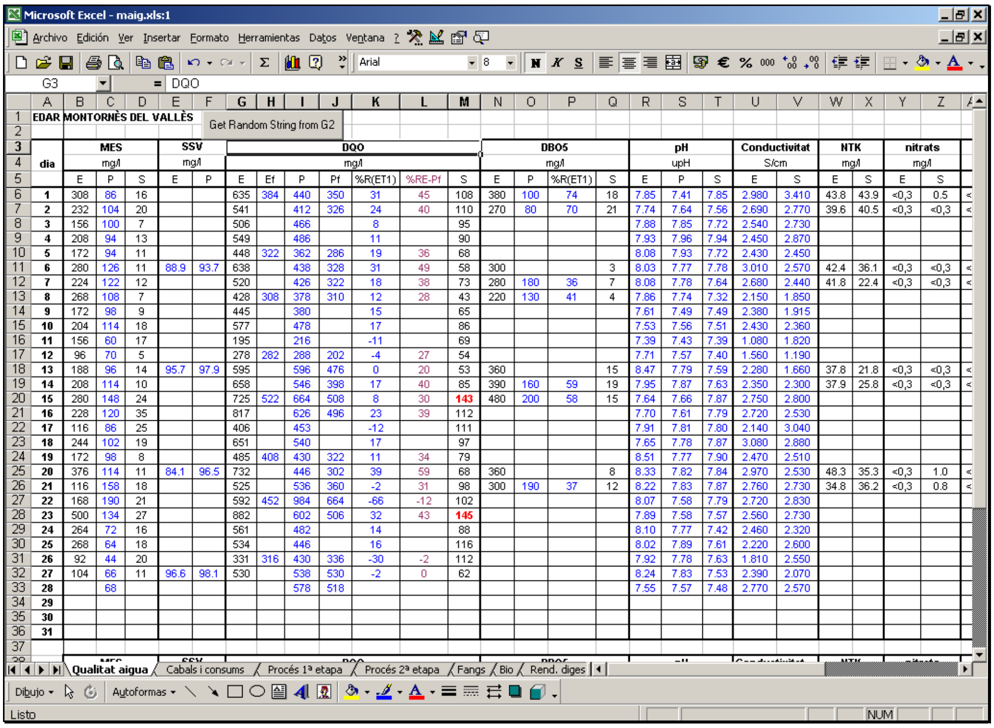


Figure 3-1: On-line data spreadsheet, the visual Basic macro and the G2gateway used to transfer the data to G2.

On-line data is generated for all kinds of physical variables, like flowrates, levels, pressures, gates, engine failure, and so on. Turbidity, colour, pH, dissolved oxygen, alkalinity or oxygen reduction potential are also measured. The Montornès WWTP generates 133 online data points every 15 seconds. A list of the online data from Montornès WWTP can be found in the annex III.

Off-line data

The plant head is responsible for the off-line databases used. These databases consist in a set of spreadsheets that collect the information generated during a month and are part of the monthly report.



EDAR MONTORNÈS DEL VALLÈS

dia	MES			SSV		DQO							DBO5				pH			Conductivitat		NTK		nitrats	
	mg/l			mg/l		mg/l							mg/l				upH			S/cm		mg/l		mg/l	
	E	P	S	E	P	E	Ef	P	Pf	%R(ET1)	%RE-Pf	S	E	P	%R(ET1)	S	E	P	S	E	S	E	S	E	S
1	308	86	16			635	384	440	350	31	45	108	380	100	74	18	7.85	7.41	7.85	2.980	3.410	43.8	43.9	<0,3	0.5
2	232	104	20			541		412	326	24	40	110	270	80	70	21	7.74	7.64	7.56	2.690	2.770	39.6	40.5	<0,3	<0,3
3	156	100	7			506		466		8		95					7.88	7.85	7.72	2.540	2.730				
4	208	94	13			549		486		11		90					7.93	7.96	7.94	2.450	2.870				
5	172	94	11			448	322	362	286	19	36	68					8.08	7.93	7.72	2.430	2.450				
6	280	126	11	88.9	93.7	638		438	328	31	49	58	300			3	8.03	7.77	7.78	3.010	2.570	42.4	36.1	<0,3	<0,3
7	224	122	12			520		426	322	18	38	73	280	180	36	7	8.08	7.78	7.64	2.680	2.440	41.8	22.4	<0,3	<0,3
8	268	108	7			428	308	378	310	12	28	43	220	130	41	4	7.86	7.74	7.32	2.150	1.850				
9	172	98	9			445		380		15		65					7.61	7.49	7.49	2.380	1.915				
10	204	114	18			577		478		17		86					7.53	7.56	7.51	2.430	2.360				
11	156	60	17			195		216		-11		69					7.39	7.43	7.39	1.080	1.820				
12	96	70	5			278	282	288	202	-4	27	54					7.71	7.57	7.40	1.560	1.190				
13	188	96	14	95.7	97.9	595		596	476	0	20	53	360			15	8.47	7.79	7.59	2.280	1.660	37.8	21.8	<0,3	<0,3
14	208	114	10			658		546	398	17	40	85	390	160	59	19	7.95	7.87	7.63	2.350	2.300	37.9	25.8	<0,3	<0,3
15	280	148	24			725	522	664	508	8	30	143	480	200	58	15	7.64	7.66	7.87	2.750	2.800				
16	228	120	35			817		626	496	23	39	112					7.70	7.61	7.79	2.720	2.530				
17	116	86	25			406		453		-12		111					7.91	7.81	7.80	2.140	3.040				
18	244	102	19			651		540		17		97					7.65	7.78	7.87	3.080	2.880				
19	172	98	8			485	408	430	322	11	34	79					8.51	7.77	7.90	2.470	2.510				
20	376	114	11	84.1	96.5	732		446	302	39	59	68	360			8	8.33	7.82	7.84	2.970	2.530	48.3	35.3	<0,3	1.0
21	116	158	18			525		536	360	-2	31	98	300	190	37	12	8.22	7.83	7.87	2.760	2.730	34.8	36.2	<0,3	0.8
22	168	190	21			592	452	984	664	-66	-12	102					8.07	7.58	7.79	2.720	2.830				
23	500	134	27			882		602	506	32	43	145					7.89	7.58	7.57	2.560	2.730				
24	264	72	16			561		482		14		88					8.10	7.77	7.42	2.460	2.320				
25	268	64	18			534		446		16		116					8.02	7.89	7.61	2.220	2.600				
26	92	44	20			331	316	430	336	-30	-2	112					7.92	7.78	7.63	1.810	2.550				
27	104	66	11	96.6	98.1	530		538	530	-2	0	62					8.24	7.83	7.53	2.390	2.070				
28		68						578	518								7.55	7.57	7.48	2.770	2.570				
29																									
30																									
31																									

Figure 3-2: Off-line spreadsheet.

In this set of spreadsheets, the plant head collects the analytical information from the process samples. The microbiological and the qualitative information are included in this file.

3.4.4. Clustering and Statistical Software

Automatic knowledge acquisition from the historical database was used in this project to extract objectively the most relevant information. An automatic data clustering was used. Automatic clustering is one of the statistical tools that add objects or individuals depending on homogeneous variables. The clustering allows the induction of possible data clusters from unsupervised databases. These techniques are best used for large data matrices without any a priori structure. The results can be represented in hierarchical trees or partitions. In our case, the process used was the hierarchical classification. This type of classification is based on repetitive partitions of the matrix. The extracted classes can be represented by dichotomies (descendent algorithms) or by groups (ascending algorithms). The results are represented by dendrograms or classification trees.

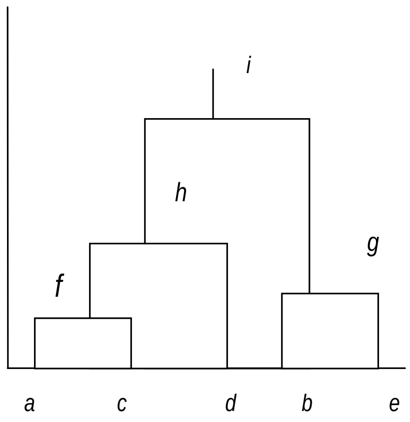


Figure 3-3: Dendogram.

The ascending classification process is based on the proximity measure among individuals. This method combines two elements, *a* and *b*, into a new element, *h*, and then recalculates the distance from the new element. The distance used is the normalised Euclidean distance because the treated data are continuous and there is a big diversity of units. The Euclidean distance is defined as:

$$d_{ii'} = \left\{ \sum_{j=1}^{p} \left(\frac{x_{ij} - x_{i'j}}{s_j} \right)^2 \right\}^{\frac{1}{2}}$$

The aggregation process has many possibilities; in this study, the Ward criterion is used. This is defined as:

$$D = \frac{\{(n_x + n_x)d(x,z) + (n_y + n_z)d(x,y) - n_z d(x,y)\}}{(n_x + n_y + n_z)}$$

where

x, y, and z are three objects.
n_x, n_y , n_z and n_h are the cardinals *x, y,* z and *h*
g_x, g_y, g_h are the gravity center from the objects *x, y* i *h*

The result of the algorithm application is a dendrogram. Different cuts in this dendrogram show different classes, which are then discussed with the plant head.

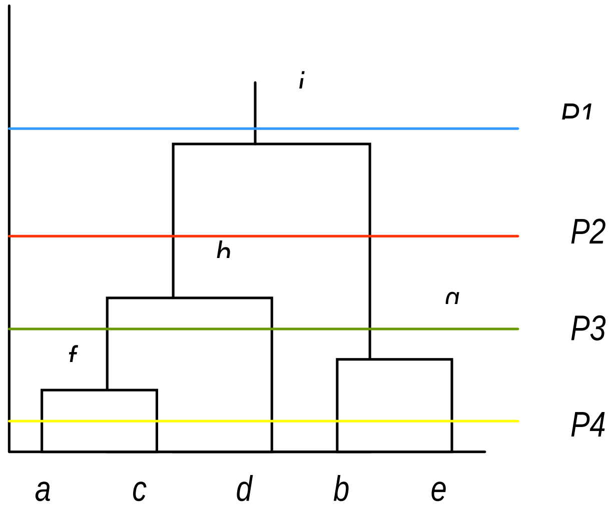


Figure 3-4: Cuts in the dendogram.

Where P4 is the hierarchical level that contains all the elements í(a),(b),(c),(d),(e)ý, and P1 is the biggest cut and has the E group í(a,b,c,d,e)ý. P2 has two sub-goups, í(a,c,d),(d,e)ý. Every partition corresponds to a class that has to be studied and classified.

The level index is used to know whether a cut is good or not. A high index represents a good cut with well-established classes. The level index is the distance between two elements before they are aggregated.

KLASS

The automatic acquisition knowledge from the historical database requires specific software. A program named KLASS [Gibert, 1992] was was selected because it allows dealing with a large number of variables and individuals. Other programs, like SPSS and Minitab, were previously evaluated, but none could work with such large amount of data.

KLASS is a clustering system oriented to the classification of ill-structured domains; it implements an adapted version of the reciprocal neighbours' algorithm; it also takes advantage of any additional information that an expert can provide about the target concepts. KLASS was implemented using the LISP language. It is necessary to have the data structured in files.

<File.dat> is a file that structures the data into a matrix of rows. There is a list of coordinates for every row. These coordinates define the value for every variable.

<File.pro> is a file that has the variable information that defines the wastewater. The name, the numeric index, the variable type and the number of individuals define each variable.

<File.obj> contains the object characterisation of the sample. As in the previous file, the identification (measurement day), the associated index and the properties list define the objects.

When the KLASS classification is finished, it offers the best cuts depending on the distance in the level jump.

Excel and Sigmaplot

Excel was used for the statistical analysis of the historical data from the plant. This analysis concerned the process data from 316 days and evaluated 22 variables. For each variable analysed, the maximum, the minimum, the median, the standard deviation, the coefficient of variation and the quartiles were calculated. This study allows discovering potentials errors in the database, and exceptional situations in the plant. The commonly database errors are missed values.

The excel worksheet is a powerful tool of data management which it's used as a host for the *Visual Basic (VBA).* The *VBA* is a very useful interpreting language to connect two or more programs and transfer information between them. *VBA* is important from the point of view of the software development engineering because it allows an easy reuse in future implantation.

When the shell is loaded and the main connections with the intern data net are established, then it's started the connection of the on-line database with the shell. Once it's established and the information is transferred, the study of this information makes these non-conformities:

- Turbidity solids exit. In a short time this signal will be available in the on-line database.
- Running confirmation of variator 2 from the second stage. It does not run properly.
- Running confirmation of variator air-pump from the first stage.
- Entrance gate settler A form the first stage (OPEN=0, CLOSED=0)
- Secondary sludge recirculation pump a,b,c.
- 3 variators, 1 for each polielectrolit pump to espessidor.
- The temperature doesn't appear when the sound has this value.

The excel program is also used to make the statistical study of the historical data from the plant. This analysis studies the process data from 316 days and evaluates 22 variables. The study makes the maxims, the minus, the median, the standard deviation, the variation coefficient and the quartiles. This study allows discovering potentials errors in the database, and exceptional situations in the plant. The commonly database errors are missed values.

Excel and Sigmaplot were also used to manage and represent the classes provided by the KLASS.

Results interpretation

The objective of this task is to quickly identify the main variables in every class with a low computational effort. Multiple boxes diagrams were used to interpret the results and find out characteristic variables that have exclusive values for this class between the first and the third quartile.

Another method was based on the comparison of the group median with the total median. In order to verify the importance of a variable X, a comparison with the class median is made under the hypothesis that the individuals are assigned to this class randomly. The T-Student statistical method was used:

$$t(x) = \frac{x_j - x}{s_j(x)}$$

$$s^2{}_j(x) = \frac{n - n_j}{n-1} \frac{s^2(x)}{n_j}$$

If t (x) ~N (0,1)

Where		
	x_j	is the class mean
	x	is the sample mean
	n	is the individual number
	n_j	is the class individual number
	$s^2_j(x)$	is the standard deviation of the class
	$s^2(x)$	is the standard deviation of the sample

Table 3-6: T-Student formula parameters.

The domain knowledge is very important in the interpretation of results. Thanks to this knowledge, the most relevant variables are chosen to assign a category to the classes. The situations typical of a given class are found out using both this domain knowledge and the interpretation methods. An important point is that not all the variables are used to cluster.

There are other automatic acquisition methods to do this task; examples are autoclass, SPSS, MATLAB and LINNEO+ [Béjar, 1995]. The latter is a semi-automatic knowledge acquisition tool concerned with building classifications for ill-structured domains.

3.4.5. **Prototype**

The starting point of this thesis is the prototype developed by Dr. Comas. Some changes and improvements, which are an important part of this document, were made in order to increase the efficiency of this prototype. In chapter 4, there is a brief description of the prototype; the improvements made to it are widely explained.

The prototype is an EDSS that includes in its architecture the data gathering, the KBS and the user-interface tools. The knowledge-based system included consists in both artificial intelligence tools: ruled-based system and case-based reasoning system (see chapter 1, section 1.5.1.).

3.4.6. **Ethernet**

The local net called Ethernet is the dominant technology in The Internet. Xerox developed this kind of technology in the seventies. The main Ethernet characteristics are the high yield, the use use of coaxial cable, and a transmission speed of 10 Mb/sec. Ethernet is a net where all personal computers have access to send packages, but only one computer can see the package addressed to it.

Ethernet is the net used to transfer the information between the SCADA and the G2. It has a bus topology with branch connections that consists of a screened coaxial cable to which the peripherals are connected with “taps” or individual twisted-pair cables to “hubs” [Olsson and Newell, 1999]. There are four personal computers connected to the Montornès net. Ethernet is a kind of net that comes from the LAN (Local Area Network); it could be said that this net is a small LAN. Ethernet does not have a network-controlling unit and all the devices independently decide when they want to access to medium. Twisted-pair cables of category 5 are used to connect the personal computers to the JAP. The personal computers run MSWindows; one with NT and the others with Windows 95/98; and the protocol used is the TCP/IP with fixed address.

LAN (Local Area Network). It is a data net with high velocity and with a low error level. This net covers a relatively small region. The LAN connects workstations, peripherals, terminals and other devices in a building or other limited area. The LAN standards specify the cables and the signals in the physical layer and in the connect data layer from the OSI (Open System Interconnection) reference model. Ethernet, FDDI and Token Ring are LAN technologies used.

MAN (Metropolitan Area Network). It is a net that covers a bigger area than a LAN net but a smaller area than WAN.

WAN (Wide Area Network). Communication data net that serves to users within an extensive geographical area. Frame Relay, SMDS and X.25 are examples of WAN.

TCP/IP is a set of protocols developed to allow computers to share resources in a net. The TCP/IP protocol is the most widely used protocol by the computers connected to the Internet to communicate among them. The main advantage of the TCP/IP is that it is compatible with any operative system and hardware. TCP/IP is not a single protocol, but an assembly of protocols that cover the different OSI model levels. The two most important protocols are *Transmission Control Protocol* (TCP) and *The Internet Protocol* (IP), which name the protocol. The information sent using TCP/IP has to be divided into small partitions. Every information unit is called *datagram*, and it is an information set that is sent independently.

The TCP divides the original message into *datagrams* and puts some necessary information into the *datagram*. The datagram is then directed throughout the IP protocol. TCP establishes the data format and generates the procedures needed to verify that the data is properly received.

The datagram is built following the structure below:

TCP Headlines.

Origin port			Destiny port
Sequence number			
Confirmation signals			
Size	Reserved	Control Bits	Window
Checksum			Urgent data

Figure 3-5: TCP headlines[5].

Two important fields are the origin port and the destiny port. The ports allow distinguishing among different transferences. The host has to send to the server a confirmation signal to detect errors in the information.

The IP is a protocol from the network level; it is used by the TCP to send message packages. The IP objective is to direct the *datagram* without checking the information. A new headline is used to make this task.

IP headline (20 byte)	**TCP headline (20 byte)**	**Data**

The IP headline has160 bytes size and it consists of many fields.

IP headline.

Version	IHL	Type of service	Length	
Identification			Flags	Fragmentation
Existence Limit		Protocol	Checking	
Origin address				
Destiny address				

Figure 3-6: IP headline[6].

[5] http://www.datafull.com/datahack/notas/nota.php?sen=sub&codigo=4
[6] http://www.datafull.com/datahack/notas/nota.php?codigo=6&sen=sub

3.4.7. **WWTP description.**

The Granollers WWTP is the plant where the first prototype was implemented; the Montornès WWTP is the plant where the new protocol and the new EDSS version derived from the prototype is implemented. Both plants are explained next. These descriptions show that both plants are based on activated sludge treatments, although they have different configuration processes. This allows us to demonstrate that the prototype can be exported to other plants with different configurations of activated sludge processes and that it can work well in these new plants.

3.4.7.1. **Granollers WWTP description**

The Granollers WWTP is a medium size biological treatment plant. Initially, it had pre-treatment and primary treatment; afterwards, it was improved with a secondary treatment. When the secondary treatment was applied, the physical-chemical process became useless. Nowadays, the plant provides preliminary, primary settler and secondary treatment to remove the contaminants from the wastewater. Under certain conditions the plant can also remove nitrogen.

Figure 3-7: Picture of Granollers WWTP.

The Granollers WWTP is designed to treat the wastewater generated by 130,000 inhabitant-equivalents. The raw influent comes from a sewer that collects both urban and industrial wastewater. The percentage of industrial wastewater in the total wastewater that arrives to the plant is 60%.

The process of the plant can be divided into two main treatment lines: water and sludge. The water line can be separated into three phases: pre-treatment, primary treatment and secondary treatment. The sludge line is composed of thickening, anaerobic digestion, dewatering and final disposal into a controlled landfill.

The water line begins with the **preliminary treatment**, whose function is to prepare the wastewater influent for the treatment and removal of the big particles from the water. The preliminary treatment includes screening for coarse particles and grit and floatable removal. The screening of wastewater removes gross pollutants to protect downstream operations and the equipment from damage.

In the **primary treatment**, physical operations such as screening and sedimentation are used to remove the floating and settleable solids found in wastewater. Specifically, the primary treatment consists of two circular sedimentation tanks with a sludge-scraping mechanism for physical sedimentation of suspended solids. Sometimes one of the sedimentation tanks is used as a flow equaliser to avoid hydraulic shocks. The flow equalisation is used to diminish the diurnal variations and the inflow to achieve a relatively constant loading of the downstream treatment process.

The plant has a by-pass between the primary treatment and the secondary treatment. The set-point of the by-pass has a value of 1200 m^3/h. When the inflow is higher than 1200 m^3/h, water is dumped in the river after the primary treatment.

The **secondary treatment** is designed to convert biodegradable, organic wastewater constituents and certain inorganic fractions into new cell mass and by-products. They can all subsequently be removed from the system by gaseous stripping, settling, and other physical means. With specific conditions, the system can also remove the nitrogen composition of the wastewater by the nitrification-denitrification process.

The Granollers biological treatment consists in the conventional suspended growth. The plant uses an activated sludge system and it has two main reactors that are divided into various compartments. Each line is made of an anoxic selector located at the beginning of the aeration tank and a compartmentalised plug-flow reactor. Every plug-flow reactor is divided into 4 aerated tanks. They are equivalent to one anoxic reactor and four continuous stirred tank reactors with a Ludzack-Ettinger configuration. With this configuration, the plant can nitrify and denitrify with great efficiency. The objective is to use the readily biodegradable substrate in the wastewater itself as an electron donor to achieve partial denitrification. Thus, the nitrate formed in the reactor system has to be sent back to the beginning of the reactor where the input substrate is.

The purge flow is made of the reactor and occasionally, of the recycle flow. The purge system has two pumps controlled by a PLC.

Three more pumps that pump the activated sludge settled in the clarifier to the aeration tank shape the recycle flow system (RAS). A fuzzy logic-based program controls the RAS flow.

The **sludge line** follows the next structure. The primary excess sludge is mixed up with the wasted sludge and then, the mixture is sent to the anaerobic digestion unit. The Granollers WWTP has two anaerobic digesters with 5000 m^3 of effective volume. After the sludge is stabilised with ferric chloride and lime, it is dewatered and dried using three centrifuges. Afterwards, the dried sludge is disposed in a controlled landfill.

Control loops in the Granollers WWTP.

There are five control loops in the Granollers WWTP. All the control loops are for a better quality in the function of the Bio-reactor.

1. Flow linearization

A constant inflow is required to achieve a good biological process operation. However, the real inflow to the plant is non-linear. The inflow linearization is achieved by means of the primary settlers. Whenever the real inflow to the plant is greater than an average inflow, overflow is accumulated in a settler. In contrast, whenever the inflow is less than an average inflow, the flow is supplemented with water accumulated in the settler.

It is very difficult to determine the average value. In the Granollers WWTP, there is a knowledge-based program used to get a more lineal inflow profile. The program determines the average value from the current time and the actual WWTP inflow. The average value is used as a set-point for the control loop (i.e. cascade controlling). The process value is measured by a sensor and the actuator of a control loop is a gate.

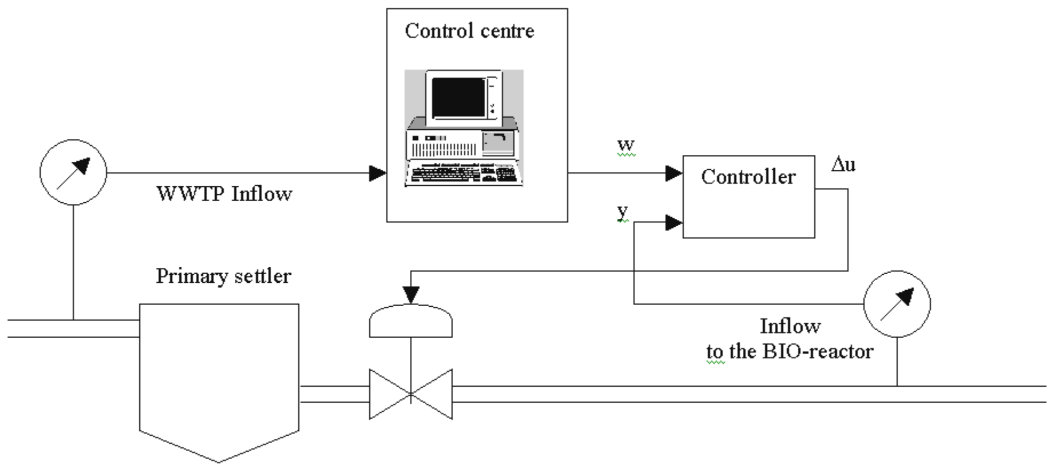


Figure 3-8: Dissolved oxygen control diagram.

Small faults in the control loop can be corrected by any other control loop, but at the expense of increasing operating costs. Extreme faults are very dangerous and have to be repaired as soon as possible.

2. By-pass.

There is an upper limitation of the inflow to the biological reactor. The maximum possible inflow is realised by a gate (coded SGA-201 in the Granollers WWTP); the overflow is directly by-passed to the Besòs river. Process value is measured by a flowmeter (FIT-201), the set-point value is given by an expert (the head of the plant). By-passed flow is measured by another flowmeter (FE-04).

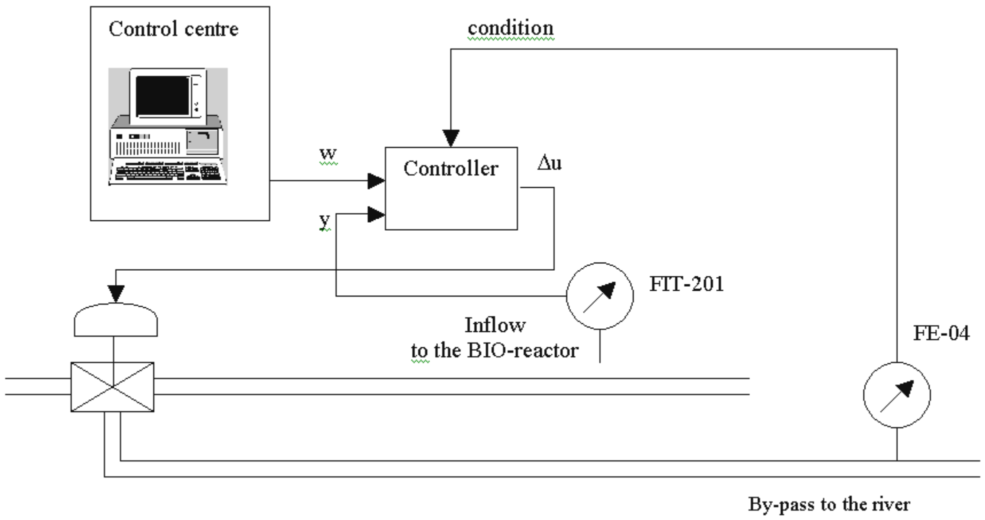


Figure 3-9: By-pass control diagram.

Small faults of the control loop could be corrected by any next control loop, but at the expense of increasing operating costs. Extreme faults are very dangerous and have to be repaired as soon as possible.

3. Sludge removal

There is a small MLSS settler behind the reactor. A specific amount of MLSS is required for a good reactor function; whenever it does not work well, excess of sludge is removed. The set-point for the controller (the MLSS amount) is given by an expert (head of the plant), the process value is measured by an MLSS sensor and the excess of sludge is removed by a pair of pumps.

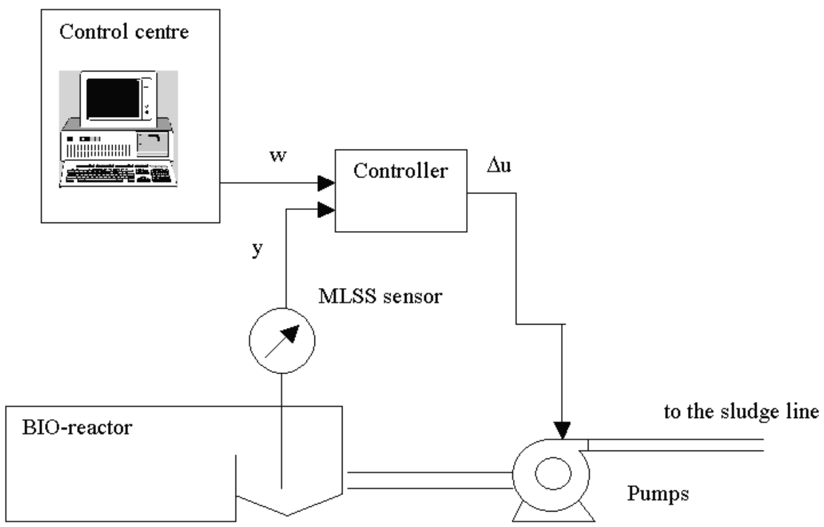


Figure 3-10: Sludge removal control diagram.

Errors in the control loop can be corrected by the control loop 4, but at the expense of an increase in the operating costs and a decrease in the treated water quality.

4. Sludge recirculation

The extra sludge in the secondary settlers is again used in the biological reactors. Sludge recirculation is provided by a pumps triplet (SP-205-A, SP-205-B, SP-205-C) - one pump works with a rank from 0 to 100%. Whenever the 100% is not enough, the second one is activated; it works with the same rank, but simultaneously with the first one (100% of power). The third one is a back-up pump. The process value is measured by a flowmeter (FIT-205), while the set-point is given by a fuzzy program (cascade controlling). The fuzzy program computes the set-point from:

a) Inflow to the plant
b) SVI – Sludge Volume Index given by a laboratory

Sludge recirculation plays a key role in the treatment process; it allows the return of nitrates to the reactor for the denitrification phase.

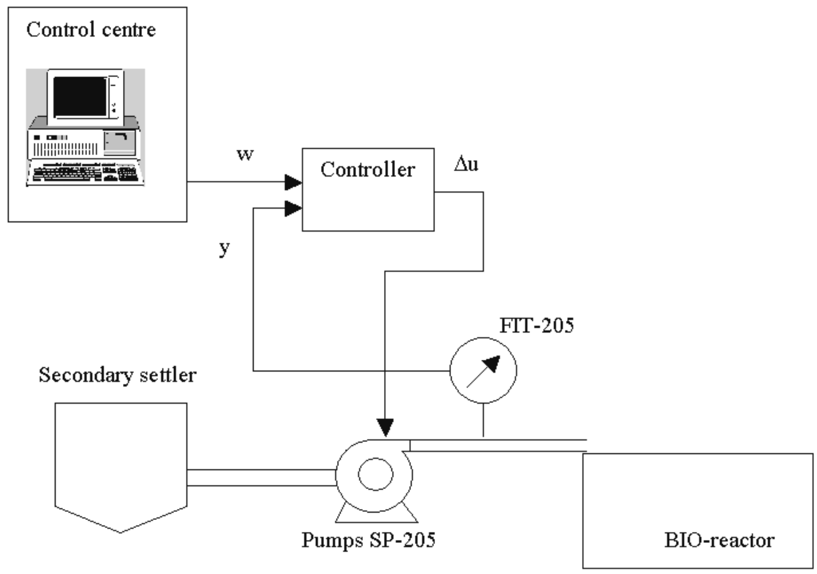


Figure 3-11: Sludge recirculation control diagram.

Small faults in the control loop can be corrected by the control loop 3, but at the expense of an increase in the operating costs and a decrease in the treated water quality.
An extreme fault has to be solved as soon as possible – excess of recirculated sludge leads to a large amount of microorganisms in the treated water; failure to recirculate leads to failure of the denitrification phase (presence of nitrates in the treated water).

5. Dissolved oxygen control loops

The transformation of the ammonia NH_4 into nitrates NO_3 is provided by the action of microorganisms. These bacteria need a high concentration of dissolved oxygen (from 2 to 3 mg/l). A cascade control loop is used in order to achieve the required value. The first control loop uses dissolved oxygen as a set-point and process value, output is a change of the air-flow. The change in the air-flow is the input of the second controller and the change is done by valves. In the Granollers WWTP there are eight partitions in the reactor with dissolved oxygen control (four in each reactor) – then, eight identical control loops are used. All the outputs from the first eight controllers are also used as an input for the triplets of compressors controller.

The set-point for the first controller is given by an expert, the process value is measured by the sensors (OIT-1 to OIT-8), the air-flow is produced by a compressors triplet (RB-201-A, RB-201-B, RB-201-C) and the relevant air-flow into the tanks is regulated by eight electric valves (EV-1 to EV-8).

The air-flow production is similar to the sludge recirculation: a compressor works with a range from 0 to 100%, if the 100% is not enough the second one is activated with a range from 0 to 100% while the first one keeps running at 100% power; the third one is a back-up compressor.

In the scheme shown in Figure 3-12, only one control loop is shown. The other control loops are similar.

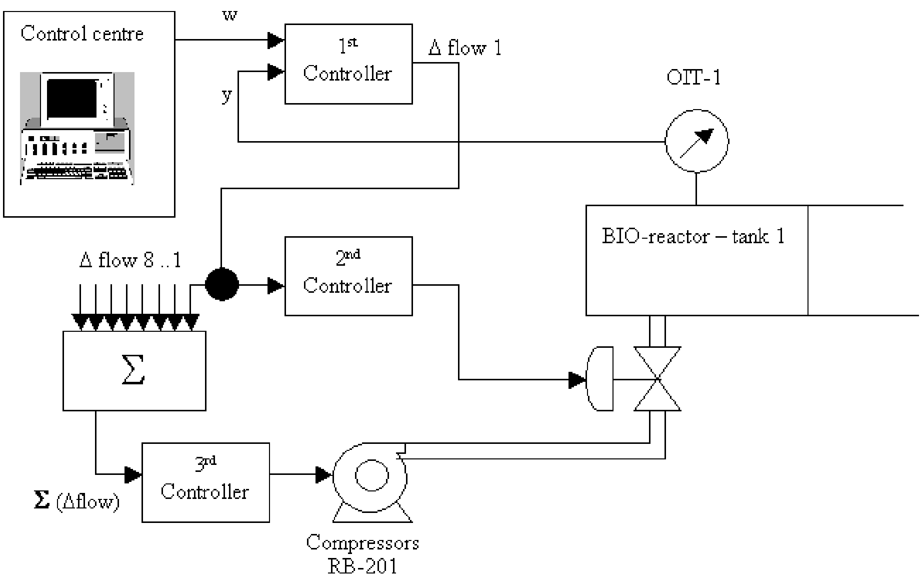


Figure 3-12: Disolved oxygen control-loops diagram.

Faults at the control loop are very dangerous. Lack of dissolved oxygen leads to a decrease in the nitrification phase efficiency and there is ammonia in the treated water. An excess of dissolved oxygen leads to an increase in the abundance of microorganisms that appear in the treated water.

At the Granollers WWTP, the activated sludge process controls the solids inventory in the system with the help of a wasting rate of activated sludge (WAS). The WAS flow rate keeps the F:M ratio balanced. The F:M ratio is the balance between the amount of microorganisms (biomass) and the amount of substrate (BOD or COD), and it is very sensitive to changes in the process operating conditions. A good operational state of WWTPs is usually achieved when the F:M ratio is guaranteed, *i.e.*, when the activated sludge process is loaded at a rate that allows microorganisms in the MLSS to use most of the food supply in the wastewater being treated. Control actions to solve or avoid situations of low removal efficiency are mainly based on: (1) automatic controllers that regulate oxygen supply as a function of established set points, (2) modifications of the recycle flow rate depending on the secondary inflow rate and SVI, and (3) flow equalisation to avoid large oscillations in the settling velocity. Modifications in the internal recycle, the anoxic/aerobic time, and in the volume and dosage of chemicals in order to improve sedimentation are much less used. A SCADA system regulates most of these control actions by means of a PLCs network.

3.4.7.2. **Montornès WWTP description**

The Montornès WWTP can be described with the information collected in the plant study protocol phase. The Montornès WWTP is in *Montornès del Vallès*, Catalunya (NE of Spain); it is on the left bank of the Besòs River. This plant treats the Wastewater from Montornès, a small portion from *Mollet del Vallès* and the wastewater generated by the industrial zone in that area (about 60-70 %). The plant is designed to treat the water generated by 265.000 inhabitant-equivalents and a medium inflow of 30.000 m^3/day.

The water line starts with a pre-treatment and goes on with a double-stage activated sludge treatment. The pre-treatment consists in a screening. A screen is a device with openings, generally of a uniform size, that is used to retain the coarse solids found in the wastewater. The first set of screens in the Montornès WWTP has a distance between openings of 10 mm, and the second set has screens with a distance between openings of 6 mm. The plant has grit and floatable removal by aerated grit-floatable.

The biological treatment consists of a double-stage activated sludge, also known as *AB* process. This kind of treatment consists of two separate stages with a sedimentation system between them. The sludge characteristics are different in each stage. The double stage process obtains a high efficiency in the first stage thanks to a microorganism selection, which is effected by the low retention time that allows the growth of bacteria but it does not allow the growth of either protozoa or rotifers. The first stage also obtains biofloculation. The first stage usually works at high load characteristics; this means that the first reactor has a small volume and a removal efficiency of 60%. All this allows working, at the second stage, with a medium-low load. This allows volume and energetic saving. The first stage is basically an aerated process with a high load; it is also called high Food-to-Microorganism (F/M) ratio (2 Kg DBO5/Kg MLSS). At this stage, there is a high removal of the easily biodegradable organic matter. The first stage consists of two aerobic complete-mix reactors. Each reactor has a volume of 1590 m^3 and the membrane diffusers are used to aerate the mixed-liquor. At the end of each reactor there is a dissolved oxygen sound. The plant has two circular primary settlers with a volume of 2200 m^3. The second stage is a conventional activated sludge treatment, which usually has less mass load than the first stage (0,26 kg DBO5/Kg MLSS). This stage consists in three plug-flow reactors with a volume of 4790 m^3. Each reactor has, at the end, a dissolved oxygen sound. Finally, the plant has three secondary settlers with a volume of 2600 m^3; they are used to separate the biomass from the treated water.

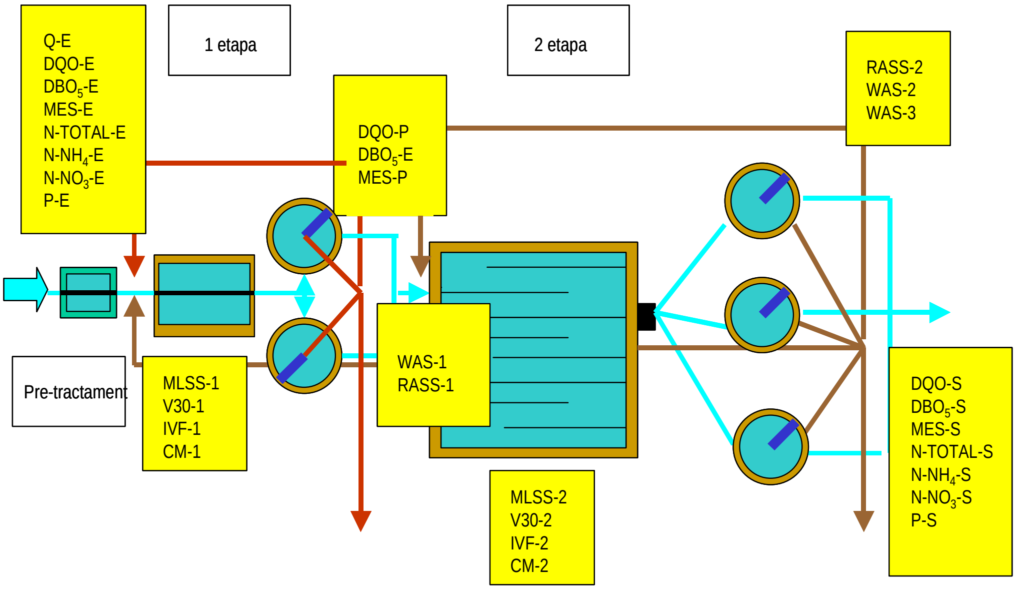


Figure 3-13: Montornès WWTP Flow sheet and sampler points.

The sludge line consists of a Waste sludge flow from both stages. The first stage sends the excess sludge to a thickener for 4 hours; afterwards, this flow is stopped for 4 more hours and then the waste sludge flow is started again. The sludge flow pump has to be started manually by an operator. The excess sludge from the second stage is sent to a thickener during eight hours at night. The pumps that send the sludge from the second stage can be started from the operation and control building.

The recycle sludge flow has also different characteristics depending on the sludge origin. If the recycle flow is done at the first stage, the pumps are started during half an hour and afterwards, stopped during the next half an hour. If the recycle flow comes from the second stage, the pumps have a variator and the flow can be modified from the operational and control building. The sludge is then sent to the anaerobic digester.

After the sludge stabilisation, the sludge is dewatered and dried using three centrifuges. Finally, the treated biological sludge is sent to a controlled landfill.

Figure 3-14: different pictures from the Montornès WWTP.

In the following table, the most important characteristics of the Montornès WWTP are summarised.

Designed for	Organic matter removal. Prevent the formation of excessive nitrate load in the reactor.	
Objective	F-Q and biological	
Configuration	The limiting factor is the sludge line	The F-Q is not used
		Biological is double stage
Control operation	Sslm = 3000	
	SRT= 10 days	
	Centrifuge	
Typical problems	Too much sludge= O_2 deficiency	
	Without 1st stage= filamentous problem in 2nd stage	
	Doesn’t work with more than 2000 m^3/h	
	Organic matter removal. Prevent the formation of excessive nitrate load in the reactor.	

Table 3-7: Table with the main characteristics of Montornès WWTP.

Control loops in the Montornès WWTP

Montornès WWTP only has three control loops that control the dissolved oxygen in the secondaries reactors, the second stage recirculation flow and the entrance water pumps.

The dissolved oxygen control loop consists in Proportional-Integral-Derivative (PID) control loop [Olsson and Newell, 1999] that is used in order to achieve the set-point value proposed by the plant head.

The P algorithm is simply that the amount of control action ($u - u_o$) is proportional to the error (e):

$$u = u_o + k_{pe}$$

Proportional action has the advantages that it is still conceptually simple and that the process output will reach a stady value in the absence of disturbances. The disadvantage is a phenomenon called *offset* which arise when the desired output is changed or the process experiences a sustained disturbance. The integral action, where the control action is proportionaql to the integral of the error, is developed to solve the *offset* problem.

$$u = u_o + k_{pe} + k_i \int edt$$

The derivative control adds a kind of predictive capability by reacting to the rate of change of the error. In the absence of noise this adds a stabilising effect, which can counteract the destabilising effect of integral action.

$$u = u_o + k_{pe} + k_i \int edt + k_d \frac{de}{dt}$$

As the dissolved oxygen control of Granollers WWTP, the first control loop uses dissolved oxygen as a set-point and process value, output is a change of the air-flow. The change in the air-flow is the input of the second controller and the change is done by valves.

In the Montornès WWTP, there are three reactors with one sensor each one and with three controllers. All the outputs from the controllers are also used as an input for the compressors controller.

The recirculation sludge flow in the second stage and the entrance pumps are controlled by a PID controls.

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Chapter 4: prototype: Granollers EDSS

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4. Prototype: Granollers EDSS.

4.0. *Abstract*

In this chapter, the Granollers WWTP case is presented. The decision support system implemented in Granollers and the improvements made in this program are offeredthe main conclusions that one can derive from this experience. In addition, the improvements in each layer of the decision support system architecture are described and commented.

First, the Granollers decision support system implementation is described in detail; then, the improvements made in each layer of this first prototype are explained. The chapter ends with the conclusions extracted from the project presented here.

4.1. *Introduction*

Since knowledge-based systems are relatively new and costly to develop, it is prudent to develop them in stages, starting with a small prototype [Mockler, 1992]. The Granollers prototype is structured following an integrated architecture. This consists of three level structures that symbolize the complexity of the wastewater treatment plant. Each level is represented by a set of modules within the program (see chapter 1, section 1.5.2.). The multi-level architecture provides easy access to the knowledge saved in each layer.

It has been proved that the best way to organize the knowledge is by means of modules. This is the reason why the application is made in a modular form and is codified in a G2 object-oriented shell. A G2 shell is a user-friendly development environment that helps to create the system (its informatics characteristics are explained in chapter 3). The application is divided in 21 modules that save both the shell and the program knowledge. Not only can this modular form be easily used in other treatment plants, but it also helps to keep all the knowledge classified. Finally, it allows us to obtain a good work method that can then be used as a guide. This method facilitates a better implementation, and the detection and correction of possible errors in an efficient way; it also makes it possible to modify any of the modules within the program application in any other plant. This project is useful because although different wastewater treatment plants have similar structure and operation, each has its own characteristics. These differences force to have a universal prototype that can be easily adapted to new and future conditions.

First, it is necessary to talk briefly about the antecedents of the system. The prototype implemented in Granollers was made 3 years ago; it was the result of Dr. Joaquim Comas' thesis. The current thesis starts with the validation of Dr. Comas' prototype results. Some of the objectives of this thesis (make a better program, solve the main bottlenecks, get better decision trees, and develop a friendlier communication interface) are directed to improving the EDSS and facilitate its exportation to others plants.

To be successful in the exportation task, the following is needed:

- A checked program.
- An exportation guide.
- Knowledge about the biological processes and about different plant configurations.

The fact that this project is based on the prototype allows the development of a protocol, which will be followed as an exportation guide. The prototype, the test and the investigation phases have to be well structured to facilitate the new system design process. A normalized document that explains how to make the exportation and the steps to follow is useful because it contributes to the exportation task in the following way:

- Provides a rational organisation of the exportation process.
- Minimises errors.
- Reduces the time and economic investment of the exportation process

The prototype provided us with knowledge and information about the necessities and bottlenecks of this program. During the validation period, the program was found to have some bottlenecks that made its re-use difficult. The most important of these bottlenecks were:

- Data acquisition.
- User-program interfaces.
- Case cycle.
- These problems have been corrected and, consequently, the operation of the program has been improved.

4.2. *Objectives.*

The objectives of this chapter are:

- Prototype validation.
- Prototype improvements.
- Evaluate if the program can become a useful tool to help the plant head in his/her decisions.

4.3. *Granollers case*

As explained in the introduction, the implementation in Granollers was consisted in several modules that reproduce the layers of the decision support system architecture. This way to implement the decision support system is one way to systematise its implementation. This implementation way is also used in the Montornès EDSS development process that is explained in chapter 6 section 6.4.

The steps to implement the decision in Granollers WWTP are explained in the following sections.

4.3.1. **Brief Plant description.**

A brief description of the plant is presented in this section. A full description can be found in chapter 3, section 3.4.7.1.

The Granollers WWTP is a medium size biological treatment plant. It provides preliminary, primary settler and secondary treatment to remove contaminants (including, under certain conditions, nitrogen).from the wastewater generated by 130.000 inhabitant-equivalents. The raw influent comes from a sewer that collects both the urban and industrial wastewater. The percentage of industrial wastewater in the total wastewater that arrives to the plant is 60%.

Water line			Sludge line	
Pre-treatment	**Primary treatment**	**Biological treatment**	**Recycle**	**Waste**
Screening	Two circular sedimentation tanks	Ludzack-Ettinger configuration	Fuzzy logic-based program controls the RAS flow.	Two anaerobic digesters
Grit and floatable removal	Flow equaliser	Two main reactors	3 pumps	3 centrifuges

Table 4-1: Granollers WWTP characteristics.

4.3.2. **Prototype design and implementation.**

The prototype was developed following a multi-level architecture that integrates data mining from different sources and artificial intelligence tools. This program was designed to help reduce the time needed to make decisions, and to improve on the consistency and quality of these decisions.

Once the system was developed, it was codified and implanted in a personal computer. The implementation is the process of converting the initial conception of a knowledge-based system into a tool that can be effectively used. The implementation of the Granollers EDSS follows the multi-level architecture.

The architecture used provides an integrated framework to have easy access to five modules: data gathering, diagnosis, decision support, planning, and action. This multi-level architecture guarantees the useful and successful supervision of wastewater treatment processes and provides an agent-based architecture with additional modularity and independence (a key factor to guarantee the re-design and transferability of the system to another WWTP). Figure 4-1 shows how the multi-layer architecture connects the user with the WWTP and the tools that it uses. The different tasks of the prototype are performed in a seven-step cycle: data gathering and update, diagnosis, supervision, prediction, communication, actuation, and evaluation. The cycle is mechanically executed once a day. However, it can also be executed manually at any time, and it is fired whenever an alarm symptom is fulfilled.

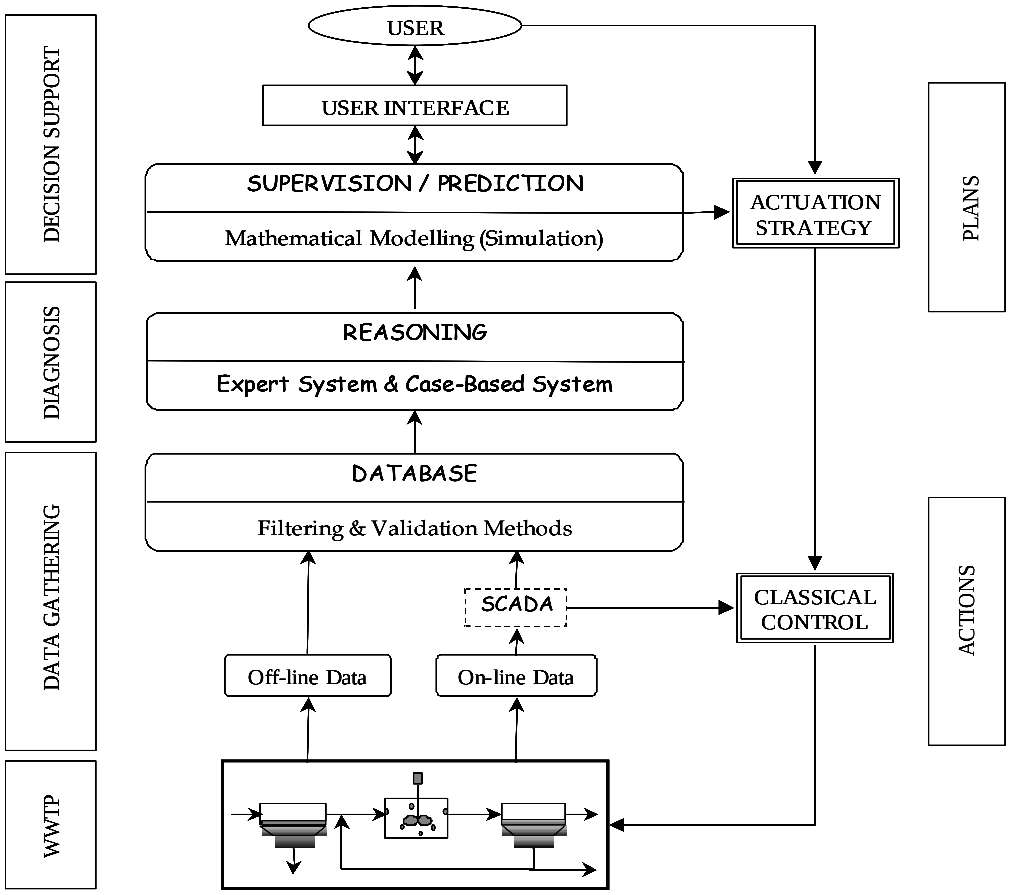


Figure 4-1: Computing approach integrated modules.

The first level controls the access of several ES and CBR to the database and supports the data-gathering and updating processes. It consists in the acquisition systems for both the on-line and off-line data. Moreover, this level implements data filtering, validation and management processes over the temporal evolution. The data acquisition system, made of three C++ communication bridges, gathers all kinds of data collected in the Granollers WWTP. On-line data, previously acquired by means of a SCADA system, includes digital and analogical signals from sensors and equipment. Off-line data includes both numerical and qualitative information acquired from analytical determinations in the laboratory, operator observations, and the result of activated sludge examination.

Original raw data, often defective, requires a number of pre-processing procedures before being registered into the database in an understandable and interpretable way. The first step is the data validation, which includes filtering the correctness of the values, the noise, and the missing values. Then, all these filtered values are integrated into a homogeneous unit and time-scale.

Three types of data were distinguished: on-line data coming from sensors and equipment, off-line and qualitative data, and microbiological data. At the beginning, on-line data includes 200 digital signals about the state of the mechanical equipment and 20 analogical signals about different variables of the process. On-line data acquisition was directly accomplished from the PLCs network of the plant. To sum up, the communication system was based on a system of PLCs and a master-PLC with a data server program built with the G2-gateway. This communication was established via TCP/IP. The operation of the server begins with the initialisation of the program variables and the communication port.

The off-line data is based on the data from the spreadsheet, which was read using a set of procedures and rules from the G2 shell, and on the combinations of numerical data allowed calculating process variables.

Data processing has to validate and integrate the original data that the program receives from the different sources into a uniform time-scale. As of now, the developed system is used to monitor the process as a SCADA.

The second level in this architecture includes two artificial intelligence techniques (Expert System and Case-Based Reasoning) that infer the state of the process. Both techniques present a reasonable proposal of action to support the whole plant supervision. This second level entails cooperation between knowledge-based control and automatic control for the supervision of this complex process. This level implements reasoning tasks that diagnose its state and behaviour and propose actions to maintain or return the process to its normal operation. Then, both results are integrated into one solution based on a combination between the heuristic knowledge of the ES and analogous experiences retrieved by the CBR. The proposed solution is passed to the third layer of the architecture. Both modules deal with qualitative information, and can interact with classical control methods based on modelling.

The third level in the architecture establishes a supervisory and predictive task on the WWTP. The goal of the supervisory module is to seek a consensus on the diagnosis and the actions proposed by the different reasoning tools. This task entails the gathering and the combined conclusion of both knowledge-based techniques (ES and CBR) in order to identify whether there is a problem or not. The final diagnosis, together with the suggested action strategy, is showed to the user by means of the computer interface message-board. This action strategy has to propose the correct action to bring back the plant to normal. This module also raises the users interaction with the computer system using an interactive and graphical user-machine interface. Moreover, the user can consult the EDSS conclusions, as well as any quantitative or qualitative variables to know the state and trend of the plant. In this layer, there are included the fourth and fifth layer procedures and rules.

In the fourth level, the plans are built and showed to the user to find out the problem solutions. The action plans are structured as specific and/or non-specific depending on whether the cause of the problem is well determined or not. Within the Expert system the plans are a list of general actions, suggested in the literature, to solve a specific problem. These actions can also be more concrete if the plant head explains what to do in precise situations; these explanations are included in the rules.

The fifth layer contains the set of actions to be performed in order to solve the problems in this domain. These rules have been defined by a generic facility and they could be easily adapted to others with the same architecture and technology. In this level, the proposed action became a real number that the plant head has to verify in advance. For instance, when the fourth level defines that the action is to increase the **recirculation** flow, the fifth layer calculates the new recirculation set-point. Apart from being needed, it doesn't have additional problems. This is the last level in the architecture and it closes the loop.

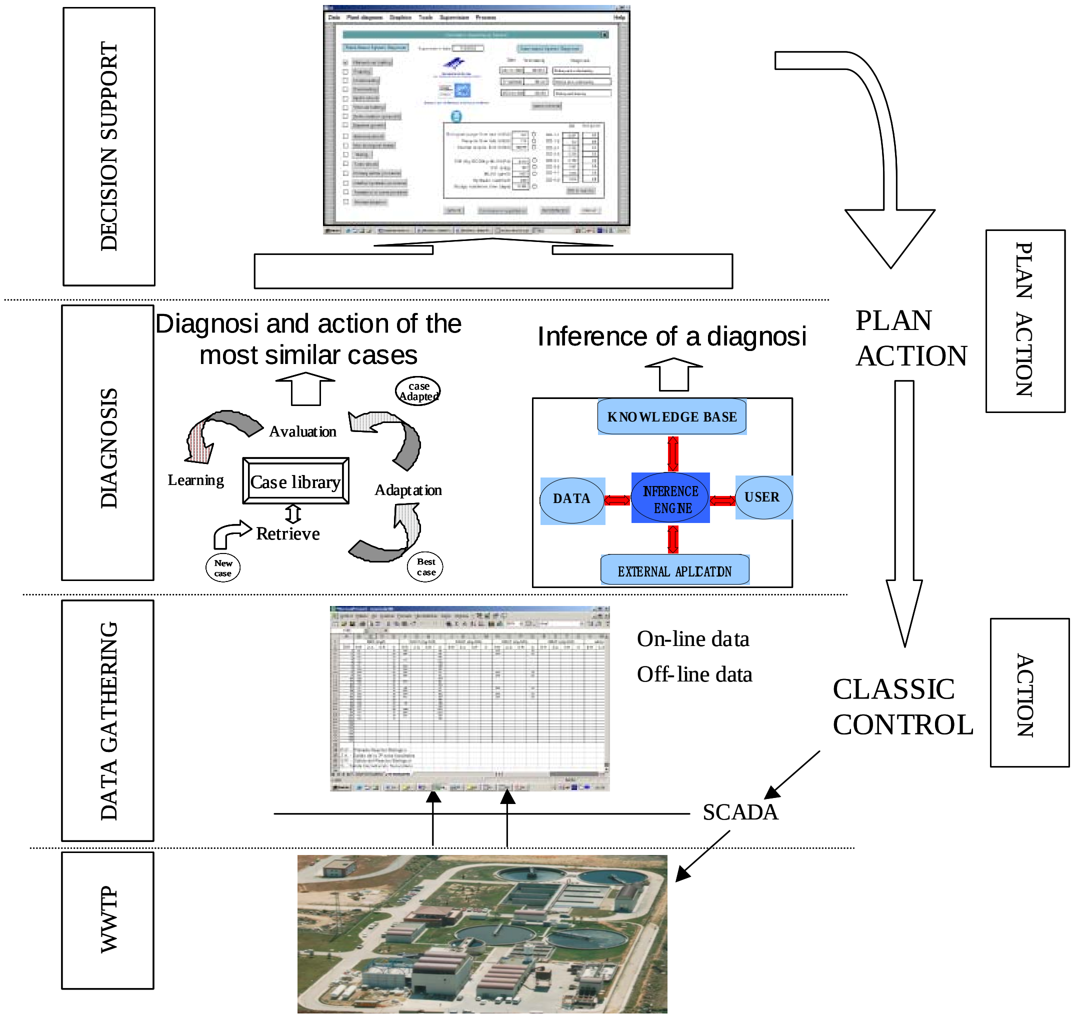


Figure 3.4: Operation program diagram.

4.3.3. The EDSS operation.

1. *Data gathering*. Data gathering is accomplished through on-line data acquisition systems and off-line acquisition systems. The data from the plant situation arrives to the EDSS and is saved into vectors. Daily, or on demand, the program is executed and it retrieves the analytical data saved and the on-line data on-time.

2. *Diagnosis.* Once the information has been collected, it is sent to the diagnosis module where the knowledge-based systems (ES and CBR) are executed. Thus, the process current state will be diagnosed through a reasoning task based on both models. Both tools come to an independent conclusion. One comes to an inferred conclusion and the other one comes to an experiential one.

3. *Decision support.* When the second level has the conclusions then, the third level in the architecture determinates the best solution for the plant situation. This determination is based on the distance between the current case and the most similar retrieved case. If the distance is very small, the retrieved case is very similar to the current case, and then, this is the best solution to the detected problem. On the other hand, when the distance is larger, the inferred solution from the system is the best one.

4. *Plans and actions.* When the best solution is chosen, the program determinates an action plan to apply it. If the model is integrated in the architecture, the proposal could be checked with the plant model. In the last step, the proposal is communicated to the manager by means of an interface; the program can also act directly on the process.

5. Finally, the system saves the current case in the case library to increase the specific knowledge about the plant.

Figure 4-2: The program implemented in Granollers WWTP.

4.4. *Prototype improvements.*

Some improvements were made in the prototype to generate a better facility and better exportable capabilities.

The main improvements made are represented in this figure (figure 4-3). During the thesis, several corrections in rules, procedures, objects and so on were made.

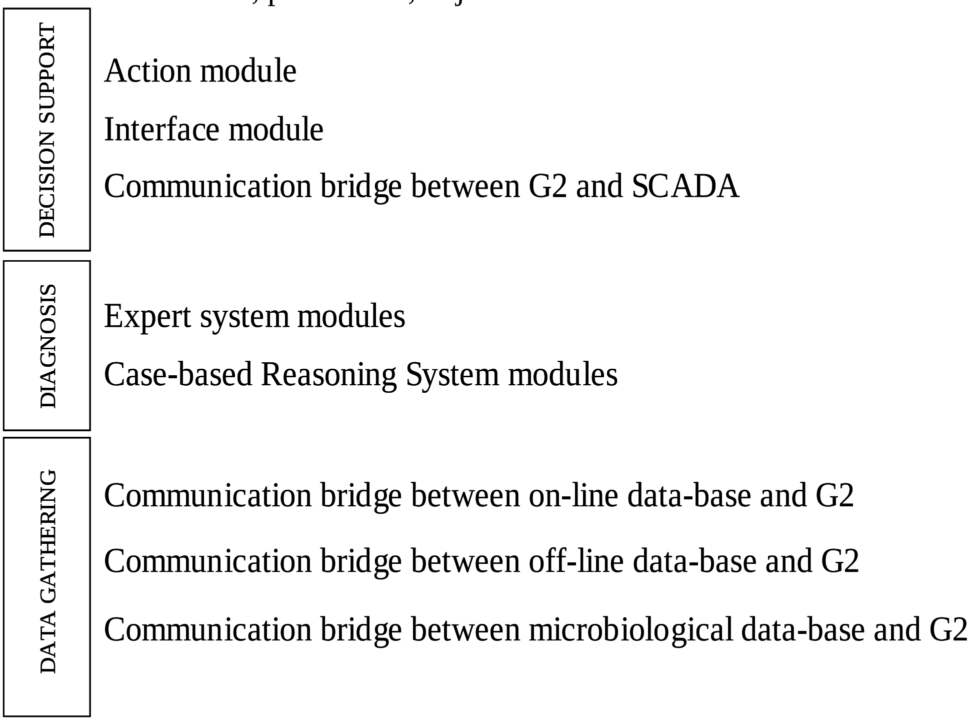


Figure 4-3: Improvements made in every prototype layer.

The first decision support system was built using two artificial intelligence tools; they were both based on knowledge. One is the expert system (or Rule-based system) and the other is the case-based reasoning system. These tools were in the second architecture layer and they did not undergo important changes. It is in the first architecture level where more changes were made. In this layer, the acquisition data system was replaced by another system that was easily used by the plant head. In the third architecture layer, big changes in the communication between the user and the program layer were made. A new interface that allowed an easier transfer of information from the program to the user was applied.

4.4.1. *First level: Data Gathering.*

The plant dynamics generate a large volume of data, and the program has to be able to study this information and produce a correct diagnosis of the plant situation. The transformation of the received value to information is not evident. We have to guarantee efficiency in the collection, transport, filtering, integration and signals interpretation processes. Data management is structured according to data origin: i) numerical data on-line, ii) analytical data and qualitative off-line data, iii) and microbiological data. All this data are collected in different ways; later, this data is uniformed and introduced in informatics spreadsheets. From these spreadsheets, the decision support system collects, by means of *ActiveXlink* bridges (tools that allow communication between various programs), the values it needs for its operation. This data flux is represented in the following figure.

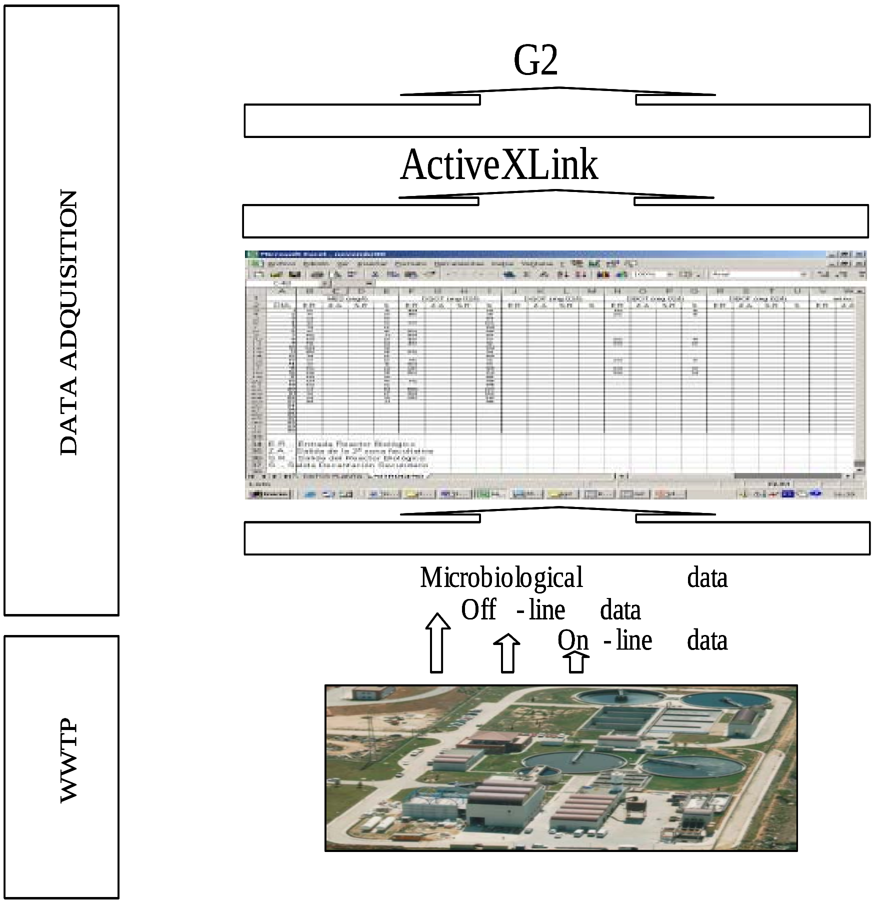


Figure 4-4: Data flux in Granollers WWTP.

This information flux is similar in several medium-sized biological treatment plants. This does not mean that all medium size biological treatment plants are equal, but that they are similar in data flux. Although different plants can have different instrumentation levels, the information flux will be similar.

Sufficient information, which has to be trustworthy and correct, is needed for the correct operation of the program. Information can be obtained in two ways: with different sensors and by sampling at different points of the plant. Both analytical and qualitative data are collected.

Inflows, suspended solids, COD, and so on are measured. The sampling points can be at the entrance, at the biological process and at the end of the plant. The information collected in the plant can be divided into on-line data, off-line data (with qualitative information), and microbiological data.

Table 4-2 shows the amount and frequency of data gathered by the EDSS in Granollers WWTP.

Data source	Quantity	Frequency
Sensors and equipments	1039	15s
Analytical measurements	110	Daily
Activated sludge observation	43	Weekly

Table 4-2: Data gathered by the EDSS in the Granollers WWTP.

The following table contains the principal kinds of on-line signals that the program receives and manages. The number of signals considered may vary depending on the kind of treatment plant. In the Granollers WWTP case, there are 1052 signals (listed in the Annex III). In the on-line data departure acquisition there is more specific information.

Zone	Equipment	Elements	Signal	Digital/analogical
Entrance	Pumping	Entrance gate	Open/closed	Digital
		Archimedes screw 1	Stop/run/failure	Digital
		Archimedes screw 2	Stop/run/failure	Digital
		Archimedes screw 3	Stop/run/failure	Digital
		Frequency variation	Stop/run/failure	Digital
	Flow	Flow meter	Flow	Analogical
		Total entrance flow	Flow	Analogical
Pre-treatment	Grit and floatable removal	Gate A	Open/closed	Digital
		Gate B	Open/closed	Digital
		Aeroflots line A	Stop/run/failure	Digital
		Aeroflots line B	Stop/run/failure	Digital
		Float removal bridge A	Stop/run/failure	Digital
		Float removal bridge B	Stop/run/failure	Digital
		Grit removal pump A	Stop/run/failure	Digital
		Grit removal pump B	Stop/run/failure	Digital
Primary treatment	Reactor	Mixer reactor A	Stop/run/failure	Digital
		Mixer reactor B	Stop/run/failure	Digital
		Frequency variation	Frequency	Analogical
	Settler	Entrance gate to settler A	Stop/run/failure	Digital
		Entrance gate to settler B	Stop/run/failure	Digital
		Settler bridge A	Stop/run/failure	Digital
		Settler bridge B	Stop/run/failure	Digital
Secondary treatment	Reactor	Entrance gate to reactor A	Open/closed	Digital
		Entrance gate to reactor B	Open/closed	Digital
		By-pass gate	Open/closed	Digital
		Blowing A	Stop/run/failure	Digital
		Blowing B	Stop/run/failure	Digital
		Blowing C	Stop/run/failure	Digital
		Frequency variator	Frequency	Analogical
		Oxygen sensors	mg O_2	Analogical
		Set-point oxygen	mg O_2	Analogical
	Settler	Entrance gate to settler A	Stop/run/failure	Digital
		Entrance gate to settler B	Stop/run/failure	Digital
		Settler bridge A	Stop/run/failure	Digital
		Settler bridge B	Stop/run/failure	Digital
		WAS Pump 1,2	Stop/run/failure	Digital
		WAS flow	Flow	Analogical
		Total WAS flow	Flow	Analogical
		RAS Pump 1,2,3	Stop/run/failure	Digital
		RAS flow	Flow	Analogical
		Total RAS flow	Flow	Analogical
		Frequency variator	Frequency	Analogical
		Treated water flow	Flow	Analogical
		Total treated water flow	Flow	Analogical

Table 4-3: The different types of on-line variables. Sensor location is in rows and parameter characteristics information in columns.

Off-line data is measured on samples collected all along the process. In this way, the dynamics of the wastewater along the plant can be known. On the other hand, it is difficult to have all the values at once because it is hard to make all the necessary analytical process at the same time.

Samples can be of two types: point sample and integrated sample. Point samples iare taken whenever the plant head detects something abnormal in the inflow and wants to know what happens to the plant. The integrated sample is the normal way to control the plant. At different places of the treatment plant, the plant head establishes points where the water is automatically sampled for 24 hours.

It is important for the decision support system to have regular information about the plant because the program takes time into account in its inference process. For instance, the program will not use data that have expired. The qualitative information is obtained every day to help control different aspects of the treatment.

Parameter	Possibilities that the user can choose
Macroscopically observation of the floc.	5 Possibilities
Settler in V30.	9 Possibilities
Height of sludge bed.	6 Possibilities
Foams in reactor.	3 Possibilities
Foams in the exit.	3 Possibilities
Floc in settler.	2 Possibilities
Incidences	3 Possibilities

Table 4-4: Table with the most common variables on qualitative inform.

The first column shows the information that can be evaluated with the qualitative questionnaire. The second column presents the possibilities that the plant head can choose from. The qualitative evaluation of the plant is made by different people. In order to unify their different points of view, a qualitative questionnaire was created.

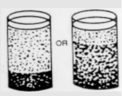
The qualitative questionnaire used to evaluate the state of the process.

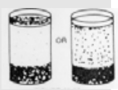
Observació macroscòpica del flòcul en la prova de la V30. (1/2/3/4/5)	
1 : Flòculs petits i dispersos, que decanten lentament. La seva sedimentació presenta una fase de de contracció poc definida, així com una àmplia interfase fang-sobrenedant. **2** : Flòculs més grans que s'aglomeren i comencen a caure ràpidament. Al cap de poc es forma una interfase fang-sobrenedant ben definida. **3** : Flòculs petits que s'aglomeren i cauen no lentament. Es diferencien clarament les fases fang/sobrenedant. **4** : Flòculs poc definits o esponjosos que no s'agreguen, que cauen molt lentament o queden en suspensió. **5** : Cap dels anteriors, sinó…	

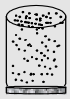
Sedimentació en la probeta en la proba de la V30. (1/2/3/4/5/6/7/8/9)

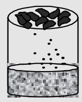
1 60 min.

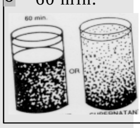
Fang que sedimenta correctament, deixant un efluent i sobrenedant clar i amb una separació entre ambdues fases ben marcada (probls.qualitat efluent deguts a clarificador)

2 30 min.

Sedimentació ràpida o lenta però el **sobrenedant** queda **tèrbol o molt tèrbol** i el fang sedimentat pot aparèixer excessivament compactat, uniforme i dens.

3 > 30 min.

Sedimentació ràpida però el **sobrenedant** és **moderadament tèrbol** amb **flòcul molt fi** (com agulles) en suspensió, degut a què el flòcul és més granular que floculant

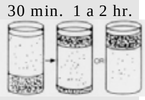
4 30 min.

No hi ha sedimentació del fang actiu perquè el **flòcul** és **tant petit que no flocula**

5 30 min.

Probeta en la que el fang sedimenta correctament però deixa una **capa de fang** en la **superfície**.

6 60 min.

Fang de color marró característic que no sedimenta o ho fa de forma molt lenta i el **sobrenedant** queda molt **clar o una mica tèrbol**. S'observa abultament o **esponjament** del **fang**.

7 60 min.

El fang, que adquireix un **color fosc** i fa **olor**, sedimenta més o menys correctament, però al cap de poc minuts **flòculs grans i esponjats ascendeixen** cap a la superfície

8 30 min. 1 a 2 hr.

Fang (amb color marró normal) que **sedimenta** més o menys **bé als 30 min però** que, **al cap de 1 o 2 h**, tot o la major part del fang **ascendeix** a la superfície, i es possible observar bombolles (de N_2) que surten del fang.

9 60 min.

Fang que **sedimenta més o menys bé però** s'observen **escumes en superfície**.

Alçada del llit de fang			
Decantador primari-1	cm.	Decantador primari-2	cm.
Decantador secundari-1	cm.	Decantador secundari-2	cm.
Espessidor-1	cm.	Espessidor-2	cm.

Presència d'**escumes al reactor (B/F/N)** **B**: Si, escumes blanques; **F**: Si, escumes marrons (filamentoses) ; **N**: No hi ha escumes	
Presència d'**escumes al decantador secundari (G/F/N)** **G**: Si, escumes greixoses; **F**: Si, escumes marrons (filamentoses) ; **N**: No hi ha escumes	
Presència d'**escumes a l'arqueta de sortida (S/N)** **S**: Hi ha escumes de tensoactius; **N**: No hi ha escumes de tensoactius	

Flòcul en el decantador (P/G/N)	
P: Escapament de flòcul petit; **G**: Escapament de flòcul gran (Desnit incont.); **N**: No hi ha flòcul en superfície	

Incidències Remarcables	

Figure 4-5: Qualitative questionnaire used to define the state of the plant macroscopically (in Catalan).

The microbiological information also needs to be managed. This kind of information is obtained by means of a spreadsheet where the results of the analysis of mixed liquor samples are stored.

Type	DATA / ABUNDANCE	
	M/ml	Abund.
Nocardia spp.	3	33210
Sphaerotilus natans	0	0
Thiothrix I	0	0
Thiothrix II	0	0
Haliscomenobacter hydrosis	0	0
Nostocoida limicola I	0	0
Nostocoida limicola II	0	0
Nostocoida limicola III	0	0
Microthrix parvicella	2	14.9
Tipus 021N	0	0
Tipus 0041	2	17.8
Tipus 0092	0	0
Tipus 0411	0	0
Tipus 0581	**4**	61
Tipus 0675	0	0
Tipus 0803	0	0
Tipus 0914	0	0
Tipus 0961	0	0
Tipus 1701	0	0
Tipus 1863	0	0
Bacillus spp.	0	0

Table 4-5: Table with the most common filamentous bacteria.

PROTOZOA Ciliated	Abundance in 1 day
Paramecium spp.	0
Litonotus spp.	0
Chilodonella uncinata	0
Uronema nigricans	0
Colpidium spp.	0
Aspidisca cicada	1140
Euplotes spp.	151
Podophya sp.	0
Trokophrya	0
Metacineta spp.	0
Acineta spp.	0
Discophrya spp.	0
Vorticella microstoma	891
Vorticella convalaria	0
Vorticella sp.	0
Vorticella infosionum	0
Vorticella similes	0
Opercularia spp.	976
Opercularia asymmetrica	0
Epistylis spp.	0
Vorticella aquadulcis	0
Acineria uncinata	0

Table 4-6: Table with the most common protozoa.

4.4.1.1. **Data acquisition**

The data acquisition layer has been strongly improved. The communication between the data source and the program was changed. The old communication system, for on-line data, was based on a MS-DOS program that transferred the information from the PLC net to the G2 Shell. At the time, this program was a great solution for the communication problem, but today there are more and better communication bridges available. The ActiveX technology is an example; these kinds of bridges are capable of achieving communication between different programs, which can be codified in different languages. Here, the ActiveXlink Bridge is used; this was developed by the G2 Gensym Corporation and is a good communication tool between the G2 shell and other programs like Excel, Word, or any type of databases. The following figure shows how the bridge connects different sources of information with the G2 shell.

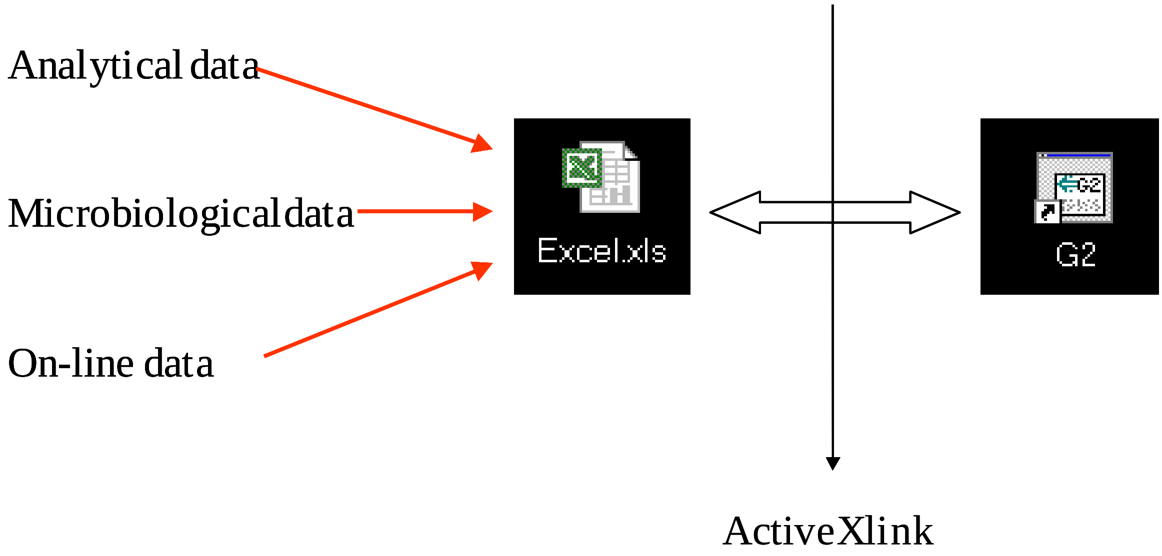


Figure 4-6: Transfer of data between informs and G2.

This technology allows the connection between different programs that can use different program languages. The bridge is codified in visual basic language and in subroutines in a macro in the spreadsheet.

On-line Data.

On-line data acquisition is centralized in a spreadsheet that is updated every 15 seconds. There can be many variables in this spreadsheet and their signals can be analogical or digital. These signals provide a lot of information about different parts of the plant, such as gates, bombs, flows, and so on.

In the case of the Granollers WWTP, 1052 on-line variables are measured every 15 seconds (see list in the annex III). But not all the collected data are necessarily used. The ActiveXlink Bridge is programmed to transfer the 1052 variables into a vector by means of the qualified connection. The position of the variable in the information vector is known and corresponds to a concrete variable in the G2 program. Different procedures and rules of filtering are applied to the vector. The main bottlenecks in this new bridge of communication are the following:

- It is difficult to know the exact position of a variable.
- Some information is difficult to transfer.

The following table summrizes the received on-line signals:

Description	Number of signals
Set-point PID	4
PV PID	2
PV sensors	10
Set-point sensors	12
Water flow	19
Sludge flow	16
Gates (open/closed)	106
Engines	120
Air flow	10
Confirmation	105
Operating time	155
Levels	33
Pumps	132
Empty	1
Others	327

Table 4-7: Number o fon-line signals received in the intelligent program.

If there were any problem with the filtering procedures due to an incorrect variable, it would take a long time to find out the concrete variable that causes the problem. There can be problems with some type of information; in that case the better solution is to modify the concrete variable in the database that causes the problem.

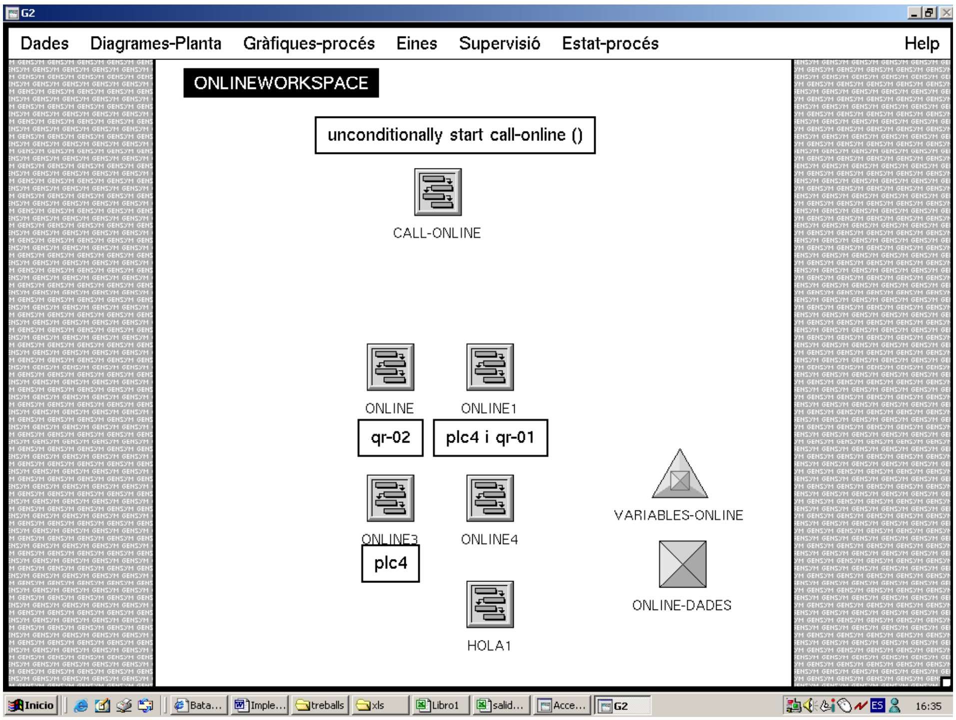


Figure 4-7: The knowledge of the on-line data acquisition is organised into this G2-Workspace.

Figure 4-7 illustrates how the knowledge needed to transfer the on-line information from the SCADA to the G2 shell is organised. An unconditional rule with a frequency of 15 seconds is responsible for the activation of the procedure that starts the subroutine.

```
unconditionally start call-online ()
```

Table 4-8: Rule that starts the procedure named call-online()

When the procedure *Call-online()* is executed, it first verifies the connection and then sends the order of activation to the subroutine of the macro in the spreadsheet.

```
Call-online()
G: class g2com-interface;
Ret: value;
Var1:quantity=3;
Begin
      if there exists a g2com-interface G then
 begin
  Ret = call g2com-call("Get",var1) across G;
  Inform the operator that "Valor enviat";
 End;
End
```

Table 4-9: The subroutine of connection between the spreadsheet and the G2 shell.

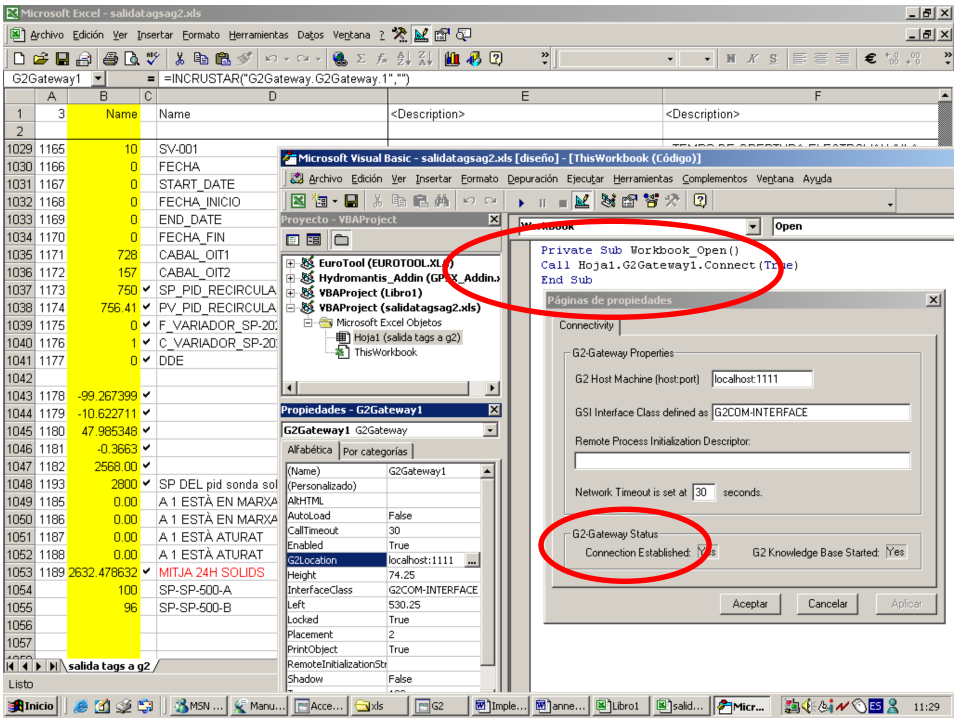


Figure 4-8: Schematic representation of the visual basic sub-routine executed when the spreadsheet is activated.

When the user activates the spreadsheet, the first sub-routine is executed automatically and builds a connection between the spreadsheet and the G2 shell.

```
Private Sub Workbook_Open()
Call Hoja1.G2Gateway1.Connect(True)
End Sub
```

Table 4-10: The sub-routine of the spreadsheet that builds a connection between the spreadsheet and the G2 Shell.

In this case, the connection is called G2Gateway1. The user can see if the connection is available in the properties of the connection. If the connection is not available, the user has to turn the spreadsheet off and turn it on again to generate a new connection.

When the connection is open, the order arrives to the macro of the spreadsheet, which verifies the order and sends the information to the shell.

```
Private Sub G2Gateway1_RpcCalled(ByVal ProcedureName As String,
InputArguments As Variant, ReturnArguments As Variant)
    If ProcedureName = "Ges" Then
    Range("a1") = InputArguments
    asd = Range("b3:b1176")
    Call G2Gateway1.Start("online", asd)
    End If
End Sub
```

Table 4-11: The subroutine that transfers the on-line information.

This subroutine sends the information in the spreadsheet, ranged from b3 to b1176, to the G2 shell by means of the generated connection. That range of data has some rows without a value. Thus, in the case of the Granollers WWTP, the ActiveXlink bridge transfers 1053 on-line variables to the program every 15 seconds. Once the data are transferred, a group of procedures filter and organise the data in different objects. The objective of the filtering procedures is to verify that each variable has a correct value. Once the variable has a value, the information is located in the corresponding object.

The program procedures that filter the received information are (see figure 4-7) *Online()*, *Online1()*, *Online3()*, and *Online4()*.

The *online()* procedure is activated by the sub-routine from the spreadsheet and receives the complete vector of values. The procedures of the G2 shell need to know what kind of information they receive. Once the procedure knows what kind of vector it has to work with, it knows the meaning of every received value.

```
online(asd: structure)
cat:sequence;
cabal-reactor-1:quantity;
begin
inform the operator that"ja la tornem a tenir";
cat=the com-elements of asd;

if cat[3] has a current value and cat[3]/="" and cat[3]/=the symbol null
then conclude that the cabal-reactor-1 of online-dades = cat[3];
if cat[28] has a current value and cat[28]/="" and cat[28]/=the symbol
null then conclude that the cabal-reactor-2 of online-dades = cat[28];
if cat[29] has a current value and cat[29]/="" and cat[29]/=the symbol
null then conclude that the cabal-reactor-total of online-dades = cat[29];
…
if cat[254] = 0.0 then conclude that I11-DATA-PLC4[15]=0 else
conclude that I11-DATA-PLC4[15]=1; end;

call online1(cat);
end
```

Table 4-12: Part of the procedure named online().

The first line of the procedure contains the name of the procedure and, in parenthesis, the type of the information that the procedure will receive. In this case, the procedure's name is *online* and the information that it receives is of type structure. Then, the procedure converts the structure type into a sequence type. The converted information is stored in a vector called *cat*. Afterwards, there are a group of rules with the mission of verifying that a determinate position in the vector *cat* has a normal value. This value is stored in the corresponding object in the program. In this case, the object used to store the value received is the variable *cabal-reactor-1* of an object called *online-dades*, another example is the position 15 of a vector called *I11-DATA-PLC4*. At the end of the procedure, a line of code calls the next procedure that continues the filtering process on the sequence cat (in parenthesis).

- The *online1()* procedure has the same architecture as the *online()* and deals with the information between position 255 and position 815 of the vector *cat*. At the end of the procedure, a line of code calls the next procedure.
- The *online3()* procedure deals with the data stored between position 816 and position 863 of the vector *cat*. At the end, it calls the last procedure.
- The *online4()* procedure can deal with the different new positions that could be of interest to the user.

Off-line Data.

Off-line data consist of a volume of 110 variables from different samples in the plant, although only 66 variables were used. Most of the off-line information comes from the process samples, but some signals derive from mathematical operations between other variables. The following table, shows the parameters extracted from the analysis of samples:

	Parameter	Entrance	Biological process	Exit
Analytical information	**Day**			
	Inflow			
	pH(units of pH)	☑	☑	☑
	Suspended solids (mg/l)	☑	☑	☑
	COD (mg/l)	☑	☑	☑
	BOD_5 (mg/l)	☑	☑	☑
	Yield of SS	☑	☑	☑
	Yield of COD	☑	☑	☑
	Yield of BOD	☑	☑	☑
	NTK (mg/l)	☑		☑
	Nitrates (mg/l)	☑		☑
	Nitrites (mg/l)	☑		☑
	Total nitrogen (mg/l)	☑	☑	☑
	Ammonia (mg/l)	☑	☑	☑
	Total Phosphorous (mg/l)	☑	☑	☑
	Conductivity	☑	☑	☑
	Turbidity	☑	☑	☑
	MLSS of return sludge		☑	
	MLSS (mg/l)		☑	
	MLVSS (mg/l)		☑	
	V30 (mg/l)		☑	
	SVI (ml/g)		☑	
	TRH (day^{-1})		☑	
	CM (KgDBO5/ d*kgMLSS)		☑	
	BOD/N		☑	
	BOD/P		☑	

Table 4-13: Off–line parameters that the head of the plant needs to adequately run the plant.

☑	Value calculated by mathematical operations
☑	Sample

The qualitative information can help an expert plant head to make a decision because it provides rich information about the state of the process.

Qualitative information	**Macroscopical observation of the floc.**	
	Settler in V30.	☑
	Height of sludge bed.	☑
	Height of sludge bed.	☑
	Height of sludge bed.	☑
	Height of sludge bed.	☑
	Height of sludge bed.	☑
	Height of sludge bed.	☑
	Foams in reactor	☑
	Foams in settler	☑
	Foams in exit	☑
	Floc in exit	☑
	Comment	☑

Table 4-14: Qualitative information collected by the operator.

The communication bridge implemented for the transfer of the off-line data provided by the laboratory is similar to the on-line data bridge. This new bridge transfers the results of the sample analyses to the program.

The off-line data is also contained in a spreadsheet provided with a macro that establishes the connection with the G2 shell. This macro is activated whenever the spreadsheet is opened and transfers the data when the user closes it.

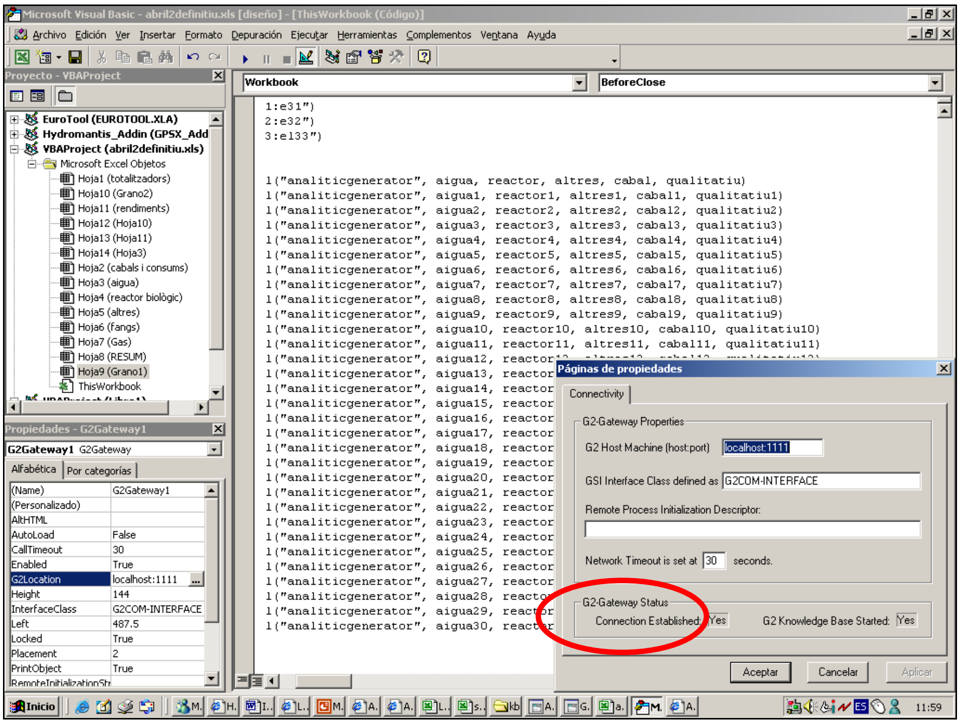


Figure 4-9: The sub-routine that connects and transfers the information from the spreadsheet to theG2 shell.

When the information arrives to the shell, it is filtered by procedures that convert or remove any abnormal data found in the transferred vector. The filtering procedure is made of code lines exemplified here:

***if** a1[5] = the symbol null or*
a1[5]=""
***then** mes-ent-1=-9999*
***else** mes-ent-1 = a1[5];*

Figure 4-10: A filtering rule.

Where *a1* is the transferred vector and *5* is the position within this vector. If this vector position has no value, then the procedure assigns the value of –9999 to the corresponding variable.

The procedure that performs this filtering task is called *analiticgenerator*. As in the case of on-line data, this procedureprocesses the received information and puts it into two vectors in the program.

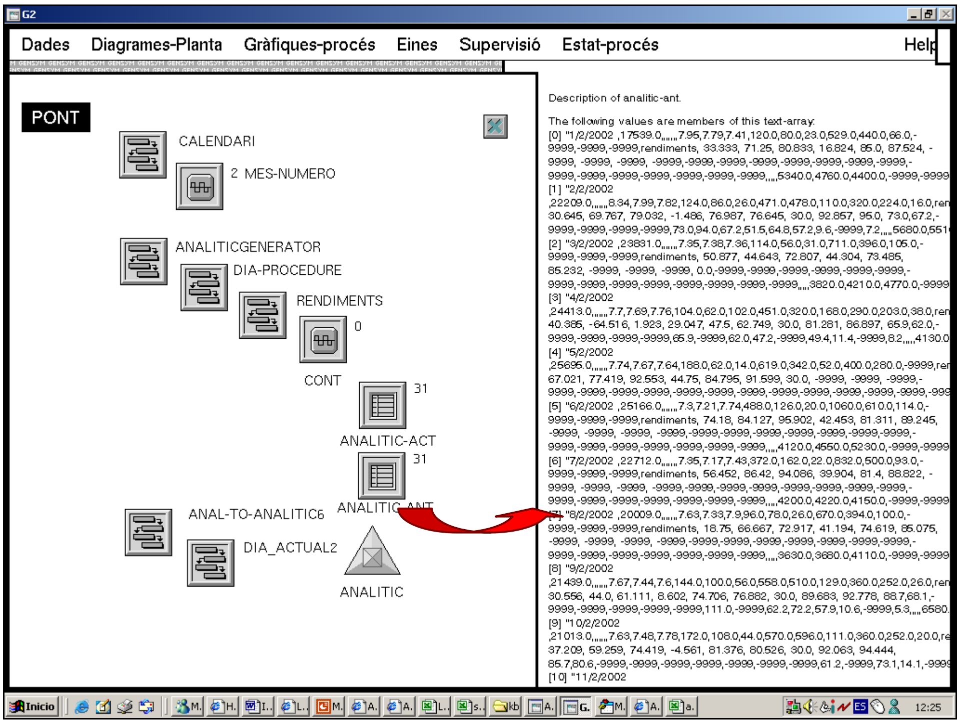


Figure 4-11: G2-Workspace where there are the procedures of filtering of the off-line information.

The *analiticgenerator* receives as many vectors as days are in a month. Once the values are filtered, they are stored in another vector in the program. With the information stored in these vectors the program calculates trends in the variables. In Granollers, the transferred data volume is normally 110 variables a day.

Microbiological information.

This information is also stored in a spreadsheet and the communication system is the same as above. The spreadsheet has a macro in Visual Basic. One macro subroutine transfers the information by means of the generated connection. There are two Excel files with the microbiological data. One file consists in filamentous bacteria information and the other in protozoa information. Each file has its own macro that, as in the case of off-line data, connects the spreadsheet with the program. Both Excel files operate in the same way; just before the user closes the excel file, these macros transfer the information by means of the bridge. Then, a procedureprocesses, classifies and filters the received information, and stores all the information in a vector.

Each macro in each Excel file calls a different procedure. The Excel file related to the filamentous bacteria calls the procedure named *FILAMENTS* and the other excel file calls the procedure named *FILAMENTS2*. Each procedure deals with the information that it receives and stores it in one vector. Consequently, there are two different vectors with information from both sources. When the two vectors are completed, another procedure, called *FILAMENTS3,* is executed. This unifies both vectors into a single vector called *FIL*.

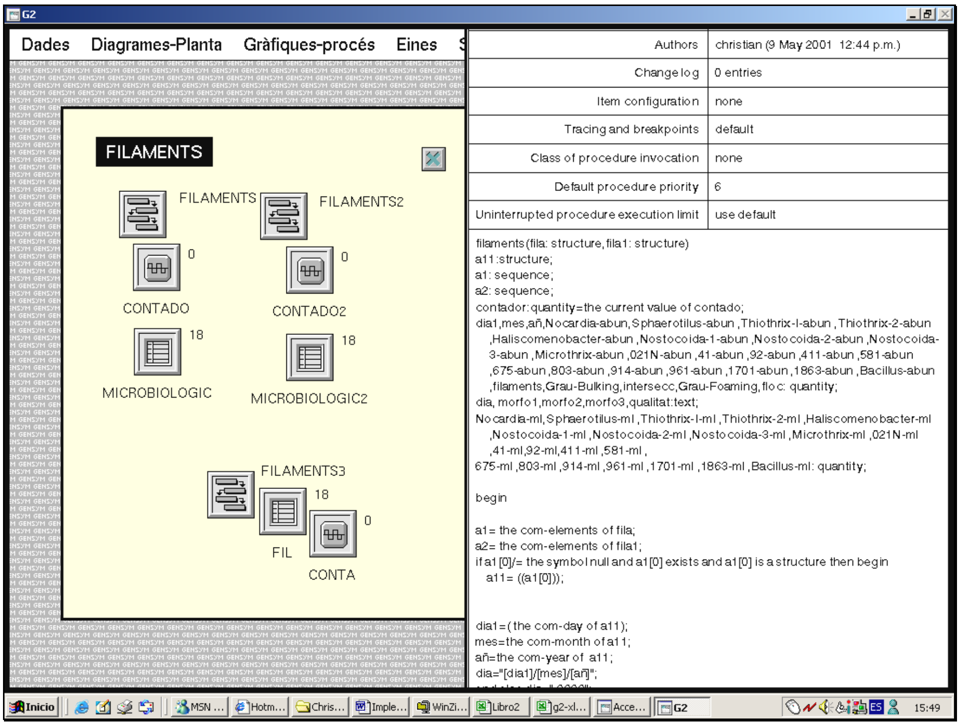


Figure 4-12: G2-Workspace with the procedures that filter the microbiological information.

In the Granollers WWTP, the transferred data volume is 43 variables a week.

4.4.1.2. **Interpretation.**

Once the acquisition and the filtering are done, the user can verify any data. The user has access both to the objects of the program, where the information is stored, and to charts.

The operator can see the information transferred and filtered by the program in different pictures.

The diagram from the secondary treatment of the plant is presented in the following picture. The information related to different parts of the plant can be seen by clicking on the corresponding object.

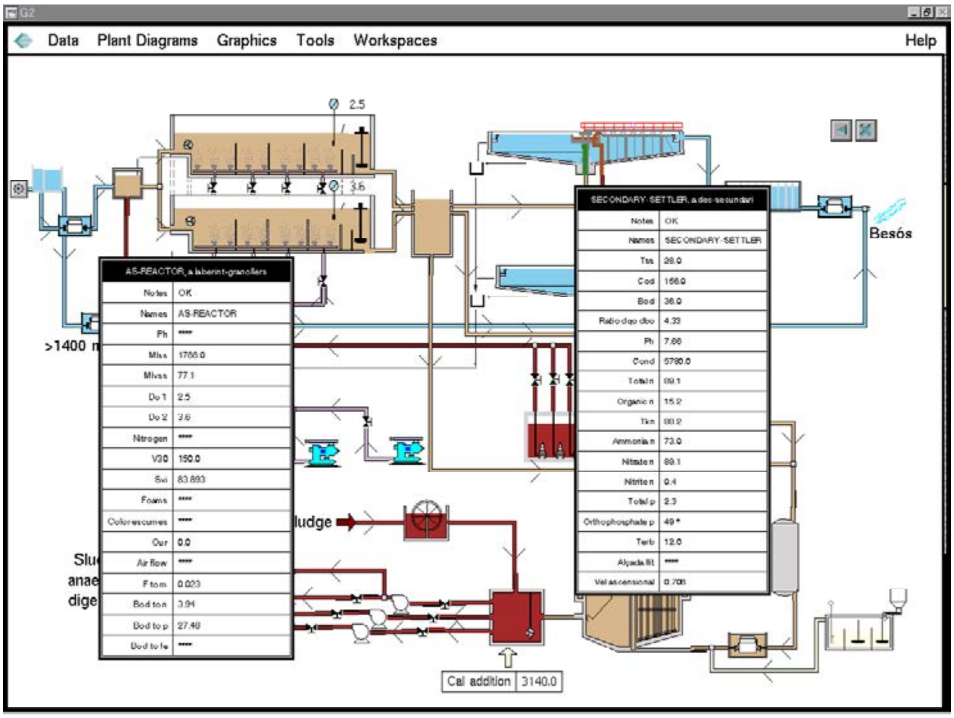


Figure 4-13: Interface of the program that shows different objects with the filtered information.

The information of these objects, defined in previous sections, is used to fill out the tables. The program offers another picture with the pre-treatment diagram and another with the primary treatment diagram. These diagrams have the same properties as the diagram explained in the paragraph above.

The program has also other screens that show different types of information to the user. These screens inform the operator of different important variables of the process.

4.4.2. *Second level: Reasoning*

The data gathering level nourishes the second level of the architecture. With this information the program tries to make a good diagnosis of the process. As described in previous chapters, two knowledge-based artificial intelligence programs are implanted: One based on rules and another one based on cases. Both programs are codified in the G2 shell. A fair approximation of the necessary volume of code lines is 600.000 that consist of 440 rules, 2534 procedures, and so on. These rules and procedures work together and can change or move information of others variables, vectors, and so on. Thus, the program has 179 text vectors, 218 quantity vectors, 1232 variables, and 71 objects.

4.4.2.1. **Expert system.**

The theoretical basis of this tool has been explained in previous chapters of this thesis (chapter 1 section 1.5.1.). Here, the knowledge acquisition and the implementation are explained. The main sources used were a literature review and a series of interviews with the process experts. With this information, decision and action trees representing the knowledge necessary to make a good diagnosis of the plant situation were built.

The knowledge was represented in decision trees before being codified in the G2 shell. In these representations the program can run over the different branches of the tree and find the situation in the leaves. In Granollers WWTP, there are 14 decision trees to diagnose the different situations in the plant.

Most important to our discussion is how the Expert system program was implemented in the personal computer. The expert system is structured in modules that make the exportation task easy. These modules contain the program knowledge about the wastewater domain and the process. All the information that the knowledge engineer collects from interviews, studies of analytical data and bibliography is represented in rules. These rules are implemented in the program in different groups that depend on the rule task and the rule category. For instance, a set of rules is based on the bulking diagnosis, rising, viscous bulking, and so on. The module division has been done taking into account the rules that make the abstraction, the diagnosis and the action for each problem.

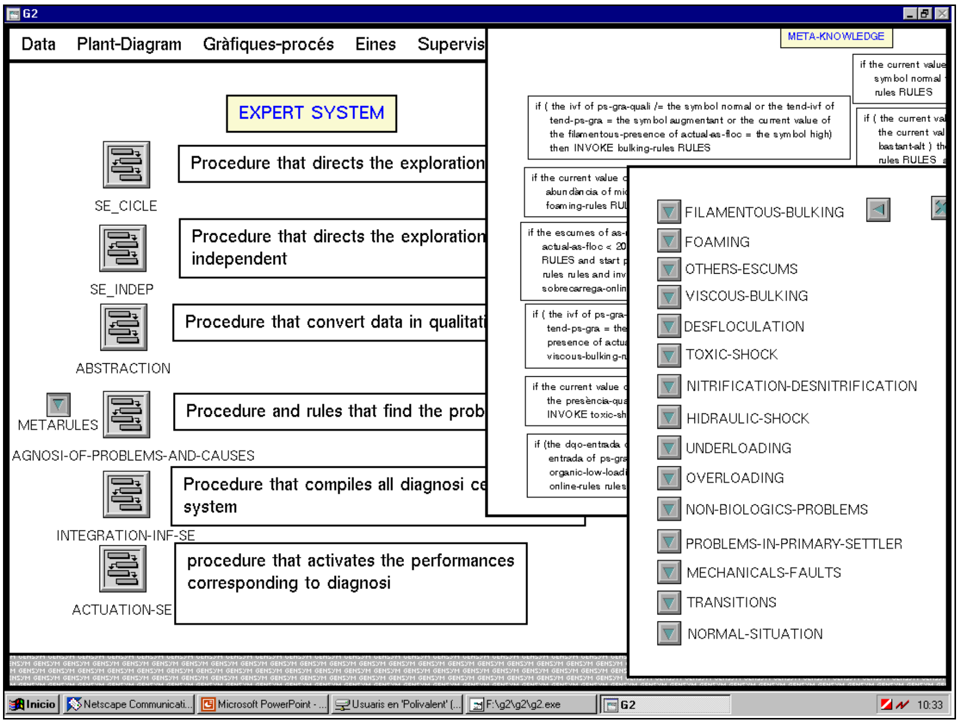


Figure 4-14: Eschematic of module implementation.

4.4.2.2. **Case-based reasoning system.**

The case-based reasoning system, explained eslewhere (chapter 1, section 1.5.1.), requieres knowledge to create the actual case, compare that case with the rest of the library, retrieve the most similar case and, finally, adapt the action of this case to the actual situation. All this knowledge has to be implemented in the program by means of modules.

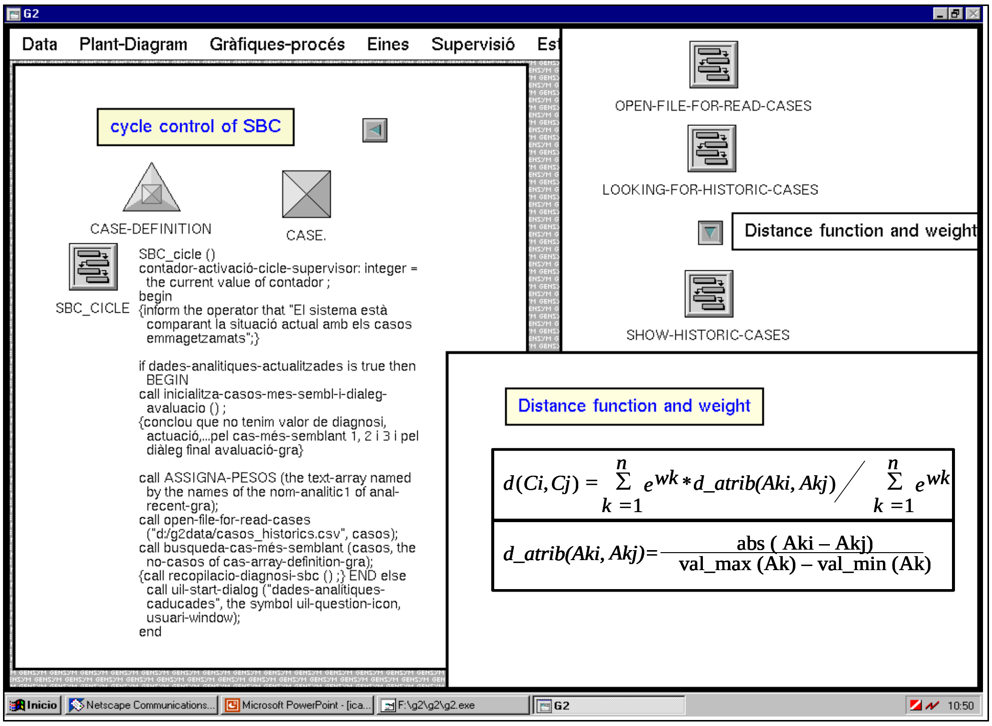


Figure 4-15: Modular implementation of the knowledge of the case-based reasoning system.

The CBR also needs rules and procedures to manage properly the knowledge it has about the treatment plant and about itself. A CBR works by structuring the specific knowledge derived from the process into cases. A case represents a situation that took place in the plant. In the Granollers prototype, the CBR used 14 variables to represent a case. The variables chosen to represent the situation in the plant were the following:

Variables chosen to define the Granollers case	Initial weight associated to the value of the variable
Treated water flow	6.0
COD wastewater	8.0
TSS wastewater	7.0
NTK wastewater	9.0
COD primary flow	9.0
TSS primary flow	7.0
COD secondary flow	8.0
TSS secondary flow	8.0
N-total secondary flow	9.0
Biomass concentration (SSML)	7.0
Sludge volume index (SVI)	8.0
Cellular residence time (CRT)	7.0
Mass load (F/M)	8.0
Dominant filamentous	8.0

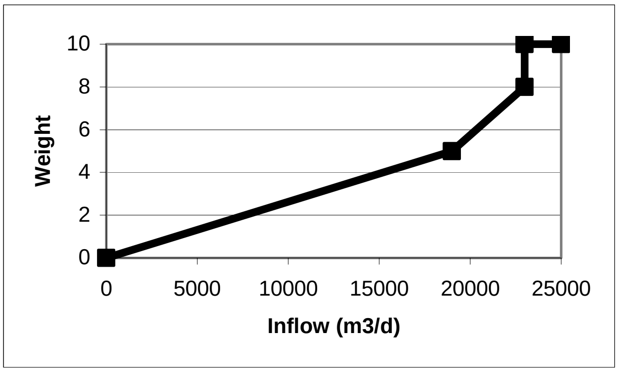
Table 4-15: Variables chosen to define the Granollers case and its weight.

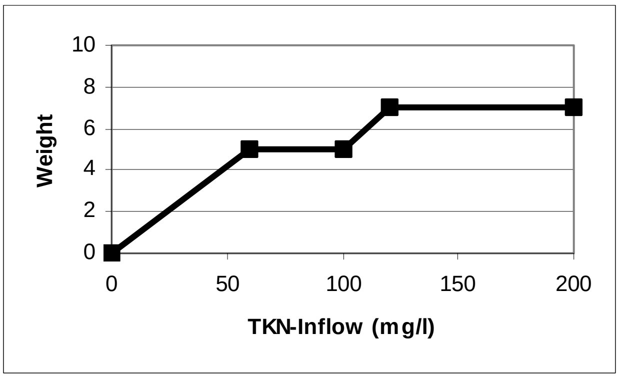
Table 4-15 shows the variables chosen to define a case in the Granollers WWTP and the weight of the variable in the normal situation (the weight rank can be between 1 and 10). The weight of each variable represents its relevance of with respect to the other variables in the case that defines the plant situation. This means that whenever one variable defines better a determinate plant situation, this variable, always, will have a higher weight. Those variables with higher weight will be those that more appropriately define the plant situation in the moment they were retrieved.

One of the improvements made in the second layer has been to create an automatic procedure that changes the variable weight according to its value. Weighting variables accurately in the CBS is a very important issue. It is done to give more relevance to those variables deemed important and, at the same time, to give less importance to irrelevant variables [Nuñez *et al*, 2002]. Most general methods for weighting use a global scheme; they associate a weight to the entire variable space. On the other hand, correlation-based global weighting algorithms assign higher weights to variables showing higher correlation between the value distribution and the class distribution in the sample training set. Finally, local weighting methods assign specific weights to specific values of the variables. Thus, a variable can be very useful to predict a class when it takes a certain value, but less so when it takes another value. The value difference metric of [Stanfill and Waltz, 1986], assigns a different weight to each value of the feature. [Howe and Cardie, 1997] propose a class distribution weighting method that computes a different weight vector for each class in the set of training cases using statistical properties of that subset of data. [Creecy *et al.*, 1992] use per-category feature importance to assign high weights to features that are highly correlated with the class.

Since the success of the CBR relies on retrieving the most similar experiences among the cases stored in the case library, the comparison between the values of the relevant variables becomes the key step. The effect of a process parameter on the process is different for each case. For some process parameters the farther the value from the average, the more influence the parameter will have on the process. For example, pH may have a minimum effect on the process if 6<pH<8 but a stronger effect if pH is below 6 or higher than 8. To reflect this phenomenon, a specific function was added to determine the weight of each variable according to its deviation from an average value. Figure 4-16 shows the weight functions of some of the main variables used to determine an experience in the Granollers WWTP. These functions were defined by the plant manager and the operators according to their experience, both in the operation of the facility and as end-users of the DSS.

As a result of this study, there is a chart for each weight that represents its variety in relation to the value of each variable [Comas *et al.*, 2002].





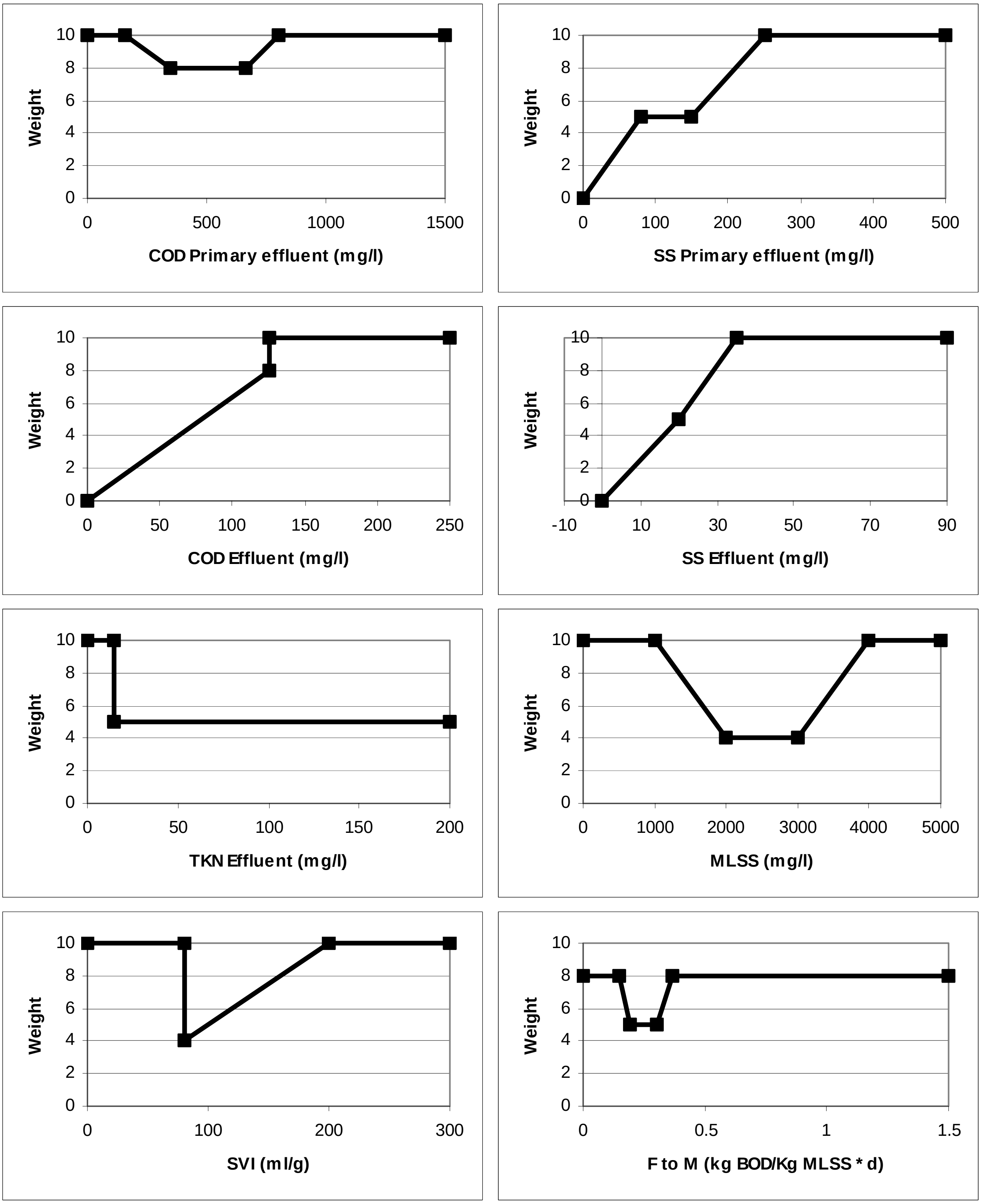


Figure 4-16: Weight function assigned to some relevant variables in the Granollers WWTP

In the case-based reasoning system, a great improvement was made; this permits to optimise the efficiency of the program when storing a new case. This improvement consists in retrieving separately non-closed cases and closed cases. The former are not considered in the general retrieve.

Case closed

A new module inside the case-base reasoning has been designed to store the cases differently depending on whether they have been evaluated or not. A set of rules and procedures was generated to achieve the objective of storing the cases in different ways. This new knowledge, represented in rules and procedures, helps the plant head to close every case carried out in the plant. The aim is to help the plant head to remember the action executed a few days earlier and then evaluate whether the action was wrong or good. All this knowledge is implemented in a new module in the second level of the architecture. Whenever the cycle is executed, a sub-cycle is activated. This sub-cycle consists of a set of rules and procedures that generates a new screen in the program. This new screen will have as many action buttons as cases to close. Every action button corresponds to a case that does not have the action evaluation. In each button label there is the date when the case will be closed. If the operator wants to, he can click on the button to see all the properties and values of the variables stored for that case. When the operator fills in the case evaluation gap, the program detects it and converts the unclosed case into a closed case that can be used in the next cycles.

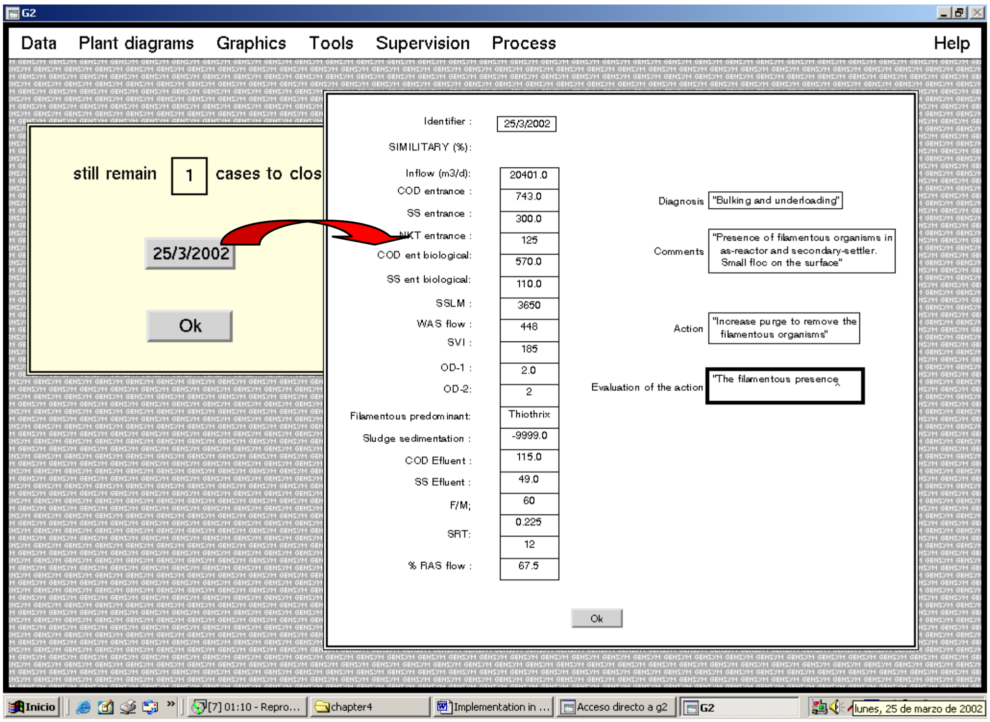


Figure 4-17: The new screen to close the cases without evaluation.

This procedure is executed whenever the user starts the supervisor cycle. Then, the new screen that informs the user about the number of cases that are still unclosed appears. In this screen, the user can close the case if he has enough information. If he does not close the case, this case will not be used in this supervisory cycle.

In order to store and retrieve the data, it is necessary to modify the library with a new column, in which there is 1 or 0 depending on whether the case is open or closed (1 if the case is open; 0 if the case is closed). The new sub-cycle starts before the real supervisory cycle. The first thing it does is to check this new column. Depending on the value of this new column, the program stores the case in one vector or another. Once these vectors are generated the program creates the buttons that will represent the unclosed case in the first screen. Then the user can fill in the gap and the program verifies whether the evaluation gap is completed or not. Afterwards, the program knows the state of the case and puts either 1 or 0 in the new column of the library.

4.4.3. *Third level: User-program communication process*

During this thesis research, various tools were implemented to improve the operation of the program and to increase its efficiency. This increase in the efficiency and a best accessibility to the information collected by the program are the main objectives for the program at this stage. A large part of these improvements comes from meetings with the head of the plant.

It is important to emphasise the implementation of new interfaces that facilitate the communication between the program and the user, new variables that increase the efficiency of the results, and new bridges of communication between the program and the process.

4.4.3.1. **Return sludge flow bridge.**

Measurements, process modelling and control can never be exact for real, complex processes. They cannot easily be modelled by equations nor even be represented by straightforward logic such as *if-then-else* rules [Olsson and Newell, 1999]. Fuzzy inference is achieved by producing a conclusion by referring the input data to a set of “if-then” rules based on expert knowledge. Finally a numeric output is obtained [Kosko,1992; Cox,1994]. The fuzzy logic program allows a certain margin in the action framework. This means that, even with abnormal and missing values, the program can propose a concrete set-point value. A fuzzy logic program has properties that make it useful for the objectives. It is needed to determinate the set-point of the external return sludge flow in order to attain the best operational conditions for the purposes of the plant head. In this case, the set-point of the return sludge flow is proposed according to the inflow in the biological reactor and to the SVI.

A bridge to establish the set-point of the external return sludge flow was made. This data was calculated with the interaction between the program and a program based on fuzzy logic and coded in MATLAB. This program calculates the necessary external return sludge flow taking into account SVI data and water inflow. Once the set-point has been calculated, these data needs to be transferred to the SCADA, which can modify the set-point value of the corresponding PID. The data is first transferred, by means of the bridge, from the G2 to a spreadsheet and then from this spreadsheet to the SCADA.

The main advantages of a fuzzy logic program to control the return sludge are the following:

- Easy to understand.
- Quantifies the uncertainty of the system.
- Treats easily the high non-linearity, complexity and the high dimensionality of the system.
- Robust
- Trouble-free implementation.

A block diagram of a fuzzy control system is shown in Figure 15. The fuzzy controller is composed of the following four elements [e]:

- A *set of If-then rules,* which contains a fuzzy logic quantification of the expert's linguistic description of how to achieve good control.
- An *inference mechanism,* which emulates the expert's decision-making in interpreting and applying knowledge about how best to control the plant.
- A *fuzzification* interface, which converts controller inputs into information that the inference mechanism can easily use to activate and apply rules.
- A *defuzzification* interface, which converts the conclusions of the inference mechanism into actual inputs for the process.

A fuzzy system is a static non-linear mapping between its inputs and outputs. It is assumed that the fuzzy system has a lot of inputs and a lot of outputs. The inputs and outputs are real numbers, not fuzzy sets. The fuzzification block converts the crisp inputs into fuzzy sets. The inference mechanism uses the fuzzy rules in the rule-base to produce fuzzy conclusions into the crisp outputs.

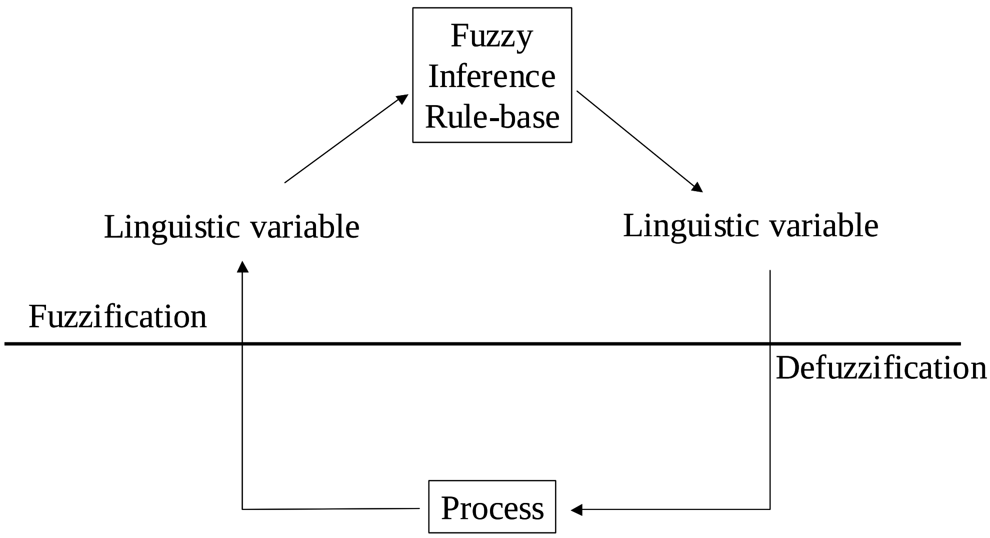


Figure 4-18: Schema of the operation cycle of a Fuzzy program.

The program gets, from this process, the value of the inflow in the biological reactor (in m^3/day) and the SVI (in ml/g). Then, the program performs a fuzzification of these values. This means that the value is converted into a linguistic value. With the latter the program makes an inference and finds a conclusion. The conclusion is also a linguistic variable and the program has to convert it into a numerical value. This last numerical value is the set-point for the return sludge flow that the program returns to the process.

4.4.3.2. **Interface.**

The creation of a new interface represents an improvement in the accessibility to the information, in the tools used for diagnosis and in the system solution. The interface helps the plant head systematise the supervision cycle step by step. This can also be a great tool to train new users of the plant.

The main purpose of the interface is to make the transfer of information from the system to the user easier. The system facilitates the reasoning path to any proposal and gives confidence to the user. Control operators receive most process information via a display screen commonly known as human-machine interface (HMI). In a distributed control system the operator has a restricted view of the process because the number of process variables that can be displayed on a screen is limited. This requires the operator to travel among various displays to obtain the needed information. Windows-based consoles do not limit the amount of information that can be displayed to an operator and it is important to simplify this information to the most important data.

Although advanced automation systems can provide more comprehensive information, they have introduced two aspects that negatively impact on an operator’s ability to effectively respond to abnormal situations. During upset conditions, operators are confronted with an avalanche of alarms that must be dealt with or ignored. At the same time, operators must quickly sift numerous displays and windows to find out the root cause of the upset.

An effective HMI should reduce operator stress and quickly provide the information required to locate and resolve the source of the abnormal situation.

To overcome these issues, the HMI must be carefully designed [Walker, 2001]:

- How the information is organized on the screen.
- What colours and character sizes should be used to provide an operator with sufficient visual cues to quickly recognize the important information.
- How consistently information is presented so that users can easily locate it on the screen and know what it will look like.
- Navigation issues between multiple levels of windows.

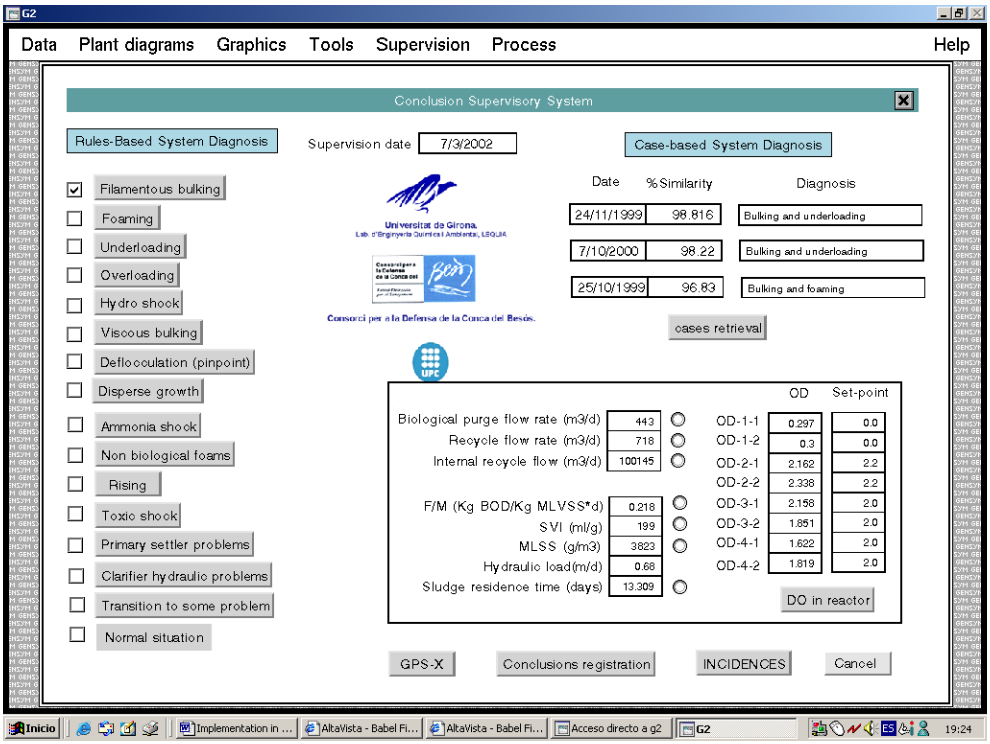


Figure 4-19: Interface implemented in the Granollers WWTP.

On the left part of the interface, you can see the action buttons to access to the diagnosis proposal from expert system whenever the button is validated. When the interface appears on the screen, the system has made all the functions and actions and can do a proposal about the situation.

This new interface permits the user to know the situation of the plant, and allows the user to gain access to the proposal solution. This makes the interface friendlier for the user. With the old interface, the user had to see all the proposed solutions at once, and sometimes these could be numerous.

Now, when the user clicks on the button, a new picture appears on the screen with information about the concrete proposal of the system. The information that the program gave the user is structured by the diagnosis, the reasoning, the cause and the action to do. If the concrete information appears insufficient to solve the actual situation in then plant, the user can access another screen with more general information.

The buttons on the left of the interface correspond to the decision trees that the program has for each problem of the plant. These buttons are the final solution after the activation of rules and procedures of each decision tree.

In the next figure, you can see how the information is transferred from the program to the user. We think that these modifications in the user-interface can be useful to the user and get better the communication between both parts.

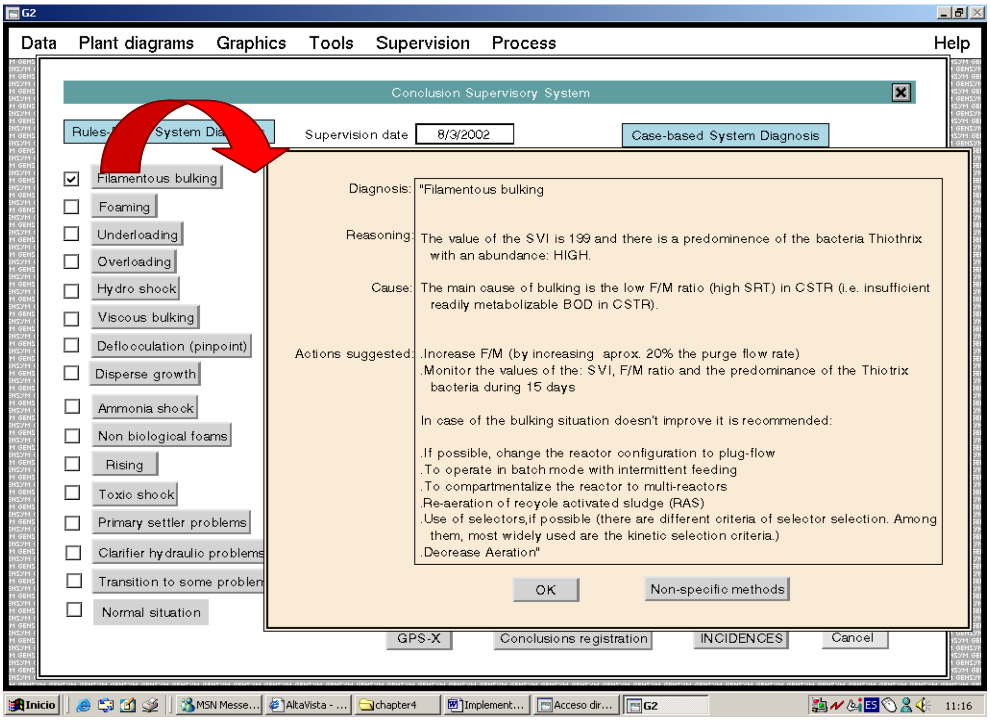


Figure 4-20: Picture showing how the expert system gives the information to the user.

After seeing the information from the expert system, the user can also choose to examine the solution proposed by the case-based reasoning system. The information from this tool is on the right part of the interface. In this part we can see that the interface shows the three cases most similar to the current case together with the percent similarity and the diagnosis of each case. This information exists to help the user to decide if the retrieval cases are important or not. If the user considered the information of this tool important, he or she could access this information by clicking on a button.

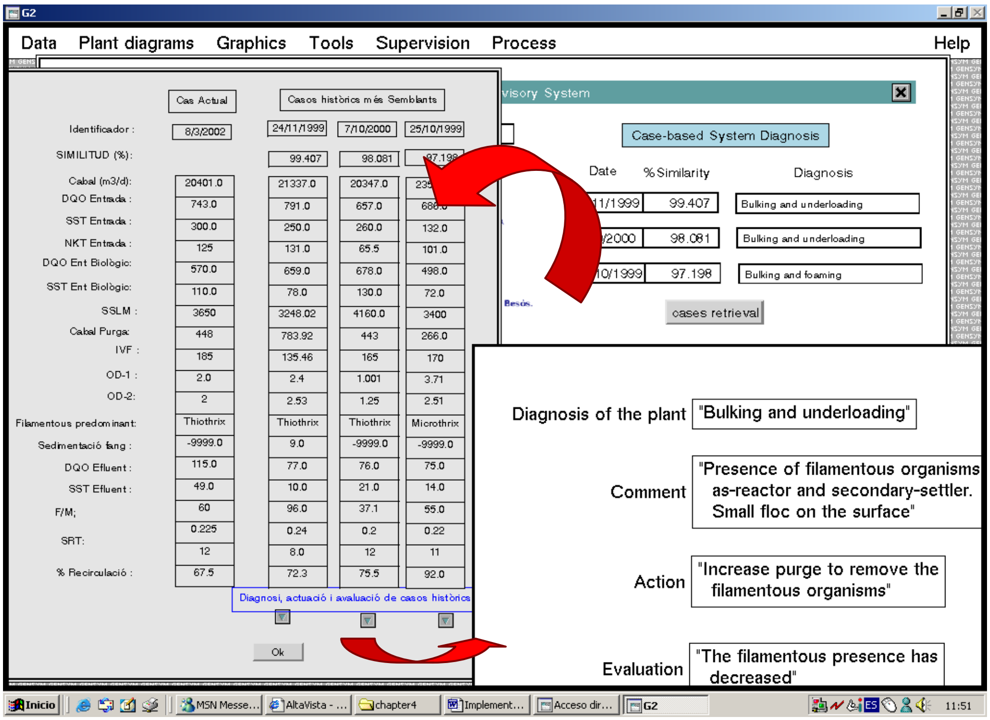


Figure 4-21: User interface for case-based reasoning system.

In this page you can see all the variables used in the retrieve cycle. If the user wants, he can see the comments for each case made by the head of the plant and see if the action was successful or not.

Once the user has seen the results proposed by both programs, he/she can see interesting information on the down bottom of the interface. This information corresponds to different variables that can be important to the head of the plant to make his/her decision. These variables have been chosen after different interviews with the head of the plant because these are important for him/her to define the plant situation. In this part of the interface we also have the set-point and the process-value of the dissolved oxygen.

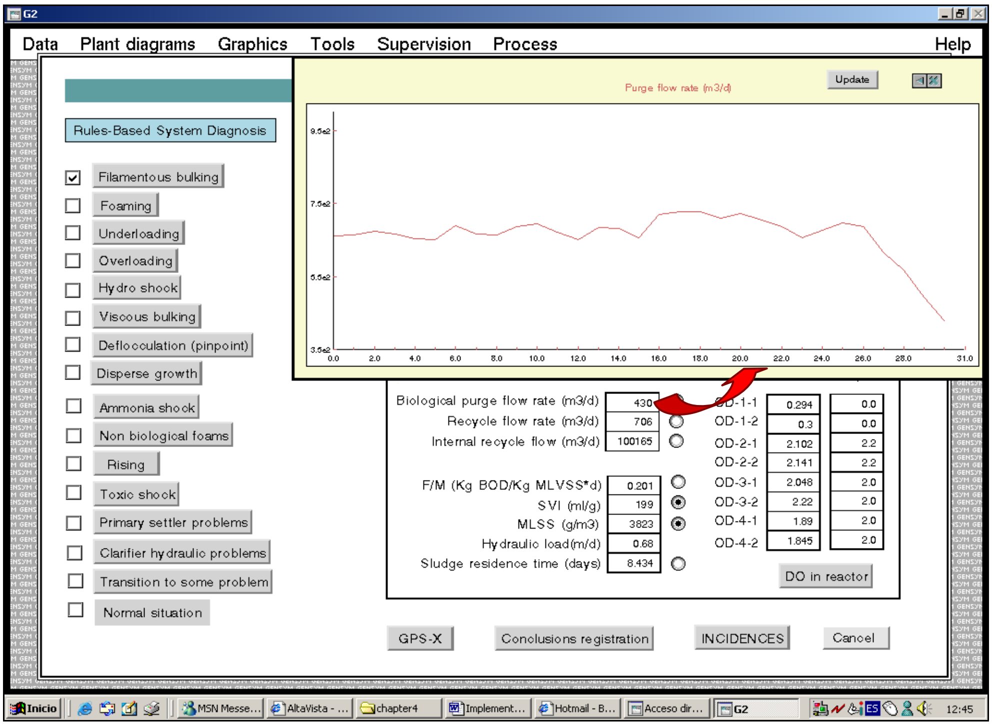


Figure 4-22: Example of a chart in the program.

The user can close the cycle of the system determining the actual situation on the plant in the actual case and with the action that he has made when he/she verifies all information that the program can give. The evaluation of the action cannot be filled until the user knows and evaluates the new situation in the plant. For this reason, we developed and implemented a new module in the system. The action of this module consists in retrieving the cases without the gap of the evaluation filled and showing these cases to the user. The user can thus be reminded of a concrete situation of the plant happened on a certain day and be able to remember if the action was successful or not. Usually this task will be performed two or three days after the situation day.

4.5. *Results*

The Montornès prototype results can be divided into two types of results. The knowledge acquired by a set of meetings with the plant head and the operational results of the prototype application. Both kinds of results give valuable information to the knowledge engineer, which afterwards has to incorporate this acquired knowledge into the new EDSS.

4.5.1. **Meetings.**

To follow the operation of the system a set of meetings with the head of the plant is needed. The aim of these meetings is to detect the main problems of operation of the system and collect the ideas and suggestions of the users about the program to accomplish a better and most useful operation of the system.

The main themes treated in these meetings, and applied in the Granollers EDSS prototype, are summarised and represented in the following table. . The results generated for every problem are represented and located in the right column of the table.

Problems detected	Solutions
A summary of the results of the system is needed to make them easier to view and consult.	The results from the expert system and the results from the case-based reasoning system are grouped in one interface to make it easy to consult both.
The results of the expert system should be more concrete as a function of the properties of the plant	Concrete proposals are made such as determining the set-point of a value from the process.
Alarms should be reviewed to make them useful to the user.	Alarms are made more concrete and less repetitive.
The values of the ranks from the expert system considering the changes in the plant should be redefined.	With help from the head of the plant, the values of the ranks from the expert system are changed and the values used by the expert system are revised because new data have been added.
The value of the weight used by the case-based reasoning system should be revised to make the retrieval step of its cycle more efficient.	A selection is made to describe the most important variables to define a case. A new weight is defined for each variable and this weight is applied automatically based on the value of the variable.
It is difficult to close a case because the plant head does not have information about the action executed.	A new module is designed to solve this problem.
Qualitative information and microbiological data should be added to the system.	A qualitative questionnaire and a bridge to communicate the microbiological information with the program is generated.
About the temporality of the data is decided that:	The data used to evaluate the state of the plant has to be the last data received. To save the case, its variables have to save the values collected that day.
A guide to operate the system is needed.	A protocol is given to the user to inform him about the operation of the program and what to do in situations of wrong running.

Table 4-16: Main themes discussed in the meetings and their solutions.

4.5.2. **Operation results**

In parallel to the operation of the decision support system, an evaluation of the results obtained was made. This evaluation consisted in a comparison between the results of both programs and the real situation of the plant.

Expert system results

During the year 2001 the decision support system was activated 70 times; of these, the head of the plant has contrasted diagnosis in only 15 cases (see annex IX). The percentage of diagnosis detected during these 70 days by the expert system is seen in the next figure:

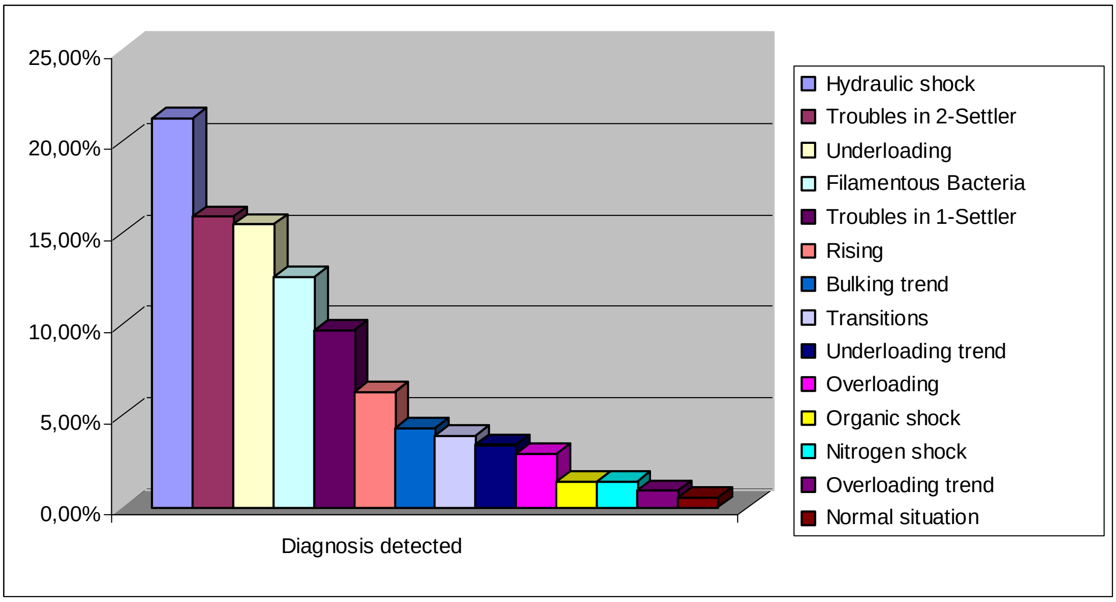


Figure 4-23: Percentage of situations diagnosed by the expert system.

The situations most commonly detected in the plant were *hydraulic shock* with a percentage of 21.3%, *non biological problems in the secondary settler* with 15.9%, *underloading* with 15.5%, and *filamentous bulking* with 12.6%. These values are provided from the 70 times that the program detected any process situation.

The plant suffers normally these situations due to the characteristics of the wastewater that it receives.

Afterwards, the evaluation of the expert system has been made by means of comparison the system solution proposed with the real state of the plant and the head of the plant evaluates the results.

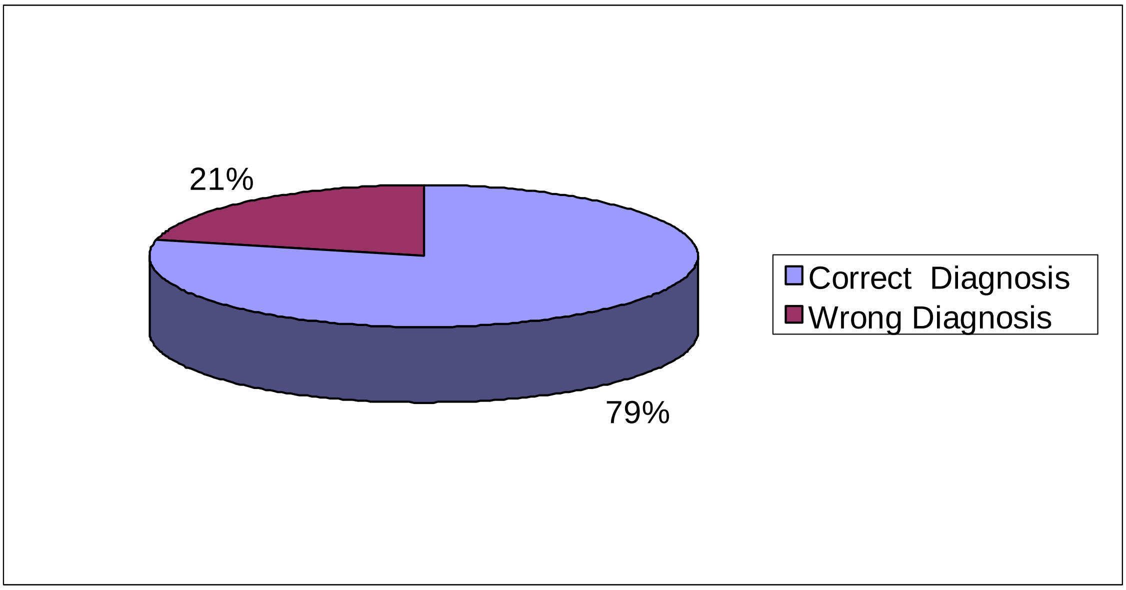


Figure 4-24: Graph with the percentage of success of the expert system during 2001.

Case-based reasoning system

The evaluation of the results of this program is made by comparison between the day of the supervision and the three most similar cases retrieved. It is considered like success all these days that the similarity between the current case and the most similar case is very high.

The case-based reasoning system has been used 70 times and 40 retrieved cases have been stored. With this number of days the percentage of success was calculated.

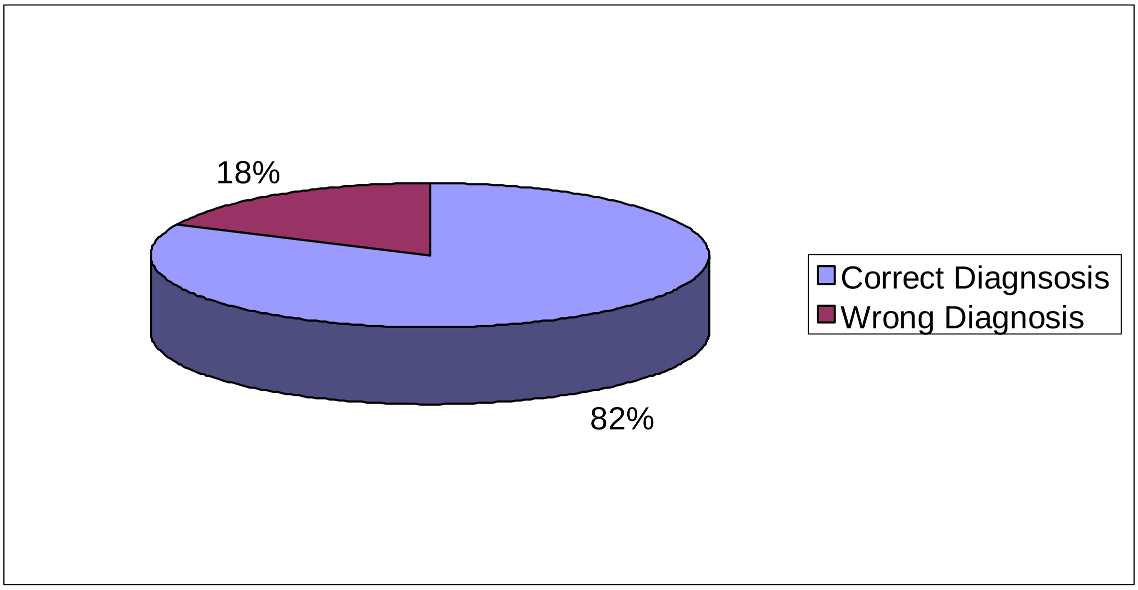


Figure 4-25: Success percentage of the case-based reasoning system.

These results confirm that the plant head seldom verifies the EDSS proposals. To solve this low use of the program, and following the proposals and advice of the plant head, it was decided to improve the results, improve the user-program interface, review the alarms and summarise the results of the system.

4.6. *Conclusions*

Three important things are explained in this chapter. The implementation of the decision support system prototype in Granollers is commented on, the improvements made to it described in detail, and the evaluation of the decision support system is presented, showing good results in its operation.

Once the implementation of the prototype in Granollers WWTP was proved to be successful, we were ready to think about the exportation of the system to another wastewater treatment plant. We think that the decision support system can help the head of the plant in certain circumstances in which the user have to handle a large amount of data in a short time.

The validation of the program during the year 2000 shows great results in the diagnosis of the program. This fact encouraged us to test the program in another plant and find out whether the program is useful for the head of the new plant.

The implementation in Granollers allowed acquiring knowledge about the protocol to follow to export the program. With this information at hand, we made an exportation protocol to do this task with success. This protocol is described in the following chapters.

The operation and improvement of the supervisory system during the period of this thesis has facilitated the extraction of conclusions that permit new knowledge about the system and its operation.

The main development incorporated into the prototype during this thesis consists, basically, in improvements in the communication layer between the database with the program and between the program and the user.

In the case of the database, the information transfer between the PLCs and the system has improved. All the information collected from the process passes to the SCADA in a spreadsheet making the acquisition and filtering of the information by the program more easy and efficient.

In the case of the communication between the program and the user, the main improvement is the creation of a new screen. In the design of this screen, we have taken into consideration the opinion of the users. Basically, we made the interface friendlier and the access to the information collected by the program easier.

Other improvements have been to make the solutions proposed by the program more concrete and specific to the actual situations encountered in the plant. Also, the management of the case library has been improved.

During the validation period of the system, many difficulties were observed, and their solutions gave us the opportunity to improve the operation of the system and to learn more about the program. Many of these difficulties occurred because the program did not have enough information to generate a good diagnosis.

Finally, we can conclude that the program has a high level of efficiency to detect problems in the plant. This premise permits us to think of exporting the program to other wastewater treatment plants to help the heads of the plant. In the following chapters a guide to achieve the exportation with guarantee of success is proposed.

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Chapter 5: EDSS Exportation Protocol: Protocol Montornès 1.0

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5. EDSS Exportation Protocol: Protocol Montornès 1.0

5.0. *Abstract*

In this chapter, a protocol is proposed to be used as a guide to re-design the EDSS prototype implemented into WWTP Montornès. Once the Granollers prototype validation process was successfully completed, we set out to develop other EDSSs in other plants. Thus, the Granollers EDSS prototype is proposed as a basis for a more refined program. These facts allowed us to consider the possibility of exporting the program to other WWTPs to help in its control process.

The exportation of the EDSS prototype is not an easy task and therefore it is advisable to elaborate a guide to ensure success in the exportation. The difficulty stems from the fact that different plants have different configurations, and demand EDSSs to work differently. Information about three very important aspects is important for design the program: i) information about design data of the plant, ii) information about the characteristics of inflow water and iii) information about what the head of the plant wants or needs to detect. The goal of the document guide is to help solve these questions.

By using this chapter as an implementation guide, the EDSS exporting process becomes easier, the rules define better the treatment plant, and the implementation becomes more efficient, faster, easier and less problematic for the plant head.

5.1. *Introduction*

The objectives of an EDSS design to aid in the control of a WWTP are to manage all the information generated by the plant and to help the plant head to control the biological treatment process. Once the prototype achieved its objectives, it is proposed to export the program to others WWTPs. This proposal is framed in the research group intention to make the access to and the transfer of knowledge from the university to the society easier. In this case, the research group wants to export all the knowledge acquired about wastewater treatment to the WWTP trying to help the plant head to make better their job.

Many systems require the same functions, which can be designed, coded, and tested once and then reused many times [Burch, 1992]. Prototype re-use is important to avoid the duplication of past model development efforts [Rizzoli *et al*. 1997]. The prototype re-use is not clear and easy; the new plant will have different configuration, different sensors and different information. Thus, the prototype has to adapt its structure to the new plant.

The purpose is not to change the main structure of the artificial tools used; but some parts of the program will be changed. The main changes, a priori, will be in the first layer of the EDSS architecture (data acquisition layer). In order to do that, a guide is needed to facilitate an effective exportation and to re-use as much as possible the knowledge about wastewater treatment acquired from our previous experience and from the literature. The guide should be a detailed protocol and explain step by step the actions that need to be done.

This document describes the working schedule followed in the creation process of a supervision system, its implementation on a personal computer and the structural and temporal needs for the implantation process. The proposal protocol is based on the experience acquired during the Granollers implementation, and in the *protocol presented for a guidance to ease the development of an EDSS and its application in any WWTP* [Roda, 1998]. The Granollers EDSS implementation showed that many aspects of the development process and implementation have to be more normalised. There are many parameters and variables that can make the new EDSS unsuccessful.

This chapter presents the protocol for the development and implementation of an EDSS in any WWTP. The decision support system prototype is generalist and the objective is to re-design and to adapt it into a more concrete program for a new WWTP. The re-design process depends on the characteristics of the new plant and follows the proposed guide. The use of a model management framework will facilitate model reuse, efficient model retrieval and integration, and incremental modelling capabilities [Rizzoli *et al*. 1997].

It is necessary to define correctly the real WWTP into rules to have the best EDSS for the current plant. Thus, it is also very important to acquire a good knowledge of the plant where the program will work. It is also very important that the head of the plant transfers his/her heuristic knowledge of the plant. The new EDSS has to modify its AI tools using both knowledge and the information extracted from the technical literature.

A questionnaire was designed to make the knowledge acquisition easier after the experience acquired during the Granollers EDSS development and implementation. This survey was intended to get from the head of plant the knowledge about the plant that, often, the manager does not know how to express. Including this knowledge in the knowledge base of the program will help to better define the rules representing the system that one wants the SDSS to help control. Some knowledge about WWTP can be found in the literature. This questionnaire uses the information about systems with suspended-growth as secondary treatment.

Due its complexity, the EDSS development process is divided into many parts or phases. These phases are, a priori, the plant study phase, the ES trees and CBR cases re-design phase, the implementation on a PC phase, and finally, the correctness and supervision period.

The plant study consists in collecting the maximum possible information by means of different sources available from different plant locations and processes. The goal of this phase is to acquire information about: the design data of the new plant, the historical data about every operational problem that the plant can suffer and the information for the process operation and control.

Once the plant information is collected, the following phase consists in building the knowledge trees and defining the cases. The next step is to implement the program on a personal computer and connect it to the database. The last stage, the correction and supervision phase, concerns the verification the system runs correctly. This phase is applied by means of two methods. One method entails specific supervision just after every finished task. The other method consists in a set of prepared situations to verify that the whole program works properly.

The actual implementation of an EDSS in a WWTP proved that every phase needed to be normalised and standardised. A normalised document always optimises a new EDSS design and development process and frees it from potential problems or anomalies. The fact that the knowledge-base program is very big and contains large amount information has to be considered in the design process. If the information and knowledge are not properly treated, then the information can be removed and lost for future EDSS.

Every phase or step needed to develop a new EDSS derived from the prototype is explained in detail (see 5.4.). In writing an exportation guide, one must consider the following points to enhance the efficiency of the exportation and develop a successful new EDSS [Burch, 1992]:

- The user has to be incorporated in the different stages of the design process [Poch *et al*., 2002].
- Planning systems and project management techniques are followed throughout the process.
- The system must be designed from the tools.
- The protocol should be usable as a guide in the different design stages of the system, including the verification stage and in the validation stage.
- Al the information included must be complete, clear and useful.
- Planning of the running validation must be included.
- Planning the maintenance program must be included.

The protocol explained in this chapter was used to develop the first EDSS version from the prototype. This protocol was built from the Granollers EDSS design, developed and implementation processes. The prototype is the starting point that allows thinking about the program exportation to help others plant heads to treat the wastewater and the result is a theoretical exportation protocol.

The proposed protocol application allows acquiring experience and allows checking the protocol efficiency. The results of the implementation in a real WWTP are explained in chapter 6. These made apparent that the protocol needed some changes and modifications. These were subsequently applied. The modified final protocol is described in chapter 7.

5.2. *Objectives*

The main goal of this chapter is describe the protocol developed to make the program implementation in an easy way and without problems to the head of the plant.

- Implement a program derived from the protocol in another WWTP and make the exportation in the best form possible and with a high level of efficiency.

- Attain new decision support systems in a short time.

- Attain an implementation methodology.
- Obtain a document for making customized software programs.
- Describe the practice case of a concrete implementation in the Montornès WWTP, prove its efficiency, and check the time needed to do this.

5.3. *Requirements for the application of a supervisor system in a WWTP:*

The EDSS needs some conditions to work properly in a new WWTP. These conditions are specific types of information, concrete net information, a personal computer, and so on. All this needed information is known as development environment. The development environment consists in a personal computer and the knowledge engineering software tools that are used during the development of an expert system.

A good design philosophy is the first requirement for any successful implementation [Lam and Swayne, 2001]. The physical requirements consist of the necessary instrumentation and historical data volume available for program development. Having enough information allows the development of made-to-measure decision support system. The EDSS cannot be integrated in any WWTP, because the necessary minimum information set and instrumentation is hard to find in a small WWTP. Because of this reason, the decision support system prototype was applied to a medium-sized WWTP (with a wastewater inflow of 10.000 to 50.000 cubic meters per day) and with active sludge as a secondary treatment.

The minimum conditions required by the decision support system to become the management tool desired, are:

I. **Database where the specific knowledge for the new plant off-line data could be obtained.**
II. **On-line data from the process.**
III. **A personal computer, which allows the management of the information in a fast and efficient way.**
IV. **Acquisition of an informatics shell for the development of the supervision system.**

I. **Database where the specific knowledge from new plant off-line data could be obtained.**

Off-line information consists of the sample analyses, the microbiological analyses and the qualitative observations. The off-line data are structured into monthly worksheets in Excel. The off-line information can help to detect the seasonal, monthly, weekly and daily patterns followed by the plant. It is important that the historical information go back at least one year. This information allows defining the maximum and minimum limits for every parameter stored. It also allows creating the case library of the case-based reasoning system using a clustering process.

Parameter	Sample point	Frequency
COD	Entrance	Daily
	Primary t. exit	
	Exit	
BOD_5	Entrance	Weekly
	Primary t. exit	
	Exit	
NH4	Entrance	Daily
	Primary t. exit	
	Exit	
Nitrate	Entrance	Daily
	Primary t. exit	
	Exit	
TN	Entrance	Daily
	Primary t. exit	
	Exit	
SS	Entrance	Daily
	Primary t. exit	
	Exit	
Microbiological inf.	Reactor	Weekly
	Secondary settler	
SVI	Reactor	Daily
	Secondary settler	
MLSS	Reactor	Daily
Filamentous	Reactor	Weekly
	Secondary settler	
Protozoa	Reactor	Weekly
	Secondary settler	
Qualitative exam	Reactor	Daily
	Secondary settler	

Table 5-1 : Off-line information required.

II. On-line data from the process.

This type of data is provided from analogical data or digital data that arrive to a SCADA or PLC's net. This data has to include dissolved oxygen values in the reactor, wastewater inflow values, recycle flow, waste flow, air flow and digital signals from mechanical engines of the plant.

On-line data consists in the real-time information that is taken directly from the process. This kind of information can facilitate important knowledge about of the process state in real time.

Parameter	Sample point	Frequency
Flows	Entrance	High (15 seconds)
	Reactor	
	Exit	
Dissolved oxygen	Reactor	High (15 seconds)
Gates	Entrance	High (15 seconds)
	Reactor	
	Exit	
Pumps	Entrance	High (15 seconds)
	Reactor	
	Settlers	

Table 5-2: Minimum on-line data needed.

III. The personal computer has to be a computer with enough data processing capability to support the informatics shell and the program**.** The minimum recommended configuration is a *Pentium III* at 800 MHz and 128 Mbytes of RAM.

IV. The informatics shell is a domain-independent expert systems “framework”, an interface engine with explanation facilities, etc… but without any domain-specific knowledge. This framework facilitates the programming of the EDSS. A commercial shell with a user-friend interface – G2 [Gensym, 2000] – was selected as the suitable inference engine to built the EDSS.

5.4. *Protocol Montornès 1.0*

The developed EDSS that is selected to be implemented in the Montornès WWTP is the result of a set of studies done during many years. The program attempts to collect the experience and knowledge acquired throughout all these years of investigation and also attempts to help the head of the plant to control the wastewater treatment process. This program started in the mid nineties with the implementation in a WWTP of an EDSS developed by J. Comas following the protocol made earlier by I. R-Roda. Once the program was implemented in the Granollers WWTP, was checked and was proved that it can help the plant head, it was proposed to implement the EDSS prototype in another WWTP. The new WWTP had to have conventional suspended growth as secondary treatment and meet the requirements listed above (see 5.3).

A good implementation of the program in a WWTP relies on a methodical document that explains step by step how to create a new environmental decision support system for wastewater treatment plants from the prototype. If re-design process entails new customized software, new database, new computer equipment and control software, new networks, and a drastic change in procedures, re-design becomes quite involved and challenging [Burch, 1992].

An exportation document generates a set of economical and temporal advantages. With a guide, the development process becomes easier and time effort required, smaller. The less time is invested, the cheaper will be the whole program. The elaboration and checking phases of the program have to be highly normalized. These phases are essential to ensure that the program runs properly and diagnoses consistently yield a high level efficiency.

The normalized phases allow adjusting the cost of the implementation. If all phases are normalized, the implementation of the program will be easier and cheaper. The implementation of any EDSS has many factors that may affect and increase the time and economical costs.

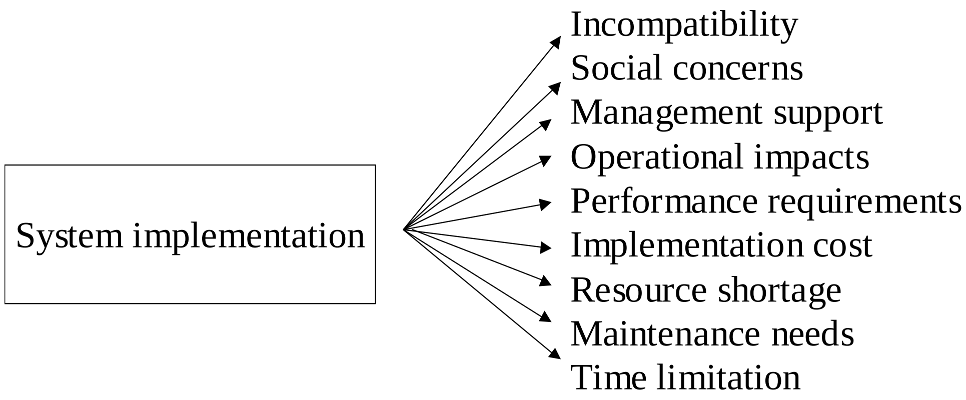

Figure 5-1: Factors that can affect the implementation.

These factors can alter the EDSS development and implementation process and render it unsuccessful [Burch, 1992]. It is important to have an implementation plan to prevent these factors and have them controlled. The factors presented above can affect in different ways the whole design and exportation process; therefore, it is necessary to take them into account. The EDSS design process has to consider the potential incompatibilities that can affect the future program.

The protocol presented in this chapter can be considered the first approach used to implement the program in Montornès WWTP. In chapter 7, the improvements and modifications made to it and the new version protocol extracted from this work are presented (Protocol Montornès 2.0).

5.4.1. **Actuation planning.**

This protocol will be responsible for the successful or unsuccessful creation and trade of the product. Making a protocol allows to define the objectives and actions needed for the success of the program.

Project scheduling and management techniques are needed to generate the systems implementation plan. These techniques, which include the Gantt chart and the Program Evaluation and Review Technique (PERT), help control timing and reduce the cost of system projects [Burch, 1992]. In our case, the Program Evaluation and Review Technique Chart was used to estimate, schedule and control a network of interdependent tasks shown by arrows and nodes or circles. The arrows represent project tasks that require time and resources. The nodes represent milestone points or events, showing the completion of one or more tasks and the initiation of one or more subsequent tasks. The PERT chart indicates which tasks must be done before others and which tasks can be performed simultaneously. The PERT chart is used to determine the minimum time needed to complete a project or a phase.

First, it is necessary to identify the tasks and then the proper sequence of tasks is determined. The tasks identified to implement the prototype in a new WWTP and the sequence that these tasks have to follow was:

- Previous study.
- Adaptation of the variables and objects.
- Calibration of rules of the rule-based system.
- Adaptation of the CBRS.
- Connection with peripheral elements.
- Computational implementation.
- Validate & Check for correctness.

Afterwards, it is estimated the time required to perform each task. The time expected is computed as follows [Burch, 1992]:

$$te = \frac{o + 4ml + p}{6}$$

Where *o* is the most optimistic time, *ml* is the most likely time, and *p* is the most pessimistic time. Using this formula and the experience acquired with earlier implementations, the time expected for each phase is:

Step	***O***	***Ml***	***P***	**Days**
Previous study	28	35	40	4,3
Adaptation of the variables and objects	8	35	40	5,3
Calibration of rules of the Rule-based System	48	30	59	7,3
Adaptation of the CBRS		30		3,5
Connection with periphery elements		40		2,5
Computational implementation		40		5
Validation & Check for correctness		30		5
Delivery	-	-	-	1
Supervision	-	-	-	(16)

Table 5-3: Temporal cost proposed.

The most optimistic, the most likely and the most pessimistic time are defined by our own experience and by interviews with experts of different domains. This time effort proposal can be changed in future iterations.

Finally, a time-scaled chart of tasks is prepared. In the following chart, each node represents an event that represents the completion task or tasks. Each arrow represents a task and the number next to each line is the task sequence code. The scale at the bottom represents the number of days required to complete the implementation.

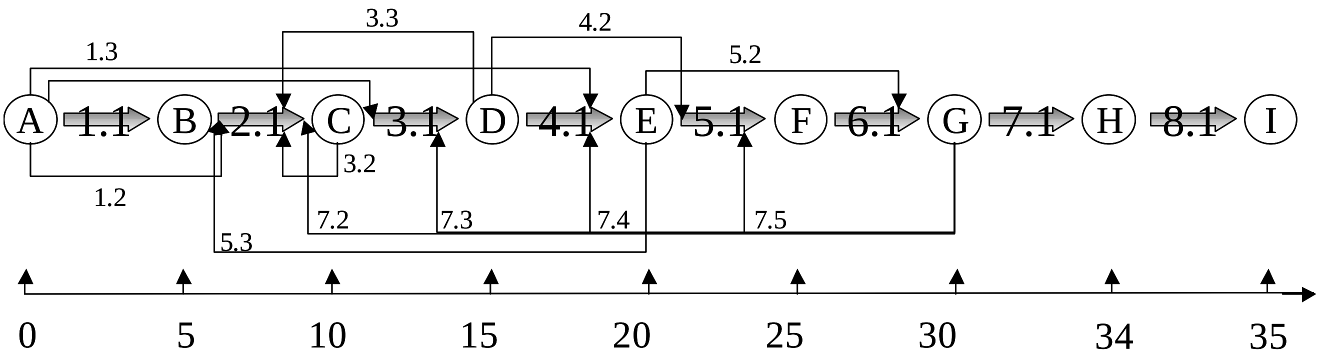

Figure 5-2: Pert chart for Montornès EDSS implementation.

Nodes		Tasks	
A	Previous study	**1.1**	Critical path: make the plant study
		1.2	Determinate the variable and objects necessaries in ES
		1.3	Determinate the variables that will be used in the CBR
B	Adaptation of the variables and objects	**2.1**	Critical path: adapt and generate, if necessary, the variables and objects
C	Calibration of rules of the Rule-based System	**3.1**	**Critical path: generate and/or modify the rules to adapt to the new plant process.**
		3.2	Verify that the objects and variables used are the correct one.
D	Adaptation of the CBRS	**4.1**	Critical path: generate and/or modify the CBR procedures for the new plant process.
		4.2	Verify that the objects and variables used are the correct ones.
E	Connection with periphery elements	**5.1**	Critical path: generate a connection between the program and the different databases.
		5.2	Define the objects and variables.
F	Computational implementation	**6.1**	Critical path: implementation of the program in a personal computer
G	Validation & Check for correctness	**7.1**	Critical path: check the program and correct the possible errors made.
		7.2	Check that the generation of variables and objects phase works properly.
		7.3	Check that the calibration of rules phase works properly.
		7.4	Check that the adaptation of CBR phase works properly.
		7.5	Check that the connections with the databases are correct.
H	Delivery	**8.1**	Critical path: deliver the program and documentation to the user
I	Supervision	**9.1**	Critical path: help the user to work with the program and correct possible faults.

Table 5-4: Completion tasks in each node.

Tasks 1.1, 2.1, 3.1, 4.1, 5.1, 6.1, 7.1 and 8.1 make up the critical path, which determines the total time needed for each task. This means that slack time exists for others tasks

5.4.2. **Previous study**

The main goal of this task was to define the characteristics and requirements of the plant. To do this, we planned a series of interviews with the head of plant. However, our experience with these interviews led us to realise that the head of the plant was unable to clearly and quickly define the wastewater treatment process in his plant. The head of the plant always explained the process in very simple terms and always neglected some important information. This posed a serious problem for the study.

Interviews are considered to be the best way to extract the maximum possible information from the plant manager. To carry out correctly the task of studying the plant, it is recommended that a questionnaire is made for the interviews. This ensures that no important questions for the plant head are left out. Three interviews were planned. The different interviews were designed to progressively increase our knowledge about the plant. The knowledge extracted from the plant manager was intended to address the following questions:

- What are the objectives of the plant?
- What kind of process is implemented in the plant?
- What is the plant configuration?
- How is the plant operated?
- What is the control of the process?

The responses of these questions provide us the knowledge needed to redesign the prototype so that it fits the characteristics of the new plant. The most important question that the protocol had to respond is:

- What does the head of the plant want to detect?

The purpose of the interviews was to learn about several interesting aspects of the plant, such as the kind of process performed, the operation carried out in the plant, the control of the process, and data and information that is routinely collected at the plant (type, format, frequency of historical data and current online and off-line data…). Additionally, we wanted to collect the process flowsheet, images, historical data and any other related information.

The temporal sequence of this process is seen in the following flux diagram:

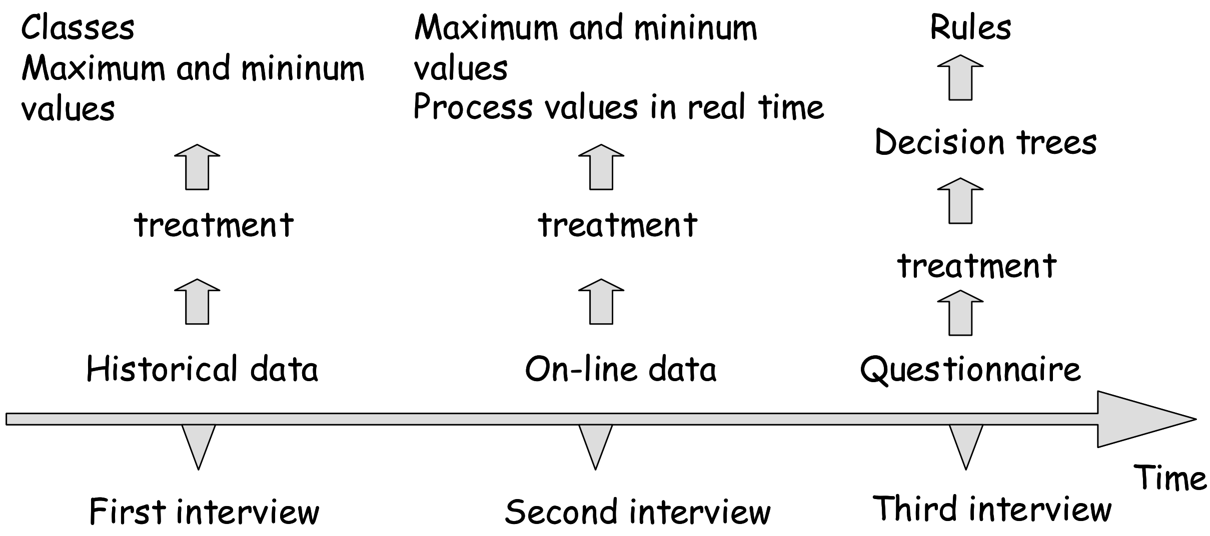

Figure 5-3: Temporal sequence of the study process.

The time estimated to do this work was 4,3 days and two knowledge management-men were needed. The set of interviews started with a demand of the historical data. The objective was to obtain the general information about the plant and its process. A second interview was held to obtain a list of the on-line signals that the process generates. The third interview allowed us to obtain more concrete information about the specific operational problems that the plant usually suffered. The third step of this diagram is composed by a set of interviews to learn all about the operational problems.

It is important to know precisely what questions to ask and what especial characteristics of the plant and the process are important to understand. To make this task properly it was necessary to do interviews with the head of the WWTP and help him fill out the questionnaire. Some important points that helped make this study efficiently are described next. Then, the document used to carry out the interviews with the heads of any wastewater treatment plant is described.

The information collected during the interviews is essential to adequately design the structure of the program. Although the architecture of the program will always be the same, some modules will be different based on the characteristics of the new sewage treatment plant. A good study of the plant is therefore important to adjust the program accordingly. Thus, if the study is not carried out correctly, the ranks and limits used in the program will not be correct and the program will not be able to make a good diagnosis of a problem situation. For instance, suppose that the plant has at some point an inflow of 2000 m^3/hour but the design limit is 1500 m^3/hour. If we failed to make a good study of the plant and did not inform the program that the maximum value of inflow sewage was 1500 m^3/hour, the program will not detect this circumstance and will inform the operator as expected.

Other example is the failure of detect a big concentration or peak of pH in the inflow. If the ranges are not well-defined, then the program cannot detect this pH peak. This circumstance can provoke the death of the biological mass in the reactor and the effluent will be wrong.

If the program does not inform the operator about the high inflow in the plant because the study is made wrongly, the situation can deteriorate and cause enormous problems to the process and the machines of the plant, with the certain consequence that the quality of the outflow water will be inadequate. Nonetheless, the operator can change the values of the maximum and minimum ranks through an interface if he thinks that he must do so or if the plant changes its structure (number of reactors, number of settlers, and so on).

After the study of the plant, the knowledge engineer has to learn about the operation of the plant. This is important because the rules of the EDSS will need to be modified as a function of the operation used.

The control of the process is another piece of information important for the knowledge management**.** Here, some plant properties can change some rules of the program. It is essential to know if the control over the aeration, the recycle activated sludge (RAS), and the control loops are automatic or manual. Also, it is important to know if the possibility of action in different parameters exists. Equally important is to define the properties that the plant treatment outflow must have and the legislated limits for outflow characteristics.

5.4.3. **Adaptation of the variables and objects**

The adaptation of the variables and objects of the object-oriented shell (G2) used to codify the intelligent decision support system is the principal objective of this task. The possibility of reusing the objects and variables defined in the prototype must be considered. But inevitably, new variables will need to be added to the program. It is recommended that before the design of the program a list be made with the variables, objects and their relationships, although we recognise that it is very difficult to identify this information a priori.

Thanks to the interviews with the head of the plant, we can define the variables that we have to modify in the rules of the program. Learning specific knowledge from the historical data by means of automatic knowledge acquisition methods is useful to determine the variables needed and their rank of operation.

Initially the objects created or modified can be from the Rules-base system or the Case-base Reasoning System.

Estimated time: 5,3 days.

5.4.4. **Calibration of rules of the Rule-based System**

Once the knowledge acquisition process is completed, the next step is to structure the acquired knowledge or, in other words, transform it into a graphical representation that is easy to understand and amend by experts. The next action is to generate decision trees (i.e., the rules of the ES) that deal with the new properties of the plant and to modify the actions and recommendations as required. Once the decision trees are made and discussed, the knowledge engineer needs to codify the collected information into rules. If the administrator designs new rules or modifies the old rules, then variations in the objects and variables must be considered. Once the knowledge base is created, it is not an easy task to modify the rules.

Estimated time: 7,3 days.

5.4.5. **Adaptation of the CBRS**

The purpose of this stage is to modify or adapt variables, modalities and weight functions, if necessary, of the reasoning case-based system. Checking the correct performance of the Case library and CBS cycle is important, too. The Case library will be the source of information to collect the case most similar to the current case.

This stage includes several sub-tasks:

- Selection of variables to define the *case* of the Case-Based System (CBS).
- Establishment of maximum values, minimum values and qualitative modalities for the variables involved in the CBS.
- Definition of new objects, variables and parameters, if required.
- Modification of the user-interfaces of the CBRS as required for new operators.

The variables that define correctly a case are chosen by means of interviews with the head of the plant and through the statistical analysis of the historical database.

Estimated time: 3,5 days.

5.4.6. **Connection with peripheral elements**

The main objective of the management-knowledge operator is adaptation of the software interfaces between G2 and data acquisition systems (e.g. SCADA) and between G2 and remote off-line databases. The secondary goals at this point are to verify the correct communication between G2 and all the external applications and modify the internal G2-procedures to filter, validate and make the abstraction of the whole data.

Estimated time: 2,5 days

5.4.7. **Computational implementation**

This stage concerns the implementation of the Decision Support System (G2-based software and bridges) on a personal computer. The implementation is made by modules, which together contain all the knowledge.

Estimated time: 5 days.

5.4.8. **Validate & Check for correctness**

This goal of this step is to validate and check for correctness, consistency and usability of the performance of the whole EDSS. This is accomplished by controlling the correct operation of the system and the consistency of its responses. The main objective is to detect and to correct possible problems within the program. To do this task an organized search for ways of improving the efficiency and effectiveness of the new system, and to provide information that will be helpful in the development of future systems is needed.

Estimated time: 5 days.

5.4.9. **Delivery**

The delivery phase consists in giving the program to the user with a user protocol that explains how to use the program.

Estimated time: 1 day.

5.4.10. **Supervision**

The supervision step consists in giving support to the users for a period of time to help them solve any problems they may encounter.

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Chapter 6: Results from Montornès EDSS implementation case

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6. Results from Montornès EDSS implementation case

6.1. Abstract

The purpose of this chapter is to offer a summary, a global view of the project and of its evaluation. The protocol used in the Montornès implementation can be considered a result of this project. The final protocol (Protocol Montornès 2.0; chapter 7, section 7.3) already includes the changes made during the application of the theoretical protocol.

The results, extracted from the real application to the Montornès WWTP, are explained for each and every step of the protocol. The final result of this thesis is the new protocol together with the Montornès Environmental Decision Support System implemented in the Montornès WWTP.

6.2. Introduction

A new EDSS derived from the prototype was obtained using the protocol presented in chapter 5. During the development process and the post-implementation review it became apparent that many points from the original document required changes to improve the function for which it was developed. These changes are included in the final protocol explained in Chapter 7, section 7.3.

In this chapter, rather than explaining the results and modifications made to each and every phase of the protocol, the main results from its application to a real WWTP are commented on. These results consist of the new plant knowledge acquired by different methods (automatic learning methods, questionnaires, technical literature, and so on), the new rules developed, the new cases developed, and the new Montornès EDSS (the complete code of which is presented in the annex).

6.3. Results from protocol Montornès 1.0 implementation.

The results are divided into protocol results, the Montornès EDSS, and the user manual. It The most important objective was to generate a protocol to export the prototype to other WWTP and improve the prototype so that it becomes a basis for future EDSSs.

One important result of this thesis is the development process of the Montornès EDSS. This new EDSS provides much information and knowledge about how to make future EDSSs and about how a good protocol should be.

The final protocol, presented in chapter 7, section 7.3, can be considered a result, too. In this protocol the knowledge acquired during all the implementation process is applied. Some protocol phases do not appear in this chapter because they do not have concrete results. However, this does not mean that these phases are not important for the whole project. Specifically, these phases are G2 installation, objects and variables generation and modularity, which are important in the new EDSS development process.

Another result of this thesis is the specific knowledge acquired during the application of the protocol application. This is the information learnt from the plant study, the new ways to apply any protocol phase, the improvements made to some phases, and the new EDSS for Montornès WWTP

There are some discoveries made during the protocol application process that can be considered results because they can affect some phases. Other results presented consist in specific knowledge about the plant.

The implementation steps for the protocol used in the development of the Montornès EDSS are explainedin the following sections.

6.3.1. **Plant study**

A thorough study of the plant is a very important step in any new exportation process since it allows acquiring the information about characteristics of the new plant on which the future program will be based.

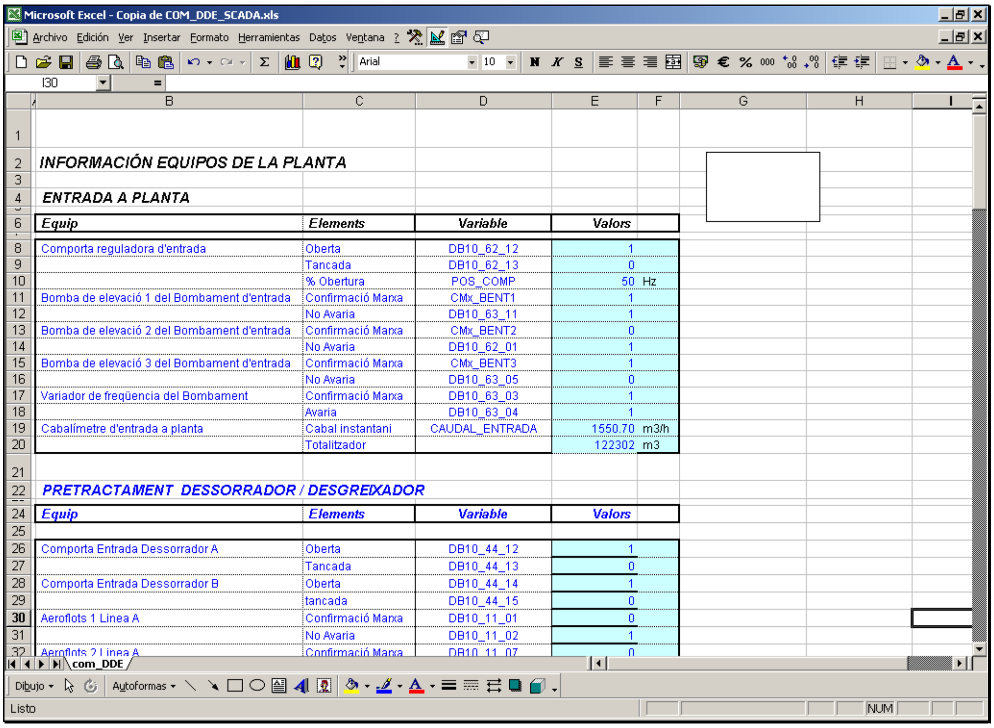
In a biological wastewater treatment plant the major challenge is to find out the current status of the process [Olsson and Newel, 1999]. Because of this reason, the plant study phase has a very important weight within the protocol. In our case, the study phase was divided into three interviews, each designed to obtain a different kind of information.

6.3.1.1. The **first meeting** was designed to obtain information about the design of the plant, specially concerning the plant limits and how the plant was built. Montornès design information is summarised in the following table:

Water line			
Parameter	**Description**	**Value/per unit**	**Total value**
Flows	Maximum theoretical inflow	3750 m^3/h	
	Design inflow	30000 m^3/d	
Inhab-eq		265.000	
Pumps	3 OMEGA pumps	1250 m^3/h	
Sands removal	2 lines	166.5 m^3	
Mixing chambers		143.5 m^3	
First stage reactor	2 reactors	1408 m^3	2816 m^3
First stage aeration	3 air-pump AERZEN	2400 Nm^3/h	
	Diffusers	504 units	1008 units
Primary volume settler	2 settlers	2214 m^3	4428 m^3
	Diameter	28.5 m	
Second stage reactor	3 reactors	4740 m^3	14220 m^3
Second stage aeration	4 air-pump AERZEN	4900 Nm^3/h	
	Diffusers	1128 units	3384 units
Secondary volume settler	3 settlers	2000 m^3	6000 m^3
	Diameter	31 m	

Table 6-1: Design data for the water line of Montornès WWTP. Source: Montornès WWTP.

6.3.2. The **second interview** was designed to obtain the on-line and the off-line information, as well as the historical plant database. The following figure illustrates a spreadsheet containing this kind of information. For a detailed discussion of the databases used in this study, see chapter 3, section 3.4.3.



INFORMACIÓN EQUIPOS DE LA PLANTA

ENTRADA A PLANTA

Equip	Elements	Variable	Valors	
Comporta reguladora d'entrada	Oberta	DB10_62_12	1	
	Tancada	DB10_62_13	0	
	% Obertura	POS_COMP	50	Hz
Bomba de elevació 1 del Bombament d'entrada	Confirmació Marxa	CMx_BENT1	1	
	No Avaria	DB10_63_11	1	
Bomba de elevació 2 del Bombament d'entrada	Confirmació Marxa	CMx_BENT2	0	
	No Avaria	DB10_62_01	1	
Bomba de elevació 3 del Bombament d'entrada	Confirmació Marxa	CMx_BENT3	1	
	No Avaria	DB10_63_05	0	
Variador de freqüencia del Bombament	Confirmació Marxa	DB10_63_03	1	
	Avaria	DB10_63_04	1	
Cabalímetre d'entrada a planta	Cabal instantani	CAUDAL_ENTRADA	1550.70	m3/h
	Totalitzador		122302	m3

PRETRACTAMENT DESSORRADOR / DESGREIXADOR

Equip	Elements	Variable	Valors
Comporta Entrada Dessorrador A	Oberta	DB10_44_12	1
	Tancada	DB10_44_13	0
Comporta Entrada Dessorrador B	Oberta	DB10_44_14	1
	tancada	DB10_44_15	0
Aeroflots 1 Linea A	Confirmació Marxa	DB10_11_01	0
	No Avaria	DB10_11_02	1
Aeroflots 2 Linea A	Confirmació Marxa	DB10_11_07	0

Figure 6-1: The on-line data worksheet.

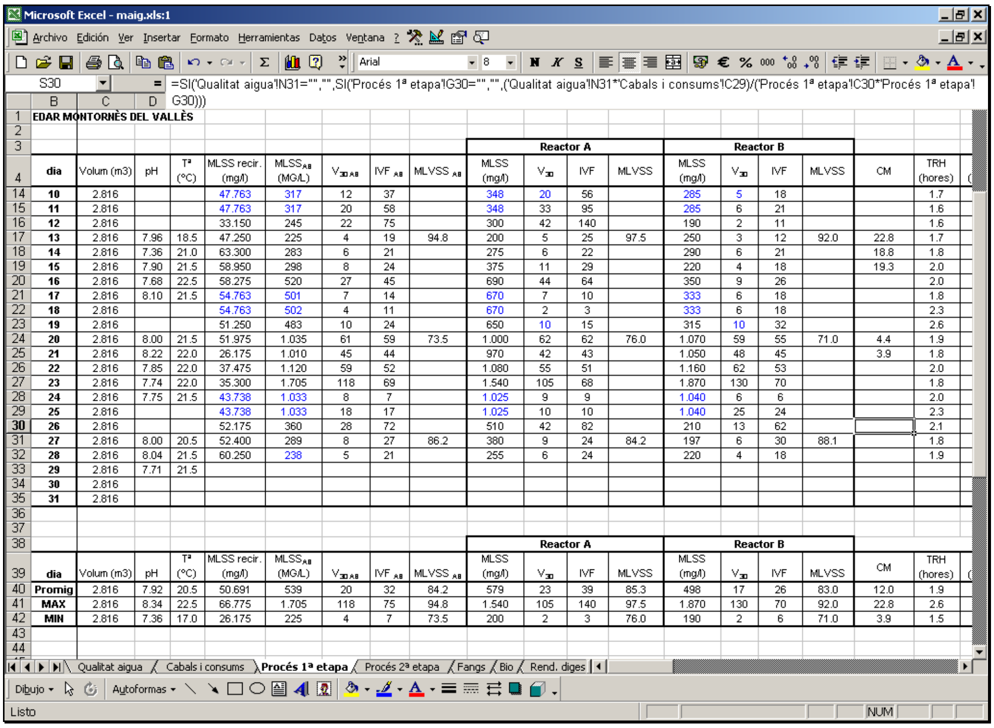
Several sensors are available at the Montornès WWTP, . Of these, some measure the quality of the wastewater, but other sensorsmeasure plant devices such as gates, pumps, centrifuges, and so on. These devices help the plant head to get a global view of treatment process. The on-line sensors that provide measures related to wastewater quality give the plant head valuable real-time information about several points of the process. Montornès WWTP stores 162 on-line data items in a spreadsheet that are updated every 15 seconds. Some sludge line data is also measured with sensors. A detailed list of the on-line parameters measured in Montornès is in the annex.

The following table lists all the on-line signals collected in Montornès together with the location of the corresponding sensors. In the first columnare the locations of the sensors in the plant, with the equipment listed in the second column. The next column lists the elements measured. In the fourth column are the possible values that the signal can take, while the last column contains the data type.

Zone	Equipment	Elements	Signal	Digital/analogical
Entrance	Pumping	Entrance gate	Open/closed	Digital
		Elevation pump 1	Stop/run/failure	Digital
		Elevation pump 2	Stop/run/failure	Digital
		Elevation pump 3	Stop/run/failure	Digital
		Frequency variation	Stop/run/failure	Digital
	Flow	Flow meter	Flow	Analogical
		Total entrance flow	Flow	Analogical
Pre-treatment	Grit and floatable removal	Gate A	Open/closed	Digital
		Gate B	Open/closed	Digital
		Aeroflots line A	Stop/run/failure	Digital
		Aeroflots line B	Stop/run/failure	Digital
		Float removal bridge A	Stop/run/failure	Digital
		Float removal bridge B	Stop/run/failure	Digital
		Grit removal pump A	Stop/run/failure	Digital
		Grit removal pump B	Stop/run/failure	Digital
Primary treatment	Reactor	Mixer reactor A	Stop/run/failure	Digital
		Mixer reactor B	Stop/run/failure	Digital
		Frequency variation	Frequency	Analogical
		Oxygen sensors (2)	mg O_2	Analogical
		Set-point oxygen	mg O_2	Analogical
	Settler	Entrance gate to settler A	Stop/run/failure	Digital
		Entrance gate to settler B	Stop/run/failure	Digital
		Settler bridge A	Stop/run/failure	Digital
		Settler bridge B	Stop/run/failure	Digital
		WAS Pump 1,2	Stop/run/failure	Digital
		WAS flow	Flow	Analogical
		Total WAS flow	Flow	Analogical
Secondary treatment	Reactor	Entrance gate to reactor A	Open/closed	**Digital**
		Entrance gate to reactor	Open/closed	Digital
		By-pass gate		
		Blowing A	Stop/run/failure	Digital
		Blowing B	Stop/run/failure	Digital
		Blowing C	Stop/run/failure	Digital
		Blowing D	Stop/run/failure	Digital
		Frequency variator	Frequency	Analogical
		Oxygen sensors (3)	mg O_2	Analogical
		Set-point oxygen	mg O_2	Analogical
	Settler	Entrance gate to settler A	Stop/run/failure	**Digital**
		Entrance gate to settler B	Stop/run/failure	Digital
		Entrance gate to settler C	Stop/run/failure	Digital
		Settler bridge A	Stop/run/failure	Digital
		Settler bridge B	Stop/run/failure	Digital
		Settler bridge B	Stop/run/failure	Digital
		WAS Pump 1,2,3	Stop/run/failure	Digital
		WAS flow	Flow	Analogical
		Total WAS flow	Flow	Analogical
		RAS Pump 1,2,3	Stop/run/failure	Digital
		RAS flow	Flow	Analogical
		Total RAS flow	Flow	Analogical
		Frequency variator	Frequency	Analogical
		Treated water flow	Flow	Analogical
		Total treated water flow	Flow	Analogical

Table 6-2: Online parameters on Montornès WWTP.

The off-line data consists in a spreadsheet that contains all the information provided by the analysis of the process samples. Each spreadsheet contains information on the process for one month.


Microsoft Excel - maig.xls:1

=SI('Qualitat aigua'!N31="","",SI('Procés 1ª etapa'!G30="","",('Qualitat aigua'!N31*'Cabals i consums'!C29)/('Procés 1ª etapa'!C30*'Procés 1ª etapa'!G30)))

EDAR MONTORNÈS DEL VALLÈS

dia	Volum (m3)	pH	Tª (°C)	MLSS recir. (mg/l)	MLSS AB (MG/L)	V30 AB	IVF AB	MLVSS AB	Reactor A MLSS (mg/l)	Reactor A V30	Reactor A IVF	Reactor A MLVSS	Reactor B MLSS (mg/l)	Reactor B V30	Reactor B IVF	Reactor B MLVSS	CM	TRH (hores)
10	2.816			47.763	317	12	37		348	20	56		285	5	18			1.7
11	2.816			47.763	317	20	58		348	33	95		285	6	21			1.6
12	2.816			33.150	245	22	75		300	42	140		190	2	11			1.6
13	2.816	7.96	18.5	47.250	225	4	19	94.8	200	5	25	97.5	250	3	12	92.0	22.8	1.7
14	2.816	7.36	21.0	63.300	283	6	21		275	6	22		290	6	21		18.8	1.8
15	2.816	7.90	21.5	58.950	298	8	24		375	11	29		220	4	18		19.3	2.0
16	2.816	7.68	22.5	58.275	520	27	45		690	44	64		350	9	26			2.0
17	2.816	8.10	21.5	54.763	501	7	14		670	7	10		333	6	18			1.8
18	2.816			54.763	502	4	11		670	2	3		333	6	18			2.3
19	2.816			51.250	483	10	24		650	10	15		315	10	32			2.6
20	2.816	8.00	21.5	51.975	1.035	61	59	73.5	1.000	62	62	76.0	1.070	59	55	71.0	4.4	1.9
21	2.816	8.22	22.0	26.175	1.010	45	44		970	42	43		1.050	48	45		3.9	1.8
22	2.816	7.85	22.0	37.475	1.120	59	52		1.080	55	51		1.160	62	53			2.0
23	2.816	7.74	22.0	35.300	1.705	118	69		1.540	105	68		1.870	130	70			1.8
24	2.816	7.75	21.5	43.738	1.033	8	7		1.025	9	9		1.040	6	6			2.0
25	2.816			43.738	1.033	18	17		1.025	10	10		1.040	25	24			2.3
26	2.816			52.175	360	28	72		510	42	82		210	13	62			2.1
27	2.816	8.00	20.5	52.400	289	8	27	86.2	380	9	24	84.2	197	6	30	88.1		1.8
28	2.816	8.04	21.5	60.250	238	5	21		255	6	24		220	4	18			1.9
29	2.816	7.71	21.5															
30	2.816																	
31	2.816																	

dia	Volum (m3)	pH	Tª (°C)	MLSS recir. (mg/l)	MLSS AB (MG/L)	V30 AB	IVF AB	MLVSS AB	Reactor A MLSS (mg/l)	Reactor A V30	Reactor A IVF	Reactor A MLVSS	Reactor B MLSS (mg/l)	Reactor B V30	Reactor B IVF	Reactor B MLVSS	CM	TRH (hores)
Promig	2.816	7.92	20.5	50.691	539	20	32	84.2	579	23	39	85.3	498	17	26	83.0	12.0	1.9
MAX	2.816	8.34	22.5	66.775	1.705	118	75	94.8	1.540	105	140	97.5	1.870	130	70	92.0	22.8	2.6
MIN	2.816	7.36	17.0	26.175	225	4	7	73.5	200	2	3	76.0	190	2	6	71.0	3.9	1.5

Figure 6-2: The off-line information worksheet.

Off-line data come from the analysis of samples taken at different points along the process. The off-line parameters measured are selected to together define the water status. These are the suspended solids, the BOD_5, the COD, the nutrients, the metals, and so on. The parameters and the plant sample points can be seen in table 30.

The microbiological analysis is done on a mixed liquor sample from the biological reactor. Both the dominant species and its abundance within the mixed liquor are measured. The microbiological information analysed is shown in table 31.

Finally, qualitative observations are made at different plant locations, some in the reactor, some in the settlers and some in test tubes. The parameters measured are in table 32.

The off-line spreadsheet includes also the microbiological and qualitative information. By having all this information in the same source, one bridge suffices to transfer all the data that are not bon-line data.

		Parameter		Unit	Location
Off-line	**Water quality**	SS		mg/l	E/P/S
		SSV		mg/l	E/S
		COD		mg/l	E/Ef/P/Pf/%R(ET1)/%RE-Pf/S
		BOD_5		mg/l	E/P/%R(ET1)
		pH		upH	E/P/S
		Conductivity		S/cm	E/S
		NTK		mg/l	E/S
		Nitrates		mg/l	E/S
		Nitrites		mg/l	E/S
		Total N		mg/l	E/S
		Ammonia N		mg/l	E/S
		Phosphorus		mg/l	E/S
		Chrome		mg/l	E/S
		Zinc		mg/l	E/S
		Sulfates		mg/l	E/S
	Flows	…			
	First stage	Volume		m^3	
		pH		pHunits	
		Temperature		ºC	
		MLSS recycle		mg/l	
		MLSS absolute		mg/l	
		V30 absolute		mg/l	
		SVI absolute		ml/g	
		MLVSS absolute		ml/g	
		Reactor A	MLSS	mg/l	
			V30	mg/l	
			SVI	ml/g	
			MLVSS	ml/g	
		Reactor B	MLSS	mg/l	
			V30	mg/l	
			SVI	ml/g	
			MLVSS	ml/g	
		Mass load		kg BOD_5 /Kg MLSS·d	
		TRH		$hours^{-1}$	
		TRC days		$days^{-1}$	
		TRC week		$days^{-1}$	
		Ascent. vel.			
	Second stage	Volume		m^3	
		pH		pHunits	
		Temperature		ºC	
		MLSS recycle		mg/l	
		MLSS absolute		mg/l	
		V30 absolute		mg/l	
		SVI absolute		ml/g	
		MLVSS absolute		ml/g	
		Reactor A	MLSS	mg/l	
			V30	mg/l	
			SVI	ml/g	
			MLVSS	ml/g	
		Reactor B	MLSS	mg/l	
			V30	mg/l	
			SVI	ml/g	
			MLVSS	ml/g	
	Sludge	…			
	Bio	…			
	Digester yield	…			
	Total	…			

E: Influent; **P**: Primary treatment; **S**: Effluent; **Ef**: influent filtered; **Pf**: Primary treatment filtered; **%R(ET1)**:Efficient removal percentage between E and P; **%RE-P**: Efficient removal percentage between E and Pf

Table 6-3: Off-line parameters measured in Monornès WWTP.

	Parameter	Unit	Location
Microbiologic	Floc characterisation	1,2,3	Reactor
	Ciliate protozoa	1,2,3	Reactor
		Dominant ssp	
	Flagellate protozoa	1,2,3	Reactor
		Dominant ssp	
	Filamentous bacteria	1,2,3	Reactor
		Dominant ssp	

Table 6-4: Microbiological parameters measured.

	Parameter	Unit	Location
Qualitative	Macroscopical floc observation	1,2,3,4,5	Reactor
	Test-tube sedimentation	1,2,3,4,5,6,7,8,9	
	Settlers bed height	D1 A	Settlers
		D1 B	
		D2 A	
		D2 B	
		D2 C	
	Foam presence	B/F/N	Second stage reactor
			Secondary settler
			Exit
	Foam in the settler	P/G/N	Settler
D1 A: primary settler number 1; **D1 B**: Primary settler number 2; **D2 A**: Secondary settler number 1; **D2 B**: Secondary settler number 2; **D2 C**: Secondary settler number 3			

Table 6-5: Qualitative parameters measured in the Montornès WWTP.

Including microbiological and qualitative variables, 82 off-line variables are used in the program in the case of Montornès WWTP.

The above tables show the way in which the information is organised in the spreadsheets. On-line information and off-line information are organised in a specific way in each plant. Once these spreadsheets are obtained, the knowledge engineer must study how the data are organised, how often the data are updated and the range of values taken by each of the parameter. Only then can the bridges, macros and filtering procedures be built in G2 that are responsible for data transferring and filtering.

The statistical analysis of the historical data allows defining the range of values taken by each variable and takes a first view at the plant problems. This statistical analysis also deals with the historical data and prepares the latter for the automatic clustering process.

Water parameters study

Once the historical data are collected in the second interview, this information is statisticallyanalysed with the help of an Excel program. The graphical representation of the data helps to detect in an easy and intuitive way any wrong data points and to make a first approach to the range limits. The collection of this specific plant information can also be considered a result of this these because it has led to a new way to carry out the plant study. The characterisation of the water helps to define the limits for any parameter. These limits are included in the rules to help discover faults in the process. The parameters used to uantify and normalise the wastewater contamination levelare divided into physical parameters (temperature, colour, odour and turbidity) and chemical parameters (foremost solids, organic matter, nutrients, pH, alkalinity, hardness, chloride and grease).

Measurements and observations are the basis for the control process, and a statistical control process is used to monitor the measurements. In this case, the statistics chosen to characterise the data distribution are: the maximum and the minimum values, the mean, the standard deviation, the covariance, the median (second quartile), and the first and third quartiles. These variables are the best to study an unknown environmental database.

The maximum and minimum values define the limits of the classes while the mean, which corresponds to the gravity centre of the class, defines the central tendency of the data. The standard deviation and the variation coefficient (standard deviation divided by mean) inform about the dispersion of the data within the sample. The median, or second quartile, is a non-parametric measure of the central tendency, while the first and second quartiles are non-parametric measures of dispersion. Data distributions are graphically characterised with box-plots, which are useful tools to interpret the classes and find the characteristic or the partial characteristic variable.

The following table shows the statistics calculated on the historical database. The parameters studied correspond to 313 days from the historical database of the plant from May 2000 to March 2001.

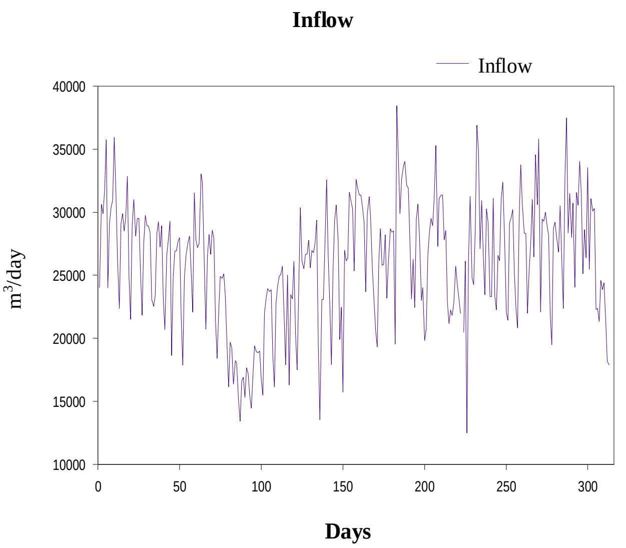
			MAX	MIN	MEAN	ST DESV	CV	MED	Q1	Q3
Q			38438.00	12480.00	**27231.24**	4916.73	0.18	26500.00	22664.00	29450.50
SS	mg/l	**E**	1130.00	106.00	**326.91**	118.21	0.36	292.00	240.00	364.00
		P	995.00	43.00	**159.23**	88.30	0.55	136.00	114.00	175.50
		S	168.00	2.00	**22.87**	22.42	0.98	23.00	16.00	34.25
COD	mg/l	**E**	1710.00	213.00	**735.65**	195.09	0.27	706.00	603.50	827.00
		P	1076.00	115.00	**579.03**	151.10	0.26	472.00	397.00	572.00
		S	252.00	11.00	**72.30**	40.63	0.56	82.00	62.00	109.00
BOD_5	mg/l	**E**	1080.00	200.00	**659.87**	181.61	0.28	520.00	440.00	683.00
		P	878.00	30.00	**486.21**	200.57	0.41	380.00	187.50	542.00
		S	154.00	4.00	**78.57**	40.81	0.52	26.00	12.00	88.00
Total-N	mg/l	**E**	86.70	27.70	**49.36**	11.53	0.23	49.00	43.50	55.30
		S	64.90	11.40	**38.25**	8.67	0.23	36.20	32.60	42.20
Nitrate	mg/l	**E**	2.90	0.30	**0.47**	0.45	0.95	0.30	0.30	0.30
		S	11.20	0.30	**0.76**	1.58	2.08	0.30	0.30	0.60
Ammonia	mg/l	**E**	60.80	8.60	**29.05**	7.77	0.27	29.10	24.48	33.20
		S	41.80	4.50	**29.37**	7.01	0.24	27.20	23.65	32.00
Phosphorous	mg/l	**E**	24.80	3.90	**8.11**	3.08	0.38	7.75	6.70	9.63
		S	7.70	0.40	**1.82**	1.61	0.88	1.65	1.20	2.83
MLSS-1	mg/l		11270.67	540.00	**3839.07**	1773.26	0.46	3510.00	2740.00	4300.00
V30-1	mg/l		7841.33	20.00	**268.39**	1985.34	7.40	257.50	181.25	320.00
SVI-1	ml/g		580.02	17.86	**69.51**	92.96	1.34	70.14	57.95	95.00
CM-1	Kg BOD_5 / Kg MLSS*d		7.29	0.11	**1.52**	1.23	0.81	1.33	0.93	2.08
MLSS-2	mg/l		5720.00	1305.00	**2727.64**	859.58	0.32	2800.00	2293.33	3450.00
V30-2	mg/l		975.00	120.00	**445.31**	259.52	0.58	360.00	260.00	661.25
SVI-2	ml/g		677.00	55.77	**174.68**	113.70	0.65	118.69	90.20	218.45
CM-2	Kg BOD_5 / Kg MLSS*d		0.75	0.02	**0.17**	0.14	0.82	0.19	0.11	0.28
RASS-1	m^3/d		37379.00	0.00	**9687.63**	6709.99	0.69	8733.00	6973.00	11765.00
RASS-2	m^3/d		21471.00	0.00	**6337.72**	4411.51	0.70	11165.00	8816.00	12845.00
WAS-1	m^3/d		15310.00	8.20	**706.37**	3026.91	4.29	629.50	434.40	875.00
WAS-2	m^3/d		4069.00	0.00	**44.64**	637.80	14.29	577.00	4.00	759.50
WAS-3	m^3/d		2594.00	0.00	**656.40**	437.58	0.67	0.00	0.00	650.00

Table 6-6: Statistical study of Montornès Historical data.

There are many parameters with a high coefficient of variation (high dispersion). Nitrate at the exit, V30 in the first stage, the SVI in the first stage, the WASS in the first stage and the WASS in the second stage. The V30 from the first stage and the waste flow present high coefficient variation. The high V30 in the first stage is due to the low settling capacity of the sludge. The coefficient of variation of the waste flow in the second stage is very high in comparison to the other variables.

Once the univariate statistical analysis is completed, the correlations among variables are calculated in search of possible relationships between variables. A variation of one variable can change other variable or set of variables. This relationships help to know the plant process and what happens when a variable is modified.

Graphics are powerful tools to shown what is going on at the plant because they present numerical information in a way that can be understood quickly. Plots of data against time help to quickly pick up apparently abnormal data that do not conform to the general patterns. The run charts also display a variable as a function of time. The database used in the following graphics is also May 2000 to March 2001. June 2000 only has thirteen days with information, so the information of only 313 days is used.



This inflow disturbance is typical of large treatment plants (Olson and Newell, 1999). Daily variations show little regularity, but the main variations are appreciated at weekly and annual cyclic timescales. Hydraulic variations are common in treatment plants due to the fact that neither the flowrate nor the composition are constant. This is also why this parameter is difficult to control.

These are the expected disturbances of flow in normal exploitation conditions. Then there are also unexpected disturbances such as rainstorms, snowmelt, industrial discharges, toxic releases, and so on.

In our case, the inflow variation was due to seasonality in industrial operations. During the summer, inflow is smaller than in the rest of the year. Whether the industry company are open or closed, the inflow can be higher or smaller. This is an important factor in Montornès because the wastewater generated by the industry complex in the zone is about 60-70 % of the wastewater reaching the plant.

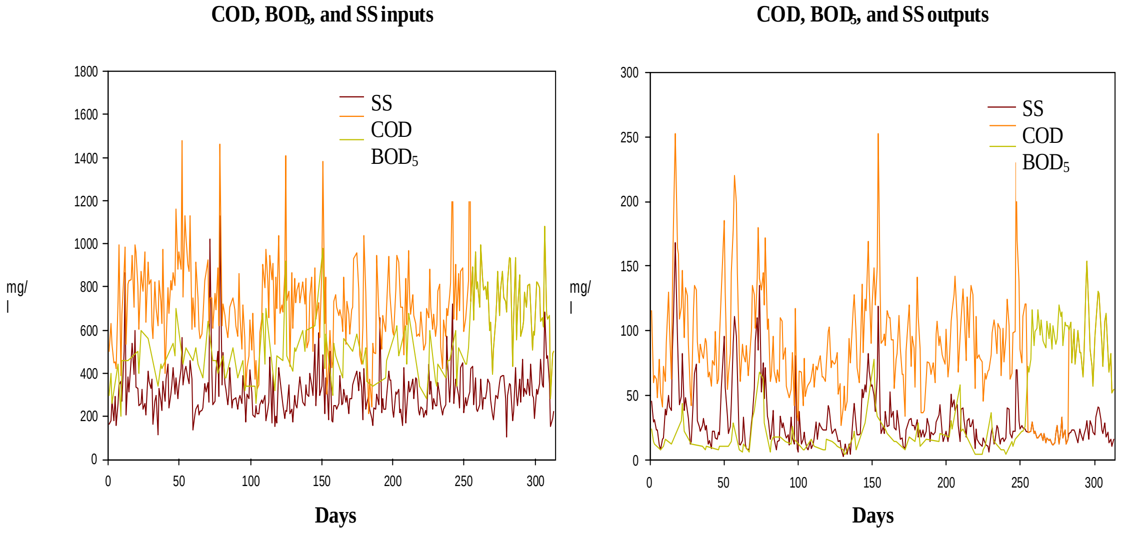


Figure 6-3: COD, BOD_5 and SS inputs and outputs.

The figure above shows the inputs and outputs of COD, BOD_5 and SS for the Montornès plant. COD can reach high values in this plant. Again, the industry is responsible for this. The concentration of easily biodegradable organic matter is usually high. This is the main reason why the plant configuration is an A–B process.

COD, BOD_5 and SS output values were considerably lower than their corresponding inputs values. COD output values had many high points that were coincident with high COD inputs values. This means that on those days the organic load was too high for the plant to treat efficiently. BOD_5 values showed a wrong stage for almost 50 days. During the same period, BOD_5 input values were also very high. The SS output values are also out of law in any times.

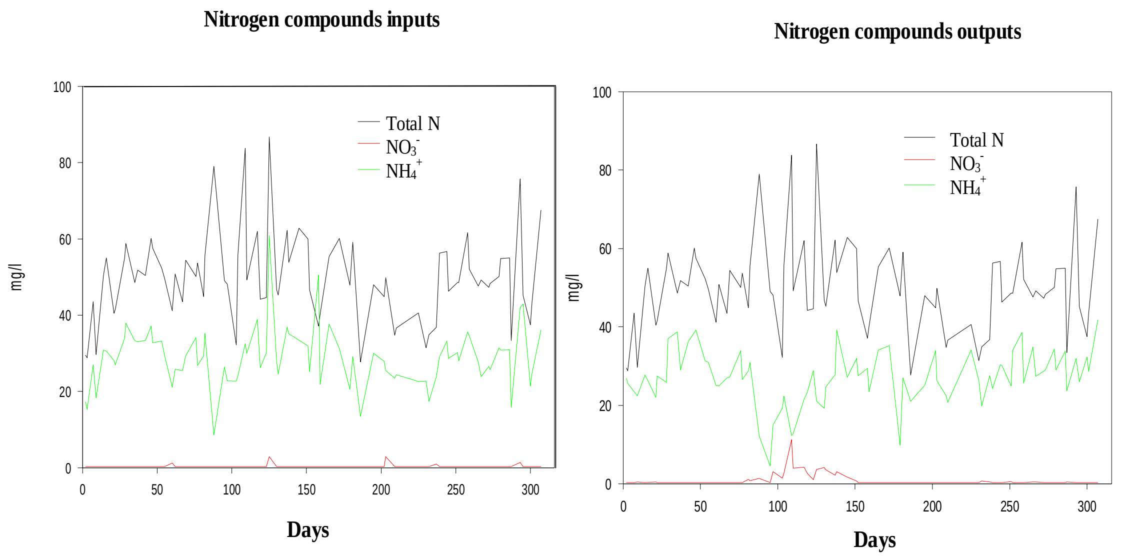


Figure 6-4: Nitrogen compounds inputs and outputs

Outputs of nitrogen compounds were approximately the same as inputs. This is because the plant was not designed to perform nitrification-denitrification process. The plant can sometimes nitrify nitrogen compounds, but this is not recommended because, afterwards, the plant will not be capable of denitrifying the by-products generated in the nitrification process (nitrites and nitrates).

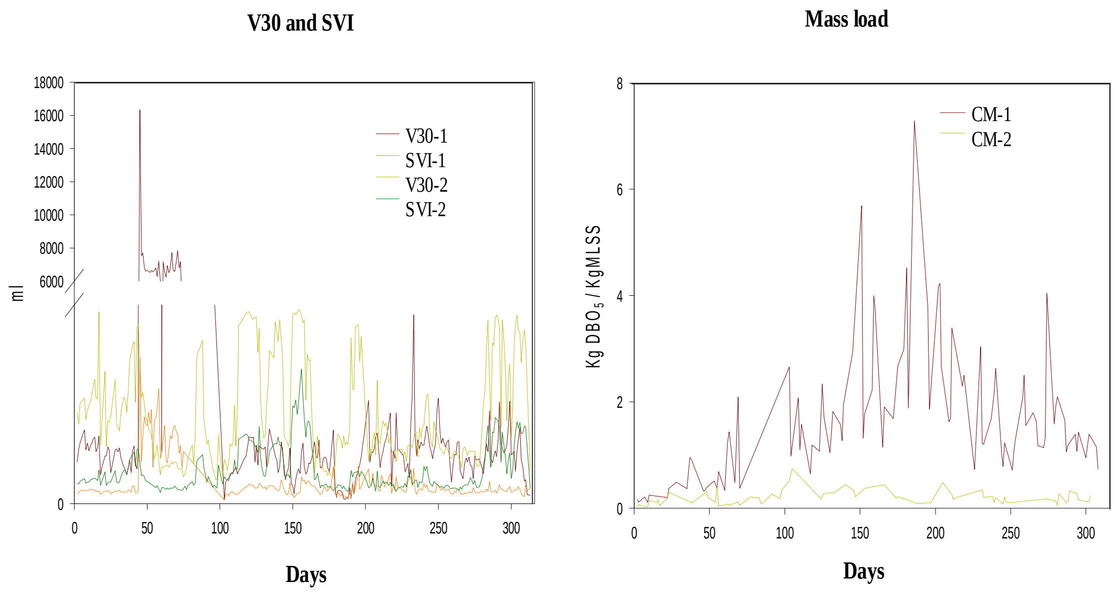


Figure 6-5: V30, SVI and Mass Load profiles.

The V30 and SVI are represented for every aeration tank, V30-1 and SVI-1 represents these parameters onto the first Reactor where the easily biodegradable organic matter is consumed. V30-2 and SVI-2 represent these values for the second biological reactor.

The mass load is also divided into two biological reactors. V30 and SVI do not follow a common pattern in the two reactors. The mass load in the first stage shows a considerable increase due to two possibilities. The first possibility could be the very high organic matter peak concentration in the wastewater inflow. Another possibility, in the case of the Montornès WWTP, could be related to operation checks performed at the plant to verify or test the hydraulic capacity, the pumps capacity, and so on.

In both the first and the second stage, the recycle flow is very variable due principally toa hydraulic test done at the plant. This kind of information is considered heuristic knowledge that the plant head can provide.

This information does not appear in the statistical study of the data; it only appears when the expert notes this anomaly and asks the plant head about it. This prompts the plant head to recall this concrete problem and explain it in detail.

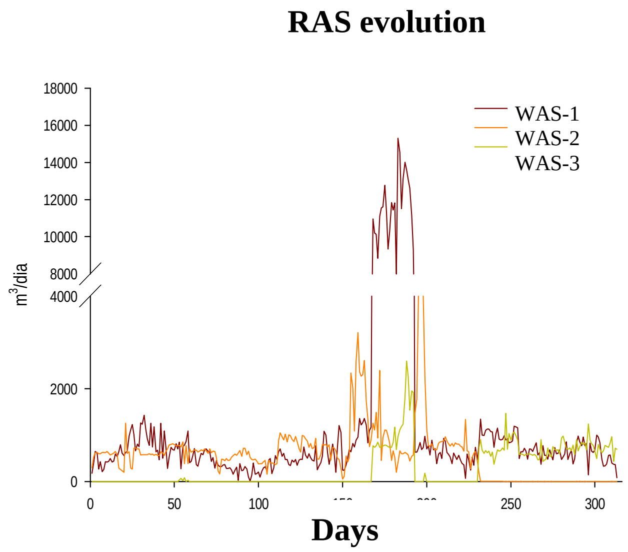


Figure 6-6: RAS profile.

The variations in purge flows coincide with the same test period. The three purge values are provided by the settlers, both primary and secondary, and by the biological reactor of the second stage.

The study of the historical data allowed us to determine that these parameters —mass load, recycle flow and purge flow— are closely interrelated due to the plant configuration and operation.

Finally, the engineer can define the normal range for each of the process variables. Both on-line variables and off-line variables have range limits. If the received value of the variable is smaller than the minimum limit, then the qualitative value of this variable is the symbol *low*. If the value is higher of maximum limit, then the corresponding qualitative variable is assigned the symbol *high*. If the value is between both limits, then the qualitative variable is assigned the symbol *normal*. This task is performed by a procedure called *abstraction().* This abstraction process is also known as *discretisation*. This procedure facilitates the program exportation because in a new plant the engineer only has to do the statistical analysis of the variables and update their operational ranges accordingly.

The on-line limits are the following:

The user can also modify these values whenever necessary. Some of these values can vary depending on the hour of the day. The flow limits can vary depending on whether the value received is from the day or from the night.

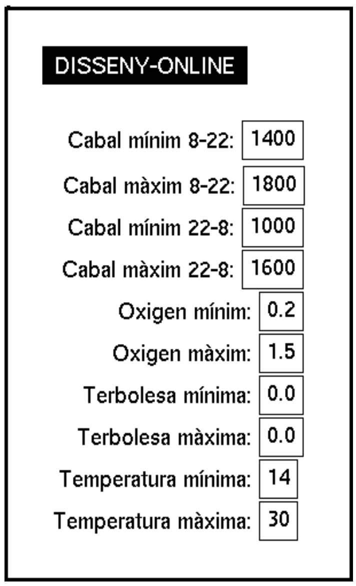


Figure 6-7: on-line limits.

Off-line variables have also a defined normal range. The limits of the range are provided by the statistical study of the information. The ranges established for the variables are proposed to the plant head, who evaluates whether they are adequate or not.

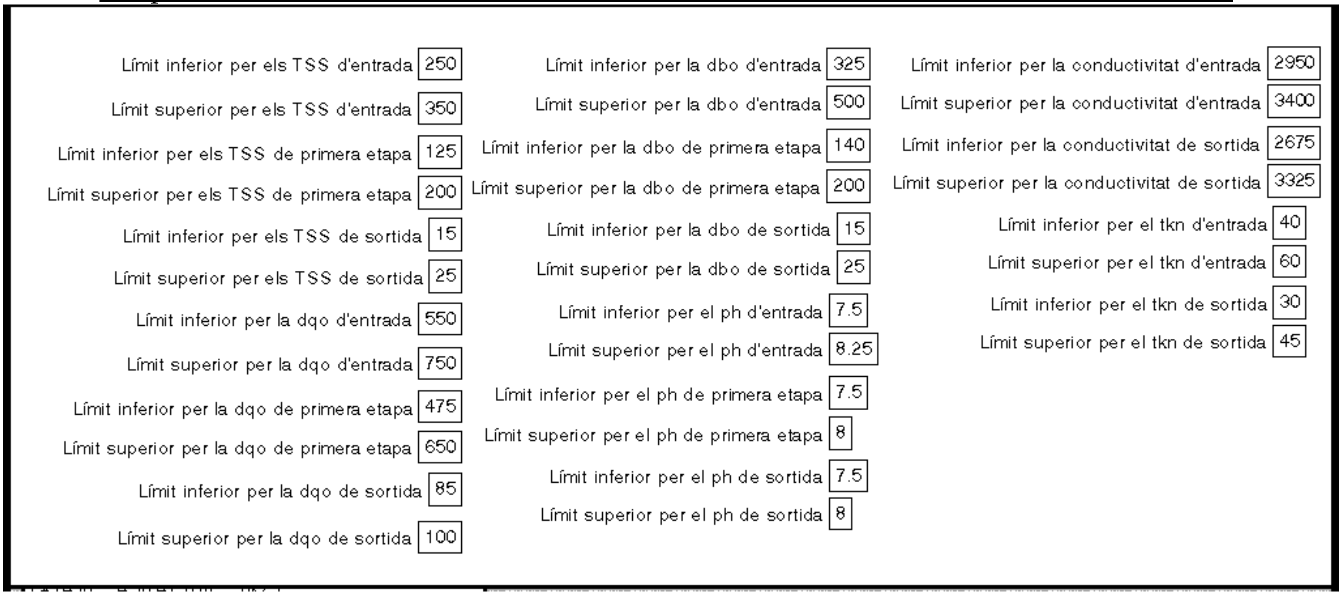


Figure 6-8: Off-line limits.

There are several statistical tools that can be used to find relationships between variables. The Pearson correlation coefficient is one of these. A correlation value close to 1 or –1 indicates that both parameters are closely related, whereas if the coefficient is close to 0 then there the variables are unrelated. Our analysis indicates that most of the variables used are independent since few variables were related with a correlation factor higher than 0.7-0.8, which is considered the minimum value to have a relation between two variables.

The following figure showsthe correlations among the variables chosen.

The matrix shows that the *WAS-1*and the *RAS-1* are closely related, but not *WAS-2* with *RAS-2*.

	Q	MES mg/l E	P	S	DQO mg/l E	P	S	DBO5 mg/l E	P	S	N-TOTAL mg/l E	S	nitrats mg/l E	S	N amoni mg/l E	S	fòsfor mg/l E	S
Q	1.000	-0.049	0.096	0.090	0.039	0.136	0.098	0.171	0.019	0.234	-0.364	0.009	0.025	-0.363	-0.078	0.143	-0.235	-0.249
MES mg/l E	-0.049	1.000	0.051	0.304	0.485	0.110	0.245	0.430	0.063	0.226	0.280	0.272	-0.084	-0.171	0.177	0.317	0.275	0.099
P	0.096	0.051	1.000	0.127	0.094	0.496	0.121	-0.146	-0.100	-0.244	-0.039	-0.016	0.196	-0.247	-0.020	0.188	0.002	-0.261
S	0.090	0.304	0.127	1.000	0.166	0.094	0.752	-0.045	-0.282	-0.022	0.083	0.196	0.081	-0.189	0.094	0.115	0.034	0.294
DQO mg/l E	0.039	0.485	0.094	0.166	1.000	0.332	0.197	0.649	0.083	0.064	0.572	0.207	0.361	0.075	0.425	0.218	0.246	0.096
P	0.136	0.110	0.496	0.094	0.332	1.000	0.102	0.351	0.363	0.202	0.315	0.192	-0.001	-0.124	0.090	0.315	-0.014	0.012
S	0.098	0.245	0.121	0.752	0.197	0.102	1.000	-0.192	-0.416	-0.205	0.074	0.308	0.050	-0.072	0.106	0.085	0.057	0.365
DBO5 mg/l E	0.171	0.430	-0.146	-0.045	0.649	0.351	-0.192	1.000	0.741	0.720	0.478	0.271	0.220	0.001	0.351	0.293	0.074	0.004
P	0.019	0.063	-0.100	-0.282	0.083	0.363	-0.416	0.741	1.000	0.789	0.325	0.315	0.205	-0.099	0.396	0.455	-0.020	-0.200
S	0.234	0.226	-0.244	-0.022	0.064	0.202	-0.205	0.720	0.789	1.000	0.067	0.330	-0.051	-0.225	0.131	0.305	-0.116	-0.084
NTOTAL mg/l E	-0.364	0.280	-0.039	0.083	0.572	0.315	0.074	0.478	0.325	0.067	1.000	0.324	0.280	0.414	0.570	0.093	0.306	0.261
S	0.009	0.272	-0.016	0.196	0.207	0.192	0.308	0.271	0.315	0.330	0.324	1.000	-0.113	-0.054	0.389	0.674	0.035	-0.015
nitrats mg/l E	0.025	-0.084	0.196	0.081	0.361	-0.001	0.050	0.220	0.205	-0.051	0.280	-0.113	1.000	0.069	0.300	-0.057	-0.030	-0.115
S	-0.363	-0.171	-0.247	-0.189	0.075	-0.124	-0.072	0.001	-0.099	-0.225	0.414	-0.054	0.069	1.000	0.164	-0.394	0.151	0.353
N amoni mg/l E	-0.078	0.177	-0.020	0.094	0.425	0.090	0.106	0.351	0.396	0.131	0.570	0.389	0.300	0.164	1.000	0.364	0.245	-0.067
S	0.143	0.317	0.188	0.115	0.218	0.315	0.085	0.293	0.455	0.305	0.093	0.674	-0.057	-0.394	0.364	1.000	-0.025	-0.371
fòsfor mg/l E	-0.235	0.275	0.002	0.034	0.246	-0.014	0.057	0.074	-0.020	-0.116	0.306	0.035	-0.030	0.151	0.245	-0.025	1.000	0.086
S	-0.249	0.099	-0.261	0.294	0.096	0.012	0.365	0.004	-0.200	-0.084	0.261	-0.015	-0.115	0.353	-0.067	-0.371	0.086	1.000
MLSS1	-0.037	0.165	0.058	0.167	0.222	0.103	0.143	0.027	-0.150	-0.046	0.052	0.069	0.017	-0.149	0.015	0.229	0.158	-0.234
V30-1	-0.111	0.140	0.023	0.241	0.191	-0.047	0.197	-0.111	-0.297	-0.225	0.096	0.191	-0.077	-0.130	0.057	0.209	0.077	-0.081
IVF-1	-0.148	0.125	0.081	0.242	0.217	-0.021	0.256	-0.151	-0.287	-0.294	0.043	0.117	0.002	-0.135	0.043	0.144	0.043	-0.083
CM-1	0.118	-0.048	-0.064	0.015	0.136	-0.073	0.013	0.174	0.233	0.047	0.034	0.044	0.169	-0.006	-0.056	-0.143	-0.169	0.164
MLSS2	0.222	0.048	0.170	0.131	0.125	0.030	0.113	-0.125	-0.311	-0.224	-0.169	-0.100	0.030	-0.232	-0.102	0.022	0.231	-0.208
V30-2	0.031	0.024	-0.065	0.003	0.044	0.034	0.153	0.111	0.084	0.138	0.167	0.110	0.077	0.137	0.300	0.040	0.236	0.126
IVF-2	-0.003	0.010	-0.100	-0.033	-0.039	0.026	0.129	0.160	0.213	0.226	0.176	0.145	0.029	0.181	0.290	0.049	0.051	0.210
CM-2	-0.204	-0.085	-0.094	-0.087	-0.191	-0.098	-0.053	-0.019	0.431	-0.147	0.299	0.197	-0.049	0.584	0.188	0.007	0.169	0.397
RASS-1	0.405	-0.069	-0.038	-0.069	-0.066	-0.091	-0.060	0.112	0.038	0.026	-0.003	0.202	-0.015	-0.142	-0.014	0.119	-0.296	-0.223
RASS-2	-0.033	-0.024	0.069	0.149	0.122	-0.052	0.111	-0.382	-0.551	-0.670	0.080	-0.162	-0.023	0.045	-0.089	-0.171	0.099	0.124
WAS-1	0.190	-0.038	-0.115	-0.083	-0.121	-0.164	-0.062	-0.101	-0.185	-0.153	-0.050	0.115	-0.050	-0.127	-0.156	-0.110	-0.222	-0.077
WAS-2	0.036	-0.069	0.198	0.038	-0.044	-0.253	0.100	-0.370	-0.465	-0.498	-0.085	-0.078	-0.012	0.000	0.094	-0.055	0.045	0.020
WAS-3	0.279	0.011	-0.112	-0.197	-0.054	0.240	-0.166	0.441	0.320	0.630	-0.018	0.150	-0.059	-0.235	-0.091	0.118	-0.259	-0.272

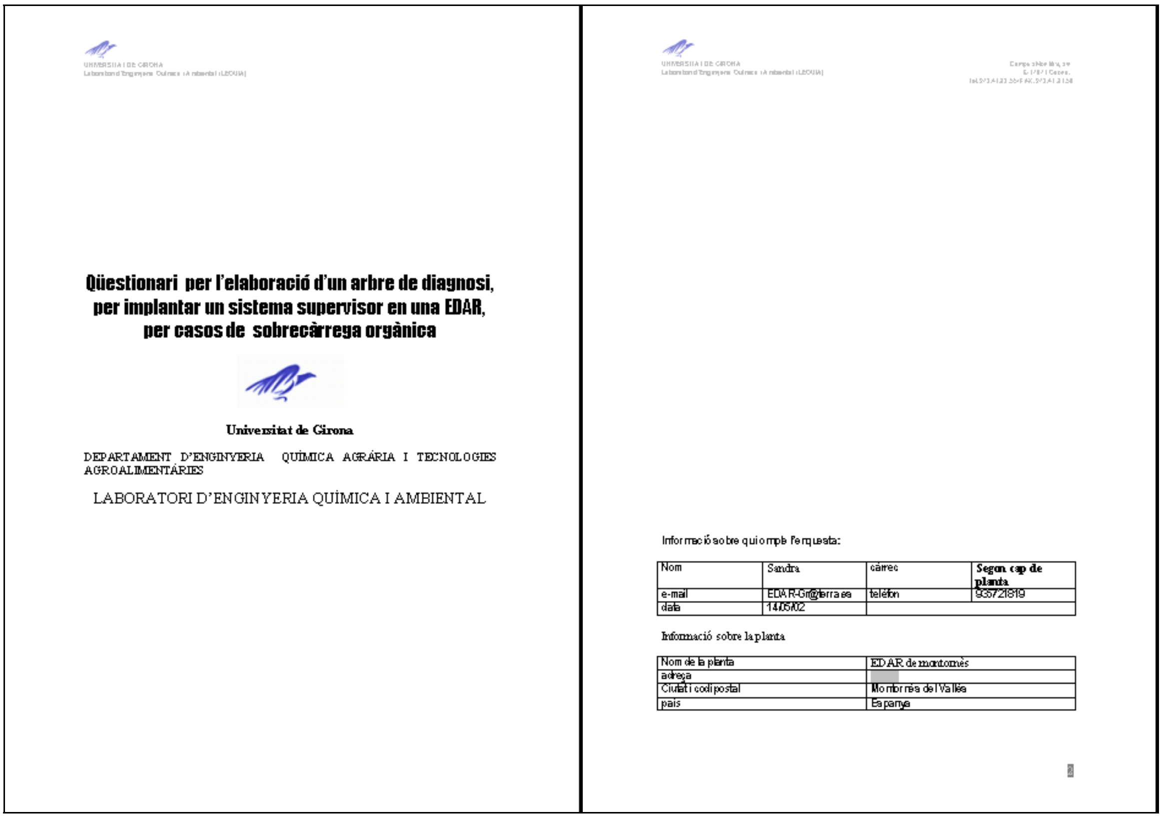
	MLSS-1 (MG/L)	V30-1	IVF-1	CM-1	MLSS-2 (MG/L)	V30-2	IVF-2	CM-2	RASS-1	RASS-2	WAS-1	WAS-2	WAS-3
Q	-0.037	-0.111	-0.148	0.118	0.222	0.031	-0.003	-0.204	0.405	-0.033	0.190	0.036	0.279
MES mg/l E	0.165	0.140	0.125	-0.048	0.048	0.024	0.010	-0.085	-0.069	-0.024	-0.038	-0.069	0.011
P	0.058	0.023	0.081	-0.064	0.170	-0.065	-0.100	-0.094	-0.038	0.069	-0.115	0.198	-0.112
S	0.167	0.241	0.242	0.015	0.131	0.003	-0.033	-0.087	-0.069	0.149	-0.083	0.038	-0.197
DQO mg/l E	0.222	0.191	0.217	0.136	0.125	0.044	-0.039	-0.191	-0.066	0.122	-0.121	-0.044	-0.054
P	0.103	-0.047	-0.021	-0.073	0.030	0.034	0.026	-0.098	-0.091	-0.052	-0.164	-0.253	0.240
S	0.143	0.197	0.256	0.013	0.113	0.153	0.129	-0.053	-0.060	0.111	-0.062	0.100	-0.166
DBO5 mg/l E	0.027	-0.111	-0.151	0.174	-0.125	0.111	0.160	-0.019	0.112	-0.382	-0.101	-0.370	0.441
P	-0.150	-0.297	-0.287	0.233	-0.311	0.084	0.213	0.431	0.038	-0.551	-0.185	-0.465	0.320
S	-0.046	-0.225	-0.294	0.047	-0.224	0.138	0.226	-0.147	0.026	-0.670	-0.153	-0.498	0.630
NTOTAL mg/l E	0.052	0.096	0.043	0.034	-0.169	0.167	0.176	0.299	-0.003	0.080	-0.050	-0.085	-0.018
S	0.069	0.191	0.117	0.044	-0.100	0.110	0.145	0.197	0.202	-0.162	0.115	-0.078	0.150
nitrats mg/l E	0.017	-0.077	0.002	0.169	0.030	0.077	0.029	-0.049	-0.015	-0.023	-0.050	-0.012	-0.059
S	-0.149	-0.130	-0.135	-0.006	-0.232	0.137	0.181	0.584	-0.142	0.045	-0.127	0.000	-0.235
N amoni mg/l E	0.015	0.057	0.043	-0.056	-0.102	0.300	0.290	0.188	-0.014	-0.089	-0.156	0.094	-0.091
S	0.229	0.209	0.144	-0.143	0.022	0.040	0.049	0.007	0.119	-0.171	-0.110	-0.055	0.118
fòsfor mg/l E	0.158	0.077	0.043	-0.169	0.231	0.236	0.051	0.169	-0.296	0.099	-0.222	0.045	-0.259
S	-0.234	-0.081	-0.083	0.164	-0.208	0.126	0.210	0.397	-0.223	0.124	-0.077	0.020	-0.272
MLSS1	1.000	0.781	0.677	-0.607	0.055	-0.210	-0.233	-0.300	-0.095	0.126	-0.335	-0.172	-0.215
V30-1	0.781	1.000	0.915	-0.271	-0.009	-0.262	-0.247	-0.156	0.052	0.232	-0.124	0.034	-0.232
IVF-1	0.677	0.915	1.000	-0.191	0.001	-0.221	-0.211	-0.095	0.013	0.255	-0.129	0.132	-0.266
CM-1	-0.607	-0.271	-0.191	1.000	-0.141	-0.043	0.074	0.216	0.291	0.035	0.419	0.203	0.161
MLSS2	0.055	-0.009	0.001	-0.141	1.000	0.157	-0.303	-0.516	0.060	0.047	0.104	0.167	0.066
V30-2	-0.210	-0.262	-0.221	-0.043	0.157	1.000	0.861	-0.046	-0.169	-0.195	-0.184	0.195	-0.077
IVF-2	-0.233	-0.247	-0.211	0.074	-0.303	0.861	1.000	0.202	-0.150	-0.216	-0.197	0.137	-0.077
CM-2	-0.300	-0.156	-0.095	0.216	-0.516	-0.046	0.202	1.000	-0.025	0.026	-0.115	0.023	-0.229
RASS-1	-0.095	0.052	0.013	0.291	0.060	-0.169	-0.150	-0.025	1.000	0.092	0.809	0.071	0.565
RASS-2	0.126	0.232	0.255	0.035	0.047	-0.195	-0.216	0.026	0.092	1.000	0.177	0.392	-0.379
WAS-1	-0.335	-0.124	-0.129	0.419	0.104	-0.184	-0.197	-0.115	0.809	0.177	1.000	0.097	0.603
WAS-2	-0.172	0.034	0.132	0.203	0.167	0.195	0.137	0.023	0.071	0.392	0.097	1.000	-0.356
WAS-3	-0.215	-0.232	-0.266	0.161	0.066	-0.077	-0.077	-0.229	0.565	-0.379	0.603	-0.356	1.000

Figure 6-9: Pearson correlation coefficients among between variables.

6.3.1.1. The third interview with the plant head consisted ina set of **questionnaires**. These questionnaires were designed to extract from the head of the plant his/her knowledge about the plant process.

Individual questionnaires were designed for each operational problem detected with the two previous interviews. The questionnaires were designed to collect as much information as possible in as little time as possible. This is because we recognise that the protocol should not use more time from the plant head that the strictly necessary. Therefore, the questionnaire must have the parameters for the operational problem for which it was designed. Then the head of the plant can choose the parameters that he considers most important in his/her plant process. Then the plant head can describe the problem with his/her own words and tell the knowledge engineer exactly what he or she expects the program to detect. (see questionnaires in annex II).

The number of questionnaires may be different for others plants, depending on their particular operational problems.



Qüestionari per l'elaboració d'un arbre de diagnosi, per implantar un sistema supervisor en una EDAR, per casos de sobrecàrrega orgànica

Universitat de Girona

DEPARTAMENT D'ENGINYERIA QUÍMICA AGRÀRIA I TECNOLOGIES AGROALIMENTÀRIES

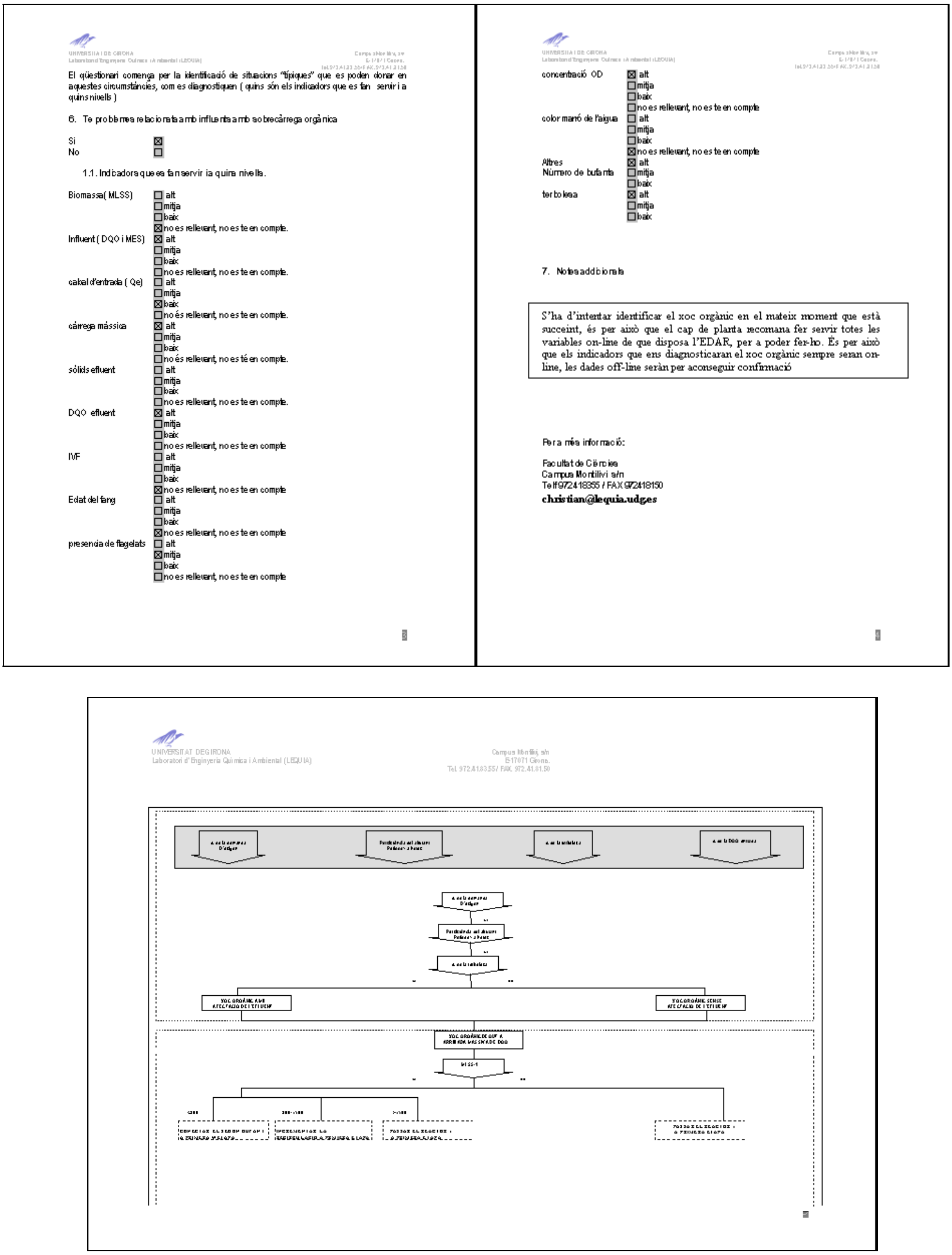
LABORATORI D'ENGINYERIA QUÍMICA I AMBIENTAL

Informació sobre qui omple l'enquesta:

Nom	Sandra	càrrec	**Segon cap de planta**
e-mail	EDAR-Gr@terra.es	telèfon	935721819
data	14/05/02		

Informació sobre la planta

Nom de la planta	EDAR de montornès
adreça	
Ciutat i codi postal	Montornès del Vallès
país	Espanya


UNIVERSITAT DE GIRONA
Laboratori d'Enginyeria Química i Ambiental (LEQUIA)

El qüestionari comença per la identificació de situacions "típiques" que es poden donar en aquestes circumstàncies, com es diagnostiquen (quins són els indicadors que es fan servir i a quins nivells)

6. Te problemes relacionats amb influents amb sobrecàrrega orgànica

Si ☒
No ☐

1.1. Indicadors que es fan servir i a quins nivells.

Biomassa (MLSS) ☐ alt ☐ mitja ☐ baix ☒ no es rellevant, no es te en compte.
Influent (DQO i MES) ☒ alt ☐ mitja ☐ baix ☐ no es rellevant, no es te en compte.
cabal d'entrada (Qe) ☐ alt ☐ mitja ☒ baix ☐ no és rellevant, no es te en compte.
càrrega màssica ☒ alt ☐ mitja ☐ baix ☐ no és rellevant, no es té en compte.
sòlids efluent ☐ alt ☐ mitja ☐ baix ☐ no es rellevant, no es te en compte.
DQO efluent ☒ alt ☐ mitja ☐ baix ☐ no es rellevant, no es te en compte
IVF ☐ alt ☐ mitja ☐ baix ☒ no es rellevant, no es te en compte
Edat del fang ☐ alt ☐ mitja ☐ baix ☒ no es rellevant, no es te en compte
presencia de flagelats ☐ alt ☒ mitja ☐ baix ☐ no es rellevant, no es te en compte

concentració OD ☒ alt ☐ mitja ☐ baix ☐ no es rellevant, no es te en compte
color marró de l'aigua ☐ alt ☐ mitja ☐ baix ☒ no es rellevant, no es te en compte
Altres
Número de bufants ☒ alt ☐ mitja ☐ baix
terbolesa ☒ alt ☐ mitja ☐ baix

7. Notes addicionals

S'ha d'intentar identificar el xoc orgànic en el mateix moment que està succeint, és per això que el cap de planta recomana fer servir totes les variables on-line de que disposa l'EDAR, per a poder fer-ho. És per això que els indicadors que ens diagnosticaran el xoc orgànic sempre seran on-line, les dades off-line seràn per aconseguir confirmació

Per a més informació:

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Figure 6-10: Organic high load questionnaire.

We consider the **questionnaires** to be an important result of the study phase. These questionnaires accelerate the specific knowledge acquisition and, thanks to their general structure, may be used in future EDSS implementations.

Questionnaires are designed to extract the information that the plant head has but does not know how to express. The report has to condense and aggregate the information to allow managers to receive the data that meets their specific requirements. In this case, the most important think that the reports had to detect were the operational problems that the plant suffered.

Once the main operational problems of the plant have been detected, the questionnaires have to obtain the specific knowledge needed to solve the problem in that concrete plant. Each questionnaire consists of two parts. The first part consists in a set of variables with a gap to mark the importance of this variable for the concrete operational problem of concern.

In the second part of the questionnaire, the plant head can express the special details or key aspects that are important for that problem in that particular plant

Finally, the summary of the information provided by the first, second and third interviews is used to develop the decision trees. These trees collect the knowledge necessary to diagnose and solve the problem.

Each questionnaire is generated to solve one or more operational problems. The operational problems detected in the Montornès treatment process were toxic shock, nitrification-denitrification, low load, hydraulic shock, storm events, organic overload, organic shock, foaming, other foams, non-biological problems, viscous bulking and bulking. These are the most important problems to solve according to the opinion of the plant head. All questionnaires designed for Montornès WWTP study can be seen in the annex II.

Operational problems
Toxic shock
Nitrification-denitrification
Low load
Hydraulic shock
Storm events
Organic overload
Bulking
Viscous bulking
Foaming
Other foams
Non-biological problems
Organic shock

Table 6-7: operational problems detected in the Montornès WWTP.

The bibliographical study is also important to study the plant and find details that the plant head may not know how to explain. Searching the Internet for relevant information is becoming more and more important every day; accordingly, some of the references cited in this thesis are Internet addresses.

6.3.2. **Objects and variables**

An object is anything that we use to deal with the environment and that exhibits certain behaviours. In information systems, attributes and operations are encapsulated to create objects that behave in certain ways. Objects provide things with identity and represent concrete entities from the application domain being designed.

The concepts of classes and objects are tightly interwoven, for we cannot discuss an object without regard for its class. A class is a set of objects that share common structure and behaviour. A class is a type; the single object is an instance of a class. From objects to classes a logical set of relationships are built. Objects can inherit attributes and operations from others objects and can add more attributes and operations of their own. Inheritance enables the sharing of properties between classes while preserving their differences. Using inheritance between classes enables designers and programmers to reduce redundancy in attributes and operations. During the general design phase, it isn't defined in detail the characteristics of the objects. The specifics of these object-oriented are determined during software design that is abstracted from systems design. Then the software design is implemented by coding the objects.

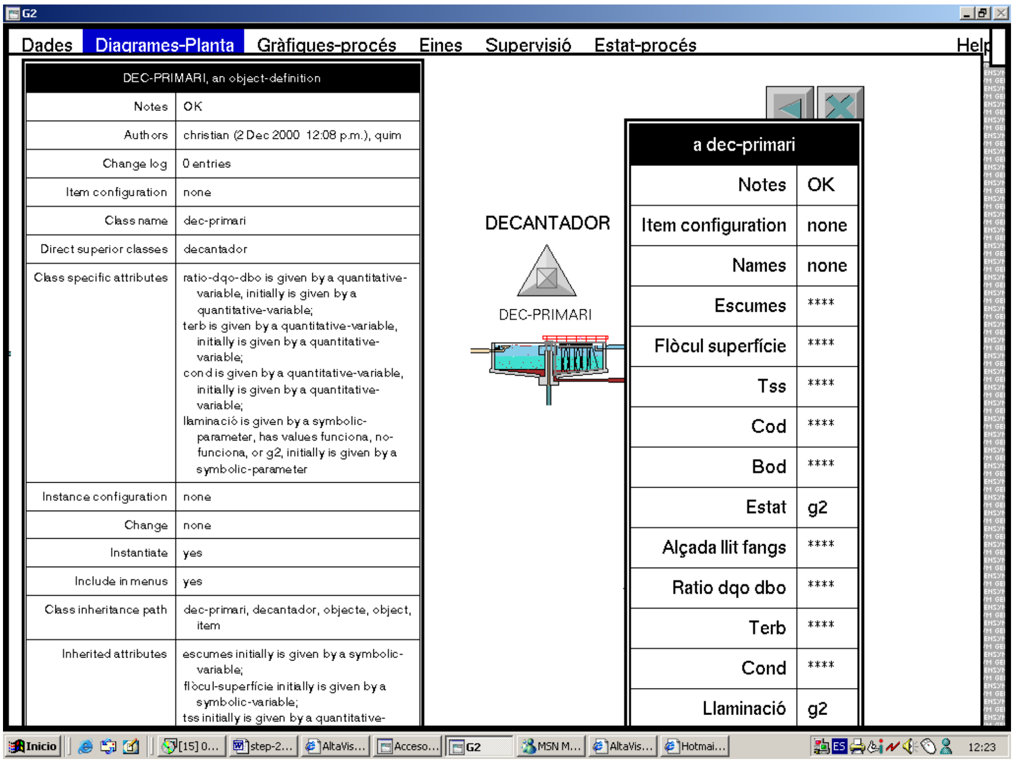

Figure 6-11: Example of an object and its variables.

6.3.3. **Creation of rules**

Once the information is collected, filtered and located in the objects, the development process continues with the design of rules. The **Creation of rules phase** (for the ES, basically) aims to represent whole knowledge acquired during the study phase and the general knowledge about the wastewater treatment processes.

249 ***if-then*** rules have been created during the re-design process. These rules were first organised within the four modules that structures the system and afterwards were also organised into categories. In the case of the Montornès EDSS, 40 categories were

considered. Categories are one way to organise the rules according to the action that they have to do. The categories organisation is divided into the different operational problems found in Montornès.

Initially, the rules for each operational problem are, divided into three categories: diagnosis, causes and actions. The 'diagnosis' category is for the rules that have to diagnose the plant situation with the information collected by the program. Once the plant situation is diagnosed, the rules of the 'causes' category have to determine the cause of the situation. Finally the rules from the action category, determines what kind of action to do.

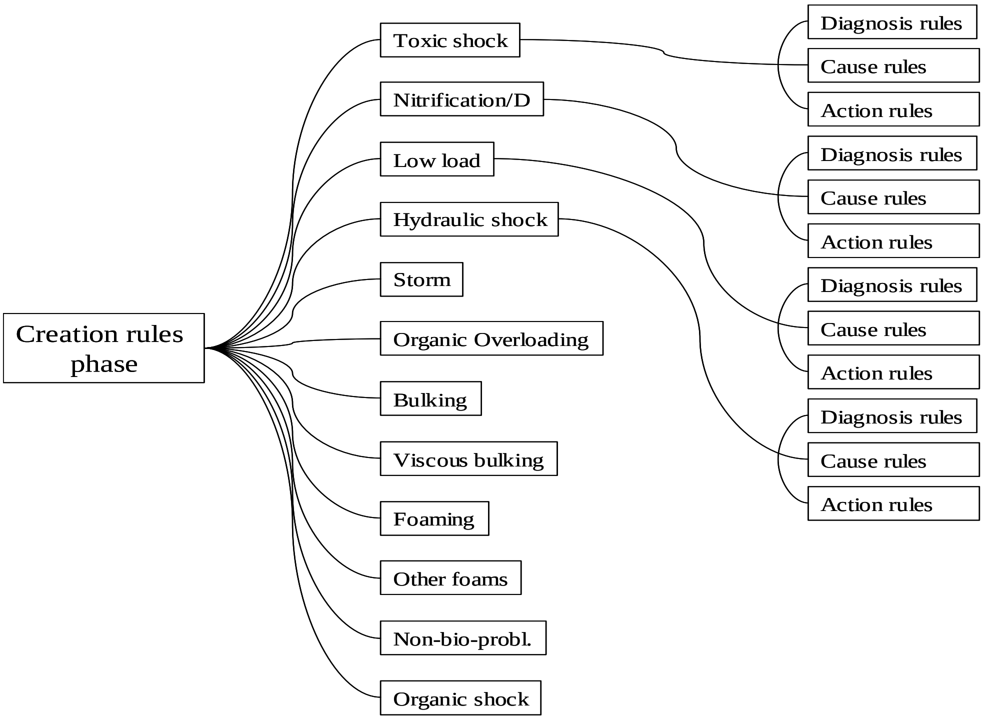

Figure 6-12: Hierarchical rule structure.

These rules should diagnose every operational problem found in the plant because they are built using all the acquired knowledge, both generalist and specific. The inference engine runs forward chaining: it starts with data, examines the *IF* clauses and searches for a solution by working from the data toward a goal or solution.

6.3.4. **CBR**

The original cases for the CBR are extracted from the historical plant database through a **study of the classes** based on a cluster analysis. The clustering method used consisted in a hierarchical classification and the software used was KLASS. The data used for the analysis corresponded to the information since January 1, 2002 to May 31,2002. Thus, dates were selected to represent the historical cases that occurred closer to the current plant situation. It is advisable to exclude from the analysis those cases that have occurred too far in the past because the plant configuration might have changed since, in which case the information derived from those cases would not be relevant for the current plant configuration. In the case of the Montornès WWTP, the original case library was composed of the following cases:

	Q	DQO-E(F)	DQO-P(F)	DQO-S	MES-E	MES-P	MES-S	NO3-S	P-E	P-S	MLSS-1	IVF-1	CM-1	T-2	MLSS-2	IVF-2	EF-2	CM-2
1.00	27703.00	502.79	381.59	96.00	289.50	143.89	17.29	0.38	7.19	1.39	3315.68	61.23	4.16	18.41	2691.46	103.57	3.55	0.24
2.00	25705.58	488.90	226.32	87.77	345.85	178.81	22.85	0.38	7.28	1.40	4529.50	70.84	4.17	17.47	3170.19	115.72	3.15	0.23
3.00	31156.75	492.23	243.92	97.50	287.00	137.80	18.00	0.45	6.89	2.93	3510.00	132.71	2.80	15.38	2532.50	125.70	2.95	0.27
4.00	31736.50	471.64	301.50	200.00	332.00	301.50	70.00	0.40	7.12	1.50	4770.00	58.48	5.76	16.50	3647.50	106.93	2.99	0.18
5.00	30608.42	473.56	433.74	111.83	324.33	144.25	24.58	0.35	7.59	1.68	3822.08	64.74	2.79	19.88	2511.67	240.65	3.08	0.23
6.00	26678.79	472.91	349.01	88.57	365.86	111.50	21.00	0.39	7.09	1.56	4254.64	66.46	4.41	18.44	2242.14	379.74	3.19	0.24
7.00	32309.29	430.72	324.82	79.11	216.16	89.76	15.48	0.40	7.03	1.48	434.37	32.50	5.83	18.65	1657.30	203.00	3.19	0.26
8.00	35271.00	429.73	303.00	73.75	232.00	119.00	12.50	0.80	5.85	1.65	925.00	34.97	3.65	20.75	2295.00	141.49	3.33	0.27
8.00	39319.25	451.19	346.75	59.38	221.00	102.75	12.00	0.39	6.13	1.18	290.56	17.14	14.93	17.50	1594.38	165.67	3.61	0.36
10.00	35743.00	481.15	446.67	107.00	246.00	122.00	18.33	0.38	8.36	1.50	292.50	18.84	17.70	20.83	1742.50	293.43	3.50	0.51
11.00	28649.82	460.07	387.47	94.27	263.27	123.09	21.27	0.40	6.91	1.45	326.05	17.17	7.08	19.97	1750.00	474.70	3.54	0.26
12.00	34455.15	469.46	454.81	101.29	243.06	111.84	21.51	0.40	7.12	1.50	920.14	31.85	5.76	22.50	1942.87	244.05	3.45	0.26

Figure 6-13: Classes extracted from the historical data of the Montornès WWTP with clustering methods.

The different classes extracted from the historical data study represent the different situations that the plant has suffered in the past and thus contain the problems most commonly encountered in the operation of the plant. These classes constitute the original cases in the case-based reasoning library.

Class number	Situation represented
1st	Normal plant situation
2nd	Normal situation with high removal efficiency in the first stage
3rd	Bulking in first stage
4th	Overloading
5th	Bulking transition in second stage
6th	Bulking in second stage
7th	Normal situation but with the first stage is working as pre-aeration
8th	Nitrification
9th	Deficit hydraulic
10th	Normal situation but the first stage is in transition between pre-aeration and first stage with a MLSS of 1000 mg/l.
11th	Viscous bulking
12th	Transition stage between bulking situation to normal situation

Table 6-8: Original cases defined for Montornès EDSS.

These cases have been chosen through a study of their values. The first class is considered as a normal plant situation with high removal efficiency in the first stage. The values for BOD_5, COD and SS are within their legal limits and the other values are within the normal process range. Here, the importance of a good statistical study can be appreciated; it allows the engineer to define normal, high and low values.

These classes can be aggregated into a smaller number of superclasses. The first superclass contains the normal situation classes, and consists of classes 1 and 2. A second superclass groups operational problems of biological origin; it contains classes 3, 6, 7, 8, 11 and 12. A third superclass comprises the classes related to hydraulic problems; i.e., classes 9 and 5.

The remaining two superclasses contain only one class each. These are the superclassof optimal situations (class4), and the toxic shock superclass (class 10).

The partition into meta-classes is important to improve accuracy in hierarchical case retrieval [Sànchez-Marrè et al., 2000]. At the beginning the memory will be flat because of the low number of classes stored in the library. As time passes and the number of cases stored in the library increases, a hierarchical case retrieval procedure offers the most efficient way to retrieve the best case for a given situation. Hierarchical memories are very effective in terms of retrieval time because only a few cases are considered for similarity assessment purposes, after a prior discriminating search in the hierarchical structure.

A statistical test of hypothesis is used to determine which variables are the most important in defining a case. This objective is also important because the more clearly the main variables that characterise a case are defined, the more efficient will the retrieval procedure be. The Student test is used to interpret the classes retrieved and define to which process situation are best correlated. The Student test gives the importance of the variable within the class and within the sample.

	Q	DQO-E(F)	DQO-P(F)	DQO-S	MES-E	MES-P	MES-S	NO3-S	P-E	P-S	MLSS-1	IVF-1	CM-1	T-2	MLSS-2	IVF-2	EF-2	CM-2
1.00	-2.30	2.52	2.15	0.97	0.21	1.43	-1.61	-1.15	0.46	-1.36	2.60	2.07	-2.31	-1.14	3.27	-4.69	4.20	-1.43
2.00	-4.08	1.34	-6.63	-0.89	3.24	5.61	1.87	-0.95	0.97	-1.21	6.11	3.83	-2.18	-3.87	7.27	-3.96	-2.77	-2.14
3.00	0.38	0.58	-2.04	0.45	0.02	0.23	-0.40	1.11	-0.54	6.25	1.11	5.69	-1.47	-3.64	0.63	-1.28	-2.18	0.15
4.00	0.40	0.00	-0.62	6.05	0.63	5.20	7.80	0.00	0.00	0.00	1.73	0.37	0.00	-1.71	2.89	-1.10	-1.40	-1.43
5.00	0.34	0.10	3.20	2.84	1.34	0.91	1.89	-1.98	1.87	1.37	2.57	1.71	-2.63	2.10	1.01	0.91	-2.53	-1.56
6.00	-2.21	0.07	0.16	-0.50	3.03	-1.79	0.52	-0.31	-0.14	0.49	3.71	2.09	-1.30	-0.69	-0.54	5.18	-1.47	-0.95
7.00	2.08	-3.10	-1.09	-2.73	-3.67	-5.08	-2.58	0.00	-0.55	-0.19	-5.98	-3.47	0.10	-0.35	-5.69	-0.21	-2.07	-0.27
8.00	1.78	-1.17	-0.85	-1.44	-1.05	-0.60	-1.61	8.90	-2.88	0.66	-1.68	-1.11	-1.05	2.12	-0.11	-1.03	0.10	0.25
8.00	4.52	-0.82	0.06	-3.70	-1.81	-1.88	-2.47	-0.40	-3.21	-2.04	-3.40	-3.37	6.52	-1.96	-3.30	-0.94	2.62	3.59
10.00	2.39	0.33	2.54	1.49	-0.96	-0.57	-0.40	-0.46	3.46	0.00	-2.92	-2.75	7.30	2.72	-2.27	1.64	1.45	7.70
11.00	-0.80	-0.55	1.47	0.33	-0.75	-0.71	0.56	0.00	-0.82	-0.41	-3.96	-3.99	1.11	2.18	-3.09	7.05	2.33	-0.11
12.00	2.29	-0.09	3.40	1.15	-1.27	-1.39	0.58	0.00	0.00	0.00	-2.58	-2.03	0.00	6.09	-1.85	0.86	1.30	-0.10

Table 6-9: Variable correlation in every class.

The sheds in colour indicate which variables are important in every class. Variables are chosen depending of their value in relation to the value they take in other classes.

Re-designing a EDSS **Case-Based Reasoning System** implies the definition of new case variables. This new variables are chosen after a statistical study and with the approval of the head of the plant. After the statistical and clustering study, a set of classes is obtained that represents different situations in the plant. Every class is defined by a set of variables, which are proposed to the plant head. These variables have to be few but sufficient to represent most of the situations that the plant can suffer.

The variables chose should be capable of defining the plant situation in every possible work condition. Every variable is assigned a weight, which is used to better describe the situation in retrieval process. To represent the situation of the plant in each 24 hour period, a case is created using these variables. In the Montornès CBRS, eighteen variables were defined. These are:

Variables chosen to define cases in the Montornès CBRS.	Initial variable weight
Inflow	8
COD-input	8
COD-primary-treatment	9
COD-out-put	8
SS-input	7
SS-primary-treatment	7
SS-output	8
Nitrates-output	6
Phosphorous-input	8
Phosphorous-output	8
MLSS-1	7
SVI-1	8
Mass-load-1	8
Temperature	7
MLSS-2	8
SVI-2	7
Mass-load-2	9
Sludge age	7

Table 6-10: Table with the variables of the Montornès case and their weight.

In the Montornès CBRS the Mass-load-2 and the COD-primary-treatment have the highest weight (an initial weight of 9 over 10). The statistical study and the knowledge extracted from the plant head together determined that these are the variables that better define the most important problems in the plant, i.e., biological problems related to bulking problems, which the plant head wants to detect earlier and more efficiently.

Establishing maximum and minimum values, and qualitative modalities. At this point, the action range is determined for every variable.

Montornès variables	Maximum value	Minimum value
Inflow	50000	0
COD-input	2000	0
COD-primary-treatment	2000	0
COD-out-put	2000	0
SS-input	750	0
SS-primary-treatment	750	0
SS-output	750	0
Nitrates-output	200	0
Phosphorous-input	200	0
Phosphorous-output	300	0
MLSS-1	5000	0
SVI-1	100	0
Mass-load-1	25	0
Temperature	25	0
MLSS-2	2500	0
SVI-2	500	0
Mass-load-2	0.5	0
Sludge age	8	0

Table 6-11: Maximum and minimum values for each variable used in the Montornès EDSS.

These values are used to standardize the value of the variable (i.e., between 0 and 1); therefore. Standardized values are used to calculate the distance of every variable for the current case to the same variable for each of the cases stored in the library.

6.3.5. **Connecting the on-line database to G2.**

The spreadsheet with the on-line information was connected to the SCADA by means of a program made in C++. This program allows updating the spreadsheet every time the SCADA receives information from the net of PLCs (Programmable Logic Controllers). When the information in the spreadsheet is updated, a macro is executed that transfers the information in column E to the EDSS program through the G2 gateway bridge *(G2gateway1)*. This macro is made in visual Basic inside the spreadsheet. The macro calls a G2 procedure named *"online"* that receives the information that exists between ranges E8 to E170.

Data acquisition systems may collect a huge amount of data, even if there relatively few significant events take place [Olsson and Newell, 1999]. The data collected is not dealt with in the SCADA systems, but in G2. The filtering of the data received aims at extracting as much information as possible from a noisy signal. There are many kinds of filtering methods. The most usual filter is the digital low pass filter. In order to examine slow variations it is necessary to remove individual spikes in measurement data. This kind of filter uses a numerical algorithm to reduce the noise in the signal. One of the most important digital low pass filter is the *moving averages.* In Montornès, this kind of filter was inplemented in G2 for dissolved oxygen and flow rates. The *moving average* is obtained as the summation of the last *n* measurements divided by *n*.

$$\hat{y} = \frac{1}{n}(y_i + y_{i-1} + ... + y_{(i-n+1)})$$

The procedure called *"online"* performs a first filtering of the received data using the following code line for every received value. The objective is to remove the missing dates and verify that the data has a numerical value. Afterwards, other procedures check that the value is within a determinate range.

```
IF cat[0]/="" and cat[0]/= the symbol null and cat[0]=1.0 then conclude that the comporta-reguladora-entrada of bombes = the symbol oberta else conclude that the comporta-reguladora-entrada of bombes = the symbol tancada;
```

Where *cat* is the vector containing the received information, and the vector index (0 in this case) is indicates the position of the data in the vector. Then, this line of code verifies that the position 0 of the vector *cat* is different from "" (i.e., this position has some value), and that it is different from *the symbol null* and equal to 1.0 (i.e., the entrance gate is open). The condition part of the line code has both the logic connector, *and*, and a sequence of conditions; whenever any of these conditions is not met, the program assigns the variable a defect value. In the example above, when the conditions are not satisfied the variable *comporta-reguladora-entrada* from the object named *bombes* takes the value *tancada*. If the conditions are met, the variable takes the value *oberta*.

The procedure performs this filtering process for each of the input variables. In the case of Montornès the data transferred consists in 162 variables. After this first filter, the G2 executes another filtering procedure (*abstraction*) that performs an abstraction of the received information.

6.3.6. **Connecting the off-line database to G2.**

The spreadsheet with off-line information has a macro that transfers the information that the plant head has filled in. The macro is made in Visual Basic and the bridge used to pass the information is the G2 gateway. This is done in the same way as with the macro of the on-line data spreadsheet.

Whenever this file is closed or whenever the G2 demands information, the macro is executed and transfers the information through the G2 gateway bridge.

The macro collects the information in rows and then transfers each row to a procedure G2.

```
aigua = Hoja1.Range("a6:al6")
primetapa = Hoja3.Range("c5:y5")
segonetapa = Hoja4.Range("c5:y5")
bio = Hoja6.Range("c5:q5")
cabal = Hoja2.Range("c4:r4")
qualitatiu = Hoja10.Range("b4:l4")
microbio = Hoja11.Range("b4:h4")
```

This action is made for each and every row, and then the macro sends the information to the G2 procedure named *analiticgenerator* using the next line of code.

```
Call Hoja1.G2Gateway1.Call("analiticgenerator", aigua, primetapa, segonetapa,
bio, cabal, qualitatiu, microbio)
```

This line of code is repeated for every row. The macros, procedures and rules can be seen in the annex. When the information arrives to the G2 procedure, this filters the received data and locates the information in a vector. The program works with time and for this reason, the program verifies the month from which the data come. When the program knows to which month the data belong to, it puts the data in a vector.

```
analiticgenerator(aigua:structure, primetapa:structure, segonetapa:structure,
bio:structure, cabal:structure, qualitatiu:structure, micro:structure)
```

Analiticgenerator is the name of the procedure executed in the program. The variables that the procedure expects to receive are in parenthesis.

```
if cataigua[1] IS a QUANTITY then TSS-ENT= quantity(cataigua[1]) else TSS-ENT
=-9999;
```

The filtering procedure uses the following line of code, which again verifies that the received value is a quantity and assigns this value to an internal variable. The procedure can also make another type of filtering depending on the value type.

```
if CATQUALITATIU[0] /="" and CATQUALITATIU[0] /=the symbol null then
flòcul = "[CATQUALITATIU[0]]"else flòcul ="-9999";
```

Finally, when the procedure has assigned a value to all its internal variables, it generates the row in the corresponding vector (depending on whether the data came from the last month or from the current month).

```
if mes = the current month then begin

conclude that the array-length of analitic-act= 31 ;

conclude that analitic-act[cont]="[wa]/[mes]/[year],[tss-ent],[tss-primar],[tss-sort],[dqo-ent-1],[dqo-ent-2],[dqo-sort-2],[dbo-ent-1],[dbo-ent-2],[dbo-sort-2],[ph-ent],[ph-ent-prim],[ph-sort],[cond-ent],[cond-sort],[ntk-ent],[ntk-sort],[nitrats-ent],[nitrats-sort],[nitrits-ent],[nitrits-sort],[nt-ent],[nt-sort],[amoni-ent],[amoni-sort],[pt-ent],[pt-sort],[cr],[zn],[sulfats-e],[sulfats-s],[temp-1],[mlssr-1],[mlss-1],[v30-1],[ivf-1],[mlssv-1],[CM-1],[trh-1],[trc-1],[trc-setmanal-1],[vel-asc-1],[temp-2],[mlssr-2],[mlss-2],[v30-2],[ivf-2],[mlssv-2],[cm-2],[trh-2],[trc-2],[trc-setmanal-2],[vel-asc-2],[cabal-ent-bruta],[q-sortida],[recirculació-primera-etapa],[recirculació-segona-etapa],[purga-1-etapa],[purga-2-a-1-etapa],[purga-2-etapa-a-espessidor],[alc-llit-dec1-a],[alc-llit-dec1-b],[alc-llit-dec2-a],[alc-llit-dec2-b],[alc-llit-dec2-c],[TIPUS-FLÒCUL],[ABUND-CILIATS],[TIPUS-CILIATS],[ABUND-FLAGELATS],[TIPUS-FLAGELAT],[ABUND-FILAMENTOSOS],[TIPUS-FILAMENT],[sedimentació_v30],[escumes-reactor-2-etapa],[escumes-dec-2-etapa],[escumes-sortida],[FLÒCUL],[FLOC-DEC],";

conclude that cont=cont+1;
if cont = 31 then begin
conclude that cont=0;
call anal-to-analitic6 (analitic-act,31, analitic-ant);
end;

end;
```

Once the vector has the 31 rows corresponding to the information received from the 31 days in a month (a set of 31 rows is always considered) each row in the generated vector is divided into a new vector with 77 positions. In this new set of vectors, the first vector, *analitic1*, always represents the current day. In this way, the program knows whether the values are expired or not.

[0]	"1/01/2002,-9999, -9999,0.0,-9999,-9999,-9999,-9999,-9999,-9999,-9999,-9999,-9999,- 999,0.0,0.0,0.0,0.0,-
[1]	"2/01/2002,-9999,"
[2]	

[0] "1/01/2002", [1] "", [2] "", [3] "", [4] "", [5] "", [6] "", [7] "", [8] "", [9] "", [10] "", [11] "", [12] "", [13] "", [14] "", [15] "", [16] "", [17] "", [18] "", [19] "", [20] "", [21] "", [22] "", [23] "", [24] "", [25] "", [26] "", [27] "", [28] "", [29] "", [30] "", [31] "", [32] "", [33] "", [34] "", [35] "", [36] "", [37] "", [38] "", [39] "", [40] "", [41] "-9999", [42] "", [43] "", [44] "", [45] "", [46] "", [47] "", [48] "", [49] "", [50] "", [51] "", [52] "-9999", [53] "-9999", [54] "-9999", [55] "-9999", [56] "-9999", [57] "-9999", [58] "-9999", [59] "-9999", [60] "", [61] "", [62] "", [63] "", [64] "", [65] "", [66] "", [67] "", [68] "", [69] "", [70] "", [71] "", [72] "", [73] "", [74] "", [75] "", [76] "", [77] "".
...

When all these processes conclude, the program locates the values in the corresponding objects and performs an abstraction of these values into high, normal or low.

6.3.7. **Interface.**

The interface is an important tool to transfer the information and the situations diagnosed in the plant to the user. The task of the interface is to transfer information to the user fast and clearly. It is important to be able to effectively analyse output data.

To this end, an easy and clear colour code is developed to inform the head of the plant about every situation defined as important that is detected in the plant. This colour code consists of a set of colours that indicates a several degrees of the alarm. The colours can be transparent, yellow and red and appear in every operational problem gap. The absence of colour means that the operational problem is not done.

The yellow colour means a low-level alarm or warning. Warnings differ from alarms in that they are activated before something has gone wrong, and there is still time to avoid malfunctions. The activation of a warning is normally based on the value or the rate of change of a process data variable. Whenever one of these parameters is higher than a pre-set limit, a warning is activated.

The red colour is used to indicate a high-level alarm, i.e., when the plant is suffering the abnormal situation.

The colours can be defined by a set of off-line or on-line rules. In the Montornès EDSS the main objective is to deal with the on-line information preponderantly to detect the process situation in real-time. Whenever the rules detect an abnormal situation and this situation has low importance, the colour of this operational problem gap will be yellow. If the problem persists, the colour is transformed to red. If the problem is solved, the colour is converted to transparent.

The on-line rules are used to diagnose in advance the possible near future situation or the process trend. Afterwards, the off-line rules are used to verify whether the warning should be converted to an alarm. This simple colour code helps the plant head to check the plant situation quickly and activate any actions needed to avoid a malfunction.

The following figure is a screenshot of the actual interface implemented in the Montornès EDSS. This interface is derived from the prototype interface and attempts to maintain the same easy access to information. On the left side of the interface, different icons representing the most important steps in the process can be seen. By clicking on any of these icos, the user can examine the most important parameters (off-line, on-line, microbiological and qualitative parameters) for the corresponding process step.

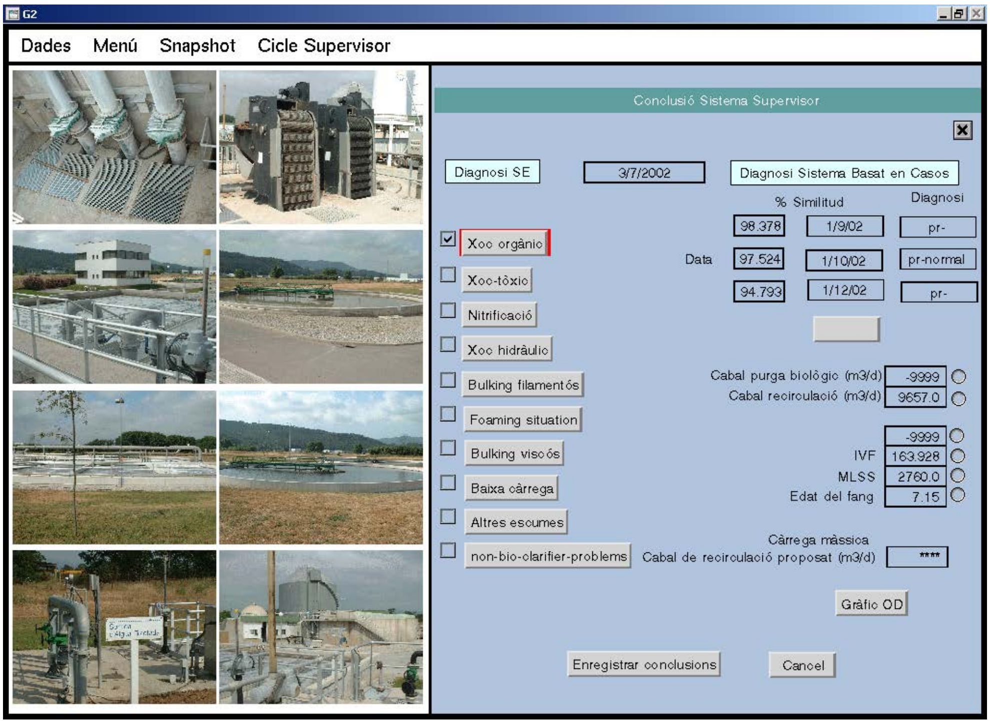

Figure 6-14: Current interface implemented in Montornès EDSS.

On the right side of the interface, it the window that shows the information suggested by both artificial intelligence tools (RBES and CBRS) is shown, together with a list of the operational problems detected in Montornès process. This set of buttons change in colour depending on the rule-based diagnosis. Next to these buttons is the CBRS space, where the headlines of the most similar cases are presented.

The interface structure is created following the suggestions and advices of the plant head. As a final user of the program, the plant head is takes part in the entire process of re-design, development and implementation of the EDSS. In order to make the program *friendlier*, the advices and comments of the plant head are included in the presented interface.

On the bottom-right-part of the interface there is also a set of buttons that represent the most important process.

With the intent of making the program friendlier and facilitating the access to the information by the user, a new interface was developed in Visual Basic.

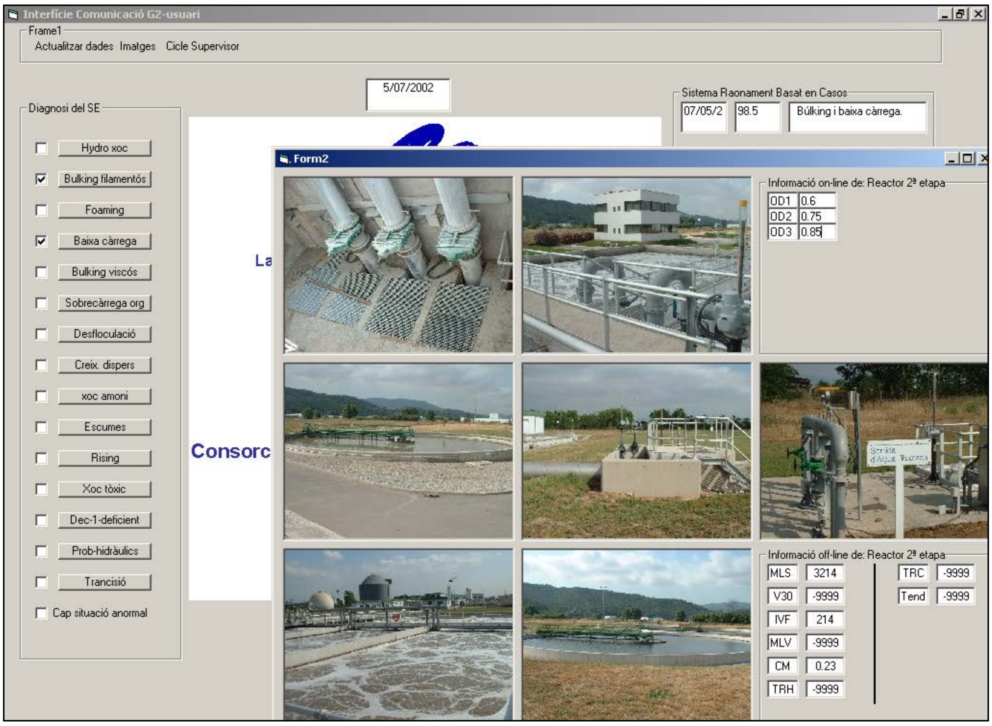

Figure 6-15: Visual Basic interface.

The visual basic interface was designed as the classical G2-interface. It has a set of operational problems buttons on the left part and the CBRS can similarly show the retrieved cases on the right part.

6.3.5. **Correctness.**

The correctness of the EDSS is checked by two means. First, all the procedures and rules of the system are checked using a number of tools provided by the G2 shell. After a procedure or a set of rules is codified, it is checked to verify that it runs properly. This is done by providing the conditions of the generated *IF* clauses. This kind of correctness only verifies small parts of the program.

The second method checks the global correctness of the EDSS. For this, a set of situations is created to check the whole program. Different sets of situations are defined especifically to check the correctness of the rule-based system and of the case-based reasoning system.

The first set of situations consists in a randomised set of numbers designed torepresent on-line data.

The second set of tests consists in a representation of a potential case with real data from the historical database. The set of cases consists of 38 different cases chosen by different criteria. Some are chosen specifically because they do not have much information and can thus be used to validate that the system can retrieve the most similar case even if there is little information for a case. Other cases are chosen because some of their parameters are higher than the maximum levels or lower than the minimum levels.

The correctness procedure consists in substituting the parameter values of the case set with the parameters values of the current case. The CBRS is then executed and the three most similar cases are retrieved from the original case library, which in the case of the Montornès EDSS contained 13 types of cases. Afterwards, the solutions given by the program are checked with the help of the plant head, who determines whether the solutions are good or not.

6.4. *Montornès EDSS*

6.4.1. **Montornès EDSS architecture**

EDSS architecture draws together the statistical/numerical methods, the artificial intelligence techniques, the environmental health regulations and the process control to help the plant head to control the biological process. The Montornès EDSS has been structured as a variant on the original architecture of the EDSS prototype. The architecture is based in 5 layers. The two new layers correspond to the new plan layer and the new action layer. These new layers were created to facilitate the conceptualisation of the architecture and the EDSS cycle.

As in the original version of the architecture, every layer has a work to do. The first layer collects information from the plant. The information can be presented in different supports (informatics support, paper support, oral, and so on) and can come from many sources (informatics files, bibliography, and so on). This layer has to collect as much information as possible, deal with these data and transfer them to the second layer.

In the second layer, the artificial intelligence tools (ES and CBRS), deal with the information that comes from the first layer to arrive at a conclusion that will be the plant diagnosis. Once the plant diagnosis is completed, the ES looks in the rules for the best (best?) plant situation to do while the CBRS does the same in the case library. Then, both programs offer an action or set of actions to return to the best plant situation.

The third layer establishes a supervisory task that entails gathering and merging the conclusions derived from knowledge based and numerical techniques. The final conclusion and some additional information are communicated to the user by means of the interfaces. In the Montornès EDSS, the possibility of merging solutions from both artificial intelligence programs has been disabled. Both sets of conclusions are presented to the decision-maker.

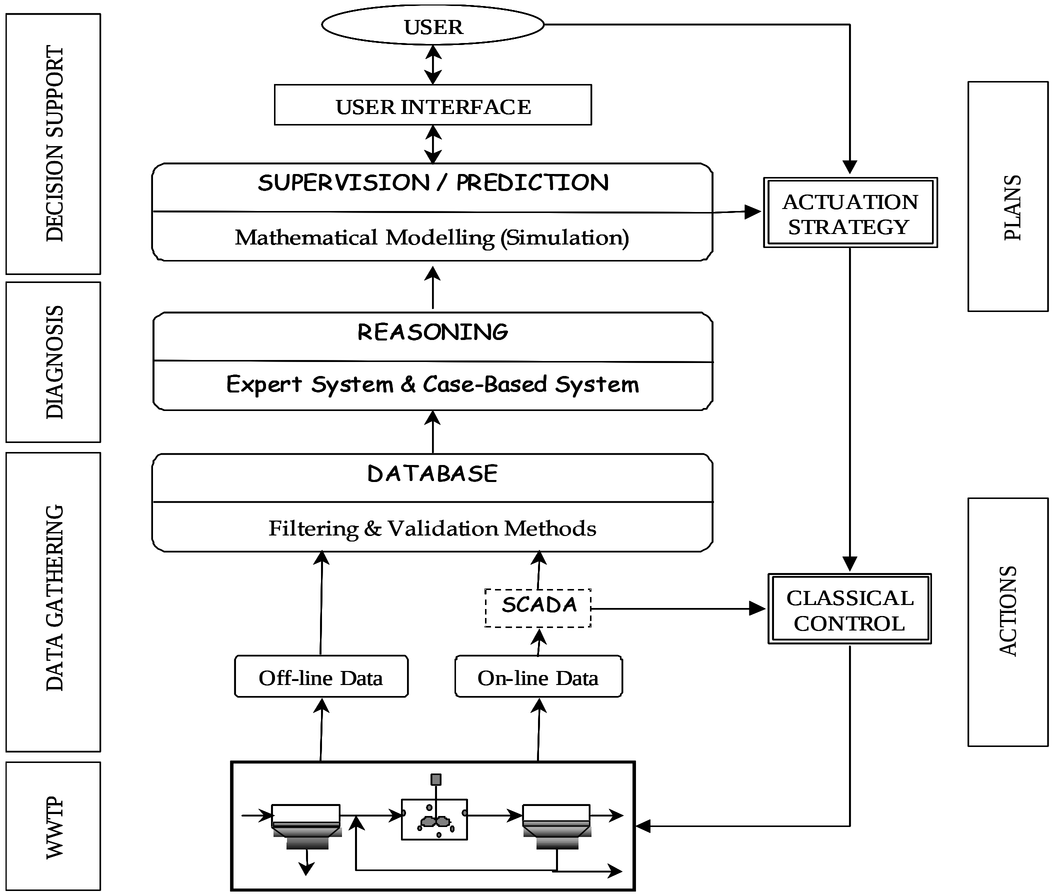

Figure 6-16: Montornès EDSS architecture.

In the fourth level, plans are formulated and presented to the managers as a list of general actions suggested to solve a specific problem [Poch et al, 2002].

The fifth layer contains the set of actions to be performed to solve problems in the domain considered. The system recommends not only the action, or a sequence of actions (a plan), but also a value that has to be accepted by the decision maker. This is the last layer that closes the decision loop. During the implementation of the Montornès EDSS both the fourth and fifth layer were codified within the second layer.

Within each layer the knowledge is also organised into workspaces. In these workspaces the objects, procedures, rules and so on can manage the information. The rules, items, objects, and so on from whole layers are distributed into four modules. These modules are *estrucura*, *dades*, *regles-sistema-expert*, and *comunicació*.

Module	Variable-parameter	Procedures	Rules	Objects	Items	Kb-workspaces
Dades	621	32	55	1061	1986	50
Regles-sistema-expert	2784	153	188	4939	8551	**154**
Comunicació	7	7	6	41	348	2
Estructura	252	0	0	270	322	36
	3664	**192**	**249**	**6311**	**11207**	**242**

Table 6-12: Montornès EDSS units.

In total, 185,000 code lines were needed to program the Montornès EDSS as an ASCII file with a .kb extension. During the EDSS development process **many variables, classes and objects are created that are necessary** for the system cycle. 11207 items, 6311 objects and 3664 item-parameter have been created during the new EDSS development process. These items are needed by the program to manage the information.

To become the successful tool that is desired, the EDSS needs to manage information. The kind and support of the information is not important; the information can be on-line data, off-line data or qualitative data. The design of the acquisition module has to take into account the kind of information. The rule development process , the problem definition, the trees design, and the rules design are also important. Thus, a good study of the plant is an essential prerequisite. With a good plant study, the knowledge engineer can join the specific information for a given plant with the general knowledge about wastewater treatment. In this way, the engineer can design the best trees for any plant, and consequently the best rules.

The whole knowledge and information of the program is structured by means of modules. These modules help to divide the system into independently operable partitions. Every module becomes a contiguous, bounded group of system functions or software code having a unique name by which it can be referenced as a unit. A module is a set of related information contained in the program [Gensym, 1997]. The objective of this modularisation is to maintain and repaire easily the whole system. There is a top-level-module called *estructura* on which the remaining modules depend. The following figure represents the module hierarchy.

Modularity is the degree to which modules are standardised and independent, and show variety in use. The goals of decomposing a software design into modules are:

- Design, code, and test modules independently.
- Revise and maintain modules easily.
- Pass as few data as possible between modules.
- Minimize the use of control data.
- Effect module independence.
- Focus modules on single functions.

The attainment of these objectives depends on the level of coupling between modules and the degree of cohesion within modules. **Coupling** measures the degree of independence and interaction between modules. When the modules are more separated between them, much better for the program. **Cohesion** is a complementary measure of module independence and measures the strength of the relationship between elements of code within a module. A system with highly cohesive modules will normally have low or loose coupling.

The modules help to divide the system into independently operable partitions. The objective of this modularisation is to maintain and repaired easily the whole system. There is a top-level-module called *estructura* where the rest modules depend.

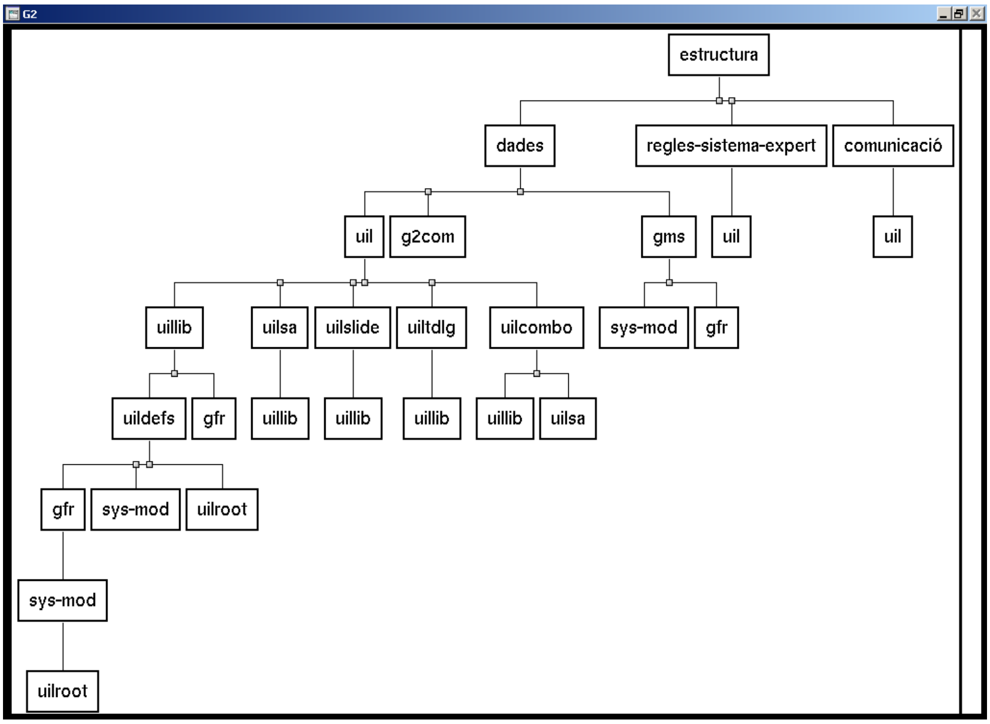

Figure 6-17: The four modules of Montornès.

The main module is called *estructura* and the others modules are hanged from it. This figure represents a hierarchy where it can be seen the modules dependences.

The first module is called *dades* and its task is to import the on-line and off-line data, do the information filtering and perform the abstraction of these data. Perhaps, a set of objects, variables, procedures and rules were created to perform this task.

The second module, called *regles-sistema-expert,* is divided into two parts: one part with the Rule-Based System and a second part with the CBRS. In the first part, the knowledge is structured in a set of rules represented in the decision trees.

Every decision tree has a set of rules that represent the knowledge. This set of rules is composed of a set of diagnosis rules, a set of cause rules and a set of action rules. In this implementation, the trees have been modified to try to diagnose the situation in as little time as possible. In this program the rule-based system tries to determine the situation of the plant based on on-line data. Whit this kind of rules an attempt is made to detect the situation of the plant in advance. Also there is a set of rules to verify the situation detected with off-line data.

The second part of this module contains the CBRS, which retrieves the three most similar cases from the case library to help the plant head make a decision.

The third module, called *comunicació*, controls the user-program interface and transfers information to the new interface.

Each module divides its knowledge into workspaces. The workspace is an area of the knowledge base that contains objects. The workspaces are used both for actions, to organise knowledge in your application, and to display an end user interface for the application [Gensym, 1997]. As an example, the *comunicació* module workspace hierarchy is shown in the following figure.

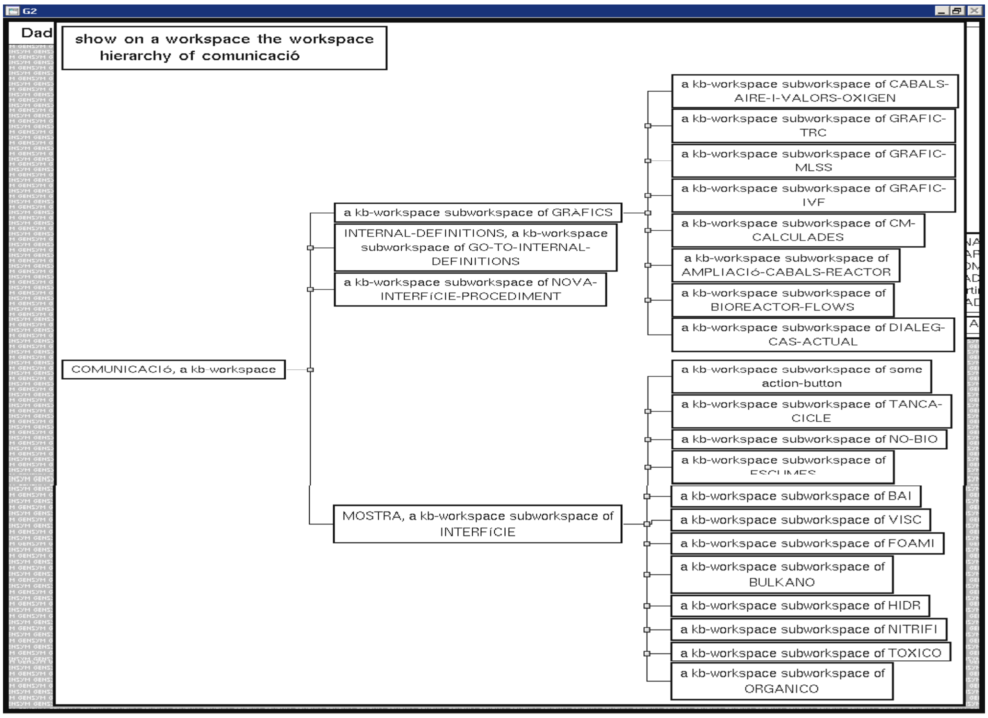

Figure 6-18: *Comunicació* module workspace hierarchy

6.4.2. **Function cycle.**

The new EDSS design is based more on the on-line information. The expert system rules and the case variables are based on on-line data, while off-line data are used by a small set of rules to verify the diagnosis. This was done in response to the preferences and the advice manifested by the plant head. In the plant study phasewe detected that the plant head preferred an EDSS based on on-line data to have a real-time plant diagnosis and avoid potential abnormal situations with preventinve action. Designing an EDSS with these characteristics is interesting and difficult because Montornès WWTP does not have many sensors or muchcontrol over the process. This is the main reason why the plant head preferred an on-line EDSS; any help that he could get wasvery important. These facts also influenced the system cycle; whenever the decision support system is activated, a set of actions is made, which allows the program to determine the plant situation and propose the correct actions.

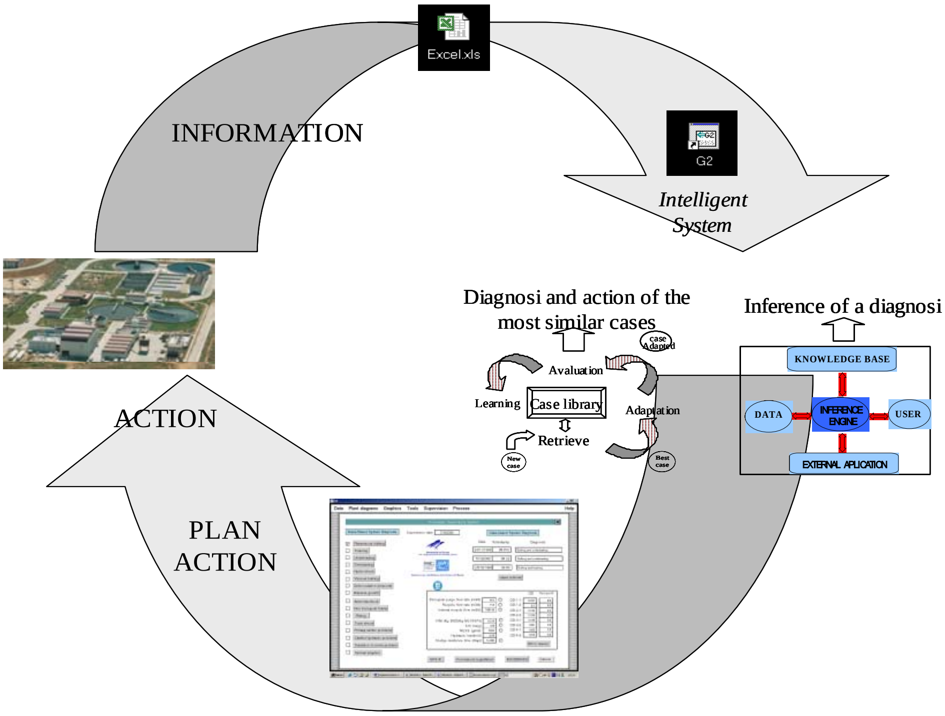

Figure 6-19: Montornès EDSS cycle.

The cycle starts by showing the cases of the library that are not closed; the plant head can close a case at this moment whether this case has been evaluated or not. Afterwards, the program activates a set of initial rules designed to define all the variables as false. These rules also generate the necessary files where the information will later be saved.

On-line data, off-line data, microbiological data and qualitative observations provided by the biological system are collected in a set of Excel spreadsheets. All this information, without any treatment or filter, is transferred to the G2 program by means of an ActiveXlink bridge. Once the information arrives to the G2 program, it is divided into two kinds of information: the on-line information and the 'off-line' information, which includes off-line, microbiological and qualitative information.

Updating the off-line data and their abstraction is the next step; off-line data are transferred from a spreadsheet using a macro that connects both programs, Excel and G2. Off-line data are composed of analytical information, microbiological information and qualitative information. In this case, the information can be transferred automatically every two hours or it can be transferred when the user wants to or when the DSS is activated.

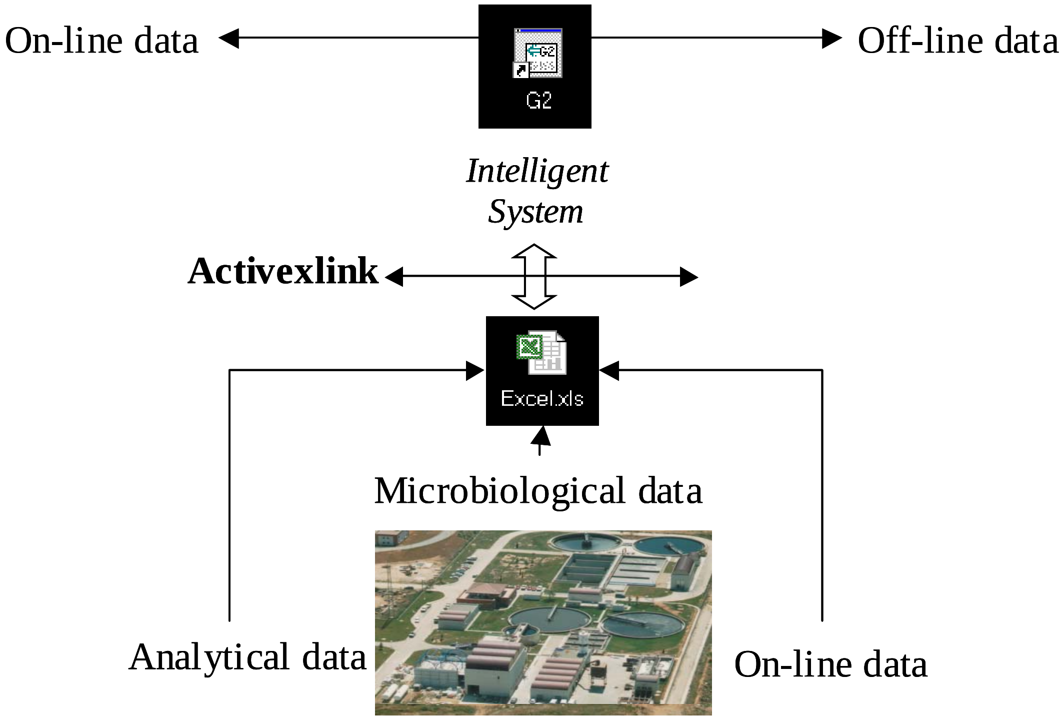

Figure 6-20: Biological process information flux diagram.

The off-line information arrives to the procedure called ***analiticgenerator***. This is the procedure in charge of filtering the information, which puts in two vectors, depending of the current month. If the analytic data received are from the current month, these data are put in the vector called ***analitic-act.*** If the information comes from the previous month, then the procedure puts the information in the vector called ***analytic-ant.*** When these vectors are generated, another procedure is activated that reorganises the information into 30 vectors, where the first vector is the information from the current day, the second vector is the information from yesterday, and so on.

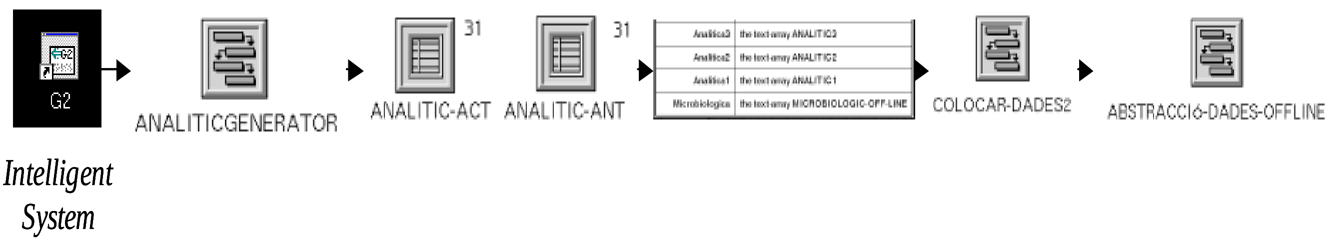

Figure 6-21: Off-line data flux.

Next, the procedure called ***colocar-dades2*** puts the information collected in the corresponding object. If values for a variable do not exist for the current day, then the procedure looks for the same data in the vector of the previous day, and so on up to seven days before. After this, the procedure that abstracts the data is executed. This procedure, called *abstraccio-dades-offline*, converts the numerical values received for every parameter into qualitative values. This action is called discretisation of the numerical values, and its objective is facilitated the work of the rules. The discretisation is made by means of the ranges developed after the statistical study. The code used for this task for every parameter received is as follows:

```
if the v30 of reactor1 has a current value and the v30 of reactor1 /=-9999
and the v30 of reactor1 /="" then begin
if the v30 of reactor1 < the limit-inferior-v30-1 of LIMITS-VAR-OFFLINE
then conclude that the v30-1 of variable-qualitativa = the symbol baix else
if the v30 of reactor1 > THE limit-superior-v30-1 of LIMITS-VAR-
OFFLINE then conclude that the v30-1 of variable-qualitativa = the symbol
ALT
else conclude that the v30-1 of variable-qualitativa = the symbol normal;
end else
conclude that the v30-1 of variable-qualitativa = the symbol g2;
```

Every time that the on-line data are updated in the Excel worksheet, they are transferred to the G2 program. Once in the program, these data are directed to a procedure called ***on-line()***that filters the information and puts the data in the corresponding objects. The data from the flows and from dissolved oxygen in each aeration tank are used as a moving average.

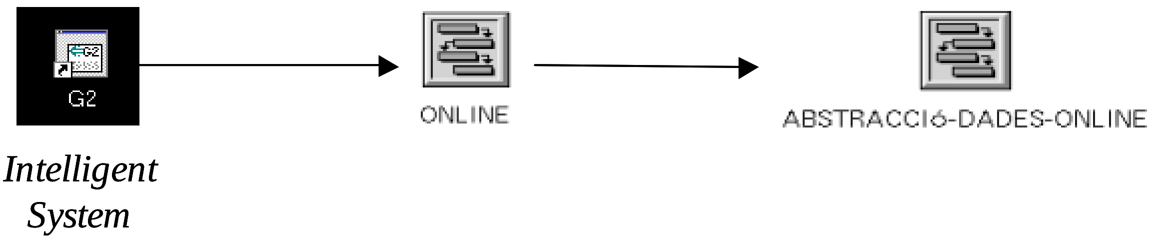

Figure 6-22: On-line data flux.

First, missing and null values are assign a value of –9999:

```
if cat[11]/="" and cat[11]/= the symbol null then conclude that the q-ent of bombes =
quantity(cat[11]) else conclude that the q-ent of bombes =-9999;
```

Afterwards, an abstraction is made of the data into qualitative information (high, low, normal).

```
if q-entrada< limit-inf-q then conclude that the q-ent of variable-qualitativa = the symbol
baix;

if q-entrada > limit-inf-q and q-entrada < limit-sup-q then conclude that the q-ent of
variable-qualitativa = the symbol normal;

if q-entrada > limit-sup-q then conclude that the q-ent of variable-qualitativa = the symbol
alt;
```

Then, the rules and procedures from the second module are activated, both artificial intelligence programs are started and a diagnosis of the plant is produced together with a proposed action plan to solve the current situation in the plant.

When the Rule-Based System is started and the plant situation is diagnosed, the cause rules and the action rules are activated to propose an action to solve the detected situation. This action plan can be executed by the program by means of modifying set-points, starting pumps, and so on, or can simply inform the plant head about the situation diagnosed and provide advice about what to do.

The CBRS starts by generating the current case, which is then compared with all the cases stored in the case library. The three most similar cases are retrieved and showed to the user in a separate interface. The current case is saved in the library, and may be saved as a closed case or as an open case depending on user input.

The program can also save the information that the plant head considers important. In the case of the Montornès EDSS, the information from the dissolved oxygen sensors is saved every five minutes, every hour and every day. Similarly, the inflow data are saved as a text file that is generated every day, and the program saves automatically the diagnosis it has produced. The data saved is the moving average of these parameters.

Finally, the interface shows the diagnosis and the actions proposed and the plant head can decide what action to do. It is necessary that the plant head closes the current case to close the decision support loop. In this way, the system increases its knowledge about the treatment plant and learns new situations.

6.4.3. **User manual**

This manual is developed to facilitate the access to the program for any user, especially the novice user.

1. **Data acquisition.**

On-line data are acquired automatically every time that any value of the spreadsheet is updated.

Off-line data are updated in three situations: i) when the user updates the data from the G2 program, ii) when the spreadsheet that contains the off-line data is closed, and iii) automatically every two hours.

If any spreadsheet is closed, the user can open it using direct accesses to both spreadsheets. These direct accesses are on the screen desktop.

Acceso directo a juliol.xls.lnk   Acceso directo a COM_DDE_SCADA.xls.lnk

The user can also look for the files; the path is the following:

On-line spreadsheet	D:\SCADA\…..
Off-line spreadsheet	D:\Public\

Once the spreadsheet is opened, the user has to click upon the button "*Habilitar Macros*"; then, another question, "*Desea actualizar este libro…*", is shown and the user has to click "*Sí*". When the spreadsheet is closed the user can save the changes made to the file. The plant head often uses these spreadsheets to write the monthly report.

2. **Supervisory cycle activation.**

Once the data are updated, the user may click on the “Cicle Supervisor” button in the menu bar.

SE diagnoses the plant situation using the information that the program has collected. The user can see the diagnosis in the left column of the interface. A colour code is used to notify the user the importance of the alarm.

Colour	Meaning
Transparent	**No problem**
Yellow	The plant trends to a problem
Red	The plant has the problem

The user may examine the cases retrieved by the **CBRS** by clicking on the button labeled: ”Recuperació de casos”. A new screen appears with the information about the three most similar retrieved cases.

The **Table** located in the botom-right side of the interfaceshows the most important process variables. The graphs and trends of these variables can be seen when the user clicks on the buttons that are to one side.

3. **Writing the case conclusions.**

By clicking on the conclusion button, a form appears on the screen where the user may write the conclusions about the current case.

This form consists of:

i. Diagnosis gap: actual plant situation.
ii. Comments: comments may be added to the diagnosis.
iii. Action: actions executed to improve the current plant situation.
iv. Evaluation: evaluation of executed actions.

Note: the text has to be enclosed in quotation marks (“”) and without commas, and after writing any text it is necessary to click “Enter”.

4. **Retrieval of non-closed cases**

The first screen, that appears when the supervisory cycle is executed, shows the non-closed cases saved in the case library. A non-closed case is a case that does no have the action evaluation. The screen shows the case information and the evaluation gap.

5. **Other options in the menu**

The menu-bar presents others options to the user. The user can choose to see plant diagrams, trend charts, change the range of variables, and so on.

Note: the G2 screens can change its size using CONTROL + B (bigger size) and CONTROL + S (smaller size).

6. Troubleshooting.

Symptoms	Problem	Solution
The computer is shut down	G2 is closed	G2 is started automatically
	On-line spreadsheet is closed	On-line spreadsheet is started automatically
	Off-line spreadsheet could be closed	Direct access or by path
The G2 does not receive data	Verify the data sources	Open the data sources
		Verify the Ethernet.
The G2 is not available to make a diagnosis and retrieve the cases	The G2 does not have information or the information has expired	Verify the information sources
Other problems	Other problems	Call on-line support

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Chapter 7: Protocol Montornès 2.0

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7. Protocol Montornès 2.0

7.1. *Abstract*

In this chapter, there is a description of the final exportation protocol created to re-design and develop new EDSS from the prototype. This final proposal consists in the original theoretical protocol plus the experiences gained during the thesis development.

The original protocol has some bottlenecks that were detected during the re-design and implementation of the new EDSS in a new WWTP. Thus, the original protocol is improved and performed into a new protocol in order to solve the bottlenecks found and ,following the plant head advises, to create a more friendly and effective system.

Finally, it is discussed the time and human effort needed to apply the new protocol are discussed. It has to be kept in mind that one of thesis objectives was to develop a protocol to generate a new program using the less possible time since the exploitation time of a WWTP can be small. The human and time effort needed to develop a new knowledge based system is very high and it is needed decreasing these necessities.

7.2. *Introduction*

The real re-design, development and implementation of a new EDSS in the Montornès WWTP allows modifying and improving the theoretical protocol based on the acquired experience.

The goal of developing quality information systems is to produce systems that are within budget, on time, and that meet user requirements. It is necessary to document and systematise the whole process of an EDSS design, development and implementation to get the objectives above. An exportation protocol has to decrease the time needed to develop new programs and moreover, the designed systems have to be efficient in their task. To evaluate the systems effectiveness, the whole process is needed to analyse what went right and wrong with successful and unsuccessful projects [Burch, 1992]. The post-implementation analysis made in the last part of this chapter (section 7.5, discussion) allows improving the efficiency and effectiveness of the new system and of the protocol used.

The post-implementation review helps to refine the estimated project time effort, costs and benefits. By comparing current time, costs and benefits with those which were estimated at the beginning, an environmental engineer can learn where the mistakes were made and how to avoid them in future projects.

The main aim of this project is to obtain, with the less possible iteration , a real protocol that can be useful, effective and helpful to design new EDSS that can help to treat the wastewater generated by the human activity and avoiding, at the same time, the environmental contamination.

7.3. *Protocol Montornès 2.0*

The implementation process in Montornès WWTP allows to know, by means of checking the new system, whether the protocol has successful or not. This process began following the proposed protocol, but during its real implementation process, it has been modified. This practice case is useful to redefine the original protocol to the reality of re-design and implement an EDSS in a new WWTP.

This part of the document will explain the experience gained from the real implementation of a decision support system derived from the prototype in Montornès WWTP. Some parts of the proposal document have been changed or improved while it was implemented. The following section can be considered the real protocol to export the EDSS prototype to any WWTP.

The new protocol proposed for the application of the decision support system in any medium size biological WWTP defines much better every step that is needed to take, the program needs, the temporal sequence to follow and facilitate sharing and reuse of knowledge.

7.3.1. **Actuation planning**

In this section, the new actuation plan that explains the steps that need to be taken in the EDSS exportation process are presented. Its main objective is to normalise and organise the process and get more systematic implementations.

The PERT diagram helps to see the new step-by-step phases, the time needed for every one and the sequence they have to follow. This new PERT diagram includes two new steps that were not considered in the first approach, it also modifies other steps and removes another. For instance the old *Connection with periphery elements* step is modified and divided in the *Connect on-line database with G2* and *Connect off-line database with G2*, the old *Delivery* step is removed and the *Modularity* and *Study of classes* are created.

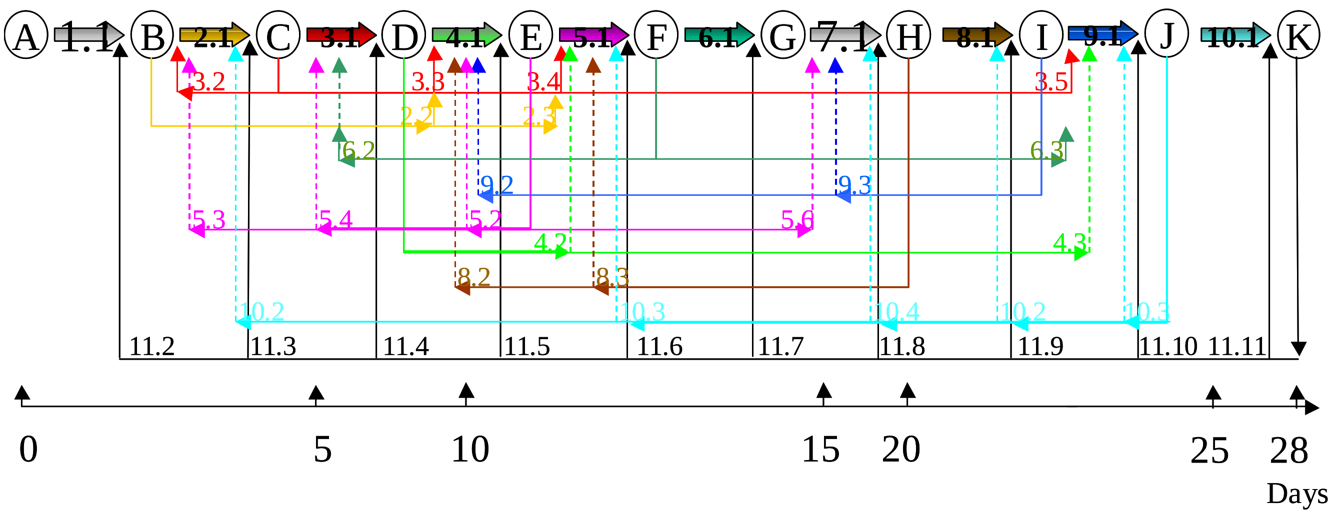

Figure 7-1: New PERT Diagram developed for the new exportation protocol

Node		Tasks	
A	Install G2	**1.1**	Critical path: install the G2 shell in the personal computer
B	Connect on-line database with G2	**2.1**	Critical path: connect online database with the G2.
		2.2	Create or modify the variables and objects
		2.3	Create the procedures that has to receive the on-line data
C	Study	**3.1**	Critical path: study the plant
		3.2	Help to design the on-line database connection
		3.3	Generate objects and variables
		3.4	Generate or modify rules
		3.5	Generate or modify the CBRS procedures
D	Creation of objects and variables	**4.1**	Critical path: generate the objects and variables
		4.2	Generate variables and objects for the rules
		4.3	Generate variables and objects for the CBRS
E	Creation of rules	**5.1**	Critical path: Generate the knowledge base by means of rules
		5.2	Check that the rules uses the correct objects and variables
		5.3	Check that the rules uses the correct information
		5.4	Check that the rules represent the plant process
		5.5	Represent the situation detected by the rules in the interface
F	Study of classes	**6.1**	Critical path: generate the case library
		6.2	Study the classes during the study of the plant
		6.3	Modify the CBRS procedures using the new variables that define the case
G	Interface	**7.1**	Critical path: Generate an useful and friendly user-program interface
H	Connect off-line database with G2	**8.1**	Critical path: generate the offline database connection with the G2
		8.2	Create or modify the variables and objects
		8.3	Create the procedures that has to receive the off-line data
I	Case-based reasoning system	**9.1**	Critical path: generate the procedures that allow retrieving the most similar cases
		9.2	Check that the objects and variables are correct
		9.3	Transfers the information to the interface
J	Modularity	**10.1**	Critical path: modularisation of the program
		10.2	Save in modules the code lines that make the data acquisition
		10.3	Save in modules the artificial intelligence tools
		10.4	Save in modules the interface
K	Correctness	**11.1**	Critical path: check the whole program
		11.2	Verify that the program was successful installed
		11.3	Verify that the on-line procedures run properly
		11.4	Verify that the plant study is made well
		11.5	Verify that the objects and variables are correct
		11.6	Verify that the rules run properly
		11.7	Verify that the classes made are correct
		11.8	Verify that the run properly
		11.9	Verify that the off-line procedures run properly
		11.10	Verify that the modules are correct
		11.11	Verify that the CBRS procedures run properly

Table 7-1: New protocol steps.

The PERT diagram helps to explain the new protocol process, the study phase and the correctness phase that has an important weight in this new protocol. The study phase is composed of various sub-phases due to its big expanse. The study phase collects the needed information in order to start others phases like the rule creation phase, the bridges creation phase, and so on.

Another important phase is the correctness phase, which has two steps. The first step is made whenever any other phase has finished. The second step consists in a global correctness of whole system.

The next chronogram shows the actions done at every row and the time needed to execute them is expressed in the columns. The actions can be executed in different periods of time, depending on many factors. The time needed, which is represented in this chronogram, is extracted from acquired experience in the real Montornès EDSS implementation process.

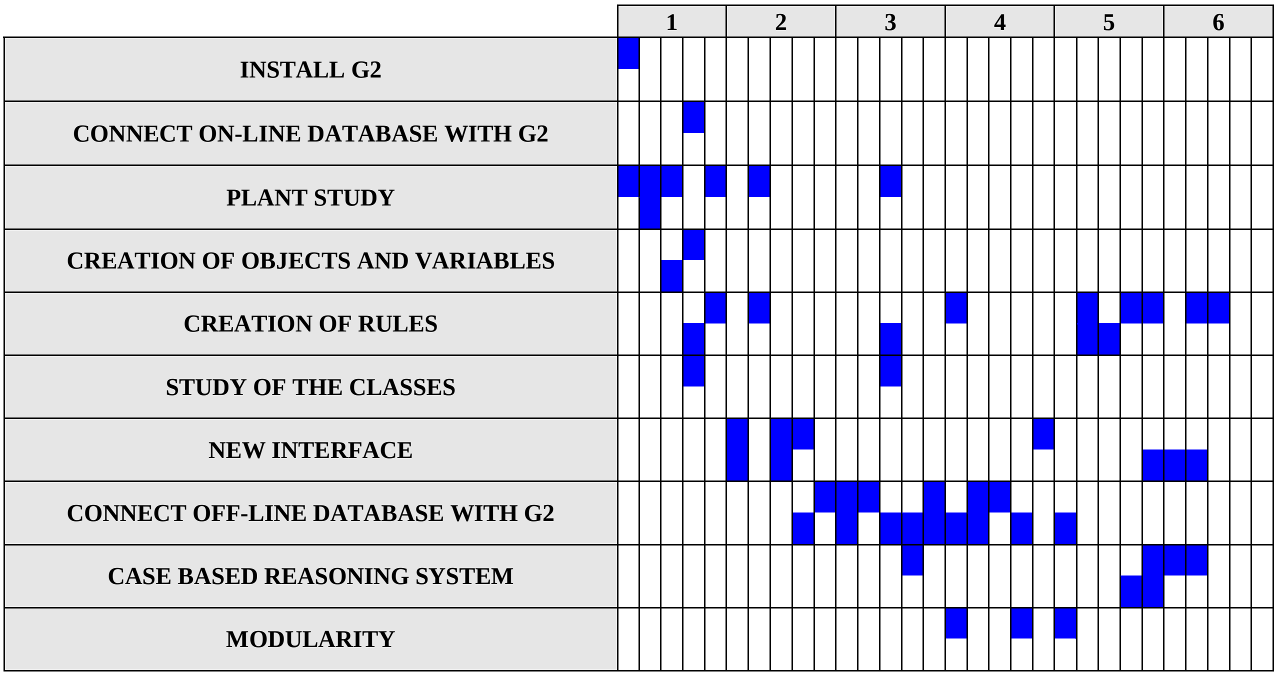

Figure 7-2: Program implantation process chronogram.

The correctness phase is included in every implantation step and for this reason, it does not appear in this table.

The time costs are divided into six main columns and each column is divided into five sub-columns that represent periods of 24 hours. Each sub-column that represents 1 day is divided into 2 rows that represent the time in the morning and in the evening.

The hours needed to develop the new EDSS are represented in the following figure. This table will allow quantifying economically the development process efforts in the project. The economical quantification is a very difficult point in this thesis because, although we do not have any experience in the commercial domain, we think that it is necessary to quantify the whole effort in the design, development and implementation of the EDSS in a WWTP. The economical and temporal costs are the main concerns of the plant head when he understands that the program can help him and he wants it.

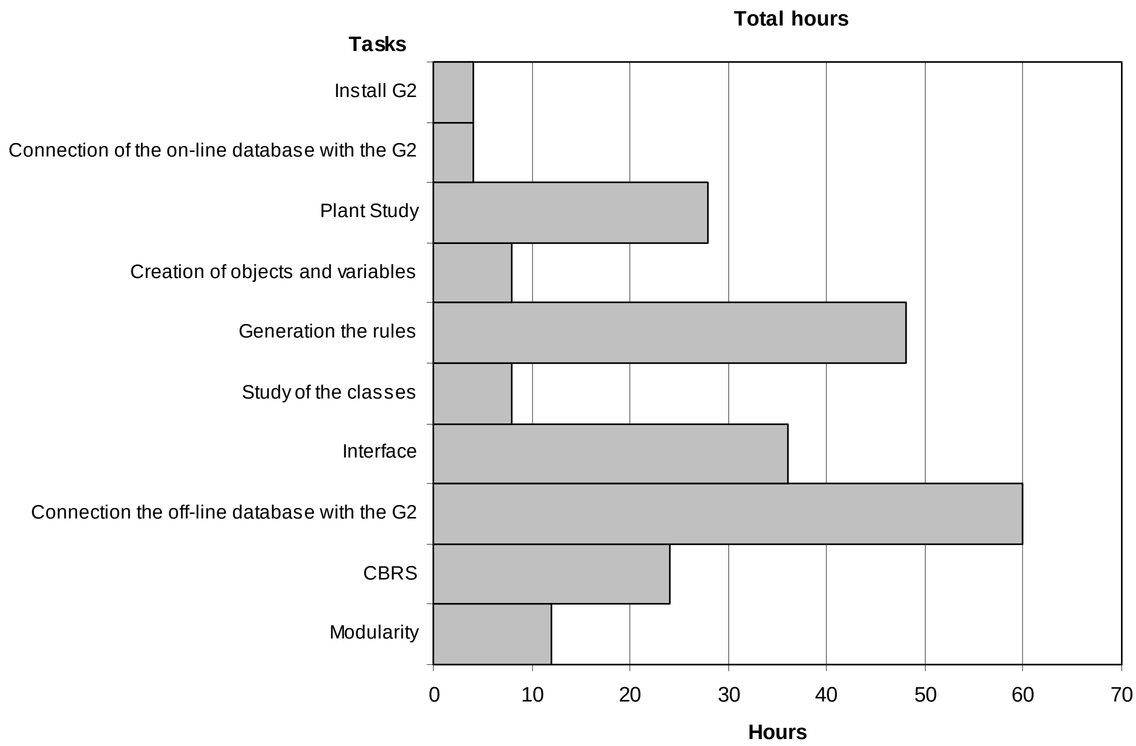

Figure 7-3: Time needed for every stage.

232 hours (aprox) will be the time effort expected to implement a new EDSS in a new WWTP.

7.3.2. **Implementation stages.**

Some of the following implementation phases could be different from the original protocol since the proposal phases were changed during the implementation. The changes were made to modify and increase the efficiency of the implementation process. These improvements are that the protocol incorporates the gained experience, the solutions made to the problems that appear during the process, and shows the best way to develop the new EDSS.

Every implementation stage is structured in three phases: the **design phase**, the **development phase** and the validation and the **correctness phase** that helps to normalise and systematise every task. First of all, the **design phase** has the objective of studying the best way to do the task and verify that the knowledge engineer has everything and all the information that he may need. Secondly, the **development phase** consists in the making process; it is the period when the step task is executed. Finally, the **validation and correctness phase** confirms that the task is well done and runs properly. The validation and correctness is made, first of all at every independent stage, with the concrete and specific proves that they need and secondly, it is made in the whole program, with specific situations introduced in it.

There is, at the end of every step, the **human and temporal effort** required to develop the required task of every implementation stage.

7.3.2.1. **Install G2.**

Design phase. In this phase, the computer supplied that contains the informatics shell and afterwards, the decision support system is evaluated. In this phase, it is proved that the computer can support the informatics programs with a high computational efficiency and that the computer complies with the computer specifications required in chapter 3 section 3.4.1.

Development phase. Once it is proved that the computer can work properly, the informatics shell is loaded in it. The informatics shell instalment is not so complicated. Which and how many program tools are needed is taken into account, this decision depends on the database that will be connected with the shell and the EDSS that will be developed. It is recommended to choose the G2 informatics shell to develop the decision support system because it is the program where the prototype is built-up

Validation and Correctness phase. Once the G2 is loaded with success, the next step was to verify the connections of the personal computer with the data net (Ethernet).

Time and human effort:

Time schedule	Time effort	Hours	Personal effort
First Week	1 morning	4	1
		4 hours	1

Table 7-2: Time expected to install the G2 shell.

7.3.2.2. **Connect on-line database with G2.**

Design phase. In any WWTP the information from the plant is neither very complete nor very valuable. The information flux goes ahead a series of PLC. When a PLC has any problem the information flux is broken up. If the information net has no problem, it arrives to the SCADA that filters the tags and makes a primary control of the process. This kind of information will be the on-line information in the EDSS.

Development phase. A communication bridge[7] between the G2 shell and the on-line database was made. This bridge can be made, before installing the program, with the information asked to the head of the plant in the second meeting during the plant study phase (see 7.3.2.3). When the bridge is connected, the online information can be transferred to the G2, which has to have the objects and variables necessaries to take the information.

Validation and correctness phase. This phase has to check that the bridge runs properly and sends the on-line data to G2.

[7] The on-line bridge is explained in chapter 3 section 3.4.3

Time and human effort:

Time schedule	Time effort	Hours	Personal effort
During the first Week	3 days	24	1
		24 hours	1

Table 7-3: Time needed for connect G2 with the on-line database.

7.3.2.3. Plant study.

Design phase. It is necessary to make a set of three meetings with the plant head following the recommendations of the study phase from the protocol Montornès 1.0. Then, it is explained what has to be made in every meeting and the information that has to be collected from them.

First meeting

The first meeting consists in the presentation of the program to the plant operators and its main objective is to demand the historical database. Questions about the treatment plant design data are made during this first meeting.

The objective is to know the plant physical structure, the pre-treatment, the primary treatment, how many settlers it has, and so on with the design data information. The questions refer to the main technical characteristics, but sometimes information about the samples , the methodology to sample, and the process operation is also asked for.

It is necessary to know where the information comes from, how it arrives, its frequency, and to make a study of the plant historical data. This study helps us to know the normal operation rank, the maximum and minimum values of the variables, the problems already suffered from in the plant, and so on. The study has to be made by means of statistical tools that allow determining the operation limits of many parameters. Whenever one variable is out of its operation rank, the EDSS starts automatically.

The historical database can also facilitate information using automatic learning methods. They are many automatic methods that can be used to obtain knowledge from the database, but we use the KLASS to cluster the data. This technique enables intensive database exploration and reduces the need of an expert, trying to increase knowledge productivity and quality and trying to automate the knowledge acquisition process. A clustering method is used in this database study.

The first data study is based on a statistical study in order to define the parameters that define the variable. The statistical data filtering prepares the data for later knowledge clustering. The study of the historical database using the clustering methods enables to develop, at the same time, the case library, the objects and the variables for the CBRS. The complete study of the data allows defining the maximum and minimum values of the variables and so on.

Second meeting. On-line information

The current plant situation can be detected with the on-line data process. The EDSS can collect data and inform the operator whenever a devices is not running properly or are wrong by means of know what kind of information comes from the process, like the variables (they come from reactor, settler, inflow, outflow, machines), the digitals signals, the analogues signals, and so on. It is also necessary to know where the information comes from, how it arrives, its frequency, and if it arrives by PLC or by SCADA.

The frequency of the collected information is important because the program works with temporality and the information can be expired whenever it does not arrive. When the program is waiting, the information is not used. In the case of the on-line data, the frequency can be of several seconds or minutes and in the case of off-line data, the timing delay can be from several hours to two or more days.

The objective is to know whether the plant has the minimum requirements for the implementation. The knowledge engineer has to develop, during this phase, the variables that the program will need for the on-line parameters.

Third meeting. Interviews.

The third meeting is to make a set of interviews with the head of the plant in order to obtain his/her knowledge about the plant. An interview is prepared for every operational problem or set of similar operational problems. The main task of these interviews is to obtain the maximum possible knowledge from the plant head, and to make this objective with his minimum effort. Thus, the questionnaires are designed to collect the information that the knowledge engineer believes is the most important to integrate in the system. It is always a problem for the developer to define what kind of information the system needs. The interviews try to systematise the process of heuristic knowledge acquisition.

Another information that is extracted from these surveys is about the operation strategies that the head of the plant applies to the treatment process. The food-to-microorganism ratio (F/M) and the cell-residence time θ_c are the most used parameters for the design and operation on activated-sludge processes.

There is an interview for every operational problem that the plant can suffer from and it tries to collect more concrete information about it in the new plant. The result is a set of decision trees that afterwards they will be converted into the knowledge base by means of ***if-then*** rules.

The bibliographical study cannot be forgotten; it is beneficial to make a good bibliographical study about the kind of process, operational problems, and so on. Visiting the plant is useful to get an idea of dimensions and to relate the information collected before with the reality of the plant.

Development phase. After the tree meetings with the head of the plant, there is a lot of information about the plant. In the first meeting, the plant design data and the on-line information is get.

With the second interview, the historical data of the plant is obtained. This information was retrieved from a set of worksheets that contained the information from the operation in the plant during a month.

In the third meeting, the information about the process, the control and the operational problems of the plant was collected.

The plant study allows determining whether the plant complies the minimum requirements or not for the program installation. It is done by defining the maximum values, the minimum values, the medium values, the standard deviation, the variation coefficient and the quartiles and generating the variables and objects that afterwards, the ES and the CBRS will need.

Validation and correctness phase. All along the study, it was verified the good data reception, filtering and treatment.

Time and Human effort:

Time schedule	Time effort	Hours	Personal effort
During the first week	2.5 days	20	2
One morning in the 2nd week	½	4	2
One morning in the 3rd week	½	4	2
		28	**2**

7.3.2.4. **Creation of variables, classes and objects.**

Design phase. An object is anything that we use to deal with both the environment and the data information. An object belongs to a class that provides it with its characteristics. An object can consist in many variables, where the program puts and leaves data, the numbers and so on.

Development phase. Different objects and variables are needed in order to describe the process in an appropriate way. These objects, classes and variables are used to build the structure of the program and to make operations between them. The parameters that are represented in these variables will then build the rules of the program.

If the COD of PRIMARY-SETTLER > the maximum-value of the COD-primary-flow then invoke overloading-shock rules

In this example the primary-settler is an object that represents the characteristics of one settler of the plant. The COD is a variable of the object primary-settler.

This phase is executed during the re-design and implementation process; whenever the rules from the rule-based system or the procedures from the CBRS need it.

Validation and correctness phase. This phase is executed during the whole stage by the validation and correctness of the objects and variables. The objective is to adjust them to the rules and procedures requirements.

Time and Human effort.

Time schedule	Time effort	Hours	Personal effort
1 Week	1 day	8	1
		8 hours	**1**

Table 7-4: Time needed for create the variables.

7.3.2.5. **Creation of rules (SE).**

Design phase. This task is distributed during the EDSS exportation process and it tries to solve the problem of representing the knowledge acquired from the plant. This task could also be named as development of the knowledge base for the ES. The information extracted from the interviews and literature is codified into rules; the first step is to represent all the knowledge collected into decision trees, which will be later on discussed with the head of the plant. Whenever a decision tree was made, it was codified into a set of ***if-then*** rules that have the form of <**IF** condition **THEN** conclusion>. ***If-then*** rules are the most common way to represent knowledge. Such rules contain premises or conditions in the ***if*** clauses, and conclusions in the ***then*** clauses.

Development phase. Whenever a decision tree was codified into rules, the same was made with the objects, variables and constants that the rules needed to inference the plant situation. Most of the general knowledge about the biological wastewater treatment can be re-used from the prototype.

The decision trees represent the main operational problems that the plant can suffer from. In order to know the operational problems of Montornès, the interviews from the third meeting with the head of the plant are used.

Validation and correctness phase. All the rules and procedures are verified whenever they are made. The validation process consists in representing the limit conditions that start the rules and verify that the rules run properly.

The program testing is made during the decision tree codification process; it is then when they are codified into rules. Whenever a set of rules is made, a set of tests is also made with that application of different values to the variables of the rules. Moreover, whenever a code error is detected, it is corrected.

Time and Human effort. This phase is made during all the process and sometimes, two or more tasks were made at the same time. In the following table, there is the most important data extracted from the questionnaires made to the head of the plant in the previous study.

Time schedule	Time effort	Hours	Personal effort
1^{st} Week	1 morning and 1 evening	8	2
2^{nd} Week	1 morning	4	
3^{rd} Week	1 evening	4	
4^{th} Week	1 evening	4	
5^{th} Week	2 mornings, 1 evening and 1 day	20	
6^{th} Week	2 mornings	8	
		48 hours	**2**

Figure 7-4: Hours needed for make the knowledge base by means of rules.

7.3.2.6. Study of the classes

Design phase. This task runs parallel with the plant study. When the previous study proves that the WWTP has the necessary requirements to allow the program working properly. This task also allows defining the new variables of the cases from the CBRS and the initial set of cases of the case library. The CBR requires a database, which stores an array of relevant cases that covers the problems that may arise in the plant.

Development phase. An automatic clustering is used. It is useful to make the study of the classes needed for the program. The automatic clustering is a kind of automatic acquisition knowledge from a historical database. In this case, the clustering process used is the hierarchical classification, which is based on repetitive partitions of the matrix, and the program used is the KLASS. The original cases for the CBR are extracted from the historical plant database by means of the KLASS.

The different classes found represent the different situations that the plant can suffer from and they will be the original cases in the case library.

Validation and correctness phase. The validation and correctness are made during all the stage. The validation consists of verifying that the classes have sense and ask the plant head if the retrieved classes represent the situations of the process.

Time and Human effort.

Time schedule	Time effort	Hours	Personal effort
During the 1st week	1	4	2
During the 3rd week	1	4	2
		8	**2**

7.3.2.7. Interface.

Design phase. Improvements in the communication between the program and the user are very important to facilitate the access of the user to the information and to the program. The interface represents one-way to invite the user to run the program and that him/her uses it.

Although this latest interface version, it is making another one in Visual Basic (VBA) because this informatics program gives more benefits to the interface. These benefits are a better visual communication with the user because the format is like the windows interface, and a more easily navigation throughout it.

The creation of the new interface supposes a better way to access to information from the first level of the structure and a better way of communication between the user and the program. The main goal of the interface is to provide the information to the user in an easier and faster way.

Development phase. This interface is like the latest interface version in the G2 from the prototype; on the left part, you can see the action buttons to access to the diagnosis proposal from the expert system; whenever the button is validated, you have access to it. When the interface appears on the screen, it means that the system has already made all the functions and actions and that now it can make a proposal about the situation. This new interface allows the user knowing the situation of the plant, and choosing whether he/she wants to access to the proposal solution or not.

When the user presses the button, he/she can see a new picture that informs him/her about the concrete proposal of the system. The diagnosis, the reasoning, the cause and the action organise the information that the program has to give to the user. The user can also see another screen with more general information; it happens whenever the concrete information does not help him/her to solve the actual situation in the plant.

The buttons on the left part of the interface correspond to the decision trees that the program has for each problem in the plant. These buttons give the final solution once the of rules and procedures of every decision tree have been activated.

Validation and correctness phase. This task is made throughout all the stage. It is periodically proved that the interface receives the data from both tools of the second layer architecture.

Time and Human effort:

Time schedule	Time effort	Hours	Personal effort
During the 2nd Week	2 days and 1 morning	20	1
During the 4th Week	1 morning	4	1
During the 5th Week	1 evening	4	1
During the 6th Week	2 evenings	8	2
		36 hours	**2**

Table 7-5: Time inverted for interface development.

7.3.2.8. Connect Off-line database with G2.

Design phase. The off-line information from the process is usually in an excel worksheet; this information corresponds to different analytical samples from the process. Afterwards, this data will be the off-line data in the program.

The bridge implementation that connects off-line database with G2 is made during the second week. This task consisted in transferring the off-line data throughout the activeXlink bridge to the system.

Development phase. The bridge generation process and its implementation needs a lot of time of preparation. The off-line information is automatically revised every two hours; it can also be revised whenever the user wants it or whenever the decision support system cycle is executed. Thus, it is sure that the off-line data that the program has is the latest information introduced in the off-line database by the head of the plant or laboratory.

The bridge has to be robust and has to transfer the information without any format changes. Once the data is transferred to the program, this information activates a set of procedures that filter, abstract and put the information in the corresponding variables and objects.

Validation and correctness phase. This phase is activated during all the stage and verifies that the bridge transfers the off-line data to the G2 in an appropriate way.

Time and Human effort.

Time schedule	Time effort	Hours	Personal effort
During the 2nd Week	1 morning and 1 evening	8	1
During the 3rd Week	2 days, 2 evenings and 1 morning	28	2
During the 4th Week	1 day, 2 evenings and 1 morning	20	2
During the 5th Week	1 evening	4	1
		60 hours	**2**

Table 7-6: Time for connecting off-line database with G2.

7.3.2.9. Case based reasoning system.

Design phase. In this stage, the work consists of redefining the variables that built up a case, and the parameters and objects of the CBRS to the new necessities of Montornès WWTP. Then, the statistical study and automatic clustering from the historical data, and the variables chosen are presented to the plant head, who will determine whether the variables define properly the plant process or not.

Development phase. The actions, at this point, are the following a) Selection of the variables to define the case, b) Establishment of the maximum values, minimum values and qualitative modalities for the variables involved in CBRS, and c) Modification of the CBRS interface.

a) **Selection of the variables to define the case.**

The selection of the variables is based on the statistical study and automatic clustering done to the historical information demanded to the head of the plant during the first meeting (chapter 7, section 7.3.2.3). The proposal variables are presented to the plant head, who verifies whether the variables are correct.

These variables should define the plant situation at every possible working conditions in the plant. Every variable has an associated weight that is used to get a better description of the process at any moment. A case is created with these variables in order to represent the situation of the plant during 24 hours.

b) **Establishment of maximum, minimum values and qualitative modalities.**

It has to determine the normal work rank of the variables chosen. This rank allows the program defining whether a variable works properly or not. If one variable has a value which is higher than the superior limit rank, the program automatically modifies its weight to increase its importance among the other variables.

These values are also used to normalise the variable value between 0 and 1, which allows retrieving the most similar case in the case library.

c) **Modification of the CBRS display screen.**

If the variables are changed, the interface of the CBRS has to change in order to represent the new variables that define the case.

Validation and correctness phase. This phase consists in verifying with the plant head the variables chosen and check the calculated distances.

Time and Human effort:

Time schedule	Time effort	Hours	Personal effort
During the 3rd Week	1 morning	4	1
During the 5th Week	1 day and 1 morning	12	1
During the 6th Week	2 mornings	8	2
		24 hours	**2**

Table 7-7: Hours inverted in CBRS.

7.3.2.10. **Modularity.**

Design phase. Modularity is the partitioning of a software design into individual components, which are called modules or objects, to reduce its complexity and facilitates, the system maintenance, reusability, reliability and its extendibility [Burch, 1992].

Development phase. The program has to be saved in a hierarchical structure where the other modules depend on one main module.

Validation and correctness phase. This stage is verified whenever the program is saved by means of modules.

Time and Human effort.

Time schedule	Time effort	Hours	Personal effort
During the 4th Week	2 mornings	8	1
During the 5th Week	1 morning	4	
		12 hours	**1**

Table 7-8: time effort to modularity the program.

7.3.2.11. **Correctness.**

Design phase. This step consists in validating and checking the correctness, consistency and usability of the performance of the whole EDSS. The whole new EDSS is checked by means of a set of tests that verify the results of both artificial intelligence programs.

Development phase. A set of situations are designed and executed in the program to verify whether the whole program runs properly.

Time and Human effort.

Time schedule	Time effort	Hours	Personal effort
During the 6th Week	**1 day**	8	**2**
		8 Hours	**2**

Table 7-9: Time to correct the program.

7.3.3. Problems with the implementation.

In this section, the problems appeared during the implementation process of the program in Montornès WWTP using the protocol Montornès 2.0 are explained.

1. Many problems with the information net have appeared during the implementation period; it is a problematic phase in most WWTPs. It is recommended to increase the time inverted in the connection of the databases with the program stages.

2. A big percentage of the objects, variables, constants, rules and procedures have been created for the Montornès EDSS. This fact is the responsible for all the process going slower. In the future, it is recommended to exploit better the prototype variables, objects, rules and so on.

3. In the CBRS, the information collected in the plant and stored in the vector ***analitic1*** to fill up the current case is used. The problem appears when this vector does not have the information updated, which is very usual because this vector stored the data from the current day.

4. In the RBS, the main bottleneck has been the creation and discussion of the new decision trees and the actions modifications.

5. With the CBRS, the main problem was to define the variables of the actual-case and then, modify the internal structure of the system with the new variables.

6. Short time for whole EDSS validation and correctness. This stage has to be more normalised using a set of tests.

7. Absence of off-line information. It is evident that the plant head has no time to introduce information in the system. This is one of the reasons to design the system using more the on-line information from the process.

These problems are then included in the protocol Montornès 2.0 to improve it and generate a better exportation protocol for future EDSS.

7.3.4. **Maintenance**

The maintenance is the phase that has to solve the concrete operation problems that they are not detected during the exportation. Although the protocol and the correctness phases are applied, some troubles can appear. The main possible problems could be that the system was not designed keeping the user requirements and organizational needs or the design is inflexible and this property does not allow systems maintenance to be performed. The problem could be difficult to detect and could appear after the implementation, which makes not easy to solve it. These problems must be considered and avoided and it is one of the reasons to apply the exportation document.

This phase is not included into the implementation calendar because this has to be an on-line program support and maintenance. If the user has any problem or he wants to modify or to increase the program code, then this task can be made on line, if it is possible, or it can need a plan for improve or to correct the code.

7.3.5. **Making a complete, clearly and useful information document.**

Users generally interact with the system via a screen and keyboard, mouse, and so on. To design user documentation for this interface, it is helpful to classify the potential users, first; and make a concrete user guide for each one [Burch, 1992].

- *Novice users.* These users have no syntactic knowledge about computers and software. Generally, they are nervous about making embarrassing mistakes.
- *Occasional users.* These users knew how to work with the system at one time, but, because of infrequent use, they have forgotten essential commands and procedures.
- *Transfer users.* They already know how to work with systems.
- *Expert users.* These people understand how to work with the new system as well as most other systems.

In the WWTPs the end-user of the system will be the head of the plant or some operator. These people could be considered novice users and the information document has to be easy, clear and useful, because they are not programmers.

7.4. *Discussion.*

A Management method based on PERT technique is used to estimate time to complete various phases or tasks. Also, the number of person-months (or another unit of time) required to produce so many lines of executable code or function points was used as a way to estimate the time to develop software; the time expected in every stage is provided from the PhD. Student experience extracted from the Montornès EDSS implantation. Thus, the time expected is more near to the real time needed plus a margin time to solve any problem that can appear.

The time scheduling is important for the plant head because in the industry, all projects are measured with the time and cost effort inverted versus the benefits and the repayment time.

If the equation does not interest for the plant head or company, he/she/it does not buy the program, although the latter is the best solution for one problem or task.

The Montornès 1.0 protocol application allows improving itself to obtain an increase of its effectiveness and a reduction of its time costs. The low time implantation allows introducing easier an EDSS in any wastewater treatment plant to help the plant head to take the best option in front any process problem to solve it.

Following, it is presented the both times scheduling from both protocol versions, 1.0 and 2.0.

Propotype Montornès 1.0 Action	**Hours**	**Persons**	**Prototype Montornès 2.0 Action**	**Hours**	**Persons**
Previous study	34.4		Install G2	4	1
Adaptation of the variables and objects	42,4		Connect on-line database with G2	4	1
Calibration of rules of the Rule-based System	58,4		Study	28	2
Adaptation of the CBRS	28		Creation of objects and variables	8	1
Connection with periphery elements	20		Creation of rules	48	2
Computational implementation	40		Study of classes	8	2
			New interface	36	1
Validation & Check for correctness	40		Connect off-line database with G2	60	1
Delivery	8		Case-based reasoning system	24	1
(Supervision)	(128)		Modularity	12	1
			(Correctness)	(16)	(1)
TOTAL	**270,4 (399,2)**		**TOTAL**	**232 (248)**	**2**

Table 7-10: Table with the comparison between both protocols.

The Montornes 2.0 protocol presented reduces in 10% the time needed to re-design, re-develop and to implement the EDSS prototype.

The implementation needs 232 hours in front of the 270 hours needed with the original protocol. The Montornès 2.0 protocol has demonstrated that it can make a better implantation and that needs less time. Thus, the new protocol is recommended as a guide for future new program exportations.

The Montornès 2.0 Protocol is the second approach to generate a good exportation document and the results are satisfactory; thus, it is expected that in next iterations the time needed will be reduced and the efficiency of the process will increase.

During the Montornès 1.0 protocol application, it was verified that some steps in the protocol 1.0 were not fulfilled or were executed in other order, and this characteristic is the responsible of the different structures of both protocols. Perharps, although, in the new protocol the study step is located in the third position, a little study of the plant was made before the first step. It could be considered that the three firsts steps were made at the same time. In the Montornès 1.0 protocol, the supervision phase consists in to verify that the program runs properly during 15 days but the plant head prefers to have online support for solve any problem.

In the Montornès 2.0 Protocol the phase in parenthesis corresponds to the correctness phase. It is considered that in the next implementations this phase will be not repeated, although, this phase maybe will need some adaptations depending of the changes that the new EDSS will suffer.

The protocol 2.0 allows extracting from the project the conclusion that the program can be exported to another WWTP with guarantees of success using it (it can be seen in chapter 7 section 7.3.). The time differences between Montornès 1.0 and 2.0 protocols are provided from the application in a real WWTP with a real schedule limits. This situation invites to increase the efficiency of every task and to increase the implementation velocity and to maximise the available resources.

The protocol 1.0 does not imply a correctness phase, which is integrated in every phase in the new protocol 2.0. With the latter, every phase has a structure of performance to follow and the knowledge engineer knows or has the how-know process to develop any step because every phase has design, development and correctness phase. Thus, any step is still open meanwhile the correctness phase is not finished and consequently the corrections in the code are easier to do.

It is also important the bottlenecks and problems found during the Montornès implementation, which have to be considered in next implantations. Some proposals to have in account in future new EDSS re-design are the following:

- To invert more time in the informatics problems. Demand good information net and good personal computer.
- Making more generalist the prototype for became the original EDDS, whose will derive the rest of the DDS in the future.
- Making a good study stage is very important for obtain a calibrated program.
- Avoid the sensors problems and solve the communication troubles.
- Make the system more robust and efficient.
- Generate an EDSS in a middle way between the plant head requirements and the plant information posibilities

7.6. *References*

Gensym Corporation. Getting starterd with G2, tutorials Version 5.0. 1997

Burch J.G. (1992). *Systems Analysis, Design, and implementation*. Boyd & Fraser publishing company.

Chapter 8: Conclusions

8. Conclusions

The thesis development leads to a lot of conclusions about the work done and the process used to export a new version of the Granollers prototype to others WWTP. These conclusions are presented following the thesis' objectives structure.

According to the main objective, that is "*To define, apply and validate a protocol for DSS development and transferability to biological treatment of any WWTP. While the Granollers EDSS is taken as a base of this study, the Montornès WWTP as an exportation case study.*", the conclusions that can be extracted are the following:

- The design, development and implementation of an EDSS are very difficult and problematic processes that need to be guided in order to be successful. There is a big amount of bottlenecks and problems in an EDSS design, development and implementation, so it is necessary to have them broadly documented.

- Although the user implication during the re-design and development of an EDSS process is very important, his/her role in an EDSS development is still poorly defined. The user has to tell about his/her necessities and what he/she wants the program to detect.

- The program implementation in Montornès WWTP provides wider implementation experience, which is used to generate the protocol 2.0.

- The integration of various sources of knowledge, intelligent techniques and numerical tools is the key step when developing successful EDSS for environmental problems.

- Protocols facilitate knowledge sharing and re-use.

- Questionnaires were designed to improve the plant information and the heuristic knowledge acquisition process from the plant head.

- A protocol to export the program is needed to re-use the wastewater treatment plant knowledge process into the prototype.

According to the objective of *reviewing the biological process in wastewater treatment, the control and artificial intelligence tools, and the different EDSS modules architecture* in the *For the develop process,* the main conclusions are the following:

- Few control loops in the water line of the Montornès WWTP make it difficult the program implementation and the control process. The program requirements should be reviewed in the protocol.
- Once the on-line and the off-line data are collected, it is very important to transfer this information from the databases to the supervisory program.

- Artificial intelligence tools are the best option to both solve the data management problem and to propose an action to solve the current plant situation.

- Automatic knowledge acquisition tools become a useful tool to identify situations from the information within databases.

According to the objectives from the exportation process, the first objective was the *EDSS Granollers study. The review includes the general maintenance, the results validation, and the knowledge bases (generals and specifics) study* that allows the following conclusions:

- The prototype is used, as a base, in the new program implanted in Montornès WWTP; thus, this has to be a robust and effective program.

- Some improvements should be made in the prototype in order to become a general basis to develop other EDSS.

- The validation process allows thinking about the possibility of exporting the prototype. Then, some changes are made in other WWTP.

- The generation of a good knowledge base is the main bottleneck that the EDSS development process can suffer from.

The *Montornès WWTP study, its biological treatment, its process characteristics, the available information and the existed operation protocols* are the second objectives in the exportation process section.

- It is necessary to make a detailed study of the new plant, where the new EDSS has to be installed.

- It is necessary to know very well the internal information system, how the sample points are made in the plant process and how often, how the values are received as on-line data, and so on.

- A detailed study of the collected off-line data allows calibrating better the program.

The last objective of this section is the *EDSS evolution by means of the improvements made in the data and knowledge acquisition, the communication bridges, and the user interface*. The conclusions are the following:

- The improvements made in the program-user interface are important because when the program has a diagnosis about the process, it needs to communicate the results and the correct actions to the user.

- A new set of bridges based on G2 activexlink technology is made to improve the communication between the databases and the program.

- Improvements in the expert system rules are made in order to make a new EDSS, which was more based on on-line data. The CBR system is improved by means of a new system that closes the cases.

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LABORATORI D'ENGINYERIA QUÍMICA I AMIENTAL

TESI DOCTORAL

Supervisory Systems in WasteWater Treatment Plants: Sistematise their Implementation

Annexes

Memòria presentada per en Christian Cortés de la Fuente,
per optar al títol de Doctor Enginyer Industrial per la Universitat de Girona

Girona, Tardor de 2002

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Annex I:Calendar

Schedule for Montornès EDSS inplantation.

	DILLUNS	DIMARTS	DIMECRES	DIJOUS	DIVENDRES
	6	7	8	9	10
10 11 12 13	INSTAL·LAR G2,REVISIÓ DEL CORRECTE FUNCIONAMENT SENYALS ON-LINE, Connexió FULLA XLS AMB DADES ON-LINE AMB G2	DISCUSSIÓ ARBRES	DISCUSSIÓ DELS PRIMERS ARBRES (bulking, Xoc orgànic i nitrificació)	CREACIÓ D'OBJECTES I VARIABLES	CREACIÓ DE REGLES QUE REPRESENTEN ELS ARBRES i INTRODUCCIÓ DE REGLES AL G2+DISCUSIÓ D' ARBRES (xoc hidràulic)
14					
15					
16 17 18 19	DISCUSSIÓ ARBRES	PRIMERA Adaptació DELS ARBRES DE GRN A MNT	CREACIÓ D'OBJECTES I VARIABLES i Creació DE NOUS ARBRES comentari de les classes	CREACIÓ DE REGLES QUE REPRESENTEN ELS ARBRES i INTRODUCCIÓ DE REGLES AL G2	
20					
	13	14	15	16	17
10 11 12 13 14	Nova interfície en visual basic	INTRODUIR REGLES AL G2 I DISCUSSIÓ DE NOUS ARBRES(foaming i xoc tòxic)	Nova interfície en visual basic	nova interfície en visual basic	Generació del pont de comunicació entre les dades off-line i el G2
15					
16 17 18 19 20	Nova interfície en visual basic		Nova interfície en visual basic	Generació del pont de comunicació entre les dades off-line i el G2	
	20	21	22	23	24
10 11 12 13 14	Generació del pont de comunicació entre les dades off-line i el G2	informe / Generació del pont de comunicació entre les dades off-line i el G2	Discussió amb l'àngel i la sandra de tres arbres	pesos de variables automàtics	off-line
15					
16 17 18 19 20	Generació del pont de comunicació entre les dades off-line i el G2		algunes regles i dades off-line	off-line	off-line

	27	28	29	30	31
10	Montornès corregir regles(causa i actuació) i començar a estructurar el cicle	off-line posar automàticament els valors als objectes	informe	Montornès	interfície
11					
12			off-line posar automàticament els valors als objectes dels 7 dies anteriors		
13					
14					
15					
16	off-line	off-line posar automàticament els valors als objectes		off-line	
17					
18					
19					
20					

	3	4	5	6	7	8	9
10	Montornès	Regles se	Regles inicialització	reunió amb àngel	SE i SBC	SE i SBC	SE i SBC
11							
12							
13							
14							
15							
16	off-line	Regles se	regles se	modificacions i sbc	sbc i Interfície		
17							
18							
19							
20							

	10	11	12	13	14
10	Sbc	Montornès: on-line i sbc	Montornès: verificar sed,causa,act	reunió amb Manel i Ignasi a Montornès	
11					
12					
13					
14					
15					
16	interfície	interfície			
17					
18					
19					
20					

Annex II:Questionnaires

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Qüestionari per l'elaboració d'un arbre de diagnosi, per implantar un sistema supervisor en una EDAR, per casos de xoc tòxic

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Informació sobre qui omple l'enquesta:

Nom	Sandra	càrrec	**Segon cap de planta**
e-mail	EDAR-Gr@terra.es	telèfon	935721819
data	14/05/02		

Informació sobre la planta

Nom de la planta	EDAR de montornès
adreça	
Ciutat i codi postal	Montornès del Vallès
País	Espanya

El qüestionari comença per la identificació de situacions "típiques" que es poden donar en aquestes circumstàncies, com es diagnostiquen (quins són els indicadors que es fan servir i a quins nivells)

1. Te problemes relacionats amb influents que suposin a la planta un xoc tòxic

Si ☒
No ☐

1.1. Indicadors que es fan servir i a quins nivells.

Biomassa(MLSS)
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte.

Influent (DQO i MES)
☐ alt
☒ mitja
☐ baix
☐ no es rellevant, no es te en compte.

cabal d'entrada (Qe)
☐ alt
☐ mitja
☒ baix
☐ no és rellevant, no es te en compte.

càrrega màssica
☐ alt
☒ mitja
☐ baix
☐ no és rellevant, no es té en compte.

sòlids efluent
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte.

DQO efluent
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte

IVF
☐ alt
☐ mitja
☒ baix
☐ no es rellevant, no es te en compte

Edat del fang
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte

concentració OD
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte

Altres
☒ alt

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Número de bufants
- ☐ mitja
- ☐ baix
- ☐ no es rellevant, no es te en compte.

Terbolesa
- ☒ alt
- ☐ mitja
- ☐ baix
- ☐ no es rellevant, no es te en compte

2. Notes addicionals

Per a més informació:

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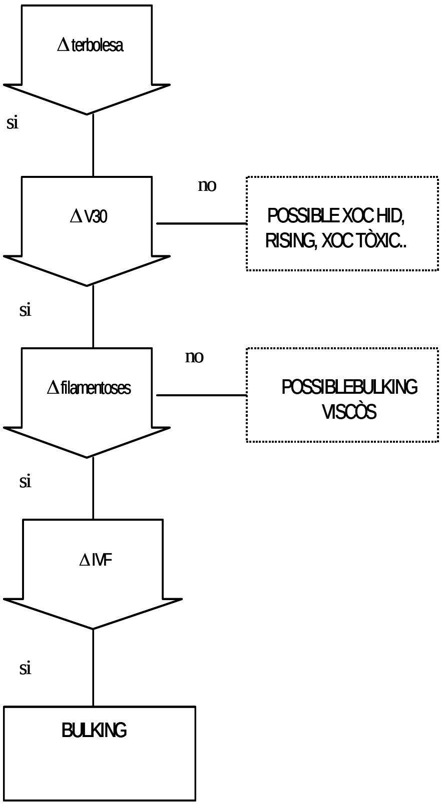
Δ terbolesa
Δ IVF
Δ V30
Δ filamentoses


Δ terbolesa
si
Δ V30
no
POSSIBLE XOC HID, RISING, XOC TÒXIC..
si
Δ filamentoses
no
POSSIBLEBULKING VISCÒS
si
Δ IVF
si
BULKING

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Qüestionari per l'elaboració d'un arbre de diagnosi, per implantar un sistema supervisor en una EDAR, per casos de nitrificació -desnitrificació

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adreça	
Ciutat i codi postal	Montornès del Vallès
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El qüestionari comença per la identificació de situacions "típiques" que es poden donar en aquestes circumstàncies, com es diagnostiquen (quins són els indicadors que es fan servir i a quins nivells)

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3. Te problemes relacionats amb temes de nitrificació-desnitrificació.

Si ☒
No ☐

1.1. Indicadors que es fan servir i a quins nivells.

biomassa
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte.

Influent (DQO i MES)
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte.

Nitrits i nitrats (efluent)
☒ alt
☐ mitja
☐ baix
☐ no és rellevant, no es te en compte.

Amoni (efluent)
☒ alt
☐ mitja
☐ baix
☐ no és rellevant, no es té en compte.

Sòlids (efluent)
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte.

REDOX
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte

edat del fang
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte

temperatura
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte

v30 –2 h
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte

Altres (terbolesa)
☒ alt
☐ mitja
☐ baix

4. Notes addicionals

L'Objectiu principal de la planta és aconseguir evitar la nitrificació . Totes els càlculs de purgues estan encaminats a aconseguir aquest propòsit, mantenir un fang jove, per evitar el desenvolupament dels autotròfics, de creixement més lent, responsables de nitrificar.

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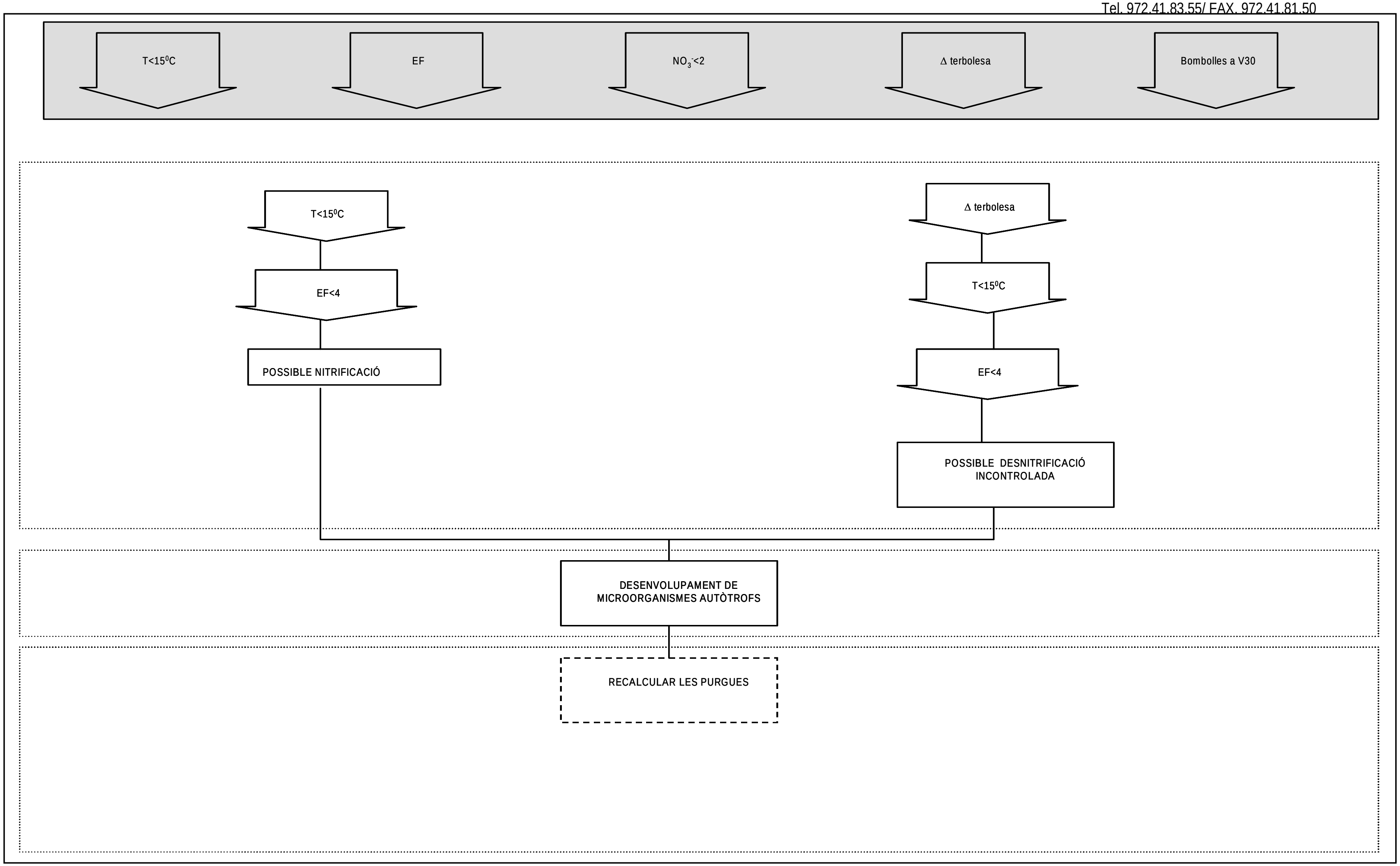
T<15ºC
EF
NO_3^-<2
Δ terbolesa
Bombolles a V30
T<15ºC
EF<4
POSSIBLE NITRIFICACIÓ
Δ terbolesa
T<15ºC
EF<4
POSSIBLE DESNITRIFICACIÓ INCONTROLADA
DESENVOLUPAMENT DE MICROORGANISMES AUTÒTROFS
RECALCULAR LES PURGUES

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Qüestionari per l'elaboració d'un arbre de diagnosi, per implantar un sistema supervisor en una EDAR, per casos de baixa càrrega, xoc hidràulic i tempesta

Universitat de Girona

DEPARTAMENT D'ENGINYERIA QUÍMICA AGRÀRIA I TECNOLOGIES AGROALIMENTÀRIES

LABORATORI D'ENGINYERIA QUÍMICA I AMBIENTAL

UNIVERSITAT DE GIRONA
Laboratori d'Enginyeria Química i Ambiental (LEQUIA)
Departament d'EQATA. Facultat de Ciències

Campus Montilivi, s/n
E-17071 Girona.
Tel. 972.41.83.55/ FAX. 972.41.81.50

Informació sobre qui omple l'enquesta:

Nom	Sandra	càrrec	**Segon cap de planta**
e-mail	EDAR-Gr@terra.es	telèfon	935721819
data	14/05/02		

Informació sobre la planta

Nom de la planta	EDAR de Montornès
Adreça	
Ciutat i codi postal	Montornès del Vallès
País	Espanya

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L'enquesta comença per la identificació de situacions "típiques" que es poden donar en aquestes circumstàncies, com es diagnostiquen (quins són els indicadors que es fan servir i a quins nivells

5. Te problemes relacionats amb influents amb poca càrrega orgànica

Si ☒
No ☐

1.1. Indicadors que es fan servir i a quins nivells.

Biomassa(MLSS)
☐ alt
☒ mitja
☐ baix
☐ no es rellevant, no es te en compte.

Influent (DQO i MES)
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte.

cabal d'entrada (Qe)
☒ alt
☐ mitja
☐ baix
☐ no és rellevant, no es te en compte.

càrrega màssica
☐ alt
☒ mitja
☐ baix
☐ no és rellevant, no es té en compte.

sòlids influent (terbolesa)
☐ alt
☐ mitja
☒ baix
☐ no es rellevant, no es te en compte.

IVF
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte

Altres indicadors
Oxigen dissolt
☒ alt
☐ mitja
☐ baix

numero de bufadors
☒ alt
☐ mitja
☐ baix

2. Com diagnostica la presencia d'un xoc hidràulic degut a pluges.

2.1. Indicadors que es fan servir i a quins nivells.

Biomassa(MLSS)
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte.

Influent (DQO i MES)
☐ alt
☒ mitja
☐ baix
☐ no es rellevant, no es te en compte.

cabal d'entrada (Qe)
☒ alt
☐ mitja
☐ baix
☐ no és rellevant, no es te en compte.

càrrega màssica
☐ alt
☐ mitja
☐ baix
☐ no és rellevant, no es té en compte.

sòlids influent
☐ alt
☐ mitja
☒ baix
☐ no es rellevant, no es te en compte.

IVF
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte

Altres indicadors

Oxigen dissolt
☒ alt
☐ mitja
☐ baix

numero de bufadors
☒ alt
☐ mitja
☐ baix

3. Com es diagnostica un xoc hidràulic degut a una punta de cabal

3.1. Indicadors que es fan servir i a quins nivells.

Biomassa(MLSS)
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte.

Influent (DQO i MES)
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte.

cabal d'entrada (Qe)
☒ alt
☐ mitja

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☐ baix
☐ no és rellevant, no es te en compte.

càrrega màssica
☐ alt
☐ mitja
☐ baix
☐ no és rellevant, no es té en compte.

sòlids influent
☐ alt
☐ mitja
☒ baix
☐ no es rellevant, no es te en compte.

IVF
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte

Altres indicadors
Oxigen dissolt
☒ alt
☐ mitja
☐ baix

numero de bufadors
☒ alt
☐ mitja
☐ baix

4. Notes adicionals

S'ha d'intentar identificar el xoc orgànic en el mateix moment que està succeint, és per això que el cap de planta recomana fer servir totes les variables on-line de que disposal'EDAR, per a poder fer-ho. És per això que els indicadors que ens diagnosticaran el xoc orgànic sempre seran on-line, les dades off-line seràn per aconseguir confirmacions.

La diferència entre un episodi de punta de càrrega i un de pluja és el temps, si aquest te una durabilitat elevada és diu que hi ha un episodi de pluja

Per a més informació:

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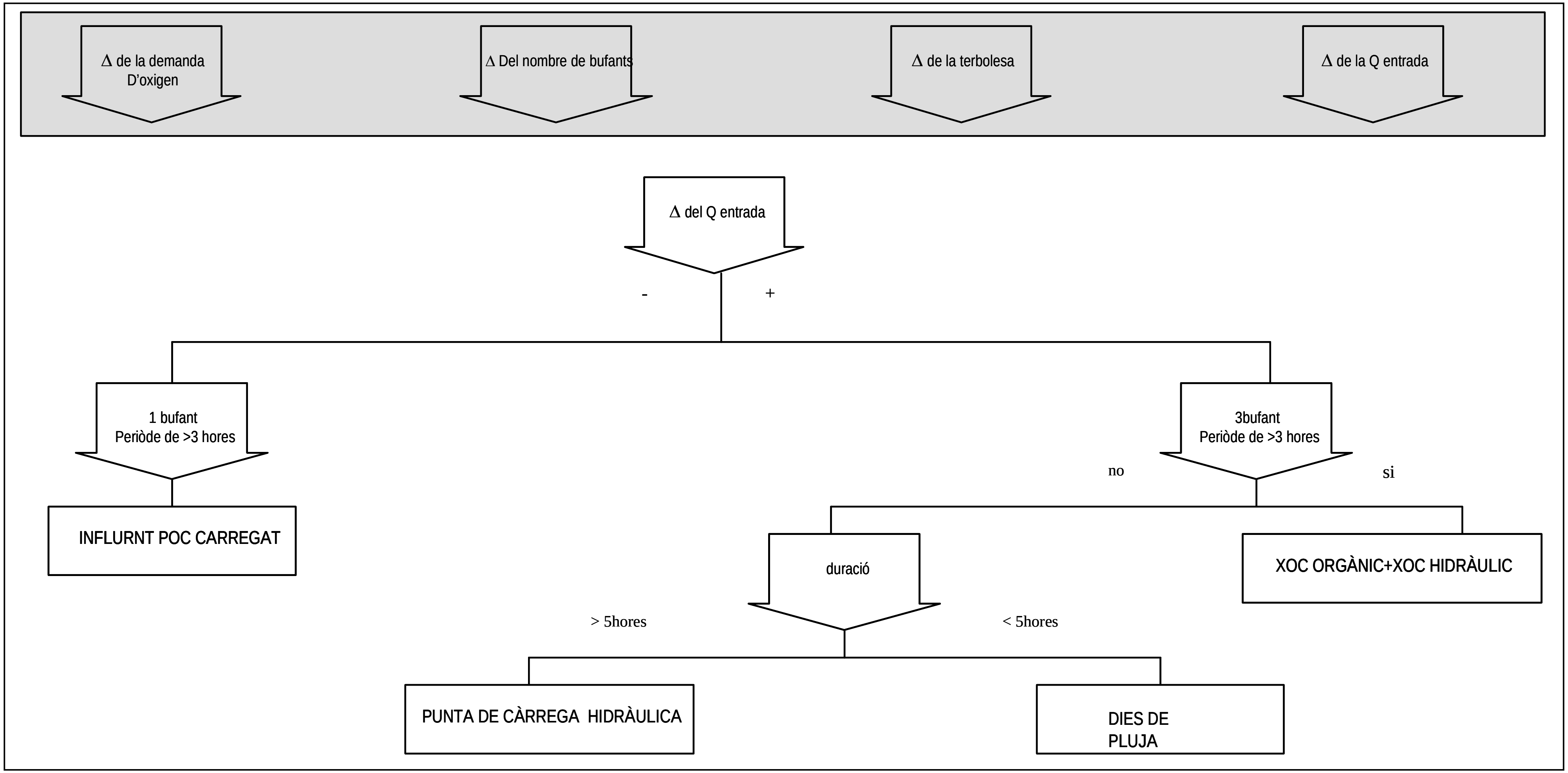

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Qüestionari per l'elaboració d'un arbre de diagnosi, per implantar un sistema supervisor en una EDAR, per casos de sobrecàrrega orgànica

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Nom	Sandra	càrrec	**Segon cap de planta**
e-mail	EDAR-Gr@terra.es	telèfon	935721819
data	14/05/02		

Informació sobre la planta

Nom de la planta	EDAR de montornès
adreça	
Ciutat i codi postal	Montornès del Vallès
país	Espanya

El qüestionari comença per la identificació de situacions "típiques" que es poden donar en aquestes circumstàncies, com es diagnostiquen (quins són els indicadors que es fan servir i a quins nivells)

6. Te problemes relacionats amb influents amb sobrecàrrega orgànica

Si ☒
No ☐

1.1. Indicadors que es fan servir i a quins nivells.

Biomassa(MLSS)
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte.

Influent (DQO i MES)
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte.

cabal d'entrada (Qe)
☐ alt
☐ mitja
☒ baix
☐ no és rellevant, no es te en compte.

càrrega màssica
☒ alt
☐ mitja
☐ baix
☐ no és rellevant, no es té en compte.

sòlids efluent
☐ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte.

DQO efluent
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte

IVF
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte

Edat del fang
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte

presencia de flagelats
☐ alt
☒ mitja
☐ baix
☐ no es rellevant, no es te en compte

concentració OD
☒ alt

	☐ mitja
	☐ baix
	☐ no es rellevant, no es te en compte
color marró de l'aigua	☐ alt
	☐ mitja
	☐ baix
	☒ no es rellevant, no es te en compte
Altres	☒ alt
Número de bufants	☐ mitja
	☐ baix
terbolesa	☒ alt
	☐ mitja
	☐ baix

7. Notes addicionals

S'ha d'intentar identificar el xoc orgànic en el mateix moment que està succeint, és per això que el cap de planta recomana fer servir totes les variables on-line de que disposa l'EDAR, per a poder fer-ho. És per això que els indicadors que ens diagnosticaran el xoc orgànic sempre seran on-line, les dades off-line seràn per aconseguir confirmació

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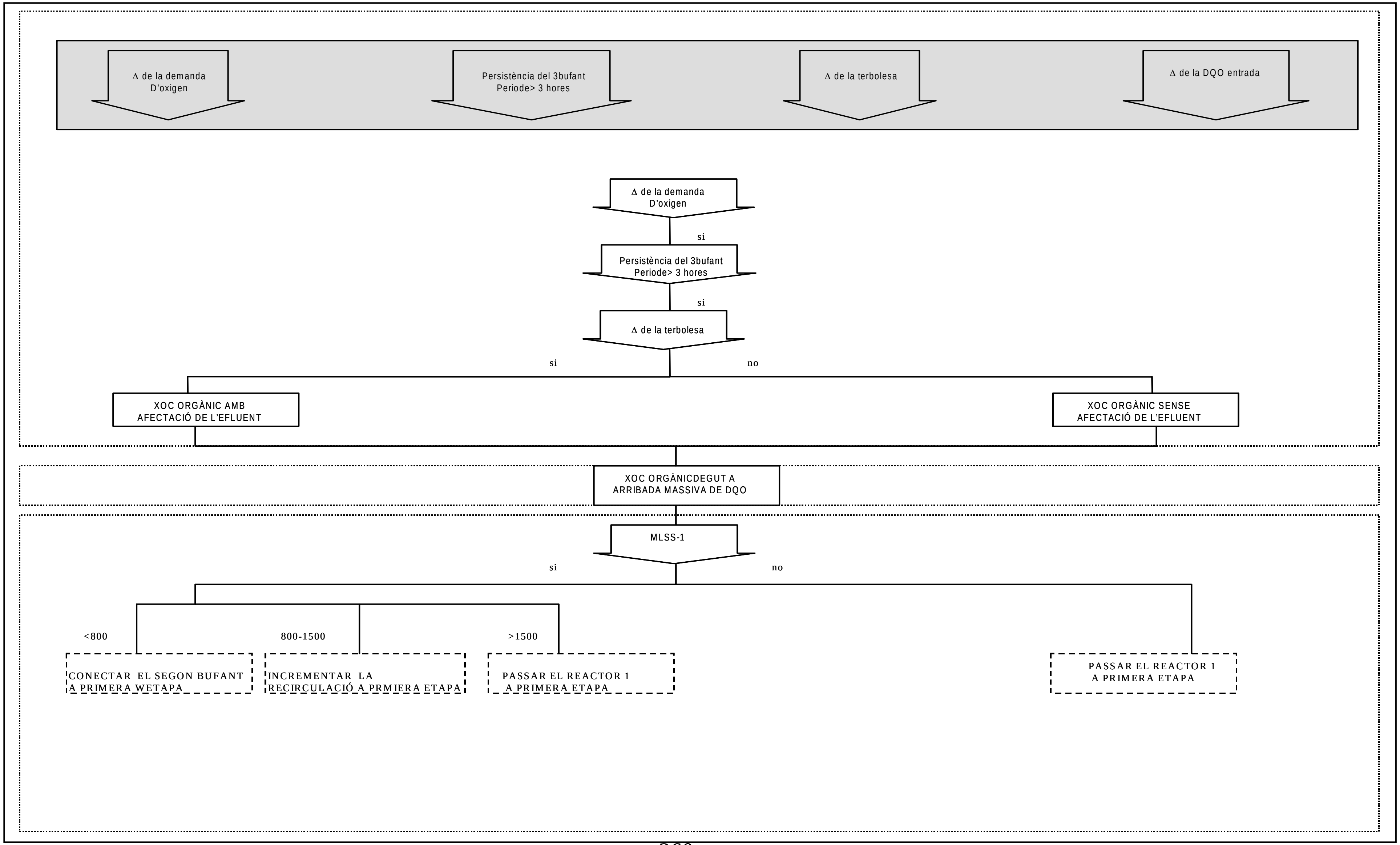

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8. Te problemes relacionats amb influents que suposin a la planta un xoc tòxic

Si ☒
No ☐

1.1. Indicadors que es fan servir i a quins nivells.

Biomassa(MLSS)
☒ alt
☐ mitja
☐ baix
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DQO efluent
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IVF
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☐ mitja
☒ baix
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Edat del fang
☐ alt
☐ mitja
☐ baix
☒ no es rellevant, no es te en compte

concentració OD
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte

Altres
Número de bufants
☒ alt
☐ mitja
☐ baix

☐ no es rellevant, no es te en compte.

Terbolesa
☒ alt
☐ mitja
☐ baix
☐ no es rellevant, no es te en compte

9. Notes addicionals

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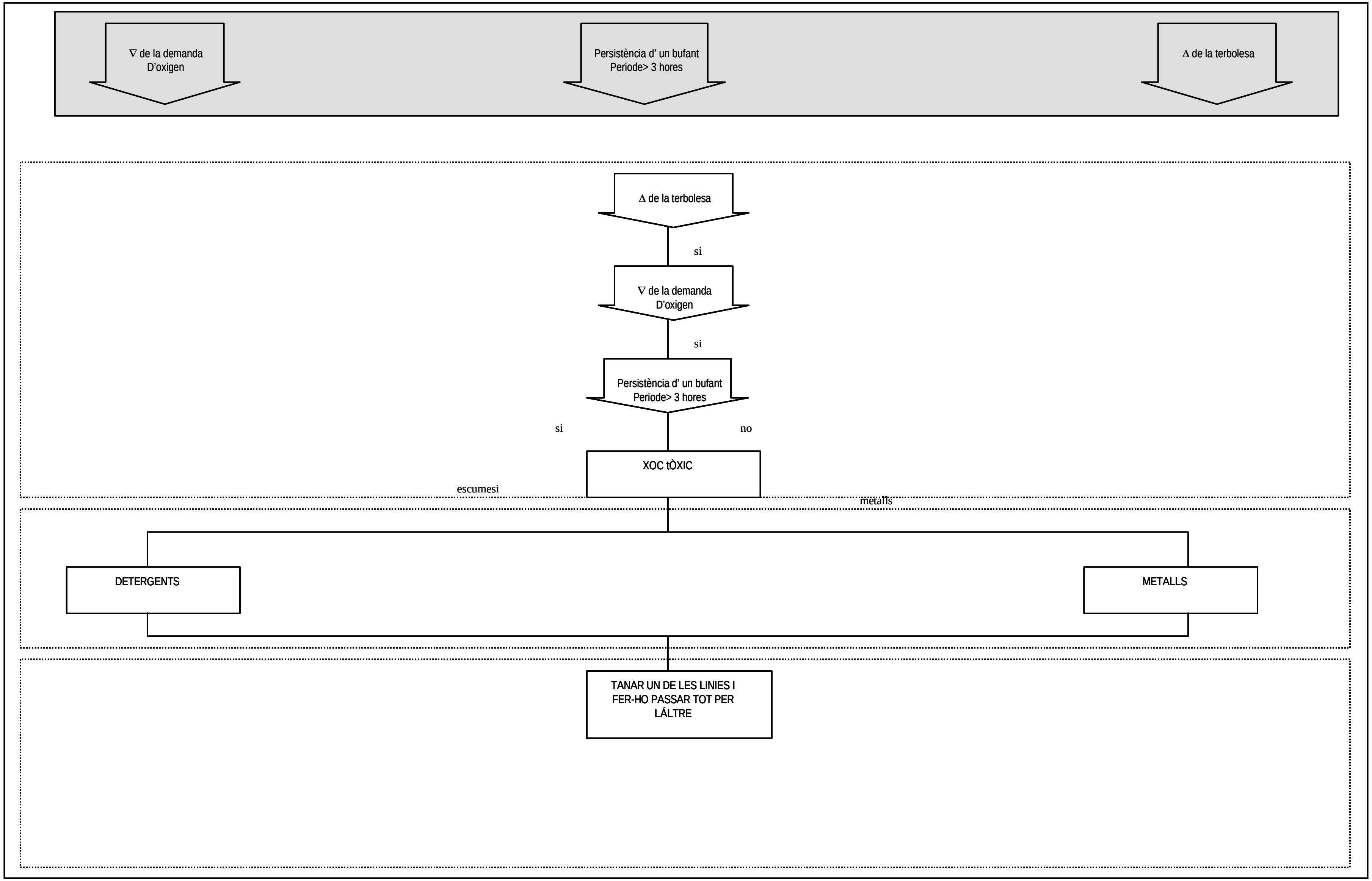


Annex III:On-line data

On-line data from Granollers WWTP:

Number	Name	<Description>
1	DIGITAL_1	
2	ANALOG_1	
3	ALARMA	
4	FIT-9	
5	OIT-8-SP	set-point of disolved oxygen in tank 8
6	OIT-7-SP	set-point of disolved oxygen in tank 7
7	OIT-6-SP	set-point of disolved oxygen in tank 6
8	OIT-5-SP	set-point of disolved oxygen in tank 5
9	OIT-4-SP	set-point of disolved oxygen in tank 4
10	OIT-3-SP	set-point of disolved oxygen in tank 3
11	FIT-3-SP	set-point of air flow in tank 3
12	FIT-3-PV	process value of air flow in tank 3
13	FIT-4-SP	set-point of air flow in tank 4
14	FIT-4-PV	process value of air flow in tank 4
15	FIT-5-SP	set-point of air flow in tank 5
16	FIT-5-PV	process value of air flow in tank 5
17	FIT-6-PV	process value of air flow in tank 6
18	FIT-6-SP	set-point of air flow in tank 6
19	FIT-7-SP	set-point of air flow in tank 7
20	FIT-7-PV	process value of air flow in tank 7
21	FIT-8-SP	set-point of air flow in tank 8
22	FIT-8-PV	process value of air flow in tank 8
23	OIT-7-PV	Process value of dissolved oxygen
24	OIT-8-PV	Process value of dissolved oxygen
25	OIT-2-PV	Process value of dissolved oxygen
26	OIT-1-PV	Process value of dissolved oxygen
27	OIT-5-PV	Process value of dissolved oxygen
28	OIT-3-PV	Process value of dissolved oxygen
29	FIT-10	total air flow in reactor 2
30	TOTAL-AIRE-REACTOR-BIOLOGIC	total ait flow
31	OIT-6-PV	Process value of dissolved oxygen
32	OIT-4-PV	Process value of dissolved oxygen
33	PID-BUFANT-REACTOR-SP	set point of PID of air's pump
34	PID-BUFANT-REACTOR-PV	process value of PID of air's pump
35	BIT-AUTO-SOPLANTE-A-BIOLOG	
36	T_ESPERA_MARCHA_SOPLANTES	
37	T_ESPERA_PARO_SOPLANTES	
38	MAPA	
39	CONFIRMA-MARXA-BAIXA-BUFANT-A	confirmation of low power of air pump
40	HM-CARGOL-ARQU-1	operating time of the screw of arquimedes 1
41	HM-CARGOL-ARQU-2	operating time of the screw of arquimedes 2
42	HM-CARGOL-ARQU-3	operating time of the screw of arquimedes 3
43	HM-REIXA-GRUIX-1	operating time of sieve
44	HM-REIXA-GRUIX-2	operating time of sieve
45	HM-CINTA-GRUIX	operating time of transporting tape
46	HM-CINTA-FINS	operating time of transporting tape
47	HM-CINTA-PREMSA	operating time of transporting tape
48	HM-PREMSA	

Number	Name	<Description>
49	HM-ACUAGUARD1	
50	HM-ACUAGUARD2	
51	HM-AEROGLOT-A	
52	HM-AEROGLOT-B	
53	HM-AEROGLOT-C	
54	HM-AEROGLOT-D	
55	HM-AEROGLOT-E	
56	HM-AEROGLOT-F	
57	HM-AEROGLOT-G	
58	HM-AEROGLOT-H	
59	HM-AEROGLOT-I	
60	HM-AEROGLOT-J	
61	HM-AEROGLOT-K	
62	HM-AEROGLOT-L	
63	HM-SEPARADOR-SORRES	
64	HM-SEPARADOR-GREIXOS	
65	HM-CARGOL-EXTRACTOR-GREIXOS	
66	HM-AGITADOR-MEZCLA-FI-QUI-A	
67	HM-AGITADOR-MEZCLA-FI-QUI-B	
68	HM-AGITADOR-CUBA-FLOCULACIO-A	
69	HM-AGITADOR-CUBA-FLOCULACIO-B	
70	HM-AGITADOR-CUBA-FLOCULACIO-C	
71	HM-AGITADOR-CUBA-FLOCULACIO-D	
72	HM-BOMBEIX-BUIDATS-DRENATGES-1	
73	HM-BOMBEIX-BUIDATS-DRENATGES-2	
74	HM-BOMBEIX-BUIDATS-DRENATGES-3	
75	HM-BOMBEIX-FLOTANTS-1	
76	HM-BOMBEIX-FLOTANTS-2	
77	HM-BOMBEIX-FANGS-PRIMARIS-1	
78	HM-BOMBEIX-FANGS-PRIMARIS-2	
79	HM-BOMBEIX-FANGS-PRIMARIS-3	
80	HM-BOMBEIX-FANGS-ESPESSITS-1	
81	HM-BOMBEIX-FANGS-ESPESSITS-2	
82	HM-BOMBEIX-FANGS-ESPESSITS-3	
83	HM-AGITADOR-GREIXOS-I-FLOTANTS-	
84	HM-AGITADOR-MESCLA-FANG-CALÇ	
85	HM-ESPESSIDOR-1	
86	HM-ESPESSIDOR-2	
87	HM-BOMBEIX-POLI-A-TRACTAMENT-1	
88	HM-BOMBEIX-POLI-A-TRACTAMENT-2	
89	HM-BOMBEIX-POLI-A-TRACTAMENT-3	
90	HM-AGITADOR-POLI-TRACTAMENT-1	
91	HM-AGITADOR-POLI-TRACTAMENT-2	
92	HM-BOMBEIX-POLI-ASSECAMENT-1	
93	HM-BOMBEIX-POLI-ASSECAMENT-2	
94	HM-BOMBEIX-POLI-ASSECAMENT-3	
95	HM-AGITADOR-POLI-ASSECAMENT-1	
96	HM-AGITADOR-POLI-ASSECAMENT-2	
97	HM-BOMBA-DOSIFIC-FE-1	
98	HM-BOMBA-DOSIFIC-FE-2	
99	HM-BOMBA-DOSIFIC-FE-3	

Number	Name	<Description>
100	HM-BOMBA-DOSIFIC-CALÇ-1	
101	HM-BOMBA-DOSIFIC-CALÇ-2	
102	HM-FILTRO-BANDA-1	
103	HM-FILTRO-BANDA-2	
104	HM-REACTOR-FILTRO-BANDA-1	
105	HM-REACTOR-FILTRO-BANDA-2	
106	HM-DESHIDRATADOR-FILTRO-BANDA-1	
107	HM-DESHIDRATADOR-FILTRO-BANDA-2	
108	HM-CINTA-TRANSP-FANG-SEC-FITRE-	
109	HM-AGITADOR-CUBA-CALÇ	
110	HM-BOMBA-NETEJA-FILTRE-BANDA-1	
111	HM-BOMBA-NETEJA-FILTRE-BANDA-2	
112	HM-BOMBA-AIGUA-TRACTADA-1	
113	HM-BOMBA-AIGUA-TRACTADA-2	
114	HM-BOMBA-AIGUA-TRACTADA-3	
115	HM-BUFANT-AIRE-RENTAT	
116	HM-BOMBA-DOSIFIC-HIPOCLORIT	
117	HM-BUFANT-AIREACIO-A	
118	HM-BUFANT-AIREACIO-B	
119	HM-BUFANT-AIREACIO-C	
120	HM-AGITADOR-ANOXIA-A	
121	HM-AGITADOR-ANOXIA-B	
122	HM-AGITADOR-FLOCULACIO-A	
123	HM-AGITADOR-FLOCULACIO-B	
124	HM-DECANTADOR-SECUNDARI-A	
125	HM-DECANTADOR-SECUNDARI-B	
126	HM-BUFANT-BUIT-DECANTADOR-A	
127	HM-BUFANT-BUIT-DECANTADOR-B	
128	HM-BOMBA-BUIDATS-A	
129	HM-BOMBA-BUIDATS-B	
130	HM-BOMBA-FANGS-EXCES-A	
131	HM-BOMBA-FANGS-EXCES-B	
132	HM-MOTOR-CENTRIFUGA-A	
133	HM-MOTOR-CENTRIFUGA-B	
134	HM-CENTRIFUGA-A	
135	HM-CENTRIFUGA-B	
136	HM-CARGOL-TRANSP-1	
137	HM-CARGOL-TRANSP-2	
138	HM-AGITADOR-FANGS-BARREJATS	
139	HM-CALDERA-A	
140	HM-CALDERA-B	
141	HM-VENTILADOR-GASOMETRE	
142	HM-COMPRESSOR-AIRE-SERVEIS-	
143	HM-FLOTADOR-DIGESTIO	
144	HM-TORXA	
145	A-SGA-203-A	automatic gate sga-203-a
146	F-SGA-203-A	failure gate sga-203-a
147	F-RB-201A	
148	F-FIT-7	failure on value of fit of tank 7
149	F-FIT-6	failure on value of fit of tank 6
150	F-FIT-5	failure on value of fit of tank 5

Number	Name	<Description>
151	F-FIT-4	failure on value of fit of tank 4
152	F-FIT-3	failure on value of fit of tank 3
153	F-OIT-8	failure on value of oit-8
154	F-OIT-7	failure on value of oit-7
155	F-OIT-6	failure on value of oit-6
156	F-OIT-5	failure on value of oit-5
157	F-OIT-4	failure on value of oit-4
158	F-OIT-3	failure on value of oit-3
159	F-OIT-2	failure on value of oit-2
160	F-OIT-1	failure on value of oit-1
161	F-FIT-9	failure of FIT 9
162	F-FIT-10	failure of FIT 10
163	A-RB-201A	
164	A-SGA-201	automatic gate sga-201(regulation flow gate)
165	AB-SGA-202	open gate sga-202
166	CE-SGA-202	closed gate sga 202
167	F-SGA-202	failure gate sga 202
168	A-SGA-202	automatic gate 202
169	AB-SGA-203-A	open gate sga-203-a
170	CE-SGA-203-A	closed gate sga 203a
171	AB-SGA-203-B	open
172	CE-SGA-203-B	closed
173	F-SGA-203-B	failure
174	A-SGA-203-B	automatic
175	AB-SGA-204-A	open
176	CE-SGA-204-A	closed
177	F-SGA-204-A	failure
178	A-SGA-204-A	automatic
179	AB-SGA-204-B	open
180	CE-SGA-204-B	closed
181	F-SGA-204-B	failure
182	A-SGA-204-B	automatic
183	CAR-RB-201-A	confirmation of starter
184	FAR-RB-201-A	failure of starter
185	RES-RB-201-A	
186	CVB-RB-201-A	confirmation of low velocity
187	CVA-RB-201-A	confirmation of high velocity
188	A-RB-201-A	automatic starter
189	CAR-RB-201B	
190	FAR-RB-201B	
191	RES-RB-201B	
192	F-RB-201-B	
193	CVB-RB-201-B	
194	CVA-RB-201-B	
195	A-RB-201-B	
196	CAR-RB-201-C	
197	FAR-RB-201-C	
198	RES-RB-201-C	
199	F-RB-201-C	
200	CVB-RB-201-C	
201	CVA-RB-201-C	

Number	Name	<Description>
202	A-RB-201-C	
203	C-HF-201-A	
204	F-HF-201-A	
205	A-HF-201-A	
206	C-HF-201-B	
207	F-HF-201-B	
208	A-HF-201-B	
209	C-HF-201-C	
210	F-HF-201-C	
211	A-HF-201-C	
212	C-PS-201-A	annoxia mixer closed
213	F-PS-201-A	annoxia mixer failure
214	A-PS-201-A	annoxia mixer open
215	C-PS-201-B	annoxia mixer closed
216	F-PS-201-B	annoxia mixer failure
217	A-PS-201-B	annoxia mixer open
218	C-PS-202-A	floculation mixer closed
219	F-PS-202-A	floculation mixer failure
220	A-PS-202-A	floculation mixer open
221	C-PS-202-B	floculation mixer closed
222	F-PS-202-B	floculation mixer failure
223	A-PS-202-B	floculation mixer open
224	C-MR-201-A	secondary settler closed
225	F-MR-201-A	secondary settler failure
226	A-MR-201-A	secondary settler open
227	C-MR-201-B	secondary settler closed
228	F-MR-201-B	secondary settler failure
229	A-MR-201-B	secondary settler open
230	C-RB-202-A	
231	F-RB-202-A	
232	A-RB-202-A	
233	C-RB-202-B	
234	F-RB-202-B	
235	A-RB-202-B	
236	C-SP-201-A	drained pump closed
237	F-SP-201-A	drained pump failure
238	A-SP-201-A	drained pump open
239	C-SP-201-B	drained pump closed
240	F-SP-201-B	drained pump failure
241	A-SP-201-B	drained pump open
242	C-CP-201-A	closed
243	F-CP-201-A	failure
244	A-CP-201-A	open
245	C-CP-201-B	closed
246	F-CP-201-B	failure
247	A-CP-201-B	open
248	F-SP-203-A	pump failure
249	F-SP-203-B	pump failure
250	F-SP-203-C	pump failure
251	F-SP-203-D	pump failure
252	C-SP-202-A	recirculation sludge pump closed

Number	Name	<Description>
253	F-SP-202-A	recirculation sludge pump failure
254	A-SP-202-A	recirculation sludge pump open
255	C-SP-202-B	recirculation sludge pump closed
256	F-SP-202-B	recirculation sludge pump failure
257	A-SP-202-B	recirculation sludge pump open
258	C-SP-202-C	recirculation sludge pump closed
259	F-SP-202-C	recirculation sludge pump failure
260	A-SP-202-C	recirculation sludge pump open
261	C-CP-202-A	excess of sludge closed
262	F-CP-202-A	excess of sludge failure
263	A-CP-202-A	excess of sludge open
264	C-CP-202-B	excess of sludge closed
265	F-CP-202-B	excess of sludge failure
266	A-CP-202-B	excess of sludge open
267	LSL-201-BOM-FILTRE-SORRA	
268	LSH-203_BOMBA_VUIDATS	
269	LSL-202_BOMBA_VUIDATS	
270	LSL-204_BOMBA_RECIRCUL	
271	LSL-216_BOMBA_FANG_EXCES	
272	AB-SVA-501	
273	A-SVA-501	electrovalve automatic
274	PA-SGA201	pulser open
275	PA-SGA202	pulser open
276	PA-SGA203-A	pulser open
277	PA-SGA203-B	pulser open
278	PA-SGA204-A	pulser open
279	PA-SGA204-B	pulser open
280	P-HF-201-A	pulser run-stop
281	P-HF-201-B	pulser run-stop
282	P-HF-201-C	pulser run-stop
283	P-PS-201-A	pulser run-stop
284	P-PS-201-B	pulser run-stop
285	P-PS-202-A	pulser run-stop
286	P-PS-202-B	pulser run-stop
287	P-MR-201-A	pulser run-stop
288	P-MR-201-B	pulser run-stop
289	P-RB-202-A	pulser run-stop
290	P-RB-202-B	pulser run-stop
291	P-SP-201-A	pulser run-stop
292	P-SP-201-B	pulser run-stop
293	P-CP-201-A	pulser run-stop
294	P-CP-201-B	pulser run-stop
295	P-SP-202-A	pulser run-stop
296	P-SP-202-B	pulser run-stop
297	P-SP-202-C	pulser run-stop
298	P-CP-202-A	pulser run-stop
299	P-CP-202-B	pulser run-stop
300	X-SGA-201	
301	X-RB-201-A	
302	X-RB-201-B	
303	X-RB-201-C	

Number	Name	<Description>
304	X-HF-201-A	
305	X-HF-201-B	
306	X-HF-201-C	
307	X-PS-201-A	
308	X-PS-201-B	
309	X-PS-202-A	
310	X-PS-202-B	
311	X-MR-201-A	
312	X-MR-201-B	
313	X-RB-202-A	
314	X-RB-202-B	
315	X-SP-201-A	
316	X-SP-201-B	
317	X-CP-201-A	
318	X-CP-201-B	
319	X-SP-202-A	
320	X-SP-202-B	
321	X-SP-202-C	
322	X-CP-202-A	
323	X-CP-202-B	
324	FIT-205	recirculation flow
325	HM-HF-201-B	
326	HM-HF-201-C	
327	HM-HF-201-A	
328	ZONAS1	
329	PULSADOR_PRUEBA	
330	CERRAR_VENTANA	
331	HM-MR-201-A	
332	HM-MR-201-B	
333	PROBAS	
334	ON	
335	1	
336	HM-MR-202	
337	P-MR-202	
338	X-MR-202	
339	F-MR-202	
340	T-M-MR-202	
341	T-P-MR-202	
342	T-PERM-MR-202	
343	A-MR-202	
344	C-MR-202	
345	T-OBERTURA-DVA-501	
346	T-TANCAMENT-DVA-501	
347	T-PERMANENCIA-SVA-505	
348	FIT-204	
349	TOT-FIT-204	
350	LSLL--207	
351	LSL--207	
352	LSH--207	
353	AB-SVA-502	
354	AB-SVA-503	

Number	Name	<Description>
355	A-SVA-503	
356	P-SVA-503	
357	X-SVA-503	
358	A-GVA-501	
359	AB-GVA-501	
360	CE-GVA-501	
361	X-GVA-501	
362	P-GVA-501	
363	A-SVA-502	
364	P-SVA-502	
365	X-SVA-502	
366	LT-205	
367	POTENCIOMETRO	
368	LSLL-LT205	
369	LSHH-LT205	
370	LSH-LT205	
371	LSL-LT205	
372	LSAH-LT205	
373	AB-DVA-501	
374	CE-DVA-501	
375	A-DVA-501	
376	X-DVA-501	
377	P-DVA-501	
378	X-PS-203	
379	P-PS-203	
380	A-PS-203	
381	F-PS-203	
382	C-PS-203	
383	T-OBERTURA-DVA-502-A-B	electrovalve
384	T-TANCAMENT-DVA-502-A-B	electrovalve
385	P-DVA-502-A	electrovalve
386	X-DVA-502-A	electrovalve
387	A-DVA-502-A	electrovalve
388	C-DVA-502-A	electrovalve
389	P-DVA-502-B	electrovalve
390	X-DVA-502-B	electrovalve
391	A-DVA-502-B	electrovalve
392	C-DVA-502-B	electrovalve
393	HM-TP201-A	
394	HM-TP201-B	
395	HM-TP201-C	
396	X-TP201-A	sludge to digestor
397	P-TP201-A	sludge to digestor
398	C-TP201-A	sludge to digestor
399	A-TP201-A	sludge to digestor
400	F-TP201-A	sludge to digestor
401	X-TP201-B	sludge to digestor
402	P-TP201-B	sludge to digestor
403	C-TP201-B	sludge to digestor
404	F-TP201-B	sludge to digestor
405	A-TP201-B	sludge to digestor

Number	Name	<Description>
406	X-TP201-C	sludge to digestor
407	P-TP201-C	sludge to digestor
408	C-TP201-C	sludge to digestor
409	F-TP201-C	sludge to digestor
410	A-TP201-C	sludge to digestor
411	FIT-206-A	sludge to digestor flow
412	TOT-FIT-206-A	sludge to digestor flow
413	FIT-206-B	sludge to digestor flow
414	TOT-FIT-206-B	sludge to digestor flow
415	TT-201-A	
416	TT-201-B	
417	TT-202-A	
418	TT-202-B	
419	DIGITAL_2	<Action gate:ON/OFF,OPEN/CLOSE>
420	ANALOG_5	<Action gate:FILL,MOVE, ROTATE>
421	ANALOG_2	<Action gate:FILL,MOVE, ROTATE>
422	P-CP-203	
423	X-CP-203	
424	F-CP-203	
425	C-CP-203	
426	A-CP-203	
427	HM-CP-203	
428	HM-TP-202-A	
429	HM-TP-202-B	
430	HM-TP-202-C	
431	HM-TP-202-D	
432	HM-TP-202-E	
433	A-PS-204	
434	C-PS-204	
435	F-PS-204	
436	X-PS-204	
437	P-PS-204	
438	P-CF-201	
439	X-CF-201	
440	F-CF-201	
441	C-CF-201	
442	A-CF-201	
443	P-TP-202-A	sludge to dry
444	X-TP-202-A	sludge to dry
445	F-TP-202-A	sludge to dry
446	C-TP-202-A	sludge to dry
447	A-TP-202-A	sludge to dry
448	P-TP-202-B	sludge to dry
449	X-TP-202-B	sludge to dry
450	F-TP-202-B	sludge to dry
451	C-TP-202-B	sludge to dry
452	A-TP-202-B	sludge to dry
453	P-TP-202-C	sludge to dry
454	X-TP-202-C	sludge to dry
455	F-TP-202-C	sludge to dry
456	C-TP-202-C	sludge to dry

Number	Name	<Description>
457	A-TP-202-C	sludge to dry
458	P-TP-202-D	sludge to dry
459	X-TP-202-D	sludge to dry
460	F-TP-202-D	sludge to dry
461	C-TP-202-D	sludge to dry
462	A-TP-202-D	sludge to dry
463	P-TP-202-E	sludge to dry
464	X-TP-202-E	sludge to dry
465	F-TP-202-E	sludge to dry
466	C-TP-202-E	sludge to dry
467	A-TP-202-E	sludge to dry
468	LT-206	sludge stored
469	LSHH-LT-206	sludge stored
470	LSH-LT-206	sludge stored
471	LSL-LT-206	sludge stored
472	LSLL-LT-206	sludge stored
473	HM-PS-204	sludge stored
474	Q_AFEGIT_SOPLANTS	plus air flow in reactor
475	SO_RB201_A	
476	P_REACTOR_1	
477	P-SVA-501	electrovalve
478	X-SVA-501	electrovalve
479	FIT-207-A	sludge to dry flow
480	FIT-207-B	sludge to dry flow
481	FIT-208-A	sludge to dry flow
482	FIT-208-B	sludge to dry flow
483	T1-CT-201-A	time centrifuge
484	T2-CT-201-A	time centrifuge
485	T3-CT-201-A	time centrifuge
486	T4-CT-201-A	time centrifuge
487	T5-CT-201-A	time centrifuge
488	T6-CT-201-A	time centrifuge
489	T7-CT-201-A	time centrifuge
490	T8-CT-201-A	time centrifuge
491	T9-CT-201-A	time centrifuge
492	T10-CT-201-A	time centrifuge
493	T11-CT-201-A	time centrifuge
494	T12-CT-201-A	time centrifuge
495	T13-CT-201-A	time centrifuge
496	T14-CT-201-A	time centrifuge
497	T15-CT-201-A	time centrifuge
498	T16-CT-201-A	time centrifuge
499	T17-CT-201-A	time centrifuge
500	T18-CT-201-A	time centrifuge
501	T19-CT-201-A	time centrifuge
502	T20-CT-201-A	time centrifuge
503	T21-CT-201-A	time centrifuge
504	T22-CT-201-A	time centrifuge
505	T1-CT-201-B	time centrifuge
506	T2-CT-201-B	time centrifuge
507	T3-CT-201-B	time centrifuge

Number	Name	<Description>
508	T4-CT-201-B	time centrifuge
509	T5-CT-201-B	time centrifuge
510	T6-CT-201-B	time centrifuge
511	T7-CT-201-B	time centrifuge
512	T8-CT-201-B	time centrifuge
513	T9-CT-201-B	time centrifuge
514	T10-CT-201-B	time centrifuge
515	T11-CT-201-B	time centrifuge
516	T12-CT-201-B	time centrifuge
517	T13-CT-201-B	time centrifuge
518	T14-CT-201-B	time centrifuge
519	T15-CT-201-B	time centrifuge
520	T16-CT-201-B	time centrifuge
521	T17-CT-201-B	time centrifuge
522	T18-CT-201-B	time centrifuge
523	T19-CT-201-B	time centrifuge
524	T20-CT-201-B	time centrifuge
525	T21-CT-201-B	time centrifuge
526	T22-CT-201-B	time centrifuge
527	C-CT-201-A	confirmation of centrifuge a
528	C-CT-201-B	confirmation of centrifuge b
529	P-CT-201-A	
530	P-CT-201-B	
531	PS-CT-201-A	
532	PL-CT-201-A	
533	PAL-CT-201-A	
534	X-CT-201-A	
535	X-CT-201-B	
536	F-CT-201-A	
537	F-CT-201-B	
538	P-BC-202	
539	X-BC-202	
540	A-BC-202	
541	C-BC-202	
542	F-BC-202	
543	P-BC-201	
544	X-BC-201	
545	F-BC-201	
546	C-BC-201	
547	A-BC-201	
548	C-BC003	
549	A-SVA-506-A	electrovalve
550	P-SVA-506-A	electrovalve
551	X-SVA-506-A	electrovalve
552	C-SVA-506-A	electrovalve
553	A-SVA-506-B	electrovalve
554	P-SVA-506-B	electrovalve
555	X-SVA-506-B	electrovalve
556	C-SVA-506-B	electrovalve
557	C-T-202-AGITADOR_1	
558	C-T-202-AGITADOR_2	

Number	Name	<Description>
559	C-T-202-DOSIFICADOR	
560	LSLL-T-202	
561	LSLL-T-201	
562	C-T-201-DOSIFICADOR	
563	C-T-201-AGITADOR-1	
564	C-T-201-AGITADOR-2	
565	HM-T-202-AGITADOR_1	
566	HM-T-202-AGITADOR-2	
567	X-TP-203-A	
568	P-TP-203-A	
569	A-TP-203-A	
570	C-TP-203-A	
571	F-TP-203-A	
572	X-TP-203-B	
573	P-TP-203-B	
574	A-TP-203-B	
575	C-TP-203-B	
576	F-TP-203-B	
577	HM-TP-203-A	
578	HM-TP-203-B	
579	HM-T-201-AGITADOR-1	
580	HM-T-201-AGITADOR-2	
581	X-TP-204-A	
582	P-TP-204-A	
583	A-TP-204-A	
584	C-TP-204-A	
585	F-TP-204-A	
586	X-TP-204-B	
587	P-TP-204-B	
588	F-TP-204-B	
589	A-TP-204-B	
590	C-TP-204-B	
591	HM-TP-204-A	
592	HM-TP-204-B	
593	X-PAC-201-A	
594	P-PAC-201-A	
595	F-PAC-201-A	
596	A-PAC-201-A	
597	C-PAC-201-A	
598	X-PAC-201-B	
599	P-PAC-201-B	
600	A-PAC-201-B	
601	C-PAC-201-B	
602	F-PAC-201-B	
603	X-PAC-201-C	
604	P-PAC-201-C	
605	A-PAC-201-C	
606	C-PAC-201-C	
607	F-PAC-201-C	
608	HM-PAC-201-A	
609	HM-PAC-201-B	

Number	Name	<Description>
610	HM-PAC-201-C	
611	X-SVA-504-A	electrovalve
612	P-SVA-504-A	electrovalve
613	A-SVA-504-A	electrovalve
614	C-SVA-504-A	electrovalve
615	X-SVA-504-B	electrovalve
616	P-SVA-504-B	electrovalve
617	A-SVA-504-B	electrovalve
618	C-SVA-504-B	electrovalve
619	X-SVA-504-C	electrovalve
620	P-SVA-504-C	electrovalve
621	A-SVA-504-C	electrovalve
622	C-SVA-504-C	electrovalve
623	X-PAC-202-A	
624	P-PAC-202-A	
625	F-PAC-202-A	
626	A-PAC-202-A	
627	C-PAC-202-A	
628	X-PAC-202-B	
629	P-PAC-202-B	
630	F-PAC-202-B	
631	A-PAC-202-B	
632	C-PAC-202-B	
633	X-PAC-202-C	
634	P-PAC-202-C	
635	F-PAC-202-C	
636	A-PAC-202-C	
637	C-PAC-202-C	
638	HM-PAC-202-A	
639	HM-PAC-202-B	
640	HM-PAC-202-C	
641	C-DE-201-A	
642	C-DE-201-B	
643	F-ME-201-A-CREMADOR	
644	F-ME-201-A-VENTILADOR	
645	F-ME-201-B-CREMADOR	
646	F-ME-201-B-VENTILADOR	
647	C-ME-201-A-	
648	C-ME-201-B-	
649	X-CP-204-A	hot water pump
650	P-CP-204-A	hot water pump
651	F-CP-204-A	hot water pump
652	A-CP-204-A	hot water pump
653	C-CP-204-A	hot water pump
654	X-CP-204-B	hot water pump
655	P-CP-204-B	hot water pump
656	F-CP-204-B	hot water pump
657	A-CP-204-B	hot water pump
658	C-CP-204-B	hot water pump
659	X-CP-204-C	hot water pump
660	P-CP-204-C	hot water pump

Number	Name	<Description>
661	F-CP-204-C	hot water pump
662	A-CP-204-C	hot water pump
663	C-CP-204-C	hot water pump
664	HM-CP-204-A	
665	HM-CP-204-B	
666	HM-CP-204-C	
667	X-HF-202	
668	P-HF-202	
669	F-HF-202	
670	A-HF-202	
671	C-HF-202	
672	HM-HF-202	
673	HM-CF-202	
674	C-IT-201-A	
675	C-IT-201-B	
676	HM-CP-205-A	recirculation sludge pump
677	HM-CP-205-B	recirculation sludge pump
678	HM-CP-205-C	recirculation sludge pump
679	X-CP-205-A	recirculation sludge pump
680	P-CP-205-A	recirculation sludge pump
681	F-CP-205-A	recirculation sludge pump
682	A-CP-205-A	recirculation sludge pump
683	C-CP-205-A	recirculation sludge pump
684	X-CP-205-B	recirculation sludge pump
685	P-CP-205-B	recirculation sludge pump
686	F-CP-205-B	recirculation sludge pump
687	A-CP-205-B	recirculation sludge pump
688	C-CP-205-B	recirculation sludge pump
689	X-CP-205-C	recirculation sludge pump
690	P-CP-205-C	recirculation sludge pump
691	F-CP-205-C	recirculation sludge pump
692	A-CP-205-C	recirculation sludge pump
693	C-CP-205-C	recirculation sludge pump
694	HM-SP-202-A	operation time of recirculation sludge pump
695	HM-SP-202-B	operation time of recirculation sludge pump
696	HM-SP-202-C	operation time of recirculation sludge pump
697	NUMERO_ALARMA	
698	TEMPORIZA_10_S	
699	X-BVA-502	
700	PA-BVA-502	
701	PC-BVA-502	
702	FMAB-BVA-502	
703	FMCE-BVA-502	
704	F-BVA-502	
705	A-BVA-502	
706	AB-BVA-502	
707	CE-BVA-502	
708	A-AT201	
709	C-AT201	
710	F-AT201	
711	LT-217	

Number	Name	<Description>
712	LSLL-LT-217	
713	LSL-LT-217	
714	LSH-LT-217	
715	LSHH-LT-217	
716	ALARMA-LSL-DMT-201	
717	ALARMA-LSH-DMT-201	
718	ALARMA-LSHH-DMT-201	
719	FIT-209	
720	FIT-210	
721	TOT-FIT-208-A	total
722	TOT-FIT-208-B	total
723	TOT-FIT-207-A	total
724	TOT-FIT-207-B	total
725	TOT-FIT-209	total
726	TOT-FIT-210	total
727	FIT-201	biological inflow
728	FIT-202	treated water flow
729	FE-04	water by-pass flow
730	TOT-FE-04	total water by-pass
731	TOT-FIT-202	total flow
732	TOT-FIT-205	total flow
733	TOT-FIT-201	total flow
734	AB-SGA201	% opening of gate sga-201
735	T-SGA-201	time of delay
736	Q-SGA-201	set-point of flow in gate sga201
737	C-POLI-FLOTACIO	
738	AB-SG001	gate open
739	CE-SG001	gate closed
740	A-SG002-A	gate automatic
741	AB-SG002-A	gate open
742	CE-SG002-A	gate closed
743	A-SG002-B	gate automatic
744	AB-SG002-B	gate open
745	CE-SG002-B	gate closed
746	A-SG002-C	gate automatic
747	AB-SG002-C	gate open
748	CE-SG002-C	gate closed
749	C-TP001-A	cornfirmation of archimedes screw 1
750	A-TP001-A	archimedes 1 automatic
751	C-TP001-B	cornfirmation of archimedes screw 2
752	A-TP001-B	archimedes 2 automatic
753	LSL-TP001-A	
754	LSL-TP001-B	
755	C-TP001-C	cornfirmation of archimedes screw 3
756	A-TP001-C	archimedes 3 automatic
757	LSL-TP001-C	
758	A-SG003-A	automatic gate sg-003
759	AB-SG003-A	gate open
760	CE-SG003-A	gate closed
761	A-SG003-B	gate automatic
762	AB-SG003-B	gate open

Number	Name	<Description>
763	CE-SG003-B	gate closed
764	A-SG004	gate automatic
765	AB-SG004	gate open
766	CE-SG004	gate closed
767	C-RR002-A	
768	A-RR002-A	
769	C-RR002-B	
770	A-RR002-B	
771	C-BC001-A	
772	C-RT001-A	
773	A-RT001-A	
774	LSH-RT001-A	
775	C-RT001-B	
776	A-RT001-B	
777	LSH-RT001-B	
778	C-BG001-B	
779	C-BC001-C	
780	C-ME001	
781	A-SG005-A	gate automatic
782	AB-SG005-A	gate open
783	CE-SG005-A	gate closed
784	A-SG005-B	gate automatic
785	AB-SG005-B	gate open
786	CE-SG005-B	gate closed
787	A-SG005-C	gate automatic
788	AB-SG005-C	gate open
789	CE-SG005-C	gate closed
790	C-NP001-B	confirmation operating aeroflot
791	C-NP001-C	confirmation operating aeroflot
792	C-NP001-D	confirmation operating aeroflot
793	C-NP001-E	confirmation operating aeroflot
794	C-NP001-F	confirmation operating aeroflot
795	C-NP001-G	confirmation operating aeroflot
796	C-NP001-H	confirmation operating aeroflot
797	C-NP001-I	confirmation operating aeroflot
798	C-NP001-J	confirmation operating aeroflot
799	C-NP001-L	confirmation operating aeroflot
800	C-NP001-K	confirmation operating aeroflot
801	C-AS001	
802	C-MSG001	
803	C-TP002	
804	A-SG008	gate automatic
805	AB-SG008	gate open
806	CE-SG008	gate closed
807	A-SG013	gate automatic
808	AB-SG013	gate open
809	CE-SG013	gate closed
810	A-AERACION-DS1	
811	A-AERACION-DS2	
812	LSHH-PGAB	
813	AB-SV001	

Number	Name	<Description>
814	S-ABCBP	
815	C-CUCHARA	
816	M-FT-AB	
817	A-SG009-A	gate automatic
818	AB-SG009-A	gate open
819	CE-SG009-A	gate closed
820	A-SG009-B	gate automatic
821	AB-SG009-B	gate open
822	CE-SG009-B	gate closed
823	A-SG010	gate automatic
824	AB-SG010	gate open
825	CE-SG010	gate closed
826	C-PS001-A	
827	C-PS002-A	
828	C-PS002-B	
829	C-PS001-B	
830	C-PS002-C	
831	C-PS002-D	
832	A-SG012	
833	AB-SG012	
834	CE-SG012	
835	A-SG011-A	
836	AB-SG011-A	
837	CE-SG011-A	
838	A-SG011-B	
839	AB-SG011-B	
840	CE-SG011-B	
841	C-SP002-A	
842	C-SP002-B	
843	C-SP002-C	
844	C-DC001-A	
845	C-DC001-B	
846	C-SP001-A	
847	LSL-SP001-A	
848	LSH-SP001-A	
849	C-SP001-B	
850	C-PS003	
851	C-CP002-A	
852	C-CP002-B	
853	C-CP002-C	
854	C-PS004	
855	C-FE001-A	
856	C-FE001-B	
857	C-FB001-A	
858	C-FB001-B	
859	C-TP003-A	
860	C-TP003-B	
861	C-TP003-C	
862	C-DP003-A	
863	C-DP003-B	
864	C-DP003-C	

Number	Name	<Description>
865	C-BC002-X	
866	C-BC003-X	
867	C-SV004-A	
868	C-SV004-B	
869	F-CUADRO	
870	LSH-CF-1	
871	LSL-CF-1	
872	LSH-CF-2	
873	LSL-CF-2	
874	C-CP001	
875	C-DPP001-A	
876	C-DPP001-B	
877	C-DPP001-C	
878	LSLL-AT-1	
879	LSL-AT-1	
880	LSH-AT-1	
881	LSHH-AT-1	
882	C-DPP002-A	
883	C-DPP002-B	
884	C-DPP002-C	
885	LSL-CC	
886	LSM-CC	
887	LSH-CC	
888	C-FM001	
889	C-MV001	
890	C-DV002	
891	C-PS005	
892	C-CP003-A	
893	C-CP003-B	
894	LSLL-BV	
895	LSL-BV	
896	LSH-BV	
897	LSHH-BV	
898	LSHH-SG	
899	A-FB1	
900	A-FB2	
901	C-PSL20	
902	LSLL-PTF	
903	LSL-PTF	
904	LSH-PTF	
905	LSHH-PTF	
906	C-DU003	
907	C-EDP002-A	
908	C-EDP002-B	
909	C-SV003	
910	C-RFB1	
911	C-RFB2	
912	C-DFB1	
913	C-DFB2	
914	C-DV001	
915	C-EDP001-A	

Number	Name	<Description>
916	C-EDP001-B	
917	C-SV002	
918	C-SV010	
919	C-SV005	
920	C-SV006	
921	C-SV007	
922	C-SV008	
923	C-SV009	
924	LSL-16	
925	LSH-16	
926	C-AS1	
927	C-AS2	
928	AB-EVSILO	
929	CE-EVSILO	
930	C-BLT1	
931	C-BLT2	
932	C-B3R1	
933	C-B3R2	
934	C-BP3R1	
935	C-BP3R2	
936	X-TP001-A	
937	X-TP001-B	
938	X-TP001-C	
939	P-TP001-A	
940	P-TP001-B	
941	P-TP001-C	
942	X-RR002-A	
943	X-RR002-B	
944	X-RT001-A	
945	X-RT001-B	
946	P-RR002-A	
947	P-RR002-B	
948	P-RT001-A	
949	P-RT001-B	
950	TM-RR002	
951	TP-RR002	
952	TM-RT001	
953	TP-RT001	
954	TM-AS001	
955	TP-AS001	
956	PA-SG001	
957	PA-SG002-A	
958	PA-SG002-B	
959	PA-SG002-C	
960	PA-SG003-A	
961	PA-SG003-B	
962	PA-SG004	
963	PA-SG005-A	
964	PA-SG005-B	
965	PA-SG005-C	
966	PA-SG006-A	

Number	Name	<Description>
967	PA-SG006-B	
968	PA-SG007	
969	PA-SG008	
970	PA-SG013	
971	PA-SG009-A	
972	PA-SG009-B	
973	PA-SG010	
974	PA-SG012	
975	PA-SG011-A	
976	PA-SG011-B	
977	P-PS001-A	
978	P-PS002-A	
979	P-PS002-B	
980	P-PS001-B	
981	P-PS002-C	
982	P-PS002-D	
983	P-DC001-A	
984	P-DC001-B	
985	P-CP002	
986	TM-CP002	
987	TP-CP002	
988	P-FE001-A	
989	P-FE001-B	
990	P-SV008	
991	P-SV009	
992	TR-SV006	
993	FIT-FE003	
994	PH-PHE03	
995	TOT-FE003	
996	TOT-FE1	
997	TOT-FE2	
998	F-PS001-A	
999	F-PS002-A	
1000	F-PS002-B	
1001	F-PS001-B	
1002	F-PS002-C	
1003	F-PS002-D	
1004	F-DC001-A	
1005	F-DC001-B	
1006	F-FE001-A	
1007	F-FE001-B	
1008	C-CP005-A	
1009	C-CP005-B	
1010	C-CP005-C	
1011	C-RB001	
1012	HM-CP-201-A	
1013	HM-CP-201-B	
1014	FIT-FE012-A	
1015	FIT-FE012-B	
1016	FIT-FE012-A_ACUMULAT	
1017	FIT-FE012-B_ACUMULAT	

Number	Name	<Description>
1018	FIT-FE003-ACUMULAT	
1019	FE-04-ACUMULAT	
1020	REPORT	
1021	Ñ	
1022	DIA_INICIO	
1023	DIA_FINAL	
1024	DATE	
1025	D1	
1026	D2	
1027	SV-001	
1028	FECHA	
1029	START_DATE	
1030	FECHA_INICIO	
1031	END_DATE	
1032	FECHA_FIN	
1033	CABAL_OIT1	
1034	CABAL_OIT2	
1035	SP_PID_RECIRCULACIO	
1036	PV_PID_RECIRCULACIO	
1037	F_VARIADOR_SP-202A	
1038	C_VARIADOR_SP-202A	
1039	DDE	
1040		
1041		
1042		
1043		
1044		
1045		
1046	SP DEL pid sonda solids	set point of pid of solids sensor
1047	A 1 ESTÀ EN MARXA	
1048	A 1 ESTÀ EN MARXA	
1049	A 1 ESTÀ ATURAT	
1050	A 1 ESTÀ ATURAT	
1051	MITJA 24H SOLIDS	process value of solids in mixed liquor
1052	SP-SP-500-A	
1053	SP-SP-500-B	

Online data from Montornès WWTP:

Equip	*Elements*	*Number*
Comporta reguladora d'entrada	Oberta	1
	Tancada	2
	% Obertura	3
Bomba de elevació 1 del Bombament d'entrada	Confirmació Marxa	4
	No Avaria	5
Bomba de elevació 2 del Bombament d'entrada	Confirmació Marxa	6
	No Avaria	7
Bomba de elevació 3 del Bombament d'entrada	Confirmació Marxa	8
	No Avaria	9
Variador de freqüencia del Bombament	Confirmació Marxa	10
	Avaria	11
Cabalímetre d'entrada a planta	Cabal instantani	12
	Totalitzador	13

Equip	Elements	Number
Comporta Entrada Dessorrador A	Oberta	14
	Tancada	15
Comporta Entrada Dessorrador B	Oberta	16
	tancada	17
Aeroflots 1 Linea A	Confirmació Marxa	18
	No Avaria	19
Aeroflots 2 Linea A	Confirmació Marxa	20
	No Avaria	21
Aeroflots 1 Linea B	Confirmació Marxa	22
	No Avaria	23
Aeroflots 2 Linea B	Confirmació Marxa	24
	No Avaria	25
Pont Degreixador A	Confirmació Marxa	26
	Avaria	27
Pont Degreixador B	Confirmació Marxa	28
	Avaria	29

REACTOR DE PRIMERA ETAPA

Equip	*Elements*	Number
Comporta Entrada a Reactor A	Oberta	30
	Tancada	31
Comporta Entrada Dessorrador B	Oberta	32

	Tancada	33
Agitador 1 Biológic A Primera Etapa	Confirmació Marxa	34
	No Avaria	35
Agitador 2 Biológic A Primera Etapa	Confirmació Marxa	36
	No Avaria	37
Agitador 1 Biológic B Primera Etapa	Confirmació Marxa	38
	No Avaria	39
Agitador 2 Biológic B Primera Etapa	Confirmació Marxa	40
	No Avaria	41
Bufant A Primera Etapa	Confirmació Marxa	42
Bufant B Primera Etapa	Confirmació Marxa	43
Bufant C Primera Etapa	Confirmació Marxa	44
Bufants Primera Etapa	No Avaria Aliment.	45
Variador Bufadors Primera Etapa	Freqüencia	46
Sonda d'Oxigen Reactor A	Lectura Oxímetre	47
Sonda d'Oxigen Reactor B	Lectura Oxímetre	48
Oxigen a mantenir en Biológic 1ª Etapa	Consigna Scada	49
Comporta BY-PASS Decantació Primaria	Oberta	50
	Tancada	51

DECANTADORS DE PRIMERA ETAPA

Equip	***Elements***	**Number**
Comporta Entrada a Decantador A	Oberta	52
	Tancada	53
Comporta Entrada a Decantador B	Oberta	54
	Tancada	55
Pont Decantador A	Confirmació Marxa	56
	No Avaria	57
Pont Decantador B	Confirmació Marxa	58
	No Avaria	59
Bomba Purga Fangs Primaris A	Confirmació Marxa	60
	No Avaria	61
Bomba Purga Fangs Primaris B	Confirmació Marxa	62
	No Avaria	63
Cabalimetre Purga Fangs Primaris	Cabal instantani	64
	Totalitzador	65
Bomba Recirculació Fangs Primaris A	Confirmació Marxa	66
	No Avaria	67
Bomba Recirculació Fangs Primaris A	Confirmació Marxa	68
	No Avaria	69
Bomba Recirculació Fangs Primaris A	Confirmació Marxa	70
	No Avaria	71
Cabalimetre Recirculación de Fangs Primaris	Cabal instantani	72
	Totalitzador	73

REACTORS BIOLÓGICS SEGONA ETAPA

Equip	Elements	Number
Comporta Entrada als Reactor Biologic 2ª Etapa	Oberta	74
	Tancada	75
	No Avaria	76
Bufador A Reactor Biológic 2ª Etapa	Confirmació Marxa	77
Bufador B Reactor Biológic 2ª Etapa	Confirmació Marxa	78
Bufador C Reactor Biológic 2ª Etapa	Confirmació Marxa	79
Bufador D Reactor Biológic 2ª Etapa	Confirmació Marxa	80
Variador 1 Bufadors Biológic 2ª Etapa	Freqüencia	81
	Confirmació Marxa	82
	No Avaria	83
Variador 1 Bufadors Biológic 2ª Etapa	Freqüencia	84
	Confirmació Marxa	85
	No Avaria	86
Sonda d'Oxigen Reactor A	Lectura Oxímetre	87
Sonda d'Oxigen Reactor B	Lectura Oxímetre	88
Sonda d'Oxigen Reactor C	Lectura Oxímetre	89
Oxigen a mantenir en Biológic 2ª Etapa	Consigna Scada	90

DECANTACIÓ SEGONA ETAPA

Equip	Elements	Number
Pont Decantador Secundari A	Confirmació Marxa	91
	Avaria	92
Pont Decantador Secundari B	Confirmació Marxa	93
	Avaria	94
Pont Decantador Secundari C	Confirmació Marxa	95
	Avaria	96
Bomba Excés Fangs Secundaris A	Confirmació Marxa	97
	No Avaria	98
Bomba Excés Fangs Secundaris A	Confirmació Marxa	99
	No Avaria	100
Cabalimetre Excés Fangs Secund. a Espessidor	Cabal instantani	101
	Totalitzador	102
Cabalimetre Excés Fangs Secund. a Decantació	Cabal instantani	103
	Totalitzador	104
Bomba Recirculación Fangs Secundaris A	Confirmació Marxa	105
	No Avaria	106
Bomba Recirculación Fangs Secundaris B	Confirmació Marxa	107
	No Avaria	108
Bomba Recirculación Fangs Secundaris C	Confirmació Marxa	109
	No Avaria	110
Cabalimetre Recirculació Fangs Secundaris	Cabal instantani	111
	Totalitzador	112

Cabal de Fangs Secudaris a Recircular	Consigna Scada	113
Variador B. Recirculacio Fangs Secundaris	Freqüencia	114
Cabal d'Aigüa Tractada	Cabal instantani	115
	Totalitzador	116

ESPESSIDOR

Equip	***Elements***	**Number**
Pont Espessidor	Confirmació Marxa	117
	No Avaria	118
Bomba de Fangs A a Digestor	Confirmació Marxa	119
	No Avaria	120
Bomba de Fangs B a Digestor	Confirmació Marxa	121
	No Avaria	122
Bomba Dosificadora Poli A a Espessidor	Confirmació Marxa	123
	No Avaria	124
Bomba Dosificadora Poli B a Espessidor	Confirmació Marxa	125
	No Avaria	126
Bomba Dosificadora Poli C a Espessidor	Confirmació Marxa	127
	No Avaria	128
Sortida Variadors B.Dosif. Poli a Espessidor	Freqüencia	129
Cabalímetre Polielectrolit a Espessidor	Cabal instantani	130
	Totalitzador	131
Cabalímetre Fangs a Digestor	Cabal instantani	132
	Totalitzador	133

```
Private Sub Workbook_Open()
Call Hoja1.G2Gateway1.Connect(True)
End Sub
```

Aquest línia de codi permet crear la connexió entre la fulla excel i el programa quan la fulla s'obre.
Una vegada creada la connexió aquesta altre codificació envia un vector de 162 posicions a traves del pont cada vegada que alguna dada de la columna "e" es actualitzada.

```
Private Sub Workbook_SheetChange(ByVal Sh As
Object, ByVal Target As Range)
asd = Range("e8:e170")
Call Hoja1.G2Gateway1.Start("online", asd)
End Sub
```

Les dades s'envien a un procediment del G2 anomenat "on-line", el qual és l'encarregat de verificar que cada posició del vector té un valor i de col·locar aquest valor en l'objecte corresponent.

```
online(asd: structure)
cat:sequence;
```

```
begin

{SENYALS ENTRADA-PLANTA}

IF cat[0]/="" and cat[0]/= the symbol null and cat[0]=1.0 then
conclude that the comporta-reguladora-entrada of bombes = the
symbol oberta else conclude that the comporta-reguladora-entrada of
bombes = the symbol tancada;

end;
```

Aquesta és una línia de codi exemple de com es fa aquest filtratge. Tota la informació que es rep correspon a algun objecte del programa. A continuació s'exposen les variables i els objectes amb que es treballa a Montornès.

```
the comporta-reguladora-entrada of bombes
the tant-per-cent-obertura of bombes
the Bomba-elevació-1 of bombes
the Bomba-elevació-2 of bombes
the Bomba-elevació-3 of bombes
the variador-frequencia of bombes
the q-ent of bombes
the Q-total of bombes

{PRE-TRACTAMENT}
the comporta-entrada-desorrador-a of TRACTAMENT-PREVI
the comporta-entrada-desorrador-b of TRACTAMENT-PREVI
the aeroflots-1-a of TRACTAMENT-PREVI
the aeroflots-2-a of TRACTAMENT-PREVI
the aeroflots-2-b of TRACTAMENT-PREVI
the pont-desgreixador-a of TRACTAMENT-PREVI
the pont-desgreixador-b of TRACTAMENT-PREVI

{REACTOR-1-ETAPA}
the comporta-entrada-reactor-1 of REACTOR1
the comporta-entrada-reactor-2 of REACTOR1
the agitador-1-reactor-1 of REACTOR1
the agitador-2-reactor-1 of REACTOR1
the agitador-1-reactor-2 of REACTOR1
the agitador-2-reactor-2 of REACTOR1
the bufant-a of REACTOR1
the bufant-b of REACTOR1
the bufant-c of REACTOR1
the bufants-1-etapa of REACTOR1
the sonda-oxigen-reactor-1 of REACTOR1
the sonda-oxigen-reactor-2 of REACTOR1
the consigna-oxigen of REACTOR1
the comporta-by-pass of REACTOR1

 {DECANTADORS 1 ETAPA}
the comporta-entrada-decantador-a of DECANTADOR-1
the comporta-entrada-decantador-b of DECANTADOR-1
the pont-decantador-A of DECANTADOR-1
the pont-decantador-B of DECANTADOR-1
the bomba-purga-fangs-primaris-A of DECANTADOR-1
the bomba-purga-fangs-primaris-B of DECANTADOR-1
the cabal-purga of DECANTADOR-1
the bomba-recirculació-fangs-primaris-A of DECANTADOR-1
the bomba-recirculació-fangs-primaris-B of DECANTADOR-1
the cabal-recirculació of DECANTADOR-1

{REACTORS BIOLÒGICS DE SEGONA ETAPA}
the comporta-entrada-reactor OF REACTOR-A
the bufant-a of REACTOR-a
the bufant-b of REACTOR-a
```

```
the bufant-c of REACTOR-a
the bufant-d of REACTOR-a
the bufants-2-etapa of REACTOR-A
the variador-1-bufadors-2-etapa of REACTOR-A
the valor-variador-1-bufadors-2-etapa of REACTOR-A
the variador-2-bufadors-2-etapa of REACTOR-A
the valor-variador-2-bufadors-2-etapa of REACTOR-A
the sonda-oxigen-reactor-A of REACTOR-A
the sonda-oxigen-reactor-B of REACTOR-A
the sonda-oxigen-reactor-C of REACTOR-A
the consigna-oxigen of REACTOR-A

{DECANTACIO SEGONA ETAPA}
the pont-decantador-A of DECANTADOR-2
the pont-decantador-B of DECANTADOR-2
the pont-decantador-C of DECANTADOR-2
the bomba-purga-fangs-1 of DECANTADOR-2
the bomba-purga-fangs-2 of DECANTADOR-2
the cabal-purga-espessidor of DECANTADOR-2
the cabal-purga-decantació of DECANTADOR-2
the bomba-recirculació-fangs-1 of DECANTADOR-2
the bomba-recirculació-fangs-2 of DECANTADOR-2
the bomba-recirculació-fangs-3 of DECANTADOR-2
the cabal-recirculació of DECANTADOR-2
the variador of DECANTADOR-2

{SORTIDA}

the cabal-sortida of EFLUENT-sortida
the pont-espessidor of digestor-fangs
the bomba-fangs-a-a-digestor of digestor-fangs
the bomba-fangs-b-a-digestor of digestor-fangs
the bomba-dosificadora-poli-a-a-espessidor of digestor-fangs
the bomba-dosificadora-poli-b-a-espessidor of digestor-fangs
the bomba-dosificadora-poli-c-a-espessidor of digestor-fangs
the sortida-variadors of DIGESTOR-FANGS
cabal-polielectrolit-a-espessidor of DIGESTOR-FANGS
the cabal-fangs-a-digestor of DIGESTOR-FANGS

{falta introduir la terbolesa}
{IF cat[162]/="" and cat[162]/= the symbol null then conclude that the terbolesa of efluent-
sortida=quantity(cat[162]);}
```

De totes les posicions del vector es treballa amb 75 que donaran un valor on-line a les corresponents 75 variables.

Abstracció on-line:

```
abstracció-dades-online()
q-entrada,oxigen,limit-inf-q,limit-sup-q,limit-inf-o,limit-sup-o,terbolesa,limit-inf-t,limit-sup-
t:quantity;
begin
collect data(timing out after 1 seconds)
q-entrada= the q-ent of bombes;
oxigen= ((quantity(the sonda-oxigen-reactor-a of REACTOR-a)+ quantity(the sonda-oxigen-
reactor-b of REACTOR-a)+ quantity(the sonda-oxigen-reactor-c of REACTOR-a))/3);
limit-inf-q= the limit-inferior-q of dades-disseny;
limit-sup-q= the limit-superior-q of dades-disseny;
limit-inf-o= the limit-inferior-oxigen-2etapa of dades-disseny;
limit-sup-o= the limit-superior-oxigen-2etapa of dades-disseny;
terbolesa= the terbolesa of efluent-sortida;
LIMIT-INF-T= THE LIMIT-inferior-terbolesa of dades-disseny;
LIMIT-sup-T= THE LIMIT-superior-terbolesa of dades-disseny;
{limit-inf-temp=the limit-inferior-temperatura of dades-disseny;
limit-sup-temp= the limit-superior-temperatura of dades-disseny;
temperatura= the temperatura of reactor-a;}
end;
```

if q-entrada< limit-inf-q then conclude that the q-ent of variable-qualitativa = the symbol baix;

if q-entrada > limit-inf-q and q-entrada < limit-sup-q then conclude that the q-ent of variable-qualitativa = the symbol normal;

if q-entrada > limit-sup-q then conclude that the q-ent of variable-qualitativa = the symbol alt;

if oxigen< limit-inf-o then conclude that the oxigen-al-reactor of variable-qualitativa = the symbol baix;
if oxigen > limit-inf-o and oxigen < limit-sup-o then conclude that the oxigen-al-reactor of variable-qualitativa = the symbol normal;
if oxigen > limit-sup-o then conclude that the oxigen-al-reactor of variable-qualitativa = the symbol alt;
if terbolesa <limit-inf-t then conclude that the terbolesa of variable-qualitativa = the symbol baixa;
if terbolesa > limit-inf-t and terbolesa < limit-sup-t then conclude that the terbolesa of variable-qualitativa = the symbol normal;
if terbolesa > limit-sup-t then conclude that the terbolesa of variable-qualitativa = the symbol alta;

{faltarà la TEMPERATURA
if temperatura>limit-sup-temp then conclude that the temperatura of variable-qualitativa = the symbol alta;
if temperatura>limit-inf-temp and temperatura<limit-sup-temp then conclude that the temperatura of variable-qualitativa = the symbol normal;
if temperatura<limit-inf-temp then conclude that the temperatura of variable-qualitativa = the symbol baixa;}

end

Annex IV:Off-line data

```
analiticgenerator(aigua:structure, primetapa:structure, segonetapa:structure, bio:structure, cabal:structure, qualitatiu:structure)
cataigua:sequence;
catprimetapa:sequence;
catsegonetapa:sequence;
catbio:sequence;
catcabal:sequence;
catqualitatiu:sequence;




mes:quantity=the current value of mes-numero;
rendiment-mes1, rendiment-mes2, rendiment-mes3, rendiment-dqo1, rendiment-dqo2, rendiment-dqo3, rendiment-dbo1, rendiment-dbo2, rendiment-dbo3 :quantity;
year:quantity=the current year;

tss-ent,tss-primar,tss-sort, dqo-ent-1, dqo-ent-2, dqo-sort-2, dbo-ent-1, dbo-ent-2, dbo-sort-2, ph-ent,ph-ent-prim, ph-sort,cond-ent,cond-sort,ntk-ent,ntk-sort,nitrats-ent,nitrats-sort,nitrits-ent,nitrits-sort,nt-ent,nt-sort,amoni-ent,amoni-sort,pt-ent,pt-sort,cr,zn,sulfats-e,sulfats-s,
temp-1,mlssr-1,mlss-1,v30-1,ivf-1,mlssv-1,cm-1,trh-1,trc-1,trc-setmanal-1, vel-asc-1,temp-2, mlssr-2,mlss-2,v30-2, ivf-2,mlssv-2, cm-2,trh-2,trc-2,trc-setmanal-2,vel-asc-2,cabal-ent-bruta, q-sortida, recirculació-primera-etapa, recirculació-segona-etapa, purga-1-etapa, purga-2-a-1-etapa, purga-2-etapa-a-espessidor:quantity;
dia,wa:text;
begin

cataigua= the com-elements of aigua;

dia="[cataigua[0]]";
wa=call dia-procedure(dia);

if cataigua[1] IS a QUANTITY then TSS-ENT= quantity(cataigua[1]) else TSS-ENT =-9999;

if cataigua[2] IS a QUANTITY then TSS-primar=quantity(cataigua[2]) else TSS-PRIMAR=-9999;
if cataigua[3] IS a QUANTITY then TSS-sort= quantity(cataigua[3]) else TSS-sort=-9999;

if cataigua[7] IS A QUANTITY then dqo-ent-1 =QUANTITY(cataigua[7]) else dqo-ent-1 =-9999;

if cataigua[9] IS A QUANTITY then dqo-ent-2 =quantity(cataigua[9])else dqo-ent-2 =-9999;
if cataigua[12] IS A QUANTITY then dqo-sort-2 = quantity(cataigua[12]) else dqo-sort-2 =-9999;

 if cataigua[13] IS A QUANTITY then dbo-ent-1 = quantity(cataigua[13]) else dbo-ent-1 =-9999;
if cataigua[14] IS A QUANTITY then dbo-ent-2 =quantity(cataigua[14])else dbo-ent-2 =-9999;
if cataigua[16] IS A QUANTITY then dbo-sort-2 = quantity(cataigua[16]) else dbo-sort-2 =-9999;

 if cataigua[17] IS A QUANTITY then ph-ent = quantity(cataigua[17]) else ph-ent =-9999;
if cataigua[18] IS A QUANTITY then ph-ent-prim =quantity(cataigua[18])else ph-ent-prim =-9999;
if cataigua[19] IS A QUANTITY then ph-sort = quantity(cataigua[19]) else ph-sort =-9999;

 if cataigua[20] IS A QUANTITY then cond-ent = quantity(cataigua[20]) else cond-ent =-9999;
if cataigua[21] IS A QUANTITY then cond-sort =quantity(cataigua[21])else cond-sort =-9999;


if cataigua[22] IS A QUANTITY then ntk-ent = quantity(cataigua[22]) else ntk-ent =-9999;
if cataigua[23] IS A QUANTITY then ntk-sort = quantity(cataigua[23]) else ntk-sort =-9999;
```

```
if cataigua[24] IS A QUANTITY then nitrats-ent = quantity(cataigua[24]) else nitrats-ent=-9999;
if cataigua[25] IS A QUANTITY then nitrats-sort = quantity(cataigua[25]) else nitrats-sort =-9999;

if cataigua[26] IS A QUANTITY then nitrits-ent = quantity(cataigua[26]) else nitrits-ent =-9999;
if cataigua[27] IS A QUANTITY then nitrits-sort = quantity(cataigua[27]) else nitrits-sort =-9999;

if cataigua[28] IS A QUANTITY then nt-ent = quantity(cataigua[28]) else nt-ent =-9999;
if cataigua[29] IS A QUANTITY then nt-sort = quantity(cataigua[29]) else nt-sort =-9999;

 if cataigua[30] IS A QUANTITY then amoni-ent = quantity(cataigua[30]) else amoni-ent =-9999;
if cataigua[31] IS A QUANTITY then amoni-sort = quantity(cataigua[31]) else amoni-sort =-9999;

if cataigua[32] IS A QUANTITY then pt-ent = quantity(cataigua[32]) else pt-ent =-9999;
if cataigua[33] IS A QUANTITY then pt-sort = quantity(cataigua[33]) else pt-sort =-9999;

if cataigua[34] IS A QUANTITY then cr = quantity(cataigua[34]) else cr =-9999;
if cataigua[35] IS A QUANTITY then zn = quantity(cataigua[35]) else zn =-9999;

if cataigua[36] IS A QUANTITY then sulfats-e = quantity(cataigua[36]) else sulfats-e =-9999;
if cataigua[37] IS A QUANTITY then sulfats-s = quantity(cataigua[37]) else sulfats-s =-9999;

catprimetapa= the com-elements of primetapa ;


if catprimetapa[2] IS A QUANTITY then temp-1 = quantity(catprimetapa[2]) else temp-1 =-9999;
if catprimetapa[3] IS A QUANTITY then mlssr-1 = quantity(catprimetapa[3]) else mlssr-1 =-9999;
if catprimetapa[4] IS A QUANTITY then mlss-1 = quantity(catprimetapa[4]) else mlss-1 =-9999;
if catprimetapa[5] IS A QUANTITY then v30-1 = quantity(catprimetapa[5]) else v30-1 =-9999;
if catprimetapa[6] IS A QUANTITY then ivf-1 = quantity(catprimetapa[6]) else ivf-1 =-9999;
if catprimetapa[7] IS A QUANTITY then mlssv-1 = quantity(catprimetapa[7]) else mlssv-1 =-9999;
{INFORM THE OPERATOR THAT"[tss-ent],[tss-primar],[tss-sort],[dqo-ent-1],[dqo-ent-2],[dqo-sort-2],[dbo-ent-1],[dbo-ent-2],[dbo-sort-2],[ph-ent],[ph-ent-prim],[ph-sort],[cond-ent],[cond-sort],[ntk-ent],[ntk-sort],[nitrats-ent],[nitrats-sort],[nitrits-ent],[nitrits-sort],[nt-ent],[nt-sort],[amoni-ent],[amoni-sort],[pt-ent],[pt-sort],[cr],[zn],[sulfats-e],[sulfats-s],[temp-1],[mlssr-1],[mlss-1],[v30-1],[ivf-1],[mlssv-1]";
}
if catprimetapa[16] IS A QUANTITY then CM-1 = quantity(catprimetapa[16]) else CM-1 =-9999;

if catprimetapa[17] IS A QUANTITY then trh-1 =quantity(catprimetapa[17]) else trh-1 =-9999;

if catprimetapa[21] IS A QUANTITY then trc-1 =quantity(catprimetapa[21]) else trc-1 =-9999;
if catprimetapa[22] IS A QUANTITY then trc-setmanal-1 =quantity(catprimetapa[22]) else trc-setmanal-1 =-9999;
if catprimetapa[20] IS A QUANTITY then vel-asc-1 =quantity(catprimetapa[20]) else vel-asc-1 =-9999;

catsegonetapa= the com-elements of segonetapa ;


if catsegonetapa[2] IS A QUANTITY then temp-2 = quantity(catsegonetapa[2]) else temp-2 =-9999;
```

```
if catsegonetapa[3] IS A QUANTITY then mlssr-2 = quantity(catsegonetapa[3]) else mlssr-2 =-9999;
 if catsegonetapa[4] IS A QUANTITY then mlss-2 = quantity(catsegonetapa[4]) else mlss-2 =-9999;

if catsegonetapa[5] IS A QUANTITY then v30-2 = quantity(catsegonetapa[5]) else v30-2 =-9999;
if catsegonetapa[6] IS A QUANTITY then ivf-2 = quantity(catsegonetapa[6]) else ivf-2 =-9999;
if catsegonetapa[7] IS A QUANTITY then mlssv-2 = quantity(catsegonetapa[7]) else mlssv-2 =-9999;


 catbio= the com-elements of bio;


if catbio[6] IS A QUANTITY then cm-2 = quantity(catbio[6]) else cm-2 =-9999;
if catbio[3] IS A QUANTITY then trh-2 = quantity(catbio[3]) else trh-2 =-9999;
if catbio[8] IS A QUANTITY then trc-2 = quantity(catbio[8]) else trc-2 =-9999;
if catbio[13] IS A QUANTITY then trc-setmanal-2 = quantity(catbio[13]) else trc-setmanal-2 =-9999;
if catbio[14] IS A QUANTITY then vel-asc-2 = quantity(catbio[14]) else vel-asc-2 =-9999;
inform the operator that"[ trc-2]";
catcabal= the com-elements of cabal;

if catcabal[0] IS A QUANTITY then cabal-ent-bruta = quantity(catcabal[0]) else cabal-ent-bruta =-9999;
if catcabal[1] IS A QUANTITY then q-sortida = quantity(catcabal[1]) else q-sortida =-9999;
if catcabal[2] IS A QUANTITY then recirculació-primera-etapa = quantity(catcabal[2]) else recirculació-primera-etapa =-9999;
if catcabal[3] IS A QUANTITY then recirculació-segona-etapa  = quantity(catcabal[3]) else recirculació-segona-etapa =-9999;
if catcabal[4] IS A QUANTITY then purga-1-etapa   = quantity(catcabal[4]) else purga-1-etapa =-9999;
if catcabal[5] IS A QUANTITY then purga-2-a-1-etapa   = quantity(catcabal[5]) else purga-2-a-1-etapa =-9999;
if catcabal[6] IS A QUANTITY then purga-2-etapa-a-espessidor  = quantity(catcabal[6]) else purga-2-etapa-a-espessidor  =-9999;

{QUALITATIU}
CATQUALITATIU= the com-elements of QUALITATIU;

{if CATQUALITATIU[0] IS A QUANTITY then purga-2-etapa-a-espessidor = quantity(CATQUALITATIU[0]) else purga-2-etapa-a-espessidor  =-9999;}
{INFORM THE OPERATOR THAT "[tss-ent],[tss-primar],[tss-sort],[dqo-ent-1],[dqo-ent-2],[dqo-sort-2],[dbo-ent-1],[dbo-ent-2],[dbo-sort-2],[ph-ent],[ph-ent-prim],[ph-sort],[cond-ent],[cond-sort],[ntk-ent],[ntk-sort],[nitrats-ent],[nitrats-sort],[nitrits-ent],[nitrits-sort],[nt-ent],[nt-sort],[amoni-ent],[amoni-sort],[pt-ent],[pt-sort],[cr],[zn],[sulfats-e],[sulfats-s],[temp-1],[mlssr-1],[mlss-1],[v30-1],[ivf-1],[mlssv-1],[CM-1],[trh-1],[trc-1],[trc-setmanal-1],[vel-asc-1],[temp-2],[mlssr-2],[mlss-2],[v30-2],[ivf-2],[mlssv-2],[cm-2],[trh-2],[trc-2],[trc-setmanal-2],[vel-asc-2],[cabal-ent-bruta],[q-sortida],[recirculació-primera-etapa],[recirculació-segona-etapa],[purga-1-etapa],[purga-2-a-1-etapa],[purga-2-etapa-a-espessidor]";


rendiment-mes1=call rendiments(mes-ent-1,mes-sort-1);
rendiment-mes2=call rendiments(mes-ent-2,mes-sort-2);
rendiment-mes3=call rendiments(mes-ent-1,mes-sort-2);
rendiment-dqo1=call rendiments(dqo-ent-1,dqo-sort-1);
rendiment-dqo2=call rendiments(dqo-ent-2,dqo-sort-2);
rendiment-dqo3=call rendiments(dqo-ent-1,dqo-sort-2);
rendiment-dbo1=call rendiments(dbo-ent-1,dbo-sort-1);
rendiment-dbo2=call rendiments(dbo-ent-2,dbo-sort-2);
rendiment-dbo3=call rendiments(dbo-ent-1,dbo-sort-2);}

if mes = the current month then begin
```

```
conclude that the array-length of analitic-act= 31 ;

conclude that analitic-act[cont]="[wa]/[mes]/[year],[tss-ent],[tss-primar],[tss-sort],[dqo-ent-1],[dqo-ent-2],[dqo-sort-2],[dbo-ent-1],[dbo-ent-2],[dbo-sort-2],[ph-ent],[ph-ent-prim],[ph-sort],[cond-ent],[cond-sort],[ntk-ent],[ntk-sort],[nitrats-ent],[nitrats-sort],[nitrits-ent],[nitrits-sort],[nt-ent],[nt-sort],[amoni-ent],[amoni-sort],[pt-ent],[pt-sort],[cr],[zn],[sulfats-e],[sulfats-s],[temp-1],[mlssr-1],[mlss-1],[v30-1],[ivf-1],[mlssv-1],[CM-1],[trh-1],[trc-1],[trc-setmanal-1],[vel-asc-1],[temp-2],[mlssr-2],[mlss-2],[v30-2],[ivf-2],[mlssv-2],[cm-2],[trh-2],[trc-2],[trc-setmanal-2],[vel-asc-2],[cabal-ent-bruta],[q-sortida],[recirculació-primera-etapa],[recirculació-segona-etapa],[purga-1-etapa],[purga-2-a-1-etapa],[purga-2-etapa-a-espessidor],";
 inform the operator that" [wa]/[mes]/[year]   [mlssv-2],[cm-2],[trh-2],[trc-2],[trc-setmanal-2],[vel-asc-2] ";
conclude that cont=cont+1;

if cont = 31 then begin
conclude that cont=0;

call anal-to-analitic6 (analitic-act,31, analitic-ant);
end;

end;



if mes = the current month - 1 then begin

conclude that the array-length of analitic-ant= 31 ;

conclude that analitic-ant[cont]="[wa]/[mes]/[year],[tss-ent],[tss-primar],[tss-sort],[dqo-ent-1],[dqo-ent-2],[dqo-sort-2],[dbo-ent-1],[dbo-ent-2],[dbo-sort-2],[ph-ent],[ph-ent-prim],[ph-sort],[cond-ent],[cond-sort],[ntk-ent],[ntk-sort],[nitrats-ent],[nitrats-sort],[nitrits-ent],[nitrits-sort],[nt-ent],[nt-sort],[amoni-ent],[amoni-sort],[pt-ent],[pt-sort],[cr],[zn],[sulfats-e],[sulfats-s],[temp-1],[mlssr-1],[mlss-1],[v30-1],[ivf-1],[mlssv-1],[CM-1],[trh-1],[trc-1],[trc-setmanal-1],[vel-asc-1],[temp-2],[mlssr-2],[mlss-2],[v30-2],[ivf-2],[mlssv-2],[cm-2],[trh-2],[trc-2],[trc-setmanal-2],[vel-asc-2],[cabal-ent-bruta],[q-sortida],[recirculació-primera-etapa],[recirculació-segona-etapa],[purga-1-etapa],[purga-2-a-1-etapa],[purga-2-etapa-a-espessidor],";
 inform the operator that" [wa]/[mes]/[year] [trh-2],[trc-2],[trc-setmanal-2]";
conclude that cont=cont+1;

if cont = 31 then conclude that cont=0;

end;


end
```

```
anal-to-analitic6
 (anal: class text-array,element-arrayname: integer,anal2: class text-array )

posició : structure = structure (start-index: 0, end-index: 0) ;
c,d, y, z,w: integer ; n: integer = 1; j: integer = 0; x: integer=1; long, dia, mes, posicio_dia, posicio_mes: integer ;
k:quantity=30;
año1, dia-actual, año2, data, canvi-format, name-case : text;
nom-analitic: symbol;
analitic: class text-array;
BEGIN

y = call dia_actual2 (anal);
    w = y - 1;
    for z = y to y+30 do

    posició = structure ( start-index : 0, end-index : 0) ;
    j=0;
```

```
   nom-analitic = symbol ("analitic[z - w]") ;
   analitic = the text-array named by nom-analitic;
   exit if z=32;
      repeat

      exit if the end-index of posició = length-of-text ( anal[element-arrayname - z]);
      c = the start-index of posició ;
      posició = find-next-pattern (",", anal[element-arrayname - z], the end-index of posició +
1);
      d = the end-index of posició ;
      change the array-length of analitic to j + 1;
      conclude that analitic[j] = get-from-text (anal[element-arrayname - z], c + 1,d - 1);
if analitic[j] ="-9999" then conclude that analitic[j]="";
      j = j + 1;
      end ;
end;



w = y - 1;
   for z = 32 to y+30 do

   posició = structure ( start-index : 0, end-index : 0) ;
   j = 0;
   nom-analitic = symbol ("analitic[z - w]") ;
   analitic = the text-array named by nom-analitic;




     repeat

      exit if the end-index of posició = length-of-text ( anal2[k]);

      c = the start-index of posició ;
      posició = find-next-pattern (",", anal2[k], the end-index of posició + 1);
      d = the end-index of posició ;

      change the array-length of analitic to j + 1;

      conclude that analitic[j] = get-from-text (anal2[k], c + 1,d - 1);
if analitic[j] ="-9999" then conclude that analitic[j]="";
          j = j + 1;

      end ;
      k= k - 1;
exit if k=31 - y;
   end;
END
```

```
colocar-dades2
()
z,x:quantity;
dia:text;
analitic: class text-array;
variab: class text-array;
nom-analitic,dad:symbol;
begin


dad = symbol("dades") ;
```

```
variab = the text-array named by dad;
for x=0 to 58 do


inform the operator that"[variab[x]]";
conclude that variable-rule= "[variab[x]]";
for z=1 to 7 do

nom-analitic = symbol("analitic[z]") ;

analitic = the text-array named by nom-analitic;
inform the operator that "[the name of analitic]";
inform the operator that "[analitic[x + 1]]";
inform the operator that"ok2";
exit if analitic[x + 1]/="";
end;

if  analitic[x + 1] ="" or analitic[x + 1] ="0.0" then conclude that analitic[x + 1] ="-9999";

conclude that mis="unconditionally conclude that [variable-rule]= [analitic[x + 1]]";
conclude that dades-offline-inter[x]="[analitic[x + 1]]";
inform the operator that"[mis]";
change the text of lolo to "[mis]";
invoke lolo rules;
wait for 0.1 second;

end;



end
```

```
abstracció-dades-offline()

begin
if the tss of bombes has a current value and the tss of bombes/=-9999 and the tss of bombes/=""
then begin
if the tss of bombes < the limit-inferior-tss-entrada of LIMITS-VAR-OFFLINE then conclude
that the tss-entrada of variable-qualitativa = the symbol baix else
if the tss of bombes > THE limit-superior-tss-entrada of LIMITS-VAR-OFFLINE then conclude
that the tss-entrada of variable-qualitativa = the symbol ALT else conclude that the tss-entrada
of variable-qualitativa = the symbol normal;
end else
conclude that the tss-entrada of variable-qualitativa = the symbol g2;

if the tss of decantador-1 has a current value and the tss of decantador-1 /=-9999 and the tss of
decantador-1 /="" then begin
if the tss of decantador-1 < the limit-inferior-tss-primari of LIMITS-VAR-OFFLINE then
conclude that the tss-primari of variable-qualitativa = the symbol baix else
if the tss of decantador-1 > the limit-superior-tss-primari of LIMITS-VAR-OFFLINE then
conclude that the tss-primari of variable-qualitativa = the symbol ALT else conclude that the
tss-primari of variable-qualitativa = the symbol normal;
end else
conclude that the tss-primari of variable-qualitativa = the symbol g2;

if the tss of efluent-sortida has a current value and the tss of efluent-sortida /=-9999 and the tss
of efluent-sortida /="" then begin
if the tss of efluent-sortida < the limit-inferior-tss-sortida  of LIMITS-VAR-OFFLINE then
conclude that the tss-sortida of variable-qualitativa = the symbol baix else
if the tss of efluent-sortida > the limit-superior-tss-sortida of LIMITS-VAR-OFFLINE then
conclude that the tss-sortida of variable-qualitativa = the symbol ALT else conclude that the
tss-sortida of variable-qualitativa = the symbol normal;
end else
conclude that the tss-sortida of variable-qualitativa = the symbol g2;
```

```
if the dqo of bombes has a current value and the dqo of bombes/=-9999 and the dqo of
bombes/="" then begin
if the dqo of bombes < the limit-inferior-dqo-entrada of LIMITS-VAR-OFFLINE then conclude
that the dqo-entrada of variable-qualitativa = the symbol baix else
if the dqo of bombes > THE limit-superior-dqo-entrada of LIMITS-VAR-OFFLINE then
conclude that the dqo-entrada of variable-qualitativa = the symbol ALT else conclude that the
dqo-entrada of variable-qualitativa = the symbol normal;
end else
conclude that the dqo-entrada of variable-qualitativa = the symbol g2;

if the dqo of decantador-1 has a current value and the dqo of decantador-1 /=-9999 and the
dqo of decantador-1 /="" then begin
if the dqo of decantador-1 < the limit-inferior-dqo-primari of LIMITS-VAR-OFFLINE then
conclude that the dqo-primari of variable-qualitativa = the symbol baix else
if the dqo of decantador-1 > the limit-superior-dqo-primari of LIMITS-VAR-OFFLINE then
conclude that the dqo-primari of variable-qualitativa = the symbol ALT else conclude that the
dqo-primari of variable-qualitativa = the symbol normal;
end else
conclude that the dqo-primari of variable-qualitativa = the symbol g2;

if the dqo of efluent-sortida has a current value and the dqo of efluent-sortida /=-9999 and the
dqo of efluent-sortida /="" then begin
if the dqo of efluent-sortida < the limit-inferior-dqo-sortida  of LIMITS-VAR-OFFLINE then
conclude that the dqo-sortida of variable-qualitativa = the symbol baix else
if the dqo of efluent-sortida > the limit-superior-dqo-sortida of LIMITS-VAR-OFFLINE then
conclude that the dqo-sortida of variable-qualitativa = the symbol ALT else conclude that the
dqo-sortida of variable-qualitativa = the symbol normal;
end else
conclude that the dqo-sortida of variable-qualitativa = the symbol g2;

if the dbo of bombes has a current value and the dbo of bombes/=-9999 and the dbo of
bombes/="" then begin
if the dbo of bombes < the limit-inferior-dbo-entrada of LIMITS-VAR-OFFLINE then conclude
that the dbo-entrada of variable-qualitativa = the symbol baix else
if the dbo of bombes > THE limit-superior-dbo-entrada of LIMITS-VAR-OFFLINE then
conclude that the dbo-entrada of variable-qualitativa = the symbol ALT else conclude that the
dbo-entrada of variable-qualitativa = the symbol normal;
end else
conclude that the dbo-entrada of variable-qualitativa = the symbol g2;

if the dbo of decantador-1 has a current value and the dbo of decantador-1 /=-9999 and the
dbo of decantador-1 /="" then begin
if the dbo of decantador-1 < the limit-inferior-dbo-primari of LIMITS-VAR-OFFLINE then
conclude that the dbo-primari of variable-qualitativa = the symbol baix else
if the dbo of decantador-1 > the limit-superior-dbo-primari of LIMITS-VAR-OFFLINE then
conclude that the dbo-primari of variable-qualitativa = the symbol ALT else conclude that the
dbo-primari of variable-qualitativa = the symbol normal;
end else
conclude that the dbo-primari of variable-qualitativa = the symbol g2;

if the dbo of efluent-sortida has a current value and the dbo of efluent-sortida /=-9999 and the
dbo of efluent-sortida /="" then begin
if the dbo of efluent-sortida < the limit-inferior-dbo-sortida  of LIMITS-VAR-OFFLINE then
conclude that the dbo-sortida of variable-qualitativa = the symbol baix else
if the dbo of efluent-sortida > the limit-superior-dbo-sortida of LIMITS-VAR-OFFLINE then
conclude that the dbo-sortida of variable-qualitativa = the symbol ALT else conclude that the
dbo-sortida of variable-qualitativa = the symbol normal;
end else
conclude that the dbo-sortida of variable-qualitativa = the symbol g2;

if the ph of bombes has a current value and the ph of bombes/=-9999 and the ph of bombes/=""
then begin
if the ph of bombes < the limit-inferior-ph-entrada of LIMITS-VAR-OFFLINE then conclude
that the ph-entrada of variable-qualitativa = the symbol baix else
if the ph of bombes > THE limit-superior-ph-entrada of LIMITS-VAR-OFFLINE then conclude
that the ph-entrada of variable-qualitativa = the symbol ALT else conclude that the ph-entrada
of variable-qualitativa = the symbol normal;
```

```
end else
conclude that the ph-entrada of variable-qualitativa = the symbol g2;

if the ph of decantador-1 has a current value and the ph of decantador-1 /=-9999 and the ph of
decantador-1 /="" then begin
if the ph of decantador-1 < the limit-inferior-ph-primari of LIMITS-VAR-OFFLINE then
conclude that the ph-primari of variable-qualitativa = the symbol baix else
if the dbo of decantador-1 > the limit-superior-ph-primari of LIMITS-VAR-OFFLINE then
conclude that the ph-primari of variable-qualitativa = the symbol ALT else conclude that the
ph-primari of variable-qualitativa = the symbol normal;
end else
conclude that the ph-primari of variable-qualitativa = the symbol g2;

if the ph of efluent-sortida has a current value and the ph of efluent-sortida /=-9999 and the ph
of efluent-sortida /="" then begin
if the ph of efluent-sortida < the limit-inferior-ph-sortida  of LIMITS-VAR-OFFLINE then
conclude that the ph-sortida of variable-qualitativa = the symbol baix else
if the ph of efluent-sortida > the limit-superior-ph-sortida of LIMITS-VAR-OFFLINE then
conclude that the ph-sortida of variable-qualitativa = the symbol ALT else conclude that the ph-
sortida of variable-qualitativa = the symbol normal;
end else
conclude that the ph-sortida of variable-qualitativa = the symbol g2;

if the cond of bombes has a current value and the cond of bombes/=-9999 and the cond of
bombes/="" then begin
if the cond of bombes < the limit-inferior-cond-entrada of LIMITS-VAR-OFFLINE then
conclude that the cond-entrada of variable-qualitativa = the symbol baix else
if the cond of bombes > THE limit-superior-cond-entrada of LIMITS-VAR-OFFLINE then
conclude that the cond-entrada of variable-qualitativa = the symbol ALT else conclude that the
cond-entrada of variable-qualitativa = the symbol normal;
end else
conclude that the cond-entrada of variable-qualitativa = the symbol g2;

if the cond of efluent-sortida has a current value and the cond of efluent-sortida /=-9999 and
the cond of efluent-sortida /="" then begin
if the cond of efluent-sortida < the limit-inferior-cond-sortida  of LIMITS-VAR-OFFLINE then
conclude that the cond-sortida of variable-qualitativa = the symbol baix else
if the cond of efluent-sortida > the limit-superior-cond-sortida of LIMITS-VAR-OFFLINE then
conclude that the cond-sortida of variable-qualitativa = the symbol ALT else conclude that the
cond-sortida of variable-qualitativa = the symbol normal;
end else
conclude that the cond-sortida of variable-qualitativa = the symbol g2;

if the tkn of bombes has a current value and the tkn of bombes/=-9999 and the tkn of
bombes/="" then begin
if the tkn of bombes < the limit-inferior-tkn-entrada of LIMITS-VAR-OFFLINE then conclude
that the tkn-entrada of variable-qualitativa = the symbol baix else
if the tkn of bombes > THE limit-superior-tkn-entrada of LIMITS-VAR-OFFLINE then conclude
that the tkn-entrada of variable-qualitativa = the symbol ALT else conclude that the tkn-entrada
of variable-qualitativa = the symbol normal;
end else
conclude that the tkn-entrada of variable-qualitativa = the symbol g2;

if the tkn of efluent-sortida has a current value and the tkn of efluent-sortida /=-9999 and the
tkn of efluent-sortida /="" then begin
if the tkn of efluent-sortida < the limit-inferior-tkn-sortida  of LIMITS-VAR-OFFLINE then
conclude that the tkn-sortida of variable-qualitativa = the symbol baix else
if the tkn of efluent-sortida > the limit-superior-tkn-sortida of LIMITS-VAR-OFFLINE then
conclude that the tkn-sortida of variable-qualitativa = the symbol ALT else conclude that the
tkn-sortida of variable-qualitativa = the symbol normal;
end else
conclude that the tkn-sortida of variable-qualitativa = the symbol g2;
end
```

Annex V: Expert system

METAREGLES:

whenever the q-ent of process-state receives a value then invoke xoc-hidraulic-diagnosi rules

if the q-ent of variable-qualitativa = the symbol alt or the q-ent of variable-qualitativa = the symbol baix or the bufants-2-etapa of reactor-a >=3 or the terbolesa of variable-qualitativa = the symbol alta then invoke xoc-hidraulic-diagnosi rules

if the temperatura of variable-qualitativa = the symbol alta or the edat-de-fang of variable-qualitativa = the symbol alta or the nitrats-sortida of variable-qualitativa = the symbol alts then invoke nitrificació-diagnosi rules

if the escumes of reactor-a = the symbol B or the ciliats-totals of microbiologic < 2000 then INVOKE altres-escumes-rules RULES and invoke toxic-shock-rules rules and invoke high-loading-rules rules

whenever the oxigen-al-reactor of variable-qualitativa receives a value or the bufants-2-etapa of reactor-a receives a value or the terbolesa of variable-qualitativa receives a value and when the oxigen-al-reactor of variable-qualitativa = the symbol baix or the bufants-2-etapa of reactor-a >=3 or the terbolesa of variable-qualitativa = the symbol alta then invoke diagnosi-xoc rules

if the terbolesa of variable-qualitativa = the symbol alta or the ivf of variable-qualitativa = the symbol alta or the v30 of variable-qualitativa = the symbol alta or the filamentoses of microbiologic = the symbol alt then invoke diagnosi-bulking rules

if (the ivf of variable-qualitativa /= the symbol normal or the tend-ivf of tend-ps = the symbol augmentant) and (the filamentoses of microbiologic /= the symbol high) then INVOKE diagnosi-bulking RULES

if (the ivf of variable-qualitativa /= the symbol normal or the tend-ivf of tend-ps = the symbol augmentant or the current value of the filamentoses of microbiologic = the symbol high) then INVOKE diagnosi-bulking RULES

if the current value of the abundància-nocardia of microbiologic>= 3 or the abundància-microthrix of microbiologic >= 4 then INVOKE foaming-rules RULES

if the terbolesa of variable-qualitativa = the symbol alta then INVOKE non-biological-problems-clarifier-rules rules

PROBLEMES OPERACIONALS

XOC ORGÀNIC I TÒXIC

Diagnosi

if the bufants-2-etapa of reactor-a >= 3 and the valor-variador-2-bufadors-2-etapa < 40 THEN conclude that the xoc-orgànic of process-state = the symbol possible

if the bufants-2-etapa of reactor-a >= 3 and the valor-variador-2-bufadors-2-etapa of reactor-a >= 40 and the sonda-oxigen-reactor-a of reactor-a < (0.8(the consigna-oxigen of reactor-a)) THEN conclude that the xoc-orgànic of process-state = the symbol cert*

if the bufants-2-etapa of reactor-a >= 3 and the valor-variador-2-bufadors-2-etapa of reactor-a >= 40 and the sonda-oxigen-reactor-a of reactor-a > (0.8(the consigna-oxigen of reactor-a)) THEN conclude that the xoc-orgànic of process-state = the symbol possible* *if the bufants-2-etapa of reactor-a = 1 and the valor-variador-1-bufadors-2-etapa of reactor-a< 50 and the sonda-oxigen-reactor-a of reactor-a > the consigna-oxigen of reactor-a THEN conclude that the xoc-tòxic of process-state = the symbol cert*

if the bufants-2-etapa of reactor-a = 1 and the valor-variador-1-bufadors-2-etapa of reactor-a< 50 and the sonda-oxigen-reactor-a of reactor-a > the consigna-oxigen of reactor-a and the terbolesa of variable-qualitativa = the symbol alta THEN conclude that the xoc-tòxic of process-state = the symbol cert

Causa

whenever the xoc-orgànic of PROCESS-STATE receives a value and when the xoc-orgànic of PROCESS-STATE = the symbol cert then invoke cause-xoc-càrrega rules

if the dqo-entrada of variable-qualitativa = the symbol alta THEN conclude that the dqo of xoc-orgànic-causes= the symbol cert

if the dqo-entrada of variable-qualitativa /= the symbol alta THEN conclude that the altres of xoc-orgànic-causes= the symbol cert

whenever the xoc-toxic of PROCESS-STATE receives a value and when the xoc-toxic of PROCESS-STATE = the symbol cert then invoke cause-xoc-tòxic rules

if the metalls-entrada of variable-qualitativa = the symbol alts THEN conclude that the metalls of xoc-tòxic-causes= the symbol cert

if the escumes of reactor-1 = the symbol b THEN conclude that the detergents of xoc-tòxic-causes= the symbol cert

if the dqo of entrada = the symbol alt THEN conclude that the dqo of xoc-tòxic-causes= the symbol cert

if the escumes of reactor-1 /= the symbol blanques and the metalls-entrada of variable-qualitativa /= the symbol alts THEN conclude that the altres of xoc-tòxic-causes= the symbol cert

ACTUACIÓ

```
organic-actuation-etapa()
dqo:quantity;
begin
inform the operator that "[the mlss of reactor1]";
collect data( timing out after 0.1 seconds)
dqo= the dqo of bombes;
end;
if the xoc-orgànic of process-state = the symbol cert then begin
   if the dqo of xoc-orgànic-causes = the symbol cert then begin

      if the bufants-1-etapa of REACTOR1 = 1 and the mlss of REACTOR1 >= 1500 then conclude that the missatge1 of organic = " Xoc orgànic a la segona etapa.

degut a una dqo elevada d'entrada([dqo]).

la primera etapa etapa està funcionant com a tal i només té en funcionament una bufant. És recomana l'activació de la segona bufant. D'aquesta manera s'intenta augmentar el rendiment de la primera etapa per aconseguir un efluent amb menys càrrega a la segona.";
  if the mlss of REACTOR1 > 800 and the mlss of reactor1 < 1500 then conclude that the missatge1 of organic = " Xoc orgànic a la segona etapa.

degut a una dqo elevada d'entrada([dqo]) i a que la primera etapa es troba en un estadi primerenc d'activació.
```

```
És recomana l'activació de la primera etapa augmentant el temps de recirculació (posar
valor!!!!!). D'aquesta manera s'intenta augmentar el rendiment de la primera etapa per
aconseguir un efluent amb menys càrrega a la segona.";
if the mlss of REACTOR1 < 800 and the mlss of reactor1 /= 0.0 and the mlss of reactor1 /= -
9999 then conclude that the missatge1 of organic = " Xoc orgànic a la segona etapa.

degut a una dqo elevada d'entrada([dqo]) i a que la primera etapa es troba en un estadi de pre-
aeració.

És recomana l'activació de la primera etapa activant la recirculació. D'aquesta manera
s'intenta augmentar el rendiment de la primera etapa per aconseguir un efluent amb menys
càrrega a la segona.";
if the mlss of reactor1 has no current value or the mlss of reactor1= 0.0 or the mlss of reactor1
= -9999 then conclude that the missatge1 of organic =" Xoc orgànic a la segona etapa.

causa entrada elevada de dqo ([dqo]) i no hi ha informació suficient sobre la primera etapa.

activar la primera etapa si aquesta no ho està.";
end;
if the dqo of xoc-orgànic-causes/= the symbol cert then begin
 if the bufants-1-etapa of REACTOR1 = 1 and the mlss of REACTOR1 >= 1500 then conclude
that the missatge1 of organic = " Xoc orgànic a la segona etapa.

no s'ha detectat la causa.

la primera etapa etapa està funcionant com a tal i només té en funcionament una bufant. És
recomana l'activació de la segona bufant. D'aquesta manera s'intenta augmentar el rendiment
de la primera etapa per aconseguir un efluent amb menys càrrega a la segona.";
  if the mlss of REACTOR1 > 800 and the mlss of reactor1 < 1500 then conclude that the
missatge1 of organic = " Xoc orgànic a la segona etapa.

no s'ha detectat la causa i la primera etapa es troba en un estadi primerenc d'activació.

És recomana l'activació de la primera etapa augmentant el temps de recirculació. D'aquesta
manera s'intenta augmentar el rendiment de la primera etapa per aconseguir un efluent amb
menys càrrega a la segona.";
if the mlss of REACTOR1 < 800 and the mlss of reactor1 /= 0.0 and the mlss of reactor1 /= -
9999 then conclude that the missatge1 of organic = " Xoc orgànic a la segona etapa.

no s'ha detectat la causa i la primera etapa es troba en un estadi de pre-aeració.

És recomana l'activació de la primera etapa posant en marxa la recirculació. D'aquesta manera
s'intenta augmentar el rendiment de la primera etapa per aconseguir un efluent amb menys
càrrega a la segona.";
if the mlss of reactor1 has no current value or the mlss of reactor1= 0.0 then
conclude that the missatge1 of organic =" Xoc orgànic a la segona etapa.

no s'ha detectat la causa i no hi ha informació suficient sobre la primera etapa.

activar la primera etapa si aquesta no ho està.";
end;
change the text of xoc to "[the missatge1 of organic]";
 show the subworkspace of organico;
end;

end
```

```
toxic-actuation-etapa()
metalls:quantity;
detergents:quantity;
begin
 collect data ( timing out after 0.1 seconds)
metalls= the metalls of bombes;
detergents= the detergents of bombes;
end;
if the xoc-tòxic of process-state = the symbol cert then begin
```

if the metalls of xoc-tòxic-causes = the symbol cert then conclude that the missatge1 of toxic = " Xoc tòxic a la segona etapa.

degut a una entrada de metalls elevada ([metalls]).

Únicament treballa una sola bufant amb el variador per sota dels 50 Hz, a més la demanda d'oxigen ha disminuit molt. això permet determinar que l'entrada d'un compost tòxic ha originat una disminució severa de la concentració microbiana.

es recomana aillar una línia del biològic i fer passar tot l'efluent amb el xoc tòxic per l'altra si és possible.";
if the detergents of xoc-tòxic-causes = the symbol cert then conclude that the missatge1 of toxic = " Xoc tòxic a la segona etapa.

degut a una entrada de detergents elevada ([detergents]).

Únicament treballa una sola bufant amb el variador per sota dels 50 Hz, a més la demanda d'oxigen ha disminuit molt. això permet determinar que l'entrada d'un compost tòxic ha originat una disminució severa de la concentració microbiana.

es recomana aillar una línia del biològic i fer passar tot l'efluent amb el xoc tòxic per l'altra si és possible.";
if the detergents of xoc-tòxic-causes/= the symbol cert and the metalls of xoc-tòxic-causes /= the symbol cert then
begin
conclude that the missatge1 of toxic = " Xoc tòxic a la segona etapa.

no s'ha detectat la causa.

Únicament treballa una sola bufant amb el variador per sota dels 50 Hz, a més la demanda d'oxigen ha disminuit molt. això permet determinar que l'entrada d'un compost tòxic ha originat una disminució severa de la concentració microbiana.

es recomana aillar una línia del biològic i fer passar tot l'efluent amb el xoc tòxic per l'altra si és possible.";
end;
change the text of tox to "[the missatge1 of toxic]";
show the subworkspace of toxico;
end;

end

NITRIFICACIÓ

diagnosi

if the Temperatura of variable-qualitativa = the symbol alta and the edat-de-fang of variable-qualitativa = the symbol alta then conclude that the nitrificació of process-state= the symbol cert

if the Temperatura of variable-qualitativa = the symbol alta AND the edat-de-fang of variable-qualitativa /= the symbol alta then conclude that the nitrificació of process-state= the symbol possible

if the edat-de-fang of variable-qualitativa = the symbol alta and the Temperatura of variable-qualitativa /= the symbol alta then conclude that the nitrificació of process-state= the symbol possible

if the Temperatura of variable-qualitativa = the symbol alta and the edat-del-fang of variable-qualitativa = the symbol normal and the tendència-edat-fang of tendències = the symbol augmentant then conclude that the nitrificació of process-state= the symbol possible

if the nitrificació of process-state = the symbol possible and the nitrats of efluent-sortida = the symbol alts then conclude that the nitrificació of process-state= the symbol cert *if the Temperatura of variable-qualitativa = the symbol alta and the edat-de-fang of variable-qualitativa = the symbol alta and the Terbolesa of variable-qualitativa = the symbol alta and (the nitrats of efluent-sortida = the symbol alts or the nitrits of efluent-sortida = the symbol alts) then conclude that the desnitrificació of process-state= the symbol cert*

Causa:

whenever the nitrificació of PROCESS-STATE receives a value and when the nitrificació of PROCESS-STATE = the symbol cert then invoke nitrificació-causes rules

if the edat-de-fang of variable-qualitativa = the symbol alta then conclude that the elevada-edat-fang of causes-nitrificació = the symbol cert

if the temperatura of variable-qualitativa = the symbol alta then conclude that the elevada-temperatura of causes-nitrificació = the symbol cert

Actuació

```
nitrificació-actuation()

begin
if the nitrificació of process-state = the symbol cert then begin
inform the operator that"ok";
call calcul-purga-2-etapa ();
inform the operator that"ok1";
if the edat-de-fang of variable-qualitativa = the symbol alt then conclude that the missatge1 of
NITRIFICACIO =" El procés es troba en fase de nitrificació.

degut a una edat de fang ([the trc of reactor-a]) i temperatura ([the temperatura of reactor-a])
molt elevades.

intentar reduir la edat de fang fins que el procés de nitrificació s'aturi. l'edat màxima per
aconseguir eliminar amb un rendiment correcte la matèria orgànica i no realitzar la
nitrificació és [edat-del-fang-proposada] dies i per aconseguir-ho cal purgar [purga-
proposada] m3/dia ";
if the edat-de-fang of variable-qualitativa = the symbol normal and the tendència-edat-fang of
tendències = the symbol augmentant then
conclude that the missatge1 of NITRIFICACIO =" El procés no es troba en fase de nitrificació
però la seva dinàmica tendeix cap a aquesta fase.

degut a una edat de fang ([the trc of reactor-a]) normal però amb una temperatura ([the
temperatura of reactor-a]) elevada i un increment de la tendència del procés cap a la
nitrificació.

intentar reduir la edat de fang fins que el procés de nitrificació s'aturi. l'edat màxima per
aconseguir eliminar amb un rendiment correcte la matèria orgànica i no realitzar la
nitrificació és [edat-del-fang-proposada] dies i per aconseguir-ho cal purgar [purga-
proposada] m3/dia ";
inform the operator that"ok3";
change the text of nitri to "[the missatge1 of nitrificacio ]";
show the subworkspace of nitrifi;
end;
end
```

BULKING

Diagnosi:

if the terbolesa of variable-qualitativa = the symbol alta and the v30 of variable-qualitativa = the symbol alta and the filamentoses of microbiologic = the symbol alts and the ivf of variable-qualitativa= the symbol alta then conclude that the Bulking of process-state = the symbol cert

if the terbolesa of variable-qualitativa = the symbol alta and the v30 of variable-qualitativa = the symbol alta and the filamentoses of microbiologic = the symbol alts or the filamentoses of microbiologic has no current value then conclude that the Bulking of process-state = the symbol possible

if the ivf of variable-qualitativa = the symbol alta then conclude that the Bulking of process-state = the symbol cert

whenever the bulking of process-state receives a value and when the bulking of process-state = the symbol possible and the filamentoses of microbiologic has a current value and the filamentoses of microbiologic = the symbol alts then conclude that the Bulking of process-state = the symbol cert

whenever the bulking of process-state receives a value and when the bulking of process-state = the symbol possible and the filamentoses of microbiologic has a current value and the filamentoses of microbiologic = the symbol baix then conclude that the Bulking of process-state = the symbol fals

Causa:

whenever the bulking of PROCESS-STATE receives a value and when the bulking of PROCESS-STATE = the symbol cert then invoke bulking-causes rules

if the f-to-m of variable-qualitativa = the symbol baix then conclude that the f-to-m of bulking-causes-gra= the symbol cert

if the f-to-m of variable-qualitativa = the symbol alt then conclude that the alta-càrrega of bulking-causes-gra= the symbol cert

if the nutrients of variable-qualitativa = the symbol baix then conclude that the nutrients of bulking-causes-gra= the symbol cert

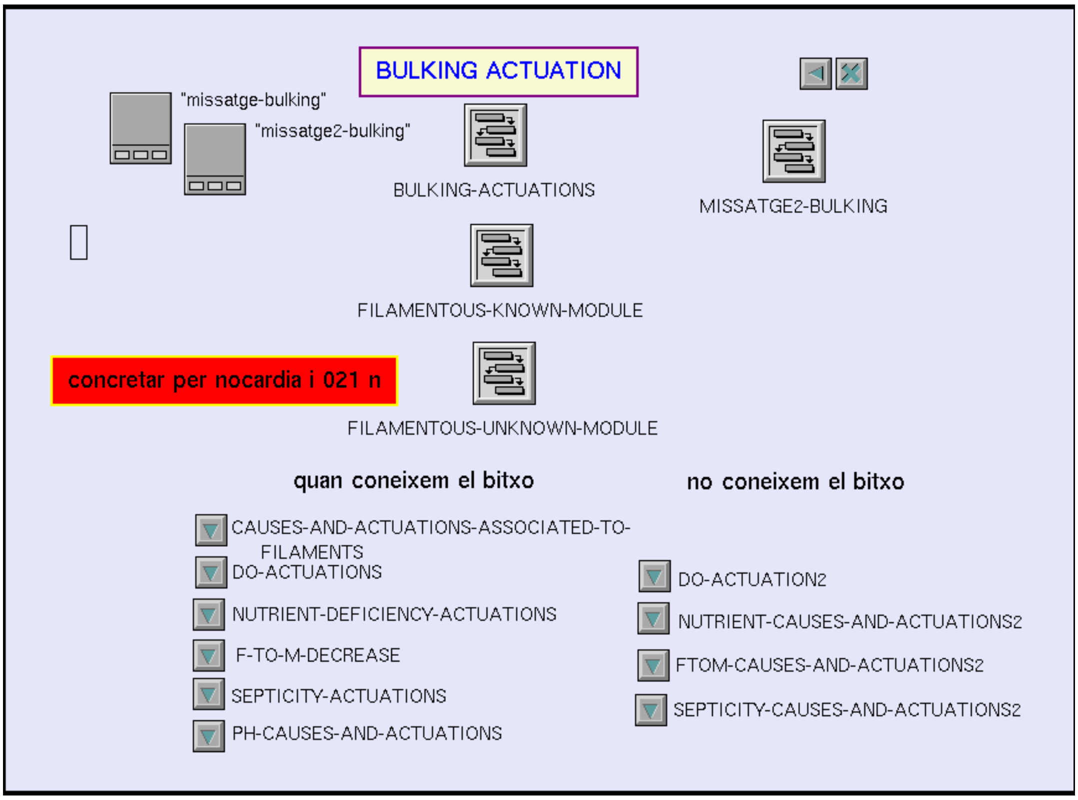
if the ph-primari of variable-qualitativa = the symbol alt or the ph-primari of variable-qualitativa = the symbol baix then conclude that the ph of bulking-causes-gra= the symbol cert

if the oxigen-al-reactor of variable-qualitativa is low then conclude that the od-b of bulking-causes-gra is cert

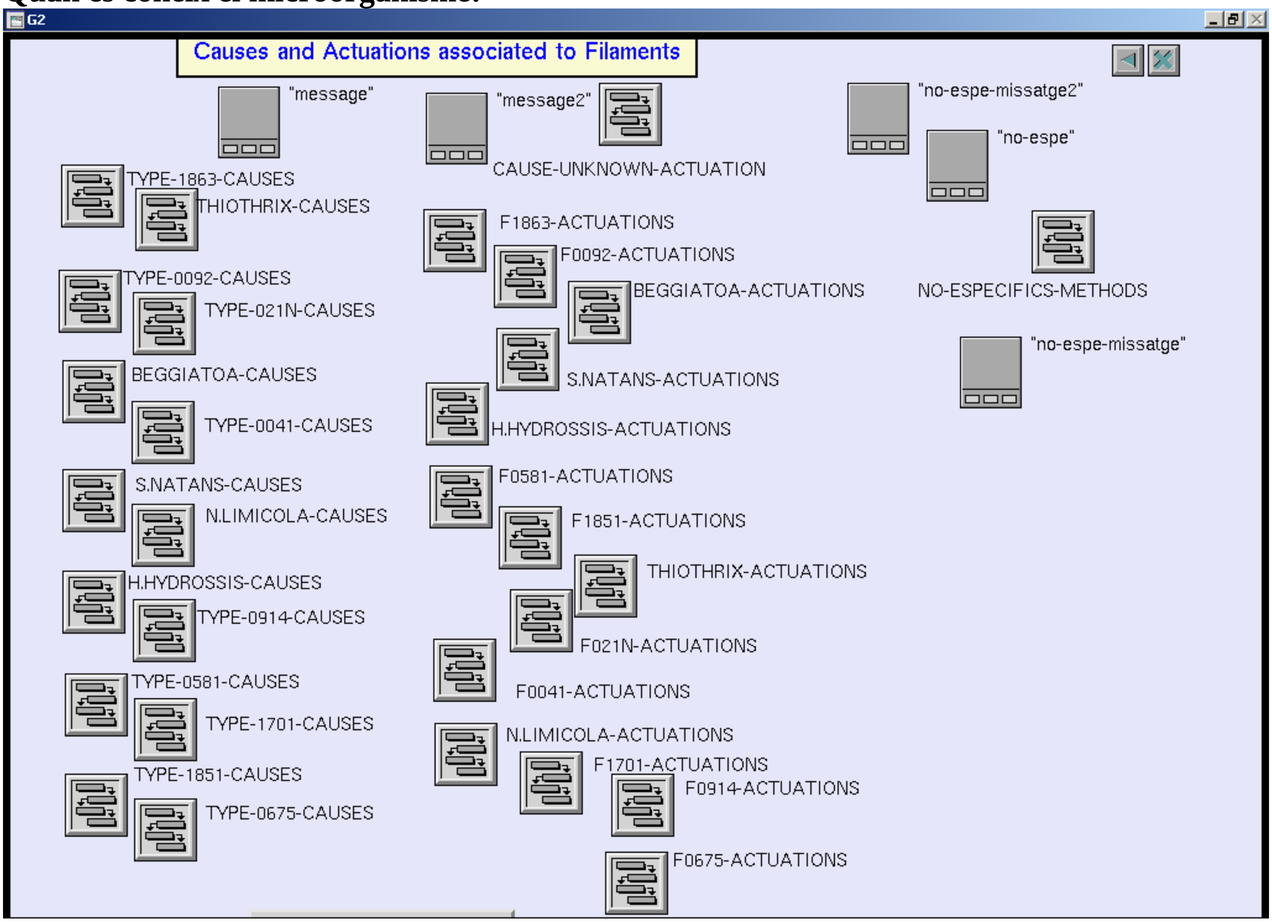
if the filamentoses of microbiologic = the symbol alt then conclude that the filaments of bulking-causes-gra= the symbol cert

if the filamentoses of microbiologic /= the symbol alt and the ph-primari of variable-qualitativa =the symbol normal and the nutrients of variable-qualitativa /= the symbol baix and the f-to-m of variable-qualitativa = the symbol normal and the oxigen-al-reactor of variable-qualitativa = the symbol normal then conclude that the altres of bulking-causes-gra= the symbol cert

Actuació:



Quan es coneix el microorganisme:



per cada un:

```
type-1863-causes ()
bk: class bulking-causes = bulking-causes-gra;
begin
if the od-a of bk is cert or the od-b of bk is cert then call o2-deficiency () else if the od-b of bk is not cert and the od-b of bk is not cert then call cause-unknown-actuation ();
end
```

```
f1863-actuations ()
svi:quantity;
abun:symbol;
begin
```

collect data (timing out after 1 second)

```
abun= the filamentoses of microbiologic;
svi = the current value of the ivf of reactor-a;
end;
conclude that the missatge1 of bulk= "Bulking filamentós: el fang es troba molt esponjat i sedimenta molt lentament, degut a un creixement excessiu de microorganismes filamentosos, que, per la seva morfologia, dificulten la compactació dels flòculs.

S'ha detectat per una ivf de [svi] ml/g i una predominància del bacteri tipus f1863 amb una abundància: [abun].

desconeguda

Com que no s'ha pogut determinar la causa exacta que provoca un creixement excessiu del bacteri f1863, es proporcionen totes les actuacions específiques o preventives per aquest bacteri, així com les actuacions no específiques:
.Es recomana comprovar el sistema d'aireació, els punts de consigna dels diferents compartiments i si cal, augmentar-los a valors al voltant de 2 mg/l O2.
.Si l'oxigen dissolt és massa baix tan sols en algunes parts del tanc, caldrà netejar alguns difusors o el sistema de distribució de l'aire (o augmentar vel. turbines o pujar el deflector de sortida).
.Si l'oxigen dissolt només és baix a l'inici del reactor, es pot intentar de canviar l'operació a alimentació esgraonada, convertir-lo en una sèrie de reactors continus de tanc agitat o realitzar aireació esgraonada.
.També es pot augmentar el punt de consigna de la concentració de sòlids del licor mescla (disminuir el cabal de purga) per obtenir una F:M adequada.";
call missatge2-bulking ();

end
```

bulking viscos

diagnosi

```
if the terbolesa of variable-qualitativa = the symbol alta then conclude that the Bulking of process-state = the symbol possible and conclude that the bulking-viscós of process-state = the symbol possible
```

```
if the terbolesa of variable-qualitativa = the symbol alta and the v30 of variable-qualitativa = the symbol alta then conclude that the Bulking of process-state = the symbol possible and conclude that the bulking-viscós of process-state = the symbol possible
```

```
whenever the bulking-viscós of process-state receives a value and when the bulking-viscós of process-state = the symbol possible and the filamentoses of microbiologic has a current value and the filamentoses of microbiologic = the symbol alts then conclude that the Bulking-viscós of process-state = the symbol fals
```

if the terbolesa of variable-qualitativa = the symbol alta and the v30 of variable-qualitativa = the symbol alta and the filamentoses of microbiologic = the symbol baixos and the ivf of variable-qualitativa= the symbol alta then conclude that the Bulking-viscós of process-state = the symbol cert

whenever the bulking-viscós of process-state receives a value and when the bulking-viscós of process-state = the symbol possible and the bacteri of microbiologic has a current value and the bacteri of microbiologic = the symbol zooglea then conclude that the Bulking-viscós of process-state = the symbol cert

causa

whenever the bulking-viscós of PROCESS-STATE receives a value and when the bulking-viscós of PROCESS-STATE = the symbol cert then invoke viscos-causes rules

if the f-to-m of variable-qualitativa =the symbol alt then conclude that the cm of viscos-causes-gra = the symbol cert

if the mlss of variable-qualitativa =the symbol baix then conclude that the mlss of viscos-causes-gra = the symbol cert

if the dqo-primari of variable-qualitativa =the symbol alt then conclude that the dqo of viscos-causes-gra = the symbol cert

if the edat-de-fang of variable-qualitativa =the symbol alt then conclude that the trc of viscos-causes-gra = the symbol cert

if the nutrients of variable-qualitativa =the symbol alt then conclude that the nutrients of viscos-causes-gra = the symbol cert

Actuació:

```
viscos-actuations ()
fil-predom: symbol ;
begin
if the bulking-viscós of process-state = the symbol cert then begin
collect data ( timing out after 1 second)
fil-predom = the current value of the bacteri of microbiologic;
end;

if fil-predom has no current value or fil-predom= the symbol g2 then fil-predom= the symbol desconegut;
if the cm of viscos-causes-gra is cert then conclude that the missatge1 of viscos= "hi ha indicis de bulking Viscós.


Mala sedimentabilitat del fang degut al creixement excessiu de [fil-predom].


degut a una  F/M molt elevada

reduir la F/M, disminuir la purga, disminuir la recirculació";

if the nutrients of viscos-causes-gra is cert then conclude that the missatge1 of viscos=" Hi ha indicis de Bulking Viscós.


Mala sedimentabilitat del fang degut al creixement excessiu de [fil-predom].


degut a una  edat del fang molt elevada

disminuir la purga, disminuir la recirculació per restablir la una relació adient de F/M.";
```

```
if the nutrients of viscos-causes-gra is cert then conclude that the missatge1 of viscos=" Hi ha
indicis de Bulking Viscós.

Mala sedimentabilitat del fang degut al creixement excessiu de [fil-predom].


degut a una  deficiència de nutrients molt elevada

intentar restablir la relació de 100:5:1 de nutrients. ";
if the cm of viscos-causes-gra is not cert and the trc of viscos-causes-gra is not cert and the
nutrients of viscos-causes-gra is not cert then conclude that the missatge1 of viscos=" Hi ha
indicis de Bulking Viscós.

Mala sedimentabilitat del fang degut al creixement excessiu de [fil-predom].


degut a una  deficiència de nutrients molt elevada

intentar restablir la relació de 100:5:1 de nutrients. ";


change the text of vici to "[the missatge1 of viscos]";
show the subworkspace of visc;
end;
end
```

XOC HIDRÀULIC

Diagnosi:

```
if the q-ent of variable-qualitativa = the symbol alt then conclude that the xoc-hidràulic of
process-state = the symbol possible
```

```
whenever the xoc-hidràulic of process-state receives a value and when the average value of the
q-ent of bombes during the last 3 hours > the limit-superior-q of dades-disseny then conclude
that the xoc-hidràulic of process-state = the symbol cert
```

causa

```
whenever the xoc-hidràulic of PROCESS-STATE receives a value and when the xoc-hidràulic of
PROCESS-STATE = the symbol cert then invoke xoc-hidraulic-cause rules
```

```
if the q-ent of variable-qualitativa = the symbol alt then conclude that the pluja of cause-xoc-
hidraulic = the symbol cert
```

```
if the q-ent of variable-qualitativa = the symbol alt then conclude that the q-ent of cause-xoc-
hidraulic = the symbol cert
```

```
if the bomba-elevació-1 of bombes = the symbol funciona and the bomba-elevació-2 of bombes
= the symbol funciona and the bomba-elevació-3 of bombes = the symbol funciona then
conclude that the 3-bombes-funciona of cause-xoc-hidraulic = the symbol cert
```

```
if the q-ent of variable-qualitativa = the symbol normal and the bufants-2-etapa of reactor-a >
1 and the bomba-elevació-1 of bombes /= the symbol funciona and the bomba-elevació-2 of
bombes /= the symbol funciona and the bomba-elevació-3 of bombes /= the symbol funciona
then conclude that the altres of cause-xoc-hidraulic = the symbol cert
```

Actuació:

```
hidraulic-xoc-actuation()


begin
if the xoc-hidràulic of process-state = the symbol cert then begin
```

```
    if the pluja of CAUSE-XOC-HIDRAULIC = the symbol cert then conclude that the missatge1
of hidric =" La planta pateix un xoc hidràulic.

    la causa, segurament, són les plujes que s'estan donant.

    l'unica actuació que es pot recomanar es la vigilància del cultiu microbiologic, ja que
associat a episodis continuats de pluja hi ha una entrada amb baixa càrrega. També vigilar que
els decantadors puguin aguantar el xoc hidràulic.";
    if the q-ent of CAUSE-XOC-HIDRAULIC = the symbol cert then conclude that the missatge1
of hidric=" La planta pateix un xoc hidràulic.

    la causa és una entrada elevada d'aigua.

    L'actuació que es pot recomanar es la vigilància del cultiu microbiologic. També vigilar que
els decantadors puguin aguantar el xoc hidràulic.";
if the 3-bombes-funciona of CAUSE-XOC-HIDRAULIC = the symbol cert then conclude that
the missatge1 of hidric=" La planta pateix un xoc hidràulic.

    la causa és l'activació de les tres bombes d'elevació a la vegada.

    L'actuació que es pot recomanar es la vigilància dels decantadors i verificar que puguin
aguantar el xoc hidràulic. També controlar el cultiu microbiològic";
if the altres of CAUSE-XOC-HIDRAULIC = the symbol cert then conclude that the missatge1 of
hidric=" La planta pateix un xoc hidràulic.

    la causa és un augment del cabal.

    L'actuació que es pot recomanar es la vigilància dels decantadors i verificar que puguin
aguantar el xoc hidràulic. També controlar el cultiu microbiològic";
 change the text of hidra to "[the missatge1 of hidric]";
show the subworkspace of HIDR;
end;
end
```

Baixa càrrega:

```
if the q-ent of variable-qualitativa = the symbol baix and the average value of the bufants-2-
etapa of reactor-a during the last 3 hours = 1 then conclude that the baixa-càrrega of process-
state = the symbol cert
```

Causa:

```
whenever the baixa-càrrega of PROCESS-STATE receives a value and when the baixa-càrrega
of PROCESS-STATE = the symbol cert then invoke baixa-carrega-cause rules
```

```
if the q-ent of variable-qualitativa = the symbol alt then conclude that the pluja of baixa-
carrega-causes = the symbol cert
```

```
if the q-ent of variable-qualitativa = the symbol baix and the bufants-2-etapa of reactor-a = 1
then conclude that the influent-poc-càrregat of baixa-carrega-causes = the symbol cert
```

```
if the q-ent of variable-qualitativa = the symbol normal and the bufants-2-etapa of reactor-a >
1 then conclude that the altres of cause-xoc-hidraulic = the symbol cert
```

Actuació:

```
baixa-carrega-actuation()


begin
if the baixa-càrrega of process-state = the symbol cert then begin
    if the influent-poc-carregat of BAIXA-CARREGA-CAUSES = the symbol cert then conclude
that the missatge1 of baix-carr=" La planta pateix un estat de baixa càrrega.
```

la causa és l'entrada d'un influent molt poca càrrega.

L'actuació que es pot recomanar es la vigilància del cultiu microbiològic";
if the pluja of BAIXA-CARREGA-CAUSES = the symbol cert then conclude that the missatge1 of baix-carr=" La planta pateix un estat de baixa càrrega.

la causa és l'entrada d'un influent molt poca càrrega degut a pluja.

L'actuació que es pot recomanar es la vigilància del cultiu microbiològic";
if the pluja of BAIXA-CARREGA-CAUSES /= the symbol cert and the influent-poc-carregat of BAIXA-CARREGA-CAUSES /= the symbol cert then conclude that the missatge1 of baix-carr=" La planta pateix un estat de baixa càrrega.

la causa és desconeguda.

L'actuació que es pot recomanar es la vigilància del cultiu microbiològic";
change the text of bais to "[the missatge1 of baix-carr]";
show the subworkspace of bai;

end;
end

FOAMING:

Diagnosi:

if (the current value of the escumes of reactor-a = the symbol f or the current value of the escumes of decantador-2 = the symbol f or the escumes of decantador-2 has no current value or the sedimentació_v30 of qualitatiu-dades = symbol ("fang-amb-escumes")) then conclude that the foaming-situation of process-state = the symbol cert

IF (the abundància-Nocardia of microbiologic >= 3 or the abundància- Microthrix of microbiologic >= 4) THEN conclude that the foaming-situation of process-state = the symbol cert

IF (the tendència-edat-fang of tendències = the symbol augmentant and the edat-de-fang of variable-qualitativa = the symbol alt) THEN conclude that the transició-foaming of trancisions = the symbol possible

IF the escumes of reactor-a = the symbol f or the escumes of decantador-2 = the symbol f THEN conclude that the transició-foaming of trancisions = the symbol possible

IF (the flòcul-superfície of qualitatiu-dades = the symbol Escapament-de-flòcul-petit or the flòcul-superfície of qualitatiu-dades = the symbol Escapament-de-flòcul-gran) THEN conclude that the transició-foaming of trancisions = the symbol possible

IF the f-to-m of variable-qualitativa = the symbol baixa or the tend-càrrega-màssica of tendències = the symbol disminuïnt THEN conclude that the transició-foaming of trancisions = the symbol possible

Causes:

whenever the foaming-situation of PROCESS-STATE receives a value and when the foaming-situation of PROCESS-STATE = the symbol cert then invoke foaming-causes rules

if the oxigen-al-reactor of variable-qualitativa is alt then conclude that the od-high of foaming-causes-gra is cert

if the f-to-m of variable-qualitativa is baixa then conclude that the fm-baix of foaming-causes-gra is cert

Actuacions:

```
Foaming-actuations ()
fil-predom: symbol ;
begin
if the foaming-situation of process-state = the symbol cert then begin
collect data ( timing out after 1 second)
fil-predom = the current value of the filaments-predominant of microbiologic;
end;

if (fil-predom has a current value and fil-predom is not g2 or fil-predom has a current value
and fil-predom is not none) then start nocardia-actuations ();
if (fil-predom has a current value and fil-predom is g2 or fil-predom has a current value and fil-
predom is none or fil-predom has no current value) then
    begin
if the od-high of foaming-causes-gra is cert then conclude that the missatge1 of foam= "hi ha
indicis de FOAMING.


 Presència d'escuma al reactor possiblement deguda a un creixement excessiu d'un filament que
no s'ha pogut identificar.


degut a un valor massa alt de la l'oxigen dissolt al reactor


Mètodes no específics i es recomana actualitzar informació microbiològica.";

if the fm-baix of foaming-causes-gra is cert then conclude that the missatge1 of foam=" hi ha
indicis de FOAMING.


 Presència d'escuma al reactor possiblement deguda a un creixement excessiu d'un filament que
no s'ha pogut identificar.


degut a un valor massa baix de la càrrega màssica.


Mètodes no específics i es recomana actualitzar informació microbiològica .";

if the greases of foaming-causes-gra is cert then conclude that the missatge1 of foam=" hi ha
indicis de FOAMING.


 Presència d'escuma al reactor possiblement deguda a un creixement excessiu d'un filament que
no s'ha pogut identificar.


 degut a una eliminació baixa de greixos per mal funcionament o avaria del desengreixador.

Mètodes no específics i es recomana actualitzar informació microbiològica ";
if the greases of foaming-causes-gra is not cert and the od-high of foaming-causes-gra is not
cert and the fm-baix of foaming-causes-gra is not cert then conclude that the missatge1 of
foam=" hi ha indicis de FOAMING.


 Presència d'escuma al reactor possiblement deguda a un creixement excessiu d'un filament que
no s'ha pogut identificar.


 no s'ha determinat la causa.

Mètodes no específics i es recomana actualitzar informació microbiològica.";
conclude that the missatge2 of foam=" FOAMING: Escumes altament hidrofòbiques causades
epl creixement d'algun tipus de microorganismes filamentós. Molt estables i flotants per què
estan formades per bombolles d'aire de l'aireació que queden atrapades en els flòculs i els
impedeixen sedimentar, per contra tendeixen a flotar. No apareixen de cop, tarda 2/3 dies a
```

donar-se plenament. El foaming produït per la Nocardia sembla implicar la naturalesa hidrofòbica (repelent a l'aigua) de la paret cel·lular de la Nocardia. Les cèl·lules de Nocardia en el licor mescla es concentren en les escumes i continuen flotant fins i tot un cop mortes. Les esumes de foaming donen problemes operacionals com pèrdua de sòlids a l'efluent, captura de sòlids en suspensió en les escumes (fins a un 30% de la biomassa) provocant una pèrdua de control del TRC i problemes en el tractament dels fangs.
La nocardia, un cop establerta, és molt difícil d'eliminar, perquè :
- no s'eliminen fàcilment mecànicament (a l'hivern es poden congelar i s'han de treure manualment i, a l'estiu, poden fer mala olor per putrefacció).
no responen a antiescumants químics
la cloració del fang retorn, tot i que pot ajudar, sovint no elimina el problema doncs la majoria de la Nocardia es troba en l'interior (?) (les partícules) del flòcul i no pas exposades al clor i, augmentar el cabal de purga té limitacions : les escumes no s'eliminen amb el fang. Suposant que s'eliminin una mica, poden donar problemes a les següents unitats com els digestors i podem reactivar el problema, per exemple, si recirculem els sobrenedants, i finalment, la reducció de l'SRT a < 9 dies pot ser inadequat, depèn de l'espècie concreta de Nocardia i de si la planta requereix nitrificació o no.
- Manipulació de l'SRT<= 2 dies si no cal nitrificar
- Si és necessària la nitrificació, llavors ús de selectors anòxics, efectius en control Nocardia i 021N, menys per M.Parvicella (selectrors òxics : només efectius a SRT baixos (5 dies))
- Agents químics i antiespumants: cloració (sprais, 2000-3000 mgCl/l), coagulants (4 g Fe/Kg·d) i antiespumants (baixa eficiència enfront escumes viscoses).
ACTUACIONS, segons causa :
.disminueix el TRC (aug.QP) a 2-9 dies,
.Seguiment F:M, disminuïr OD amb molta precaució (dism.o tancar aport d'aire durant un curt períde de t cada dia) (Sezgin i Kan, 1986; Gasser, 1987)
F:M Baixa (causa poc definida) : S'ha constatat que quan hi ha un gradient de conc. de substrat soluble en el reactor, el fang té una IVF inferior. Quan no hi ha gradent o la concentració de substrat és baixa, els organismes filamentosos poden créixer a velocitat superior als formadors de flòculs, probablement perquè l'estructura dels filamentosos presenten major superfície a través de la qual poden adsorbir i difondre el susbtrat (fonament del selector). El selector pot ser que no funcioni si la capacitat d'acumulació de substrat (AC) dels organismes formadors de flòcul està saturada (doncs llavors no tenent capacitat per acumular i consumir substrat, per tant l'eliminació de substrat és més baixa i per tant, la seva taxa de creixemetn és molt menor, de manera que pot arribar a ser del mateix ordre que la dels filamentosos. Per això, per aconseguir l'esgotament de la AC dels org.no filamentosoos i promoure el seu creixment, és útil la reaireació del fang de retorn. En els sistemes d'eliminació en discontinu (batch) hi ha una evident manca del fenòmend el bulking és una consequència de que, en aquests, la configuració és pràcticament la d'un flux pistó ideal. (P.e.per composició de l'aigua rica en HC de baix PM. La presència de lípids de cadena llarga també afavoreixen el seu creixement. Estressos mecànics, com ara presència de bombes centrífugues, poden conduir a la ruptura de cèl·lules microbianes i a l'alliberament de lípids de les membranes que oden fer proliferar aquests microorganismes filamentosos).
.ús selectors anòxics";
{call uil-start-dialog ("missatge-foaming",the symbol none, usuari-window);
call open-file-for-write-diagnosi-Sistema-supervisor (the text-array named by the names of the nom-analitic1 of anal-recent-gra , the missatge1 of foam);}
end;
change the text of foa to "[the missatge1 of foam]";
show the subworkspace of foami;
end;
end

ALTRES-ESCUMES

Diagnosi:

if (the current value of the escumes of reactor-a= the symbol b or the current value of the escumes of reactor-a= the symbol m or the current value of the escumes of decantador-2 = the symbol g) and (the current value of the filamentoses of microbiologic /= the symbol high or the filamentoses of microbiologic has no current value) then conclude that the altres-escumes of process-state = the symbol cert

Causes

if the oxigen-al-reactor of variable-qualitativa=the symbol alt then conclude that the od-alt of altres-escumes-causes-gra is cert

if the oxigen-al-reactor of variable-qualitativa = the symbol baixa then conclude that the od-baix of altres-escumes-causes-gra is cert

if the f-to-m of variable-qualitativa is alta then conclude that the fm-alt of altres-escumes-causes-gra is cert

IF the separador-greixos of falles-mecàniques = 0 THEN conclude that the greixos of altres-escumes-causes-gra is cert

if the f-to-m of variable-qualitativa is baixa then conclude that the fm-baix of altres-escumes-causes-gra is cert

Actuacions:

```
altres-escumes-actuations ()
ftom:quantity;
od1:quantity;
begin
if the altres-escumes of process-state = the symbol cert then begin
ftom=the cm of reactor-a;
od1= the od of reactor-a;

if the fm-alt of altres-escumes-causes-gra is cert then conclude that the missatge1 of escum =
"Presència d'escumes en el reactor.


 Escumes Blanques, flotants, rígides o estables o com escumes de sabó en superfície tanc
aireació:


Degut a una f/m alta ([ftom]) que provoca un fang jove en un tanc sobrecarregat (F:M alta,
SSLM baixos) (típica situació durant starts-up. Si és així, no preocupar-se)



    .F:M molt alt i SSVLM baixos (incloure retorns en el càlcul de F) (durant augm.
Càrr.orgànica) : .disminuïr F:M : no purgar durant uns dies o mantenir la purga al mínim. Pot
conduïr a creixement dispers
    .Pèrdua no-deliberda de biomassa per l'efl. secundari (efl.tèrbol): Reducció MLSS i
sobrecàrrega. Mantenir QR suficient per evitar pèrdua de sòlids, esp. en períodes de puntes de
Q
    .Recuperació d'un xoc tòxic: Considerar la possibilitat de ressembrar amb fang saludable
d'una EDAR en bon funcionament.
- Excessiva purga que causa tanc sobrecarregat: Tend. Disminució VSS, de SRT, de l'aireació
pels mateixos nivells OD i augment F:M i Q-P: Reduïr Q-P fins a un 10%/dia fins procés
s'acosti a paràm. normals. Augmentar Q-R per minimitzar pèrdua sòlids i mantenir llit de fang
a menys de 0.9 m. d'alçada del fons del clarifiicador. Possible 1863.
- Aboc. ind. amb tensoactius difícilment biodegradables, presents ja a l'influent: Addició
antiescumant ";


if the od-baix of altres-escumes-causes-gra is cert then
    conclude that the missatge1 of escum =" Altres escumes en el reactor.

Escumes color Marró fosc, quasi negre com sabó (LM de color marró molt fosc, quasi negre)
amb olor a ous podrits.

degut a oxigen dissolt baix ([od1]) que genera unes condicions anaeròbiques al tanc : Fang
sèptic (possible presència d'espiroquetes i spirillum)

Manca aireació. Augmnetar aireació per mantenir OD entre 2-3 mg/l) o per problemes
equipament (Netejar difusors o/i fulles de les turbines de parracs o gel). ";
```

if the od-alt of altres-escumes-causes-gra is cert then
conclude that the missatge1 of escum = " Altres escumes en el reactor.

Escumes Blanques, flotants, rígides o estables o com escumes de sabó en superfície tanc aireació

Degut a excessiva aireació (pin-point)

Mantenir nivell OD entre 2 i 3 mg/l i agitació adequada. ";

if the greixos of altres-escumes-causes-gra is cert then
conclude that the missatge1 of escum = " Altres escumes en el reactor.

Escumes Blanques, flotants, rígides o estables o com escumes de sabó en superfície tanc aireació

degut a la presència de greixos.

.Cabals d'entrada i/o recicrculació a cada reactor inapropiats: Distribució Q-E o Q-R inadequats, provocant difs. grans de SSLM, per tant sobrecàrrega illavors, escumes. Modificar i igualar el Q-E i Q-R per cada tanc.
.Def. nutrients, pH anormal, insuficient OD, aigües resid. + fredes o variacions grans en T (OUR i RR baixa però si hi ha activitat de la microfauna. La deficiència de nutrients provoca l'aparició d'una escuma deguda a la formació, per part dels microorganismes. de material polimèric extracel·lular actiu a superfície.

** Escumes Brillant i marró fosc : Q-B i Q-R difs. per dos o més tancs pot sobrecarregar-ne un de SSLM. Igualar Q-B i Q-R a cada reactor.*

** Escuma marró fosc, quasi negre com sabó (LM de color marró molt fosc, quasi negre) sense fer olor a ous podrits: Possible RI.*
Xoc tòxic recent suau de càrrega : pot causar efluent tèrbol. Les observacions microscòpiques de SSLM mostraran la inactivitat dels protozoos. Serà necessari una ressembra des d'una altra planta. S'ha de fer complir un pre-tractament dels residus industrials. El primer que es nota és el cessament del moviment dels cilis. Els perítrics queden inactius però ciliats swimming i crawling queden majoritàriament actius. La RR (taxa de respiració) del LM és més baix del normal.

** Petites quantitats d'escuma fresca, lleugera i marronosa : Signe de planta ben operada amb bona qualitat d'efluent. ";*
{call uil-start-dialog (" missatge-escumes" , the symbol none, usuari-window);
call open-file-for-write-diagnosi-Sistema-supervisor (the text-array named by the names of the nom-analitic1 of anal-recent-gra , the missatge1 of escum) ;}
if the fm-alt of altres-escumes-causes-gra is NOT cert and the od-baix of altres-escumes-causes-gra is NOT cert and the od-alt of altres-escumes-causes-gra is NOT cert then
conclude that the missatge1 of escum = " Altres escumes en el reactor.

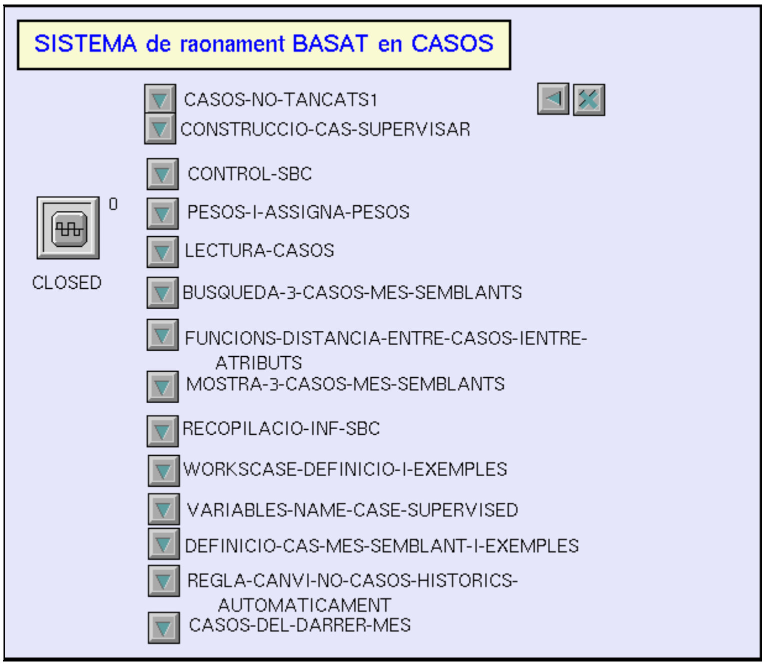
Escumes Blanques, flotants, rígides o estables o com escumes de sabó en superfície tanc aireació.

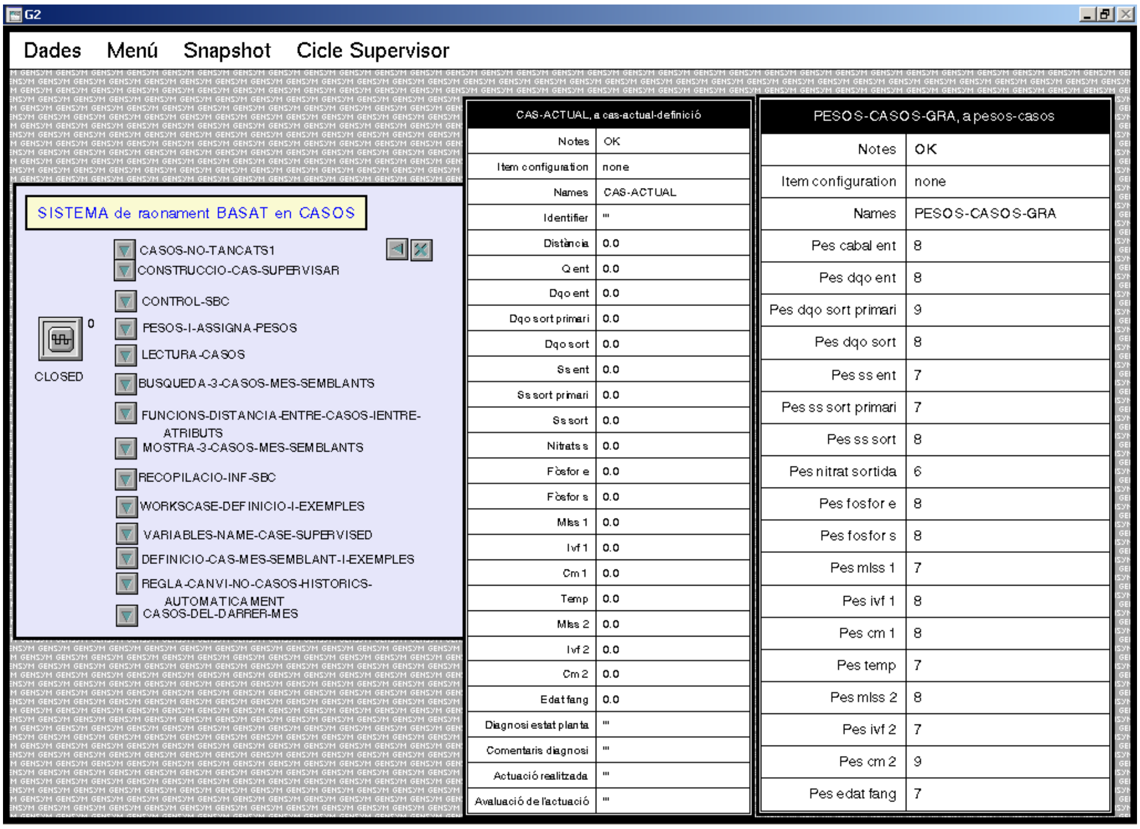
es desconeix la causa.

Mètodes no específics.
";
{call uil-start-dialog ("missatge-escumes" , the symbol none, usuari-window);
call open-file-for-write-diagnosi-Sistema-supervisor (the text-array named by the names of the nom-analitic1 of anal-recent-gra , the missatge1 of escum) ;}

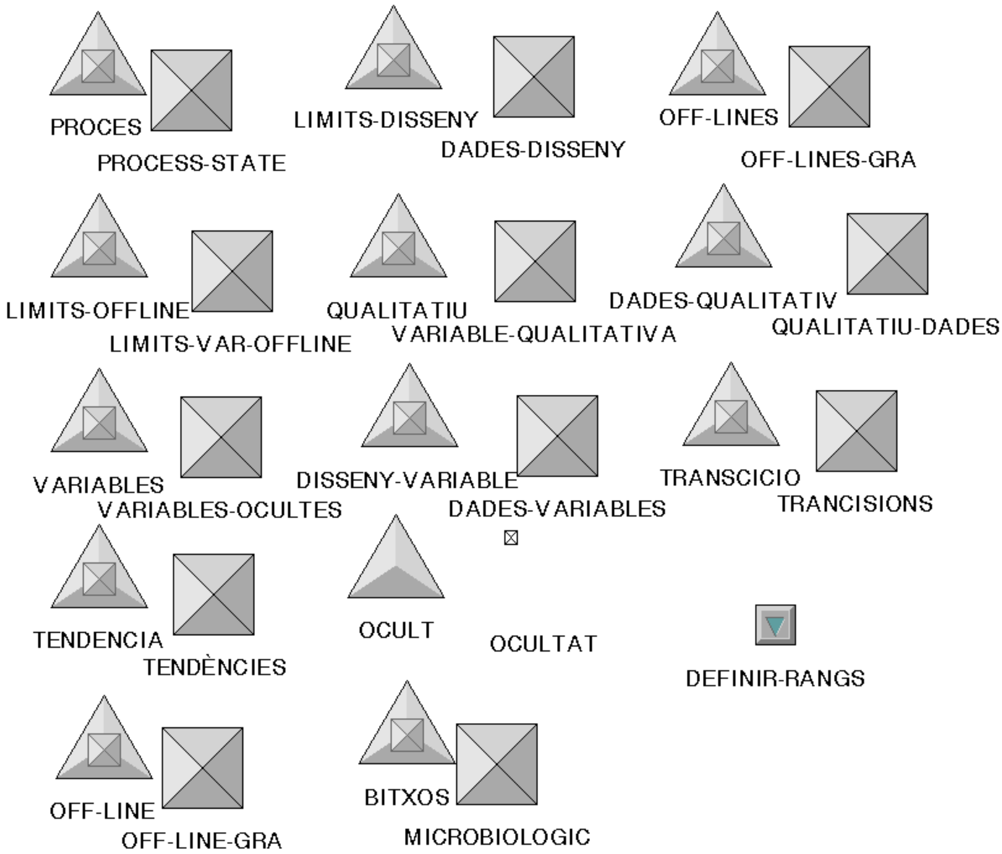
```
conclude that the missatge2 of escum=" .Cabals d'entrada i/o recicrculació a cada reactor
inapropiats: Distribució Q-E o Q-R inadequats, provocant difs. grans de SSLM, per tant
sobrecàrrega illavors, escumes. Modificar i igualar el Q-E i Q-R per cada tanc.
.Def. nutrients, pH anormal, insuficient OD, aigües resid. + fredes o variacions grans en T
(OUR i RR baixa però si hi ha activitat de la microfauna. La deficiència de nutrients provoca
l'aparició d'una escuma deguda a la formació, per part dels microorganismes. de material
polimèric extracel·lular actiu a superfície.

* Escumes Brillant i marró fosc : Q-B i Q-R difs. per dos o més tancs pot sobrecarregar-ne un
de SSLM. Igualar Q-B i Q-R a cada reactor.

* Escuma marró fosc, quasi negre com sabó (LM de color marró molt fosc, quasi negre) sense
fer olor a ous podrits: Possible RI.
 Xoc tòxic recent suau de càrrega : pot causar efluent tèrbol. Les observacions microscòpiques
de SSLM mostraran la inactivitat dels protozoos. Serà necessari una ressembra des d'una altra
planta. S'ha de fer complir un pre-tractament dels residus industrials. El primer que es nota és
el cessament del moviment dels cilis. Els perítrics queden inactius però ciliats swimming i
crawling queden majoritàriament actius. La RR (taxa de respiració) del LM és més baix del
normal.

* Petites quantitats d'escuma fresca, lleugera i marronosa : Signe de planta ben operada amb
bona qualitat d'efluent. ";
change the text of scum to "[the missatge1 of escum ]"; show the subworkspace of escumes;
end;
 end
```

Annex VI: SRBC

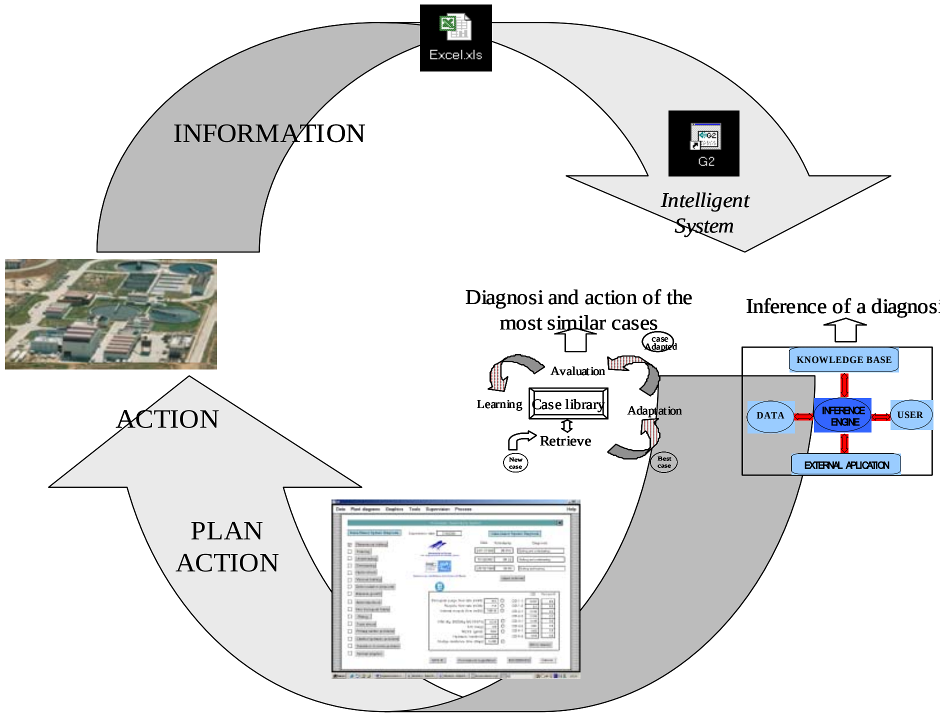

SISTEMA de raonament BASAT en CASOS
CASOS-NO-TANCATS1
CONSTRUCCIO-CAS-SUPERVISAR
CONTROL-SBC
PESOS-I-ASSIGNA-PESOS
LECTURA-CASOS
BUSQUEDA-3-CASOS-MES-SEMBLANTS
FUNCIONS-DISTANCIA-ENTRE-CASOS-IENTRE-ATRIBUTS
MOSTRA-3-CASOS-MES-SEMBLANTS
RECOPILACIO-INF-SBC
WORKSCASE-DEFINICIO-I-EXEMPLES
VARIABLES-NAME-CASE-SUPERVISED
DEFINICIO-CAS-MES-SEMBLANT-I-EXEMPLES
REGLA-CANVI-NO-CASOS-HISTORICS-AUTOMATICAMENT
CASOS-DEL-DARRER-MES
0
CLOSED


G2
Dades
Menú
Snapshot
Cicle Supervisor
SISTEMA de raonament BASAT en CASOS
CASOS-NO-TANCATS1
CONSTRUCCIO-CAS-SUPERVISAR
CONTROL-SBC
PESOS-I-ASSIGNA-PESOS
LECTURA-CASOS
BUSQUEDA-3-CASOS-MES-SEMBLANTS
FUNCIONS-DISTANCIA-ENTRE-CASOS-IENTRE-ATRIBUTS
MOSTRA-3-CASOS-MES-SEMBLANTS
RECOPILACIO-INF-SBC
WORKSCASE-DEFINICIO-I-EXEMPLES
VARIABLES-NAME-CASE-SUPERVISED
DEFINICIO-CAS-MES-SEMBLANT-I-EXEMPLES
REGLA-CANVI-NO-CASOS-HISTORICS-AUTOMATICAMENT
CASOS-DEL-DARRER-MES
0
CLOSED
CAS-ACTUAL, a cas-actual-definició
Notes OK
Item configuration none
Names CAS-ACTUAL
Identifier ""
Distància 0.0
Q ent 0.0
Dqo ent 0.0
Dqo sort primari 0.0
Dqo sort 0.0
Ss ent 0.0
Ss sort primari 0.0
Ss sort 0.0
Nitrats s 0.0
Fòsfor e 0.0
Fòsfor s 0.0
Mlss 1 0.0
Ivf 1 0.0
Cm 1 0.0
Temp 0.0
Mlss 2 0.0
Ivf 2 0.0
Cm 2 0.0
Edat fang 0.0
Diagnosi estat planta ""
Comentaris diagnosi ""
Actuació realitzada ""
Avaluació de l'actuació ""
PESOS-CASOS-GRA, a pesos-casos
Notes OK
Item configuration none
Names PESOS-CASOS-GRA
Pes cabal ent 8
Pes dqo ent 8
Pes dqo sort primari 9
Pes dqo sort 8
Pes ss ent 7
Pes ss sort primari 7
Pes ss sort 8
Pes nitrat sortida 6
Pes fosfor e 8
Pes fosfor s 8
Pes mlss 1 7
Pes ivf 1 8
Pes cm 1 8
Pes temp 7
Pes mlss 2 8
Pes ivf 2 7
Pes cm 2 9
Pes edat fang 7

Annex VII:Variables i objectes.


PROCES
PROCESS-STATE
LIMITS-DISSENY
DADES-DISSENY
OFF-LINES
OFF-LINES-GRA
LIMITS-OFFLINE
LIMITS-VAR-OFFLINE
QUALITATIU
VARIABLE-QUALITATIVA
DADES-QUALITATIV
QUALITATIU-DADES
VARIABLES
VARIABLES-OCULTES
DISSENY-VARIABLE
DADES-VARIABLES
TRANSCICIO
TRANCISIONS
TENDENCIA
TENDÈNCIES
OCULT
OCULTAT
DEFINIR-RANGS
OFF-LINE
OFF-LINE-GRA
BITXOS
MICROBIOLOGIC

Annex VIII: Cicle de funcionament


Excel.xls
INFORMATION
G2
Intelligent System
Diagnosi and action of the most similar cases
Inference of a diagnosi
Avaluation
Learning
Case library
Adaptation
Retrieve
KNOWLEDGE BASE
DATA
INFERENCE ENGINE
USER
EXTERNAL APLICATION
ACTION
PLAN ACTION

Annex IX: Granollers Results

Data	**Dianosi Sistema Expert**	**Estat "real" Planta**
14/2/01	-Sobrecàrrega hidráulica. -Problemes no bio als dec 2aris. -Problemes al dec 1ari. -Baixa càrrega. -Búlking filamentos	
18/2/01	-Sobrecàrrega hidráulica. -Problemes no bio als dec 2aris. -Búlking filamentos	
22/2/01	-Sobrecàrrega hidráulica. -Problemes no bio als dec 2aris. -Problemes al dec 1ari. -Baixa càrrega. -Rising	
26/2/01	-Sobrecàrrega hidráulica. -Problemes no bio als dec 2aris. -Problemes al dec 1ari. -Rising	
1/3/01	-Rising. -Búlking filamentós.	
5/3/01	-Rising -Sobrecàrrega hidràulica -Problemes al dec 1ari.	
10/3/01	-Sobrecàrrega hidráulica. -Problemes no bio als dec 2aris. -Problemes al dec 1ari. -Baixa càrrega. -Rising	
14/3/01	-Rising. -Sobrecàrrega hidràulica. -Procés en baixa càrrega -Problemes no biològics als dec 2aris. -Búlking filamentós.	
19/3/01	-Sobrecàrrega hidràulica. -Procés en baixa càrrega. -Problemes no biològics . -Búlking filamentós.	
22/3/01	-Rising (desconegut) -Baixa càrrega (per tempesta i per F/M baixa) -Búlking filamentós.	
25/3/01	-Rising (desconegut) -Sobrecàrrega hidràulica -Baixa càrrega -Problemes no biològics als dec. 2aris	

28/3/01	-Rising (desconegut) -Sobrecàrrega hidràulica -Baixa càrrega -Problemes no biològics als dec 2aris -Trancisió cap a baixa càrrega	
4/4/01	-Sobrecàrrega hidráulica. -Problemes no bio als dec 2aris. -Problemes al dec 1ari. -Baixa càrrega. -Rising	
17/4/01	-Baixa càrrega per F/M baixa. -Problemes d'origen no biològic als dec 2aris. -Problemes al dec. 1ari per eliminació de fang baixa.	
22/4/01	-Baixa càrrega	
23/4/01	-Baixa càrrega per F/M baixa. -Problemes d'origen no biològic als dec 2aris. -Trancisió cap a baixa càrrega -Sobrecàrrega hidràulica per augment de vel. ascensional.	
1/5/01	-Procés en baixa càrrega -Problemes d'origen no biològic als dec 2aris	
3/5/01	-Sobrecàrrega hidràulica per Q entrada elevat. -Sobrecàrrega hidràulica per augment de la vel. ascensional. -Baixa càrrega -Problemes no biològics als dec. 2aris -Bülking filamentos	
7/5/01	-Sobrecàrrega hidráulica. -Problemes no bio als dec 2aris. -Problemes al dec 1ari. -Baixa càrrega. -Tendència baixa càrrega. -Búlking filamentos.	
9/5/01	-Problemes als dec.1ari per eliminació de fang baixa. -Problemes al dec.1ari per falla mecànica.	
15/5/01	-Sobrecàrrega hidràulica per augment de Q entrada elevat -Sobrecàrrega hidràulica per augment de vel. ascensional. -Problemes no biològis als dec 2aris per Q entrada a biològic elevat. -Sobrecàrrega hidràulica per augment de vel. ascensional. -Problemes al dec.1ari per falla mecànica -Tendència cap a baixa càrrega.	

21/5/01	-Xoc hidràulic -Sobrecàrrega orgánica -Problemes no biològics als Dec.2aris -Problemes als Dec.1aris	
28/5/01	-Sobrecàrrega hidráulica per Q entrada elevat. -Sobrecàrrega hidráulica per augment de vel. ascensional. -Problemes no biològics als dec 2aris per Q entrada biològic elevat. -Trancisió cap a búlking per IVF elevada. -Búlking filamentós per F/M baix.	
29/5/01	-Sobrecàrrega hidráulica. -Problemes no bio als dec 2aris. -Xoc de nitrògen -Xoc de càrrega orgánica -Sobrecàrrega orgánica -Búlking filamentos	
30/5/01	-Sobrecàrrega hidràulica per Qent elevat. -Sobrecàrrega hidràulica per vel. Ascensional elevada. -Xoc de nitrògen. -Sobrecàrrega orgánica per DQOent elevada i F/M elevada. -Xoc de càrrega orgánica. -Problemes no biològics als decantadors 2aris per Qent elevat.	-Sobrecàrrega hidráulica degut a l'elevat Q abocat pels regants. -Sobrecàrrega orgánica. -NO és cert el xoc de nitrògen.
1/6/01	-Rising (per TRC elevat) -Sobrecàrrega hidràulica per Q entrada elevat I per augment de la velocitat ascensional. -Baixa càrrega per F/M baixa. -Problemes no biològics als dec 2aris per Q entrada elevat. -Problemes al Dec 1ari per eliminació del fang baixa i per falla mecánica al dec 1ari-1.	
5/6/01	-Sobrecàrrega hidràulica per Qent elevat. -Sobrecàrrega hidràulica per vel. Ascensional elevada. -Sobrecàrrega orgánica per DQOent elevada i F/M elevada. -*Xoc de càrrega orgánica.* -Tendència a continuar amb sobrecàrrega orgánica (degut a elevada concentració de MO pels corrents interns de retorn). -Problemes no biològics als decantadors 2aris per Qent elevat. -Rising.	-Sobrecàrrega hidráulica degut a l'elevat Q abocat pels regants. -Sobrecàrrega orgánica degut al buidatge del 1ari i als retorns provinents de centrífugues.
10/6/01	-Sobrecàrrega hidráulica. -Problemes no bio als dec 2aris. -Búlking filamentos	

19/6/01	-Sobrecàrrega orgánica. -Xoc orgànic. -Tendència cap a xoc orgànic. -Búlking filamentos. -Sobrecàrrega hidráulica	-La V30 es força elevada (600-700) per presencia de Microthrix i Thiotrix. -Els retorns de planta són molt elevats i carregats (sobretot degut al buidat del digestor). Això pot ser el causant de la presencia de Mic i Thio. -Possible búlking.
20/6/01	-Sobrecàrrega hidráulica. -Problemes no bio als dec 2aris.	
21/6/01	-Sobrecàrrega hidràulica per augment vel. ascensional. -Problemes no biològics als dec. 2aris (per valor molt elevat de MLSS). -Trancisió cap a búlking per augment de IVF.	-La IVF es bastant elevada des de fa uns dies, el que pot provocar una situació de búlking
24/6/01	-Sobrecàrrega hidràulica per augment vel. ascensional. -Problemes no biològics als dec. 2aris (per valor molt elevat de MLSS). -Trancisió cap a búlking per augment de IVF.	-La IVF es bastant elevada des de fa uns dies, el que pot provocar una situació de búlking
25/6/01	-Sobrecàrrega hidráulica per augment vel. ascensional. -Problemes no biològics als dec. 2aris -Trancisió cap a búlking per IVF elevada.	
1/7/01	-Sobrecàrrega hidráulica per augment vel ascensional. -Baixa càrrega per F/M baixa. -Problemes no biològics als dec 2aris. -Problemes al dec. 1ari (per baix rendiment d'eliminació de sòlids i per falla mecánica al dec 1ari-1) -Búlking filamentós per F/M baixa.	-Sobrecàrrega hidràulica. -Baixa càrrega
4/7/01	-Sobrecàrrega hidráulica per augment del Q entrada i per augment vel. ascensional. -Problemes no biològics al dec.2ari -Problemes al dec. 1ari (per baix rendiment d'eliminació de sòlids i per falla mecánica al dec 1ari-1) -Trancisió cap a búlking per augment de IVF.	-La IVF presenta un valor molt elevat (>150) des de fa més d'una setmana. -Encara s'està realitzant el buidat del digestor el que provoca aports importants de sòlids.
8/7/01	-Sobrecàrrega hidráulica per augment de Q entrada i per augment velocitat ascensional. -Baixa càrrega. -Problemes no biològics als decantadors secundaris. -Búlking filamentos per F/M baixa.	

15/7/01	-Baixa càrrega per tempesta o dies de pluja. -Trancisió cap a búlking per disminució de càrrega . IVF molt elevada = 224. -Búlking filamentos per F/M baixa.	-Dies 14 i 15 pluja intensa, per tant la planta es troba en una situació de baixa càrrega.
16/7/01	-Búlking per IVF elevada (225). -Tendència cap a búlking.	
17/7/01	-Sobrecàrrega hidráulica per augment vel. ascensional. -Baixa càrrega per F/M baixa. -Tendència baixa càrrega. -Problemes no biològics als Dec. 2aris. -Búlking fil. per F/M baixa.	
22/7/01	-Sobrecàrrega hidràulica per augment vel. ascensional. -Baixa càrrega per tempesta. -Problemes no biològics als dec. 2aris -Búlking fil. per F/M baixa.	-Tempesta important. -Búlking fil. per presència de 058N. -Baixa càrrega.
24/7/01	-Baixa càrrega. -Tendència baixa càrrega. -Búlking fil. Per F/M baixa.	
25/7/01	-Problemes al dec.1ari per eliminació de fang baixa. -Problemes al dec.1ari per falla mecánica al dec.1ari-2. -Possible tendencia cap a búlking.	-S'està buidant el dec.1ari-2 per reparació.
12/8/01	-Sobrecàrrega hidráulica per augment vel.ascensional. -Baixa càrrega per F/M baixa. -Búlking filamentós per F/M baixa.	
15/8/01	-Baixa càrrega per F/M baixa. -Tendència cap a baixa càrrega. -Búlking filamentos per F/M baixa. -Possible tendència cap a bulking per IVF elevat.	
23/8/01	-Sobrecàrrega hidràulica per augment vel.ascensional. -Baixa càrrega per F/M baixa. -Búlking filamentós per F/M baixa.	
26/8/01	-Sobrecàrrega hidràulica per augment vel. Ascensional. -Baixa càrrega per F/M baixa -Tendència cap a baixa cèrrega. -Búlking filamentos per F/M baixa.	

1/9/01	-Rising per TRC alt.	-S’ha detectat rising a causa d’una falla del cabalimetre de purga que fa que el TRC sigui molt elevat. -Hi ha búlking i foaming.
2/9/01	-Sobrecàrrega hidràulica per augment vel. Ascensional. -Baixa càrrega per F/M baixa -Tendència cap a baixa càrrega. -Búlking filamentos per F/M baixa. -Trancisió cap a búlking.	-Diagnosi correcta del SE.
11/9/01	-Tendència cap a búlking per IVF elevat.	
16/9/01	-Sobrecàrrega hidràulica per augment vel. Ascensional. -Tendència cap a búlking.	
17/9/01	-Sobrecàrrega hidràulica per augment vel. Ascensional. -Tendència cap a búlking.	
20/9/01	-Tendència cap a búlking.	
1/10/01	-Tendència cap a búlking.	
14/10/01	-Situació de normalitat.	
16/10/01	-Baixa càrrega	
18/10/01	-Baixa càrrega	
25/10/01	-Baixa càrrega	
1/11/01	-Búlking filamentos	
5/11/01	-Problemes al dec 1ari	
6/11/01	-Problemes al dec 1ari -Búlking filamentos	

5. Resultats Sistema basat en casos.

DATA	DIAGNOSI SE	DIAGNOSI SBC		
9/5/01	-Problemes al Dec. 1ari per eliminació fang baixa. -Problemes al Dec. 1ari per falla mecánica.	19/5/00	3/5/00 -Baixa càrrega. -Sobrecàrrega hidr. -Búlking fil. -Problemes no bio. als Dec. 2aris.	29/9/00
1/3/01	-*Rising*. -Búlking filamentós.	30/6/00: 96,1% -Rising -Búlking	4/12/99: 94,9% -Microthrix	14/7/00: 94,2% -Baixa càrrega -Xoc hídric -Rising
5/3/01	-Rising -Sobrecàrrega hid. -Problemes al dec 1ari	20/9/99: 98,1% -Normal	28/9/99 -Baixa càrrega	27/5/00
19/3/01	-Sobrecàrrega hid -Baixa càrrega. -Problemes no bio al dec 2ari. -Búlking filamentós.	29/9/99: 97,3% -Principi de foaming per Mic i baixa càrrega.		
4/4/01	-Sobrecàrrega hid. -Problemes no bio als dec 2aris. -Problemes al dec 1ari. -Baixa càrrega. -Rising	29/5/00 -Baixa càrrega -Sobrec. hid. -Rising -Probl no bio al dec 2ari. -Problemes al dec 1ari		10/9/99 -Búlking
17/4/01	-Baixa càrrega per F/M baixa. -Problemes d'origen no biològic als dec 2aris. -Problemes al dec. 1ari per eliminació de fang baixa.	12/9/99 -Búlking		20/9/99 -Normal
22/4/01	-Baixa càrrega	12/9/99 -Búlking		
23/4/01	-Baixa càrrega per F/M baixa. -Problemes d'origen no biològic als dec 2aris. -Trancisió cap a baixa càrrega -Sobrecàrrega hid. per augment de vel.ascens.	28/9/99 -Baixa càrrega		

1/5/01	-Procés en baixa càrrega -Problemes d'origen no biològic als dec 2aris	29/10/99 -Búlking -Foaming (Mic) -Baixa càrrega	16/5/00 -Búlking	10/9/99 -Búlking
7/5/01	-Sobrecàrrega hid -Problemes no bio als dec 2aris. -Problemes al dec 1ari. -Baixa càrrega. -Tend baixa càrrega. -Búlking filamentos.	28/9/99 -Baixa càrrega	18/5/00	
21/5/01	-Xoc hidràulic -Sobrecàrrega orgánica -Problemes no biològics als Dec.2aris -Problemes als Dec.1aris	7/10/99 -Foaming (Mic) -Baixa càrrega. -Rising. -Probl. hidr. als dec. 1aris	25/11/99	10/9/99 -Búlking.
28/5/01	-Sobrecàrrega hidr. per Q entrada elevat i per augment de vel. ascens. -Problemes no bio. dec 2aris per Q ent.bio. elevat -Trancisió búlking per IVF elevada. -Búlking filamentós per F/M baix.	10/12/99: 95,6%	19/7/00: 95,5%	14/7/00: 95,5% -Baixa càrrega. -Xoc hidràulic. -Rising.
30/5/01	-Sobrecàrrega hidr. per Qent elevat. -Sobrecàrrega hidr. per vel. Ascens. elevada. -Xoc de nitrògen. -Sobrecàrrega orgánica per DQOent elevada i F/M elevada. -Xoc de càrrega org. -Problemes no bio. als dec 2aris per Qent elevat.	10/9/99 -Búlking	19/7/00	7/7/00
5/6/01	-Sobrecàrrega hid per Qent elevat. -Sobrecàrrega hid per vel. Ascen elevada. -Sobrecàrrega orgánica per DQOent elevada i F/M elevada.	30/5/01: 95,7% -Sobrecàrrega hid. -Sobrecàrrega org. -Probl. no bio.	5/6/00: 94,8%	1/6/01: 94,6% -Rising -Sobrecàrrega hid. -Baixa càrrega. -Probl. no bio. als dec. 2aris.

	-Xoc de càrrega org -Tendència sobrecàrrega org(degut als corrents interns de retorn). -Problemes no bio als dec 2aris per Qent elevat. -Rising.	als dec 2aris.		
10/6/01	-Sobrecàrrega hidr. -Problemes no bio als dec 2aris. -Búlking filamentós	7/5/00 -Búlking		
19/6/01	-Sobrecàrrega orgánica. -Xoc orgànic. -Tend xoc orgànic. -Búlking filamentos. -Sobrecàrrega hid	19/7/00: 96,2%	18/7/00: 95.5%	14/7/00: 95,4% -Baixa càrrega. -Xoc hídric. -Rising.
21/6/01	-Sobrecàrrega hidràulica per augment vel. ascensional. -Problemes no biològics als dec. 2aris (per valor molt elevat de MLSS). -Trancisió cap a búlking per augment de IVF.	9/12/99: 97% -Búlking.	18/7/00: 95%	20/7/00: 95% -Búlking. -Baixa càrrega. -Rising.
24/6/01	-Sobrecàrrega hid per augment vel. Ascen. -Problemes no bio als dec. 2aris (per valor molt elevat de MLSS). -Trancisió cap a búlking per augment de IVF.	9/12/99 -Búlking		
25/6/01	-Sobrecàrrega hid per augment vel. ascen -Problemes no biològics als dec. 2aris *-Trancisió cap a búlking per IVF elevada.*	29/10/99 *-Búlking.* -Foaming (Mic). -Baixa càrrega.	9/12/99 -Búlking	19/7/00
1/7/01	-Sobrecàrrega hid per augment vel ascen. -Baixa càrrega per F/M baixa.	21/11/99 -Foaming per Mic I Noc		9/12/99 -Búlking

	-Problemes no bio als dec 2aris. -Problemes al dec. 1ari (per baix rendiment d'eliminació de sòlids i per falla mecánica al dec 1ari-1) -Búlking filamentós per F/M baixa.			
4/7/01	-Sobrecàrrega hidráulica per augment del Q entrada i per augment vel. ascensional. -Problemes no biològics al dec.2ari -Problemes al dec. 1ari (per baix rendiment d'eliminació de sòlids i per falla mec. al dec 1ari-1) -Trancisió cap a búlking per augment de IVF.	21/11/99: 98,2% -Foaming per Mic i Noc.	12/6/99: 98,1%	9/12/99: 96,1% -Búlking
8/7/01	-Sobrecàrrega hidráulica per augment de Q entrada i per augment vel. ascensional. -Baixa càrrega. -Problemes no biològics als decantadors secundaris. -Búlking filamentos per F/M baixa.	8/11/00 -Búlking. -Baixa càrrega.	22/8/00	28/5/00 -Baixa càrrega per F/M baixa.
15/7/01	-Baixa càrrega per tempesta o dies de pluja. -Trancisió cap a búlking per disminució de càrrega . IVF molt elevada = 224. -Búlking filamentos per F/M baixa.	21/5/00: 96,9% -Búlking. -Baixa càrrega	14/5/00: 96,6%	12/5/99: 96,4%
22/7/01	-Sobrecàrrega hidràulica per augment vel.ascens. -Baixa càrrega per	9/12/99: 99,2% -Búlking	8/11/00: 97,6% -Búlking. -Baixa càrrega.	26/9/99: 97,2% -Normal

	tempesta. -Problemes no biològics als dec. 2aris -Búlking fil. per F/M baixa.			
24/7/01	-Baixa càrrega. -Tendència baixa càrrega. -Búlking fil. Per F/M baixa.	28/9/99: 95,6% -Baixa càrrega.	9/7/00: 95,4% -Búlking. -Baixa càrrega. -Rising	8/11/00: 95,1% -Búlking. -Baixa càrrega.
12/8/01	-Sobrecàrrega hidráulica per augment vel.ascensional. -Baixa càrrega per F/M baixa -Búlking filamentós per F/M baixa.	12/12/99: 97,7%	11/8/00: 96,7% -Búlking. -Baixa càrrega.	28/11/99: 96,5% -Foaming
15/8/01	-Baixa càrrega per F/M baixa -Tendència baixa càrrega. -Búlking filamentos per F/M baixa. -Possible tendència cap a bulking per IVF elevat.	18/8/00: 96,0% -Baixa càrrega.	11/8/00: 95,6% -Búlking. -Baixa càrrega.	12/8/01:94,9% -Baixa càrrega. -Búlking per baixa càrrega.
23/8/01	-Sobrecàrrega hidràulica per augment vel.ascensional. -Baixa càrrega per F/M baixa. *-Búlking filamentós per F/M baixa.*	12/9/99: 98,7% -Búlking.	12/12/99: 95,9%	18/8/00: 95,8% -Baixa càrrega.
26/8/01	-Sobrecàrrega hidràulica per augment vel.ascen. -Baixa càrrega per F/M baixa -Tendència baixa cèrrega. -Búlking filamentos per F/M baixa.	21/11/99: 97,1% -Foaming per Mic i Noc.	18/8/00: 96,6% -Baixa càrrega.	28/11/99: 96,3% -Foaming
1/9/01	-Rising per TRC alt.	3/5/01: 91,4% -Baixa càrrega. -Sobrecàrrega hid. -Búlking.	26/11/99: 90,7%	1/12/99: 90,6% -Microtrhrix. -Baixa càrrega.
2/9/01	-Sobrecàrrega hidràulica per augment	12/9/99: 98,3%	18/8/00: 95,4% -Baixa càrrega.	11/8/00: 94,9% -Búlking.

	vel. Ascen. -Baixa càrrega per F/M baixa -Tendència cap a baixa càrrega. -Búlking filamentos per F/M baixa. -Trancisió cap a búlking.	-Búlking.		-Baixa càrrega.
11/9/01	-Tendència cap a búlking per IVF elevat.	23/7/00: 94,8% -Normalitat.	18/8/00: 94,7% -Baixa càrrega.	21/11/99: 92,7% -Foaming per Mic i Noc
16/9/01	-Sobrecàrrega hidràulica per augment vel.ascens. -Tendència cap a búlking.	12/9/99: 99,3% -Búlking.	23/7/00: 97,1% -Normalitat.	4/12/99: 95,7% -Microthrix.
17/9/01	-Sobrecàrrega hidràulica per augment vel. Ascensional. -Tendència cap a búlking.	29/10/99: 98,6% -Búlking. -Foaming (Mic). -Baixa càrrega.	14/7/00: 98,1% -Baixa càrrega. -Xoc hídric. -Rising.	4/12/99: 96,1% -Microthrix.
20/9/01	-Tendència cap a búlking.	29/10/99: 98,8% -Búlking. -Foaming (Mic). -Baixa càrrega.	4/12/99: 97,6% -Microthrix.	14/7/00: 96,8% -Baixa càrrega. -Xoc hídric. -Rising.
1/10/01	-Tendència cap a búlking.	10/12/99: 97,8%	23/7/00: 97,8% -Normalitat.	18/8/00: 96,7% -Baixa càrrega.
16/10/01	-Baixa càrrega	9/7/00 -Búlking -Baixa càrrega -Rising	8/11/00 -Búlking -Baixa càrrega	26/9/99 -Normal
18/10/01	-Baixa càrrega	26/9/99 -Normal	20/9/99 -Normal	30/8/99 -Tall elèctric
25/10/01	-Baixa càrrega	29/10/99 -Búlking -Foaming(Mic) -Baixa càrrega	29/9/99 -Normal -Foaming per Mic I baixa càrrega	11/7/00 -Sobrecàrrega hid. -Probl no bio als dec 2aris -Tend búlking
1/11/01	-Búlking filamentós	12/9/99 -Búlking	26/9/99 -Normal	21/5/00 -Búlking -Baixa càrrega