LIFE Project Number

# LIFE05 ENV/IT/000846

# FINAL REPORT

Reporting Date

## 31/03/2009

LIFE PROJECT NAME

# BATTLE

Data Project

| | |
|---|---|
| **Project location** | Rome, Italy |
| **Project start date:** | 01.12.2005 |
| **Project end date:** | 30.11.2008 **Extension date:** none |
| **Total Project duration (in months)** | 36 months **Extension months** none |
| **Total budget** | € 2.037.844 |
| **EC contribution:** | € 968.402 |
| **(%) of total costs** | 47.52 % |
| **(%) of elibible costs** | 50.00 % |

Data Beneficiary



| | |
|---|---|
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## 1. LIST OF CONTENTS

## 2. LIST (I) KEY-WORDS AND (II) ABBREVIATIONS

### I: Keywords

Textile industry; Textile BAT; Textile wastewater; Wastewater characterisation; Wastewater minimisation; Wastewater reuse; Respirometry; Membrane technology; Submerged membranes; Ultrafiltration; Textile BAT

### II: Abbreviations

| **Abbreviations** | **Description** |
|---|---|
| BAT | Best Available Technique |
| BREF | Best available techniques REFerence |
| CID | Colour Index Detector |
| CIDA | Centro Imprese Depurazione Acque |
| COD | Chemical Oxygen Demand |
| DC | Total Dissolved Carbon |
| DIC | Dissolved Inorganic Carbon |
| DOC | Dissolved Organic Carbon |
| ENEA | Ente per le Nuove Tecnologie, l'Energia e l'Ambiente |
| ES | Expert System |
| IPPC | Integrated Pollution Prevention and Control |
| IRR | Internal Rate of Return |
| LCA | Life Cycle Assessment |
| MBR | Membrane BioReactor |
| NPV | Net Present Value |
| OUR | Biological Oxygen consUmption Rate |
| PIDACS | Process Identification and DAta Collection Sheet |
| SdM | Stamperia di Martinengo |
| SME | Small-Medium Enterprise |
| TSS (SST) | Total Suspended Solids |
| UF | Ultra Filtration |
| UNIFI | UNIversità degli Studi di FIrenze, Dipartimento di Ingegneria Civile |
| VSS | Volatile Suspended Solids |
| WPR | WasteWater Pollution Rate |
| WWrTP | Wastewater reuse Treatment Plant |
| WWTP | Wastewater Treatment Plant |

## 3. EXECUTIVE SUMMARY

A brief introduction of the project is presented in chapter 4, followed by the project framework and the partners profile, which are included in chapter 5. Then, the technology developed during the implementation of the project is presented in chapter 6, while the results per task, the progress and the encountered problems are included in chapter 7. The dissemination actions are presented in detail in chapter 8. The next chapter (9) includes the evaluation and conclusions of the implemented activities, while chapter 10 contains the after life dissemination-communication plan. Next chapter contains comments on the financial report, followed by the appendices which contain a catalogue with all Annexes. Finally, the Layman's report –two versions in English and Greek- is attached at the end of the report.

## 4. INTRODUCTION

### Background and objectives

The textile sector is highly water demanding and its biggest impact on the environment is related to primary water consumption (80-100 $m^3$/ton of finished textile) and wastewater discharge (115-175 kg of COD/ton of finished textile, large range of organic chemicals, low biodegradability, colour, salinity). According to the IPPC Directive 96/91/CE, the textile BREF (Best available techniques REFerence document) should be implemented by all big companies and by small and medium-sized enterprises (SMEs) having a production capacity over the threshold of 10 tons/day. Also smaller companies are interested in the BREF recommendations since the document is meant to become a guideline for the overall sector. The textile BREF contains several BATs (Best Available Techniques) to prevent pollution and reduce the impact in the production processes but only general advices on wastewater treatment and reuse. The water recycling is not exhaustively considered and available techniques for the purpose are not provided.

The BATTLE project aims at configuring and applying on demonstrative scale a new BAT for low impact water management in textile industry with the development and prototypal application of a clean technology for the water reuse, at present not envisaged in the BREFs. The new BAT for low impact water management in textile industry proposed by BATTLE designs an innovative water scheme implementing effluent reuse, and apply a methodology which integrates the different aspects involved in reuse (data collection, on-line characterization, streams segregation, final effluent treatability evaluation and impact control, reclaimed water reusability evaluation, costs analysis), based on the prototypal multicriteria methodology built up within the EU funded RTD project TOWEF0 (Toward effluents Zero – EVK1-CT-2000-00063).

### Technical/methodological solution

Feasibility and efficiency of the new BAT has been shown by its demonstrative application in a representative textile finishing medium enterprise, Stamperia di Martinengo. The new BAT proposed methodology relies on the concept of separation of the process effluents as opposed to the end of pipe approach. The process effluents with suitable characteristics are mixed and the resulting stream is diverted to a treatment station (membrane plant) for subsequent reuse after mixing with primary water in the necessary proportion. The effluents not suitable for reuse, mixed with the concentrates produced by the membrane plant will constitute the inlet of the existing WWTP whose operation will have to be optimised to adapt it to the treatment of smaller volumes of more concentrated effluents.

Membrane technology has emerged as a reliable and feasible option in the treatment of various textile effluent streams. At present it represents the most widely applied treatment for on-site reuse, allowing the recovery not only of water but also of chemicals and energy. Attractive features of membranes are also: the low weight and footprint of the equipment, the reduced use of chemicals, a constant quality permeate and the high potential for automated operation.

Water recycling has several important environmental benefits and a saving of at least 50% of fresh water by substitution with reclaimed effluents is the first expected result of the project.

The quality standards for reuse water have been tailored to the production requirements and it was online controlled by an appropriate monitoring system. In fact, the extreme variability of reusable streams of the textile wastewater process effluents requires on-line water quality measurements and implementation of on-line control plus the development and instruction of a prototype Expert System.

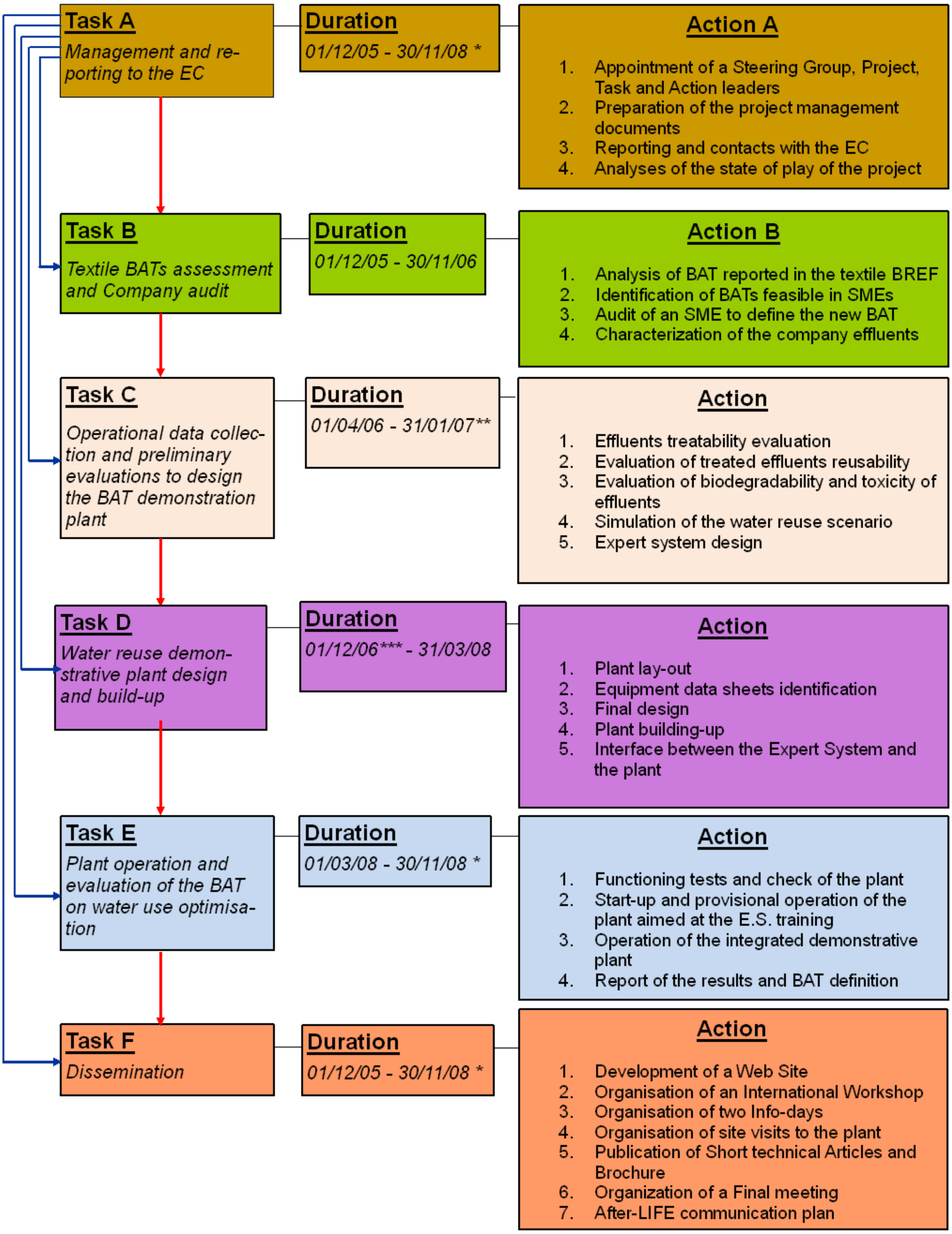
**Expected results and environmental benefits**

Expected results of BATTLE project can be summarised as follows:

- “BREF type” guidelines for optimisation of water cycle in textile SMEs and further submission to the IPPC bureau
- Handbook of the proposed BAT
- A saving of at least 50% of fresh water by substitution with reclaimed effluents is expected. To reach the standards for reuse, which will be determined by production requirements, the treatment system performance is expected to comply with the following targets 80-90% removal of total organic matter, 99% for total suspended solids 95-98% for colour and 80% for surfactant
- Sensitization of at least hundred European companies in view of implementation of the technique in their factories

For what concerns the BATTLE environmental benefits, they are focused on water, a scarcely renewable resource, which has a high environmental value but the actual cost, very different across Europe, often does not take into account its real value. Around 120 million $m^3$ of primary water are used in Europe by textile industry. On average, 90% of the water input in textile finishing operations needs to be treated end-of-pipe and discharged. 36 million tons of chemicals and auxiliaries have to be removed from the wastewater. Specific water usage rates may vary among different textile operations from 50 to over 500 $m^3$/t. Particularly high amounts of water are used by printing and dyeing where 50% reduction is possible by the BAT proposed while considering the overall textile sector a water saving of 30% seems feasible.
In Europe, the textile and clothing industry represents 3.4% of the EU manufacturing industry turnover, 3.8% of the added value and 6.9% of the industrial employment. In a scenario of water scarcity or when an incentive regulatory policy on the water tariffs is implemented, the capability of carrying out the production with reclaimed water can be strategic for the economical competitiveness.
The introduction of water reuse will cause an increase in the overall energy consumption, being the membrane treatment plants normally more energy consuming than conventional WWTPs. Increase in energy consumption, alongside its impact on key environmental categories has been already evaluated on the base of the pilot experimental data by means of LCA carried out in the RTD EU project Towef0. LCA evidenced that membrane treatment of selected medium-low polluting load effluents is the best solution because the benefits related to the reduction of primary water use and wastewater reduction overcome environmental costs related to increase in energy consumption.
Beside the local situation, these considerations can be extended to the overall textile sector in order to implement useful technical changes for the economical and environmental sustainability of the production.

## 5. LIFE-PROJECT FRAMEWORK




* due to the plant breakdown tasks duration was extended to 31/03/09
** task C ended with a two months delay: 31/03/07
*** task D started with a two months delay: 01/02/07

## ORGANIGRAM:

| Task ID | Task Title | Task Leader | Action Leader | Participants |
|---|---|---|---|---|
| A | Management and reporting to the EC | ENEA | A1 - ENEA | All |
| | | | A2 - ENEA | All |
| | | | A3 - ENEA | All |
| | | | A4 - ENEA | All |
| B | Textile BATs assessment and Company audit | CIDA | B1 - Centexbel | Centexbel |
| | | | B2 - Centexbel | Centexbel, ENEA |
| | | | B3 - CIDA | CIDA, ENEA, SdM |
| | | | B4 - SdM | CIDA, ENEA, SdM |
| C | Operational data collection and preliminary evaluations to design the BAT demonstration plant | ENEA | C1 - ENEA | ENEA, SdM, UNIFI |
| | | | C2 - Centexbel | Centexbel, ENEA, SdM |
| | | | C3 - UNIFI | ENEA, SdM, UNIFI |
| | | | C4 - CIDA | CIDA, ENEA, SdM, UNIFI |
| | | | C5 - ANOVA | ANOVA, ENEA |
| D | Water reuse demonstrative plant design and build-up | SdM | D1 - ENEA | ANOVA, CIDA, ENEA, SdM |
| | | | D2 - CIDA | ANOVA, CIDA, ENEA, SdM |
| | | | D3 - CIDA | CIDA, ENEA, SdM |
| | | | D4 - SdM | ENEA, SdM |
| | | | D5 - ANOVA | ENEA, SdM, UNIFI |
| E | Plant operation and evaluation of the BAT on water use optimisation | ENEA | E1 - ENEA | ENEA, SdM, UNIFI |
| | | | E2 - ENEA | ANOVA, ENEA, SdM |
| | | | E3 - ENEA | ANOVA, ENEA, SdM, UNIFI |
| | | | E4 - ENEA | ENEA, UNIFI |
| F | Dissemination | ENEA | F1 - ENEA | All |
| | | | F2 - ENEA | All |
| | | | F3 - ENEA | All |
| | | | F4 - SdM | ENEA, SdM |
| | | | F5 - ENEA | All |
| | | | F6 - ENEA | All |

**BATTLE Organisation:**

- **Project beneficiary**:

**ENEA**, the Italian National Agency for Energy, New Technology and the Environment. ENEA is a public research organisation whose specific mission is in applied research activities, technology transfer and dissemination of innovations to companies thanks to its expertise in new technologies, energy and the environment.

- **Partners:**

**ANOVA s.a.s**., Napoli, Italy. ANOVA - Knowledge Based Software Solutions is a private R&D Laboratory, operating in Knowledge Engineering and Artificial Intelligence, software applications in Environmental and Agro-Industrial fields.

**CENTEXBEL** (wetenschappelijk en technisch centrum van de Belgische textielnijverheid), Brussels, Belgium. The Scientific and Technical Centre of the Belgian Textile Industry Centexbel is a no-profit organisation with a private structure. At national level, Centexbel supports the finishing companies to optimise their water management.

**C.I.D.A. - CENTRO IMPRESE DEPURAZIONE ACQUE S.p.A.,** Fino Mornasco (COMO) Italy. CIDA is a private consulting company for textile sector waste minimisation, carrying out environmental consulting, design and coordination tasks related to the upgrading of the centralised water and wastewater treatment plants, studies and experimental investigation on advanced tertiary and polishing wastewater treatments for water reuse, water service (plants and networks) management of the Como area.

**Stamperia di Martinengo s.r.l.**, Martinengo (Bergamo), Italy. **SdM** is a medium-sized textile printing and dyeing company, treating around 10.000 metres of textiles per year and employing 140 workers. In its production, SdM treats the main types of fibres and dyes of the textile sector.

**Università degli Studi di Firenze, Dipartimento di Ingegneria Civile**, Firenze, Italy. The Department, running ten specialized laboratories, carries out the academic and research activities in the field of civil and environmental engineering.

Note that no modifications have been made in the partnership or in their functions and tasks with respect to the project initial proposal. However it is to be noted here that, due to ENEA internal reorganization previous Head of the Environment Department Dr Giorgio Gavelli has been replaced by Dr Marcello Claudio Garozzo.

## 6. TECHNOLOGY

The main objective of the Project BATTLE (Best Available Technique for water reuse in TextiLE SMEs) is the development and prototypal application of a clean technology for the water reuse, to be proposed as reference BAT for textile companies. The methodology, techniques and technologies applied in the pursue of this objective are here described, following the logical and temporal sequence of their application and presented per task and respective action:

*Task B: Textile BATs assessment and company audit*

*Action B.1 and B.2: Analysis of BAT reported in the textile BREF - Identification of BATs feasible in SMEs*
The first step of the Battle project was the analysis of the BATs as reported in the textile BREF. This screening of the techniques was carried out at two different levels. The first evaluation of the BAT applicability by the SMEs as well as by large enterprises of the textile finishing sector, has been carried out by means of a specifically conceived questionnaire capable of collecting detailed information on the implementation degree of every single measures in the BREF.The questionnaire was composed of 4 parts; general information on the company: administrative data, survey of processed raw materials and end products; BAT of a general nature focused on water management and wastewater purification; process related BAT focused on reduced water consumption and improved wastewater quality and product related BAT focused on prevention and improvement of wastewater quality. The questionnaire was constructed in order to have the possibility to identify those applied or considered applicable both by IPPC companies and by smaller ones. Each of the selected measures was shortly described. In fact, the questionnaire was composed of cells allowing to indicate for each measure; the relevance of the measure to the company's activities; if relevant, the actual application or not of the measure; the main reason for the application status; facultative further comments for better comprehension and evaluation of the status. In order to facilitate and to harmonise the answers, several feasible reasons for implementation or not, were foreseen; with the possibility to add extra reasons. The second level of data collection was obtained by performing audits/interviews in IPPC companies with persons responsible for different departments (eg environmental affairs) and this by a direct visit or if not possible by a sending an adapted questionnaire.

*Action B.3: Audit of an SME aimed at defining the new BAT*
The second step was a complete characterization of the SME. An auditing procedure referred to as PIDACS was carried out and it provided a detailed description of the company and the identification of the main processes and their environmental impact. The audit covered relevant data concerning production, water use and specifically supplied water, process water quality and treatment for internal use, water for steam production, discharged water, energy consumption, solid wastes, off-gas emissions, departments and working time, equipment. The data collected were elaborated to produce: a material flow chart, an energetic flow chart, a water flow chart, quantitative evaluation of water consumptions and discharges, water analytic data, production model, general process scheme and detailed process schemes for the main company departments (general facilities, preparation, dyeing, printing and finishing).

*Action B.4: Characterisation of the company effluents*
The subsequent step consisted in the chemical characterisation of all the main company effluents. The analytical parameters were selected according to the following criteria:

- compounds expected in significant concentration from the analysis of process recipes
- parameters potentially affecting effluents treatability reusability and discharge
- parameters usually found in scientific literature on textile wastewater

The selected parameters are: pH, conductivity, hardness, turbidity, TSS, VSS, DC, DIC, DOC, Colour (absorbance). All parameters were analysed according to standard methods. Only effluents from the significantly water consuming processes were selected for the chemical characterisation (i.e. printing department and textile washing department), in total 45 different process effluents (104 samples).

*Task C: Operational data collection and preliminary evaluations*

*Action C.1 and C.2: Effluents treatability evaluation - Evaluation of treated effluents reusability*
Then the treatment technology was selected and the effluents treatability assessed. Preliminary evaluations and comparison were carried out among MBR, membrane filtration, activated carbon adsorption and clariflocculation. From literature analysis and preliminary treatability tests UF filtration emerged as the ideal treatment technology efficiently allow the complete removal of suspended material and a significant colour reduction while containing the treatment costs. Hollow fibres were selected for the possibility of maintaining high fluxes and their resistance to clogging. The UF membrane selected was hollow fibre membrane ZeeWeed® by GE Zenon (non-ionic hydrophilic PVDF surface with nominal pore diameter of 0.04 micron), that is particularly suitable at dealing with high turbidity effluents without pretreatment.
Experimental evaluation of membrane filterability of the effluents was carried out for all the 45 process effluents characterised and for final effluent of the company's waste water treatment plant. Tests were carried out at lab scale by employing a single hollow fibre membrane.
The experimental apparatus consisted of a feed beaker 250 ml where the membrane was immersed and connected trough a vacuum pump to a permeate vessel. Pressure and temperature were maintained during the tests at -40 KPa and 25℃ respectively.
Before testing the effluents, a characterization was carried out on the membrane by circulation of deionised water and flow rates were determined. After the characterization, batch tests were carried out using real effluents by continuously discharging permeate from the feed tank and therefore increasing the feed concentration until 75% of the feed volume was permeated. Flux drop were measured during the tests and diagrams were drawn. When necessary (i.e. flux drop > 50%), brief counter washing of 10 ml of permeate were carried out by inverting the pressure on the membrane from negative to positive. After this, another characterisation by deionised water was performed. Whenever the second characterisation evidenced a big flux drop respect to the first the membrane was thoroughly counter-washed and if this was insufficient to recover the original performances it was chemically washed in a sodium hypochlorite solution.
The filterability evaluation of the effluents was based on the removals of the selected contaminants and on flux consideration. The permeate quality obtained by the simple lab scale apparatus is normally in accordance with the values obtained at bigger scale. On the contrary, flux values measured at bench scale, are not reliable for pilot-scale/full-scale flux estimation but they were significant for preliminary comparison among different effluents.
The treated water reusability was assessed by specific tests, carried out at the company site. The permeate for the tests was produced by using a pilot scale plant schematised in Figure 6.1.

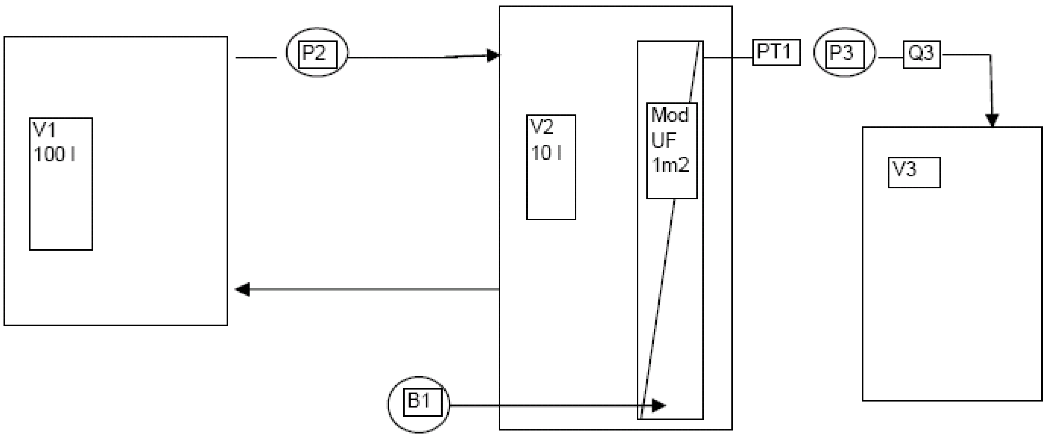



*Figure 6.1: scheme of the pilot plant(V1= effluent storage tank; V2= membrane vessel; V3= permeate storage tank; P3= volumetric pump reversible flux for permeate extraction and membrane backwashing; P2= submerged centrifugal pump for filling the membrane tank with effluent from the storage tank; B1= blower for membrane shaking; PT1= transmembrane pressure monitor; Q3: flow rate monitor for pump P3)*

The pump P2 fills the membrane vessel. The effluent, exceeding the membrane filtration, returns to the storage tank by overflowing. The blower B1 continuously flows air through the membranes to keep them moving and, thus, preventing clogging.
The pump P3 extracts the permeate and, periodically reverses the flux for backwashing and, thus, keeps the membrane clean.
In each test 100 l effluent was treated by ultrafiltration.
The membrane filtration system used is ZeeWeed®10 by Zenon Environmental Inc., it is installed in a stainless steel tank. The transmembrane pressure was between -0.01 and -0.02 bar during the permeate production phases and between 0.08 and 0.12 bar during the backwashing phases. The permeate flux ranged between 15 and 21 l/h, depending on the pollution in the effluent.
Based on effluents characterisation and filterability evaluations, a selection of potentially reusable effluent streams was made. 8 different segregated process effluents, 10 different mix of process effluents and several samples of the final effluent of the WWTP were tested.
The treated effluents, i.e. permeates, were reused for different textile processes. The quality of textile materials, treated with permeate, was always compared with a reference treatment, for which 100% fresh process water has been used. The reuse tests have been evaluated by making use of different parameters for comparing the textiles processed (i.e. degree of whiteness, colour difference, colour fastness to water, white reserve of printed textile, hand feeling)
Since the reuse of permeate for the washing of the rotative printing belt could not be tested in laboratory, an “ad hoc” procedure was worked out, using a flat screen printing table.

*Action C.3: Evaluation of biodegradability and toxicity of effluents*
In parallel, WWTP performance trials for the evaluation of biodegradability and toxicity of more concentrated effluents were carried out by respirometric/titrimetric tests; simulation of effects on the WWTP effluents were calculated by using the Activated Sludge Model n. 1 (ASM1).
In order to assess the effect of water recycling on the biological WWTP were carried out:

- a characterization of WWTP influent;
- an evaluation of potential toxicity/inhibition effects on biological activity.

For the assessment of different wastewater components were used both physical-chemical analysis (COD both soluble and particulate, ammonium, suspended solids, conductivity, pH…) and biodegradation tests (setting up respirometric procedures). Respirometry is the measurement and interpretation of the biological oxygen consumption rate; therefore with a respirometer biodegradable components of wastewater can be directly detected.
The potential inhibitory effects of more concentrated WWTP influents were investigated mainly on nitrifying micro-organisms known to be slow growing bacteria compared to aerobic heterotrophs ones and to be very sensitive to inhibiting compounds. This method is related to the assessment of the nitrification activity by pH-stat titration. The investigation on inhibitory effects were performed with samples of WWTP effluent as well as samples of equalization tank to evaluate impact of both not biodegradable and biodegradable components.
All these tests were carried out in order to predict the behaviour of the WWTP under critical conditions such as the reduction of inlet flow and the consequent increasing in concentration of substances contained in the printing process water.
The first activity was the characterization of organic compounds of wastewater. The organic compounds of wastewater (expressed as COD) has been divided in 4 different forms with regard to their biodegradability and dimension:

- $S_S$: soluble biodegradable substrate (readily biodegradable);
- $S_I$: soluble inert organic matter;
- $X_S$: particulate biodegradable substrate (slowly biodegradable);
- $X_I$: particulate inert organic matter;

Soluble and particulate inert organic matter ($S_I$ and $X_I$) are not involved in any conversion processes; in particular $S_I$ is a critical component because of it contributes to the effluent COD. $X_I$ is removed by sludge disposal and it does not contribute to the effluent COD. $S_S$ is removed biologically under either aerobic or anoxic condition while $X_S$ is also removed but a previous hydrolization process is necessary.
The second activity concerned of the determination of potential inhibitory effects of biological activity. In particular a series of experimental trials were carried out in order to evaluate potential inhibitory effects on nitrifying micro-organisms due to the higher concentration of biodegradable and not biodegradable compounds in wastewater depending on different water reuse schemes.
At the time of respirometric and titrimetric tests, a detailed project for reuse implementation was not elaborated yet. For this reason different reductions of the industrial effluent flow (40 and 60%) were considered and the global impact of concentrated effluents was tested.
The assessment of biological activity inhibition due to higher concentrations of biodegradable and/or not biodegradable contaminants expressed in terms of COD, was investigated. In particular the potential inhibition due to biodegradable and/or not biodegradable compounds was investigated monitoring the rate of nitrification process before and after spikes of concentrated samples of WWTP influent and effluent (named ‘toxicant’).
All the data collected were necessary for the application of the model used for the WWTP modelling.
As a first step a model based on AMS1 was implemented in order to correctly simulate the behaviour of the WWTP at present time (without reuse).
Successively, the results obtained from the trials carried out for the assessment of biodegradable/inhibitory factors have been used in order to verify the behaviour of the WWTP under different water reuse scenario using the model implanted in the first step.
The ASM1 presented by the IWAQ Task group on Mathematical modelling for design and operation of biological of biological wastewater treatment processes is generally accepted as state-of-the-art and is used for simulation of waste water treatment plants in many studies.
However, the biological nature of WWTP processes implies that the characteristic of the process be determined over and over again according to the local situation.
Analyzing all respirometric and titrimetric tests carried out during the experimental activities, we estimated:

- kinetic parameters
  - heterotrophic maximum growth rate, decay rate, half-semisaturation constant: $\mu_{H,max}$, $b_H$; $K_S$;
  - autotrophic maximum growth and decay rate: $\mu_{A,max}$, $b_A$;
  - hydrolysis kinetic constants: $k_h$, $K_X$;

- stoichiometric parameters
  - heterotrophic yield: $Y_H$;

- component concentrations in the influent
  - $S_S$ readily biodegradable substrate;
  - $S_I$ soluble inert organic matter;
  - $X_S$ slowly biodegradable substrate;
  - $X_I$ particulate inert organic matter.

- component concentrations in the sludge
  - SST total suspended solids;
  - SSV volatile suspended solids.

All these parameters (determined for the present case) were necessary in order for a model to have utility in design and operation of wastewater treatment system; all the other necessary parameters were assumed according with literature data.

*Action C.4: Simulation of the water reuse scenario*

All the above evaluations were the basis for the demonstrative plant design.

Four different water treatment reuse scenarios were identified and compared to select the better solution for the company.

The Net present value method was used for the financial appraisal of project and for scenarios comparison.

NPV is the sum of each cash inflow / outflow from year 0 to $n^{th}$ year. Each cash flow is discounted back to its present value. NPV positive means that the investment would add value and the project should be accepted. Therefore:

$$NPV = \Sigma_{t=0}^{n} \frac{C_t}{(1+r)^t} \qquad (1)$$

with:
- t = the time of the cash flow
- n = the total time of the project
- r = the discount rate
- $C_t$ = the net cash flow (the amount of cash) at time t;

To assess the project two other methods were used:

- the payback period method: it measures the time required for the cash inflows to equal the original outlay;
- the internal rate of return method: the IRR is the annualized effective compounded return rate which can be earned on the invested capital.

*Action C.5: Expert System design*
On-Line/Real-time monitoring of wastewater quality remains a scarcely resolved problem into the wastewater treatment industry. A water quality assessment requires of more then fifty of specific chemical and physical parameters to be properly detected, all of them on samples by off-line laboratory instrumentation. Moreover, for water reuse scope (by using membranes technologies), on-line automatic controller and regulating flow valves require process real-time data-input.
In spite of a deep changeability of textile segregated wastewater stream quality, there are only a few chances (instrumentation technologies) to on-line detect water quality parameters and, no one of them, it is directly correlated to a specific pollutant. So, the decision of applying real-time Expert System process control technology.
An Expert System, also known as a knowledge based system, is a computer program that contains some of the subject-specific knowledge, and contains the knowledge and analytical skills of one or more human experts. This class of program was first developed by researchers in artificial intelligence during the 1960s and 1970s and applied commercially throughout the 1980s.
The most common form of expert systems is a program made up of a set of rules that analyze information (usually supplied by the user of the system) about a specific class of problems, as well as providing mathematical analysis of the problem(s), and, depending upon their design, recommend a course of user action in order to implement corrections. It is a system that utilizes what appear to be reasoning capabilities to reach conclusions.
The general architecture of an expert system involves two principal components: a problem dependent set of data declarations called the knowledge base or rule base, and a problem independent (although highly data structure dependent) program which is called the inference engine.
A knowledge base (or knowledge base; abbreviated KB or kb) is a special kind of database for knowledge management. It provides the means for the computerized collection, organization, and retrieval of knowledge. The most important aspect of a knowledge base is the quality of information it contains. The best knowledge bases have carefully written articles that are kept up to date, an excellent information retrieval system (search engine), and a carefully designed content format and classification structure.
An inference engine is a computer program that tries to derive answers from a knowledge base. It is the "brain" that expert systems use to reason about the information in the knowledge base, for the ultimate purpose of formulating new conclusions.
From a methodological point of view, in developing the Expert System Framework, it has been used the follow basic approach:

a) **WPR - WasteWater Pollution Rate** – based on a Not-Deterministic (*Fuzzy Logic*) on-line detection of water quality by using an integration (fusion) of conductivity, pH, temperature and colour index measurements, to better detect and to decide if an effluent has to be sent to the UF reuse plant or to the WWTP (how much fresh water has to be mixed with the permeate and all operative actions for the maximisation of reuse, in respect of the limits at the final discharge):

   **WPR** [0÷1] = $f$ uzzy(*Conductivity; pH, Temperature, Colour Index*)

   In spite of a main list of essential real-time parameters to characterize textile wastewater streams (most of them not easily on-line measurable) about biological treatability as pH, DOC, colour, solids, ammoniacal nitrogen, nitrates, toxic chemicals, so as residual salinity and TOC for membrane technologies, WPR has to be easy on-line directly measurable.

b) **CID – Colour Index Detector** – based on a look-like color *concentration concept* that is able to transpose the complex (tridimensional) multi-dimensional size of colors (RGB) in a mono-dimensional parameter, so to be better used in a loop-control as BATTLE's water recycling;

$$\textbf{CID}\ [0\div 1] = [Ks] \otimes \psi_{syntesis}\ (f_{uzzy}(R)\ ;\ f_{uzzy}(G)\ ;\ f_{uzzy}(B))$$

c) **Wireless based Distributed Control**: based on WiFi communication cheap technology with a network of control nodes, fast to be installed, with the minimum impact in plant interfacing;

d) **Evolutive Programming /Process Control GA** – based on application of Genetic Algorithms and Software Cognitive Networks, to on-line upgrade process control ability of Expert System, installed in a variability of reusable streams of the textile wastewater process.

In particular, each node in the knowledge base is formalized through Fuzzy functions that shows the relations existing between the inputs received from sensors (PH, Temperature, Conductivity, Color) and quality of water (WPR).
Evolutive programming provides on the basis for self–learning, the detection of inconsistencies and thus for the chosen learning for the analysis is based on two key points:

- The modeling is necessary to have a theoretical model of the process with which to compare the actual operation. This allows us to identify any inconsistencies or simply to simulate the described flow.
- The learning algorithm are introduced to obtain the vector of K index that make the base of knowledge, contained in the nodes, the closest to real conditions in the given range of time. Vectors are calculated to ensure the optimum index difference between the WPR input and that calculated is as small as possible. It is again the logical schema of the problem by introducing, however, the components that come into play in the process of identifying of inconsistencies and in the learning process.

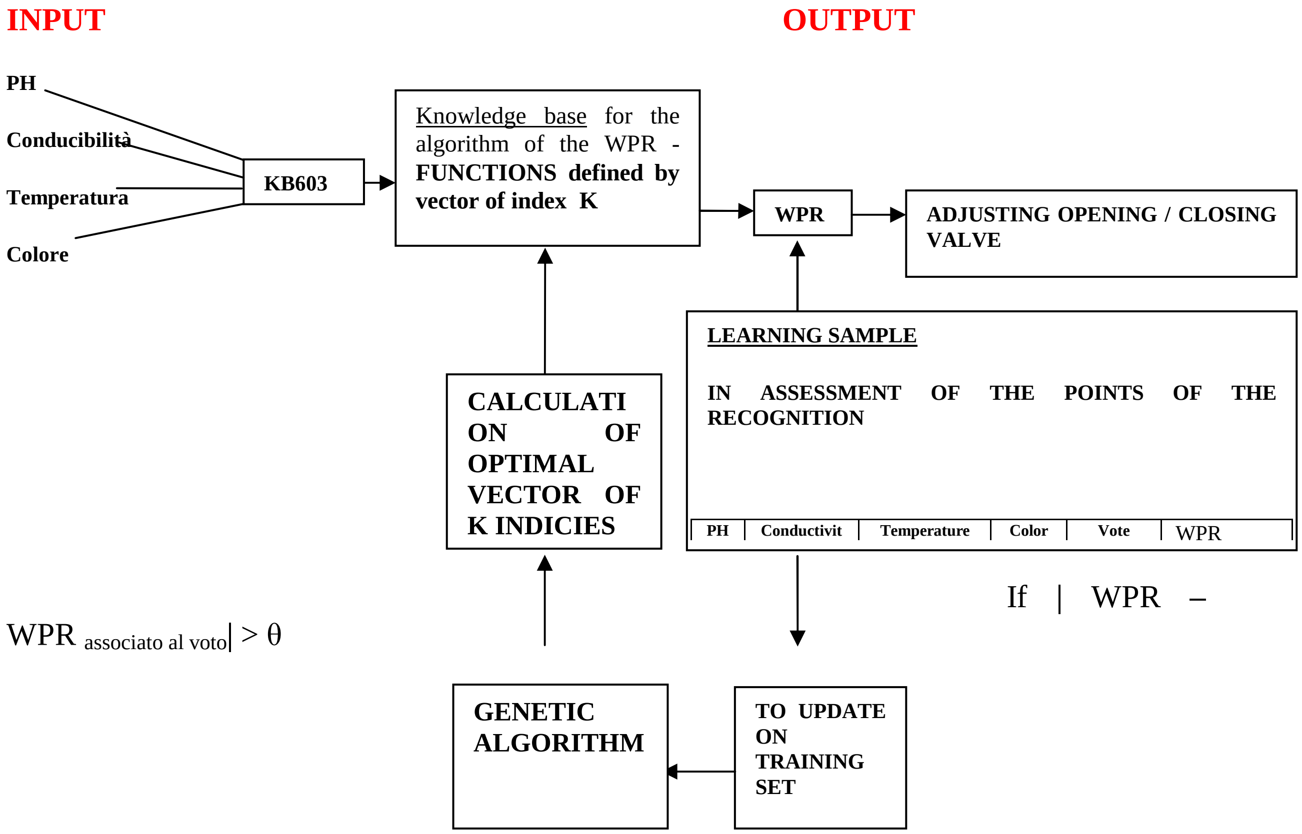



*Fig. 6.2: Kb Learning/Matching scheme*

From a technological point of view the Expert System Prototype is described in each of its parts

- **EXPERT SYSTEM FRAMEWORK:**

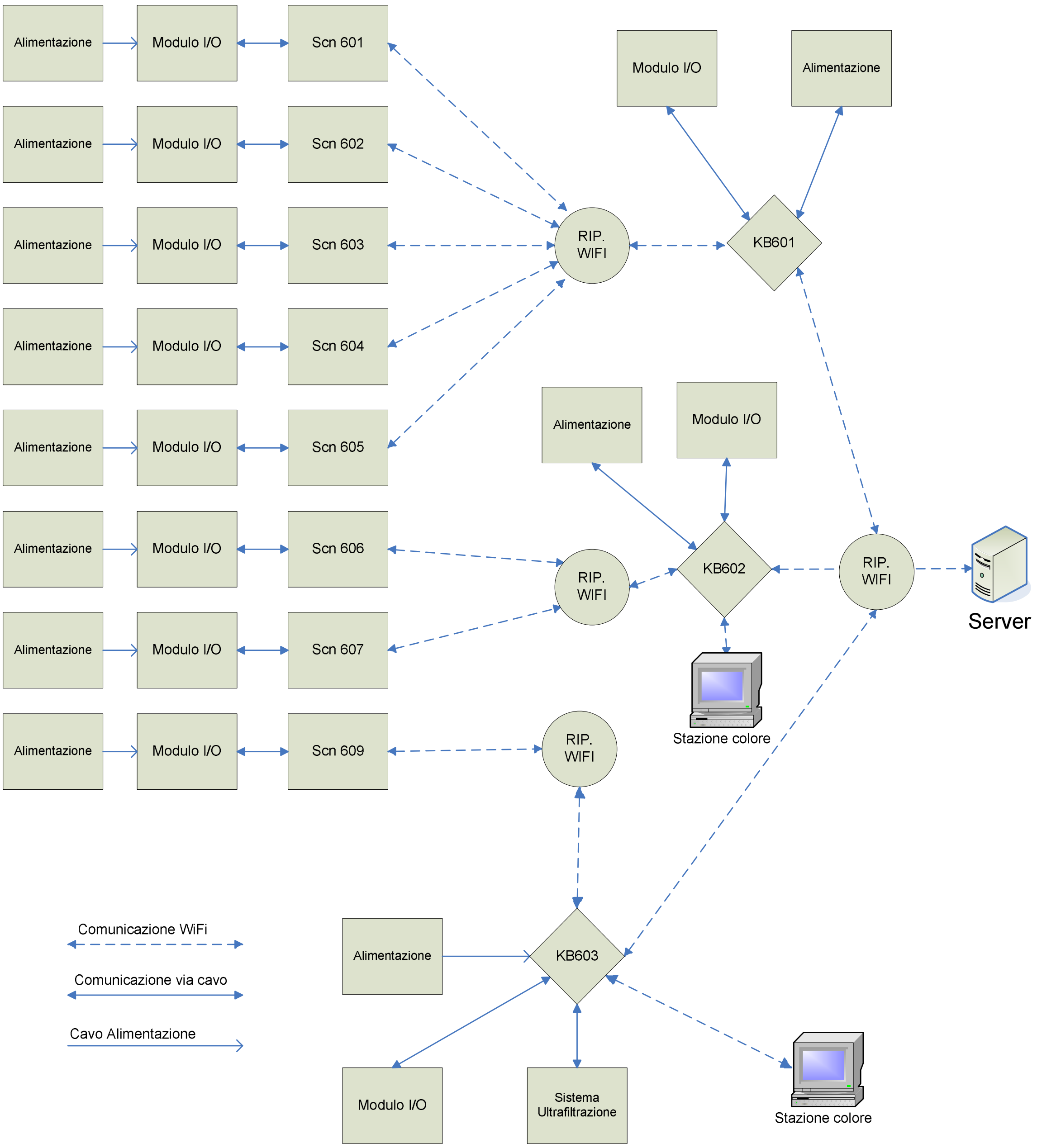



*Fig.6.3: Expert System Framework*

- **REMOTE CONTROL EXPERT NODES** (**Kb** and **SCn** modules):

  The Remote Control Node **SCn Module** (SCn601, SCn602, SCn603, SCn604, SCn605, SCn606, SCn607) and **Kb Module** (Kb601, Kb602, Kb603) are developed both on the base of a same "Rabbit RCM3700" Microchip CPU (see Fig.3)

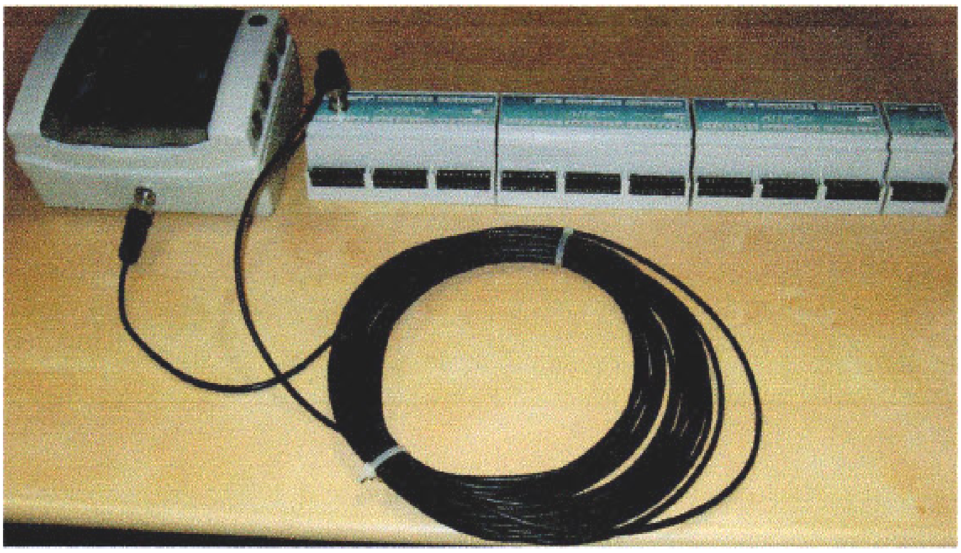


*Fig. 6.4: Expert Node Kb/SCn device and related I/O Modules*

| Kb CPU-Rabbit RCM 3700 Type | Characteristic |
|---|---|
| Clock | 22.1 MHz |
| Memoria Flash | 512 Kb |
| SRAM | 512 Kb |
| Serial Flash | 1 Mb |
| Ethernet | 10 Base-T, RJ-45 |
| Temp.di esercizio | -40 ℃ to +70 ℃ |
| Umidità | 5-95% |
| Alimentazione | 4.75-5.25 Vdc |
| Temp.di esercizio | -40 ℃ to +70 ℃ |
| I/O Configurabili | 32 |

The main structural difference between Kb and SCn, is relate to the presence in KB of a Display (NETMEDIA SER4X20-BU Model) and n.5 buttons, to drive Kb functionalities

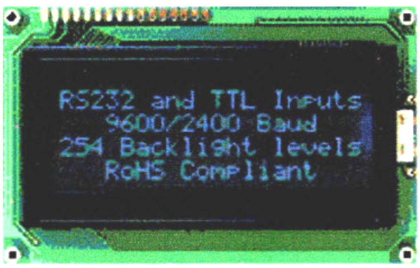



*Fig. 6.5: Display on Kb Device*

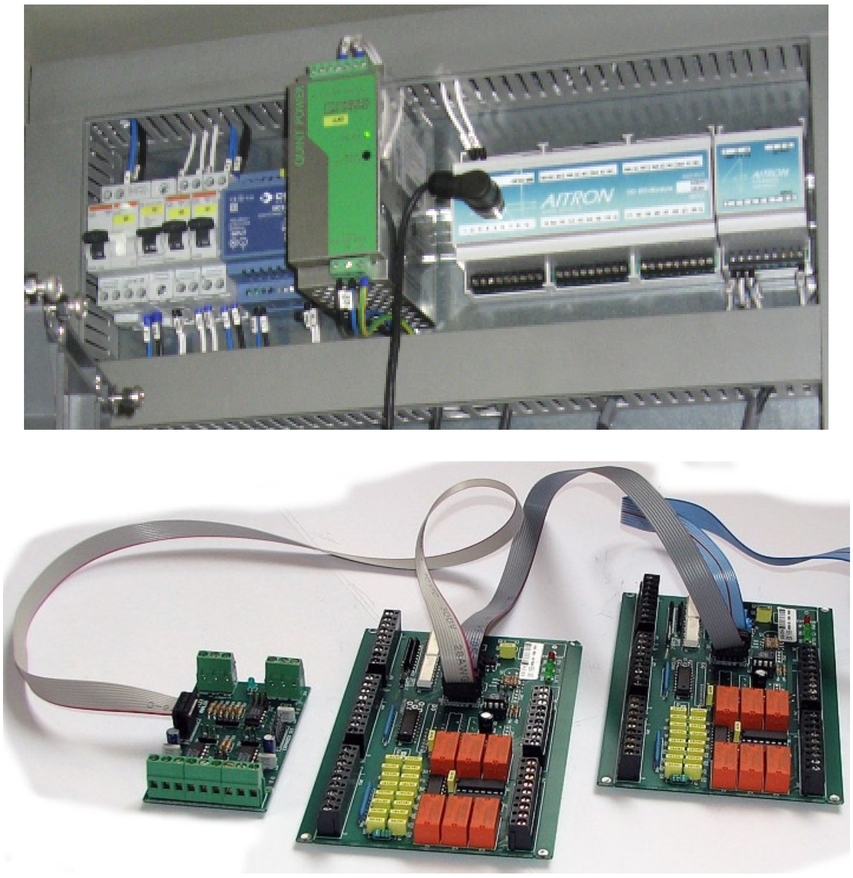



*Fig. 6.6: Communication chain between SCn/Kb and I/O Modules*

AITRON I/O D-Module Data Sheet

| | |
|---|---|
| **Dimensioni geometriche** | 158x90x58 |
| **Tipo di ancoraggio meccanico** | Guida din 25mm |
| **Alimentazione** | 5Vdc Da Bus |
| **Ingressi digitali** | 8 Ingressi diretti TTL (0 - 5V)<br>8 Ingressi filtrati TTL (0 - 5V)<br>8 Ingressi optoisolati Vdc max 24V |
| **Uscite digitali** | • Uscite digitali derivate |
| **Diagnostica** | |
| **Comunicazione** | FLEX IN, FLEX OUT |

## <u>PC/EXPERT SYSTEM - SERVER STATION</u> (BTL) :

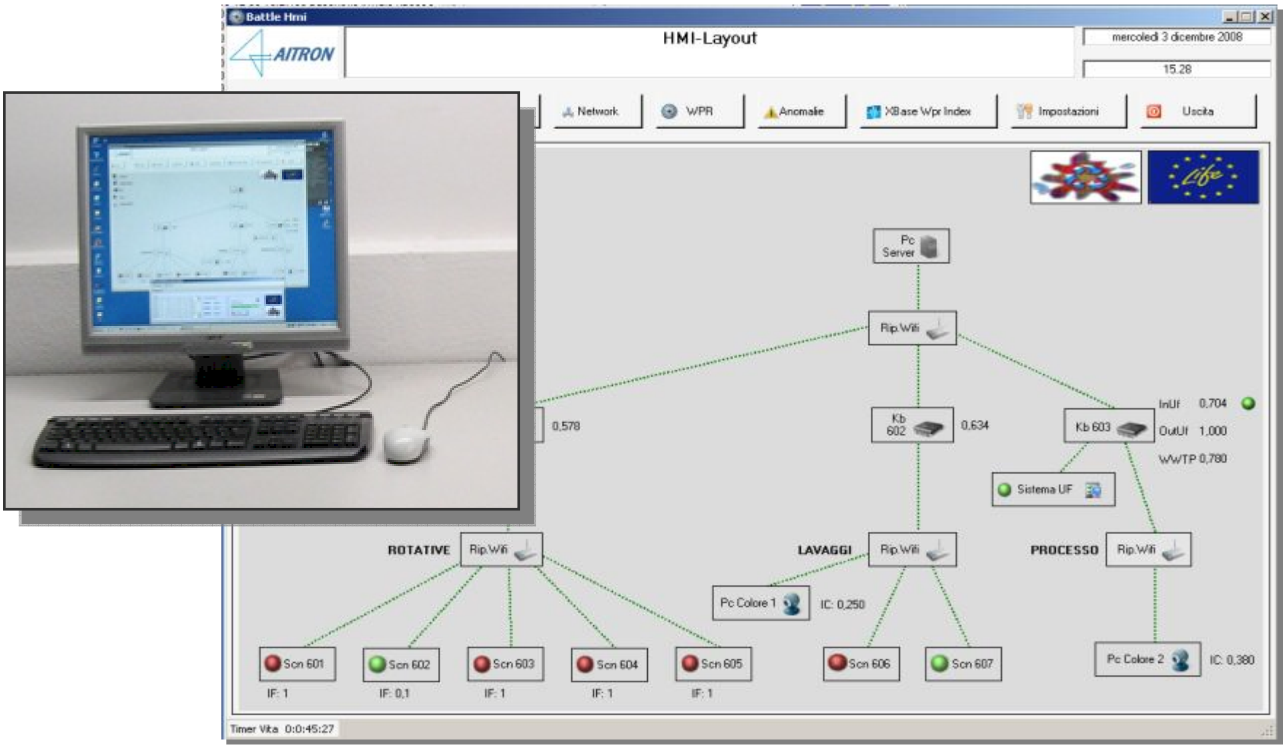



*Fig. 6.7: Expert System Lay-out Supervision*

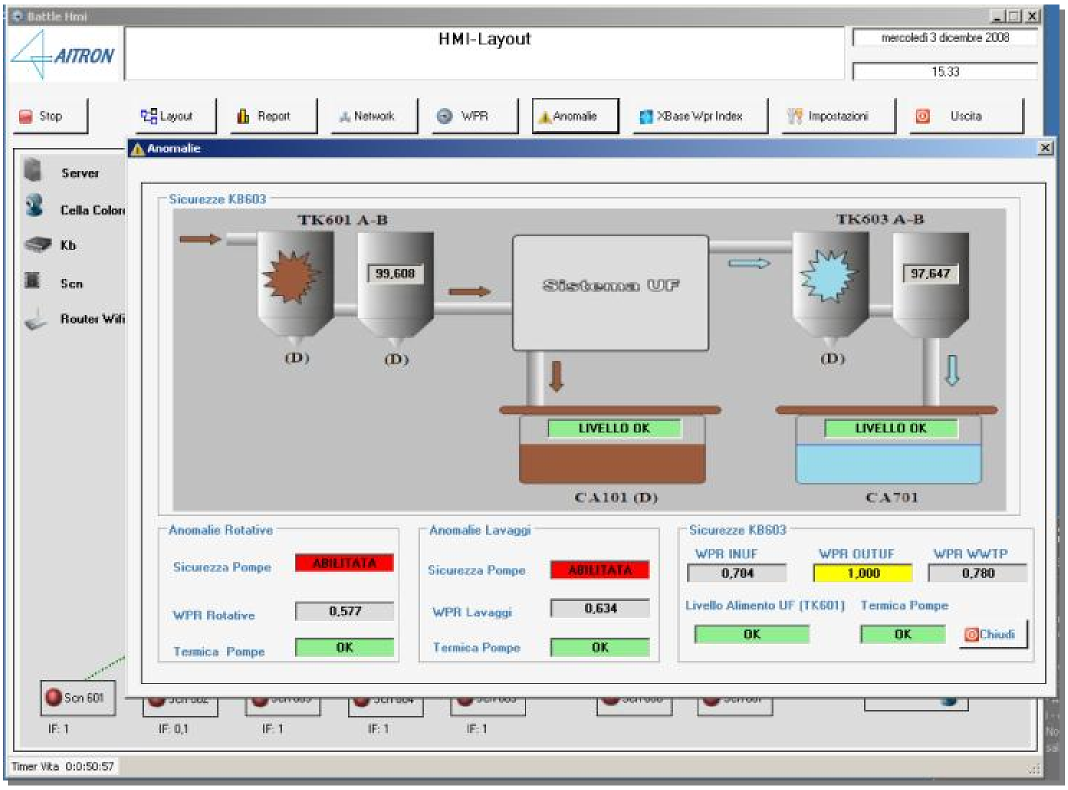



*Fig. 6.8 - Kb603 Alarms Windows*

- **<u>ELECTRONIC EQUIPMENTS</u>** and electrical material for the installation of the whole Prototype System:

**WIFI NETWORK**

| Articolo | Marca | Modello | Caratteristiche salienti |
|---|---|---|---|
| Wireless MAXg Router | US Robotics | US R805461A | Standard : 802.11 b/g<br>Protezione WiFi : WPA-2WPA<br>Crittografia WEP a 64/128 bit |
| Wireless MAXg Range Extender | US Robotics | USR805441A | Standard : 802.11 b/g<br>Protezione WiFi : WPA-2WPA<br>Crittografia WEP a 64/128 bit |
| Antenna Omnidirezionale | US Robotics | USR5481B | Guadagno: 5dBi<br>Impedenza nominale: 50 ohm<br>Gamma di frequenze: 2,4-2,5 Ghz |
| Antenna Omnidirezionale<br>con prolunga | US Robotics | USR5484B | Guadagno: 5dBi<br>Impedenza nominale: 50 ohm<br>Gamma di frequenze: 2,4-2,5 Ghz |


*Fig. 6.9 - Wireless MAXg Router US R805461A and Unidirectional Antenna*

## 7. PROGRESS, RESULTS

The activities and the output produced in the course of the project are here described, following the logical and temporal sequence of their achievement and presented per task and respective action:

*Task B: Textile BATs assessment and company audit*

| Task start / end date | Action | Expected results | Achieved results |
|---|---|---|---|
| *Task B:* *Textile BATs assessment and company audit* **1.12.2005 / 30.11.2006** | **B.1**- Analysis of BAT reported in the textile BREF | The analysis of the BREF should lead to the following knowledge:<br>- state of the art on BAT application in textile industry<br>- differences in application in different countries: law system, textile production, history, etc.<br>- the driving force to implement the BAT<br>- quantitative evaluation of the costs and benefits of the BAT<br>- possibility to integrate the TOWEF0 results as a BAT in the BREF document | All of the task expected results have been achieved according to the proposal |
| | **B.2**- Identification of BATs feasible in SMEs | The contacts with SMEs concerning the application of the BREF should lead to the following knowledge:<br>- state of the art on BAT application in textile SMEs<br>- differences in application in different countries: law system, textile production, history, etc.<br>- cost-benefit analysis of BAT application in SMEs | |
| | **B.3**- Audit of an SME aimed at defining the new BAT | -Detailed report on the company<br>- Identification of the main processes and their impact | |
| | **B.4**- Characterisation of the company effluents | - General classification of the productive processes referring to the quality and quantity of the effluents produced<br>- Definition of the parametres to be online controlled | |

*Actions B.1 and B.2: Analysis of BAT reported in the textile BREF - Identification of BATs feasible in SMEs*

The first two actions of task B (Action B.1 and B.2 by CENTEXBEL supported by ENEA) respectively addressed the analysis of BAT reported in the textile BREF and the identification of BATs feasible in SMEs. As was also stated in the targets, these analyses led to the knowledge of state of the art on BAT application in the textile industry, differences in application in different countries, the driving force to implement the BAT, a quantitative evaluation of the costs and benefits of the BAT, the possibility to integrate TOWEF0 results as a BAT in the BREF

document, and specific for action B.2 the cost-benefit analysis of BAT application in SMEs. The deliverables of these two actions were documented in two reports on BAT application in the textile industry and on BATs applicability in SMEs.
According to the European IPPC Directive 96/61/CE “Integrated Pollution Prevention and Control”, BATs (Best Available Techniques) had to be identified and applied in order to minimize environmental impacts of industrial/economic activities through the use of clean technologies and integrated systems. The IPPC bureau, settled in order to enhance the Directive implementation, elaborated reference documents BREF (BAT REFerence document) related to different industrial activities, identifying BATs to be implemented by IPPC companies. For textile companies the threshold is a production capacity of 10 t/day, over which a company should be considered an IPPC company. The BREF recommendations are conceived to stand as guideline target for the overall sector, therefore also for smaller companies and small-medium enterprises (SMEs). The formulated BREF for the textile sector contains a number of BATs, but no specific measure for the implementation of reuse strategies.
The BATTLE project, in support of activities addressing obstacles to the development of clean technologies not covered by IPPC, aims at configuring and applying on demonstrative scale a new BAT for low impact water management in textile industry. As a preliminary step, this survey has been conducted on the application/ applicability of the BATs, already reported in the BREF, to sample companies. The resulting reports generated the following knowledge:

- State of the art on BAT application in textile industry (B1) and SMEs (B2)
- Differences in application in different countries: law system, textile production, history, etc (B1-B2)
- Driving force to implement the BAT (B1) and specific in SMEs (B2)

In these two reports a description is given on: the tool used for the company survey (questionnaire); its elaboration and the response received; the results gained in terms of applicability evaluation of the BATs (B1) and specific in SMEs (B2), leading to several overall conclusions.
The evaluation part within these reports were divided into 4 chapters: a general evaluation of all kind of measures whose application was considered “state of the art” and over 80% of the contacted companies (or 75% of the SMEs) is implementing them; a chapter for each kind of measure (general, process related and product related) reporting the implementation status of the single measures (grouped by subject or operation) with a preliminary highlight on the measures which were implemented only to a limited extent within a production site (partly implemented). All results were commented and left space for further discussion in following workshops and dissemination occasions.
The evaluation of the BAT applicability in the SMEs as well as in large enterprises of the textile finishing sector, has been carried out by means of a specifically conceived questionnaire capable of collecting detailed information on the implementation degree of every single measures in the BREF. The questionnaire was composed of cells allowing to indicate for each measure; the relevance of the measure to the company’s activities; if relevant, the actual application or not of the measure; the main reason for the application status; and facultative further comments for better comprehension and evaluation of the status. In these comments and during the interviews it became obvious that some of the measures are only partly implemented for a variety of reasons. These answers were as such evaluated and are separately reported. The collection of a wide number of representative questionnaires permitted to figure out a scenario of the current European situation, its achieved results as well as weak points and needs. The analysis of the BATs, as reported in the textile BREF document, has been performed by the screening of the overall document itself, focussing on measures related to the water cycle (both the quality of the generated wastewater and the amount of water used for each process involving all wet textile activities).
The overall number of measures related to the water cycle is 94. These measures were grouped and numbered for the elaboration of a practically feasible questionnaire i.e. general (26), process (43) and product (25) related measures.
The general measures were divided in measures concerning water management (1-10) and others have the treatment of the wastewater (11-26) as subject.

The process measures were related to distinct steps in the production cycle: wool scouring, pre-treatment (desizing, mercerising), dyeing (batch, continuous), printing, finishing and washing (here rinsing is meant).
In the series of product related measures, a distinction was made in general arrangements regarding dosing /dispensing and those regarding the selection and minimum use of chemicals. Additional measures are related to the chemicals used in specific processes: pre-treatment (bleaching), dyeing of polyester, cotton and wool.
The questionnaire was spread in several countries. In total 61 (35 SME) filled questionnaires from 5 (4) different countries were received: Belgium: 35 (16), the Netherlands: 5 (5), Italy: 15 (13), Czech Republic: 5 (1) and Croatia: 1 (0). In the time span of the survey, 33 (22 SME) companies were visited, of which 19 (9) in Belgium, 10 (9) in Italy and 4 (4) in The Netherlands and the response was very positive during these visits. Most of the companies considered it a good chance to know more about some measures and to identify those to be possibly implemented.
The answers of all 61 (35 SME) companies concerning the implementation of each of the 94 measures were collected as the global results. Next to this, the results per country were also evaluated and the most important differences with global results and the biggest differences in between the countries were evaluated as well. These differences in implementation degree can be correlated with the development of an activity, the type of companies (big/small in size or integrated company/commission finisher), the legislation in the respective countries, etc.
The most implemented measures in each of the participating countries (both large and SME) can be characterised by the following features:

- Limited investment cost;
- Limited logistic changes: need for piping and/or storing equipment;
- Obvious savings in chemicals, energy, water and process time;
- Improved textile quality.

The most implemented BREF measures have combined ecologic and economic advantages and are therefore since many years state of the art in the majority of the European textile companies. Some examples are:

- Batch dyeing: choose the machinery that is most fitted to the size of the lot to be processed to allow as much as possible an optimal liquor ratio
- Continuous dyeing/printing/finishing: Reduce losses of concentrated liquor by various preventive measures
- Combine as much as possible different treatments in 1 single step
- Install high efficiency washing machinery
- Avoid the use of chemicals as much as possible, if not feasible: select biodegradable chemicals

For most of the measures the implementation degree only differs slightly with the size of the company. An important reason for implementation or not is the importance of a certain activity in the total overview of activities in the company. The measures related to the main activities of the company, have in most cases the highest implementation degree. The fact that some of the participating commission finishers have a very broad scope of activities and processed raw materials is the main reason why these companies have difficulties in the application of predominantly the process related measures. Also the fact that automated dosing and dispensing systems are much more in use in Italy than in the other European countries, makes it likely that the closer contact with the suppliers, which are mostly situated in Italy, has a positive effect on the implementation degree. The suppliers of these systems can persuade the textile companies easier of the enormous advantages their systems have.
The most implemented strategy for the treatment of wastewater is a central treatment off site. The noticed difference between the countries can be related to the size of the companies and more specific to the amount of discharged wastewater. Companies generating a high flow rate of wastewater are in quite some cases obliged to install a treatment plan on site. Moreover, if the treatment is well dimensioned and chosen the costs (exploitation and depreciation) can be lower than the taxes for discharge of untreated effluent in the sewer. The smaller volume of wastewater to be treated and the fact that the knowledge of wastewater treatment is restricted

in SMEs, results in a decision to discharge the effluent via the sewer and let it be treated in the municipal treatment plant.
Measures related to the characterisation and segregation of process streams are very poorly implemented in all of the countries and regardless of the size of the company. However, most of the companies visited showed quite some interest in the start-of –pipe methodology which forms the topic of the BATTLE project. A lack of information and being prejudiced are the most heard answers. The dissemination of the practical results of the BATTLE project will be very important to persuade potential users in the textile finishing industry. With reference to the water reuse options, the fact that the company in an SME cannot be considered an obstacle for implementation.

For what concerns a comparison with the planned output, all the deliverables of this two actions were presented.
Regarding the encountered drawbacks, although a huge (more than 150) number of companies was invited to take part in the survey (sending them the questionnaire accompanied by an explaining letter, via the dedicated webpage on the Battle website), the response was less than expected.
Reason: many companies, contacted via telephone, answered sceptic on the reason of the survey, diffident in giving information and opening their gates to a visit/interview, not informed of the IPPC directive and not aware of the importance of the IPPC implementation, especially in Italy. Higher response was gained in Belgium thanks to the relationship based on mutual trust between Centexbel and the textile finishing companies. For this reason, the survey campaign was prolonged in order to collect enough data.

*Action B.3: Audit of an SME aimed at defining the new BAT*

The company characterisation (Action B3 by CIDA supported by SdM) results allowed to draw the material flow chart reported in Figure 7.1 and to quantify the textile subjected to each textile operation as in Figure 7.2.

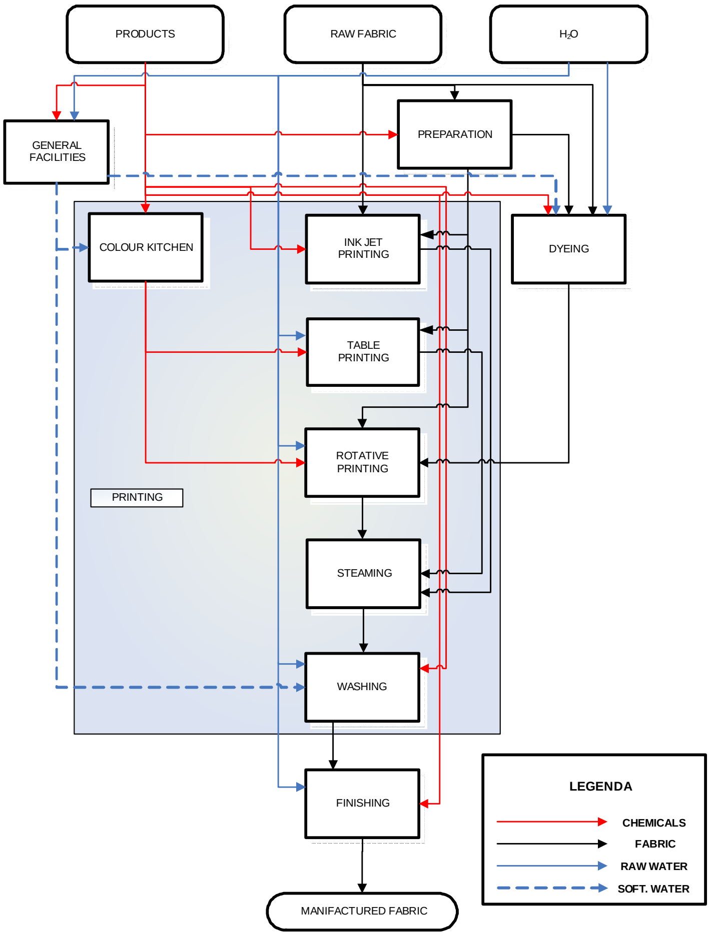



*Figure. 7.1 - Material flow chart*

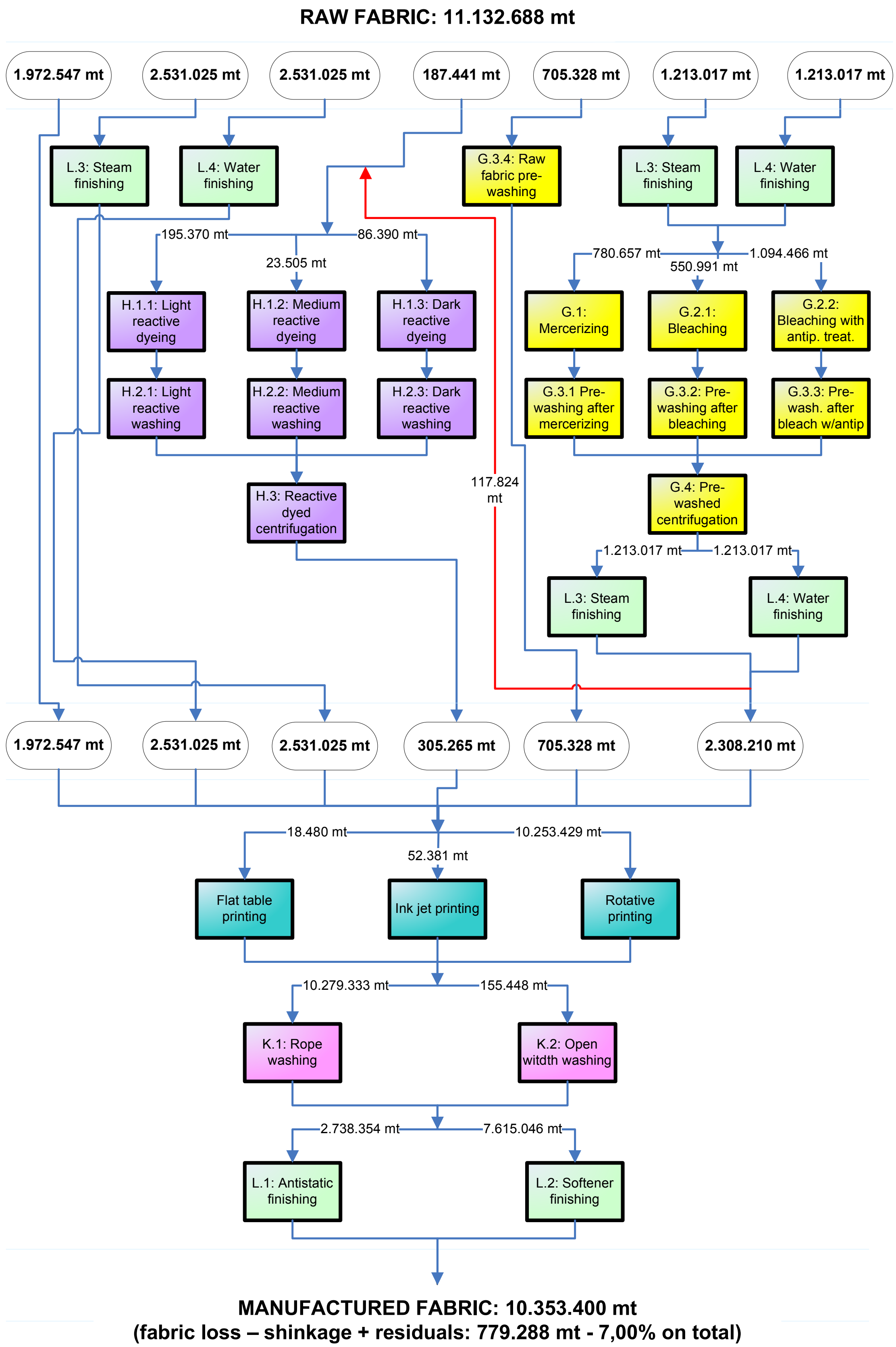



*Figure. 7.2 - Schematic description of textile operations*

Water fluxes were thoroughly assessed and a synthetic scheme of the main machines involved in water use and effluents production at SdM is presented in Figure 7.3. This representation of company equipment is functional to water use and effluent production. Several processes machines, using little amount of water are grouped together in the scheme, while other are split in different process operation in detail:

- the departments using low amounts of water (i.e. dyeing department, comprising all the batch dyeing equipment that discharges the exhausted dyeing baths after each dyeing cycle; printing department, comprising several textile pretreatment machines; and finishing department with all the finishing equipment) have been grouped under the department label and are represented by the three boxes “**dyeing**”, “**preparation**” and “**finishing**”.
- the printing department, that accounts for nearly 40% of the total company water needs is represented in detail. The five rotative printing machines (R1, R2, R4, R5,R6), using the most common dyes (reactive, disperse, acid, Indanthrene, cationic and pigments), produce a continuous effluent discharge due to printing belt washing (in the scheme “**R 1-6 carpet washing**”) and a batch stream due to the final washing operations of the equipment (in the scheme “**R 1-6 washing**”). After the printing cycle all the printing cylinders need to be washed in one of the different machines here grouped under the “**cylinders washing**” label. Squeeges need to be washed as well in one of the machines represented by the “**squeeges washing**” box . Finally the tubs containing the leftover printing paste, are stocked for possible reuse but, if not reused in few days they need to be washed, before paste deterioration, in dedicated equipment represented by “**tubs washing**” box. All the remaining minor printing operation (kids washing, hand printing screens and tables washing,...) have been grouped under the “**other printing**” label.
- the washing department water demand is almost 50% of total company. Two continuous washing lines “**SAT2 + WR14**” and “**WR 8 + WR 12**” for continuous rope washing and several batch equipment (“**Boats + Intes**” in the scheme) are used for textile washing of printed, dyed, prepared or raw fabrics. They produce a continuous effluent discharge during operations and a batch stream due to the equipment draining. The remaining department uses are represented by the “**Other washing**” box.

No effluent streams were reused before the project and all production processes were supplied with primary ground water pumped from the company wells. Water for the printing department is not pretreated and is stored in the “**S101**” tank and. The rest of water is stored in the “**S102**” tank before “softening”. The soft water is stored in the “**S103**” tank and most of it is fed to the washing, dyeing, preparation and finishing departments, while a little amount is demineralised in “**Reverse osmosis**” plant and sent to the “**Steamer**” where steam is produced continuously for production needs.
Discharged effluents are collected in two separated storage tanks and mixed together before final treatment and discharge.

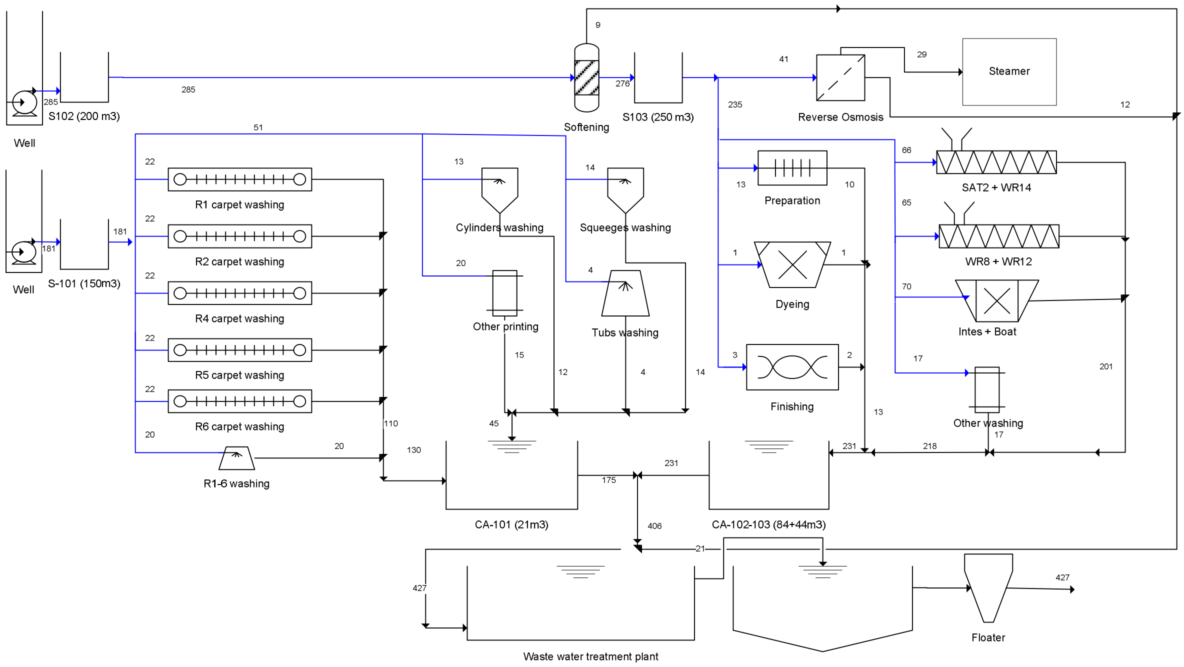



*Figure.7.3 - Hydraulic company balance*

The company WWTP process scheme is reported in Figure 7.4.

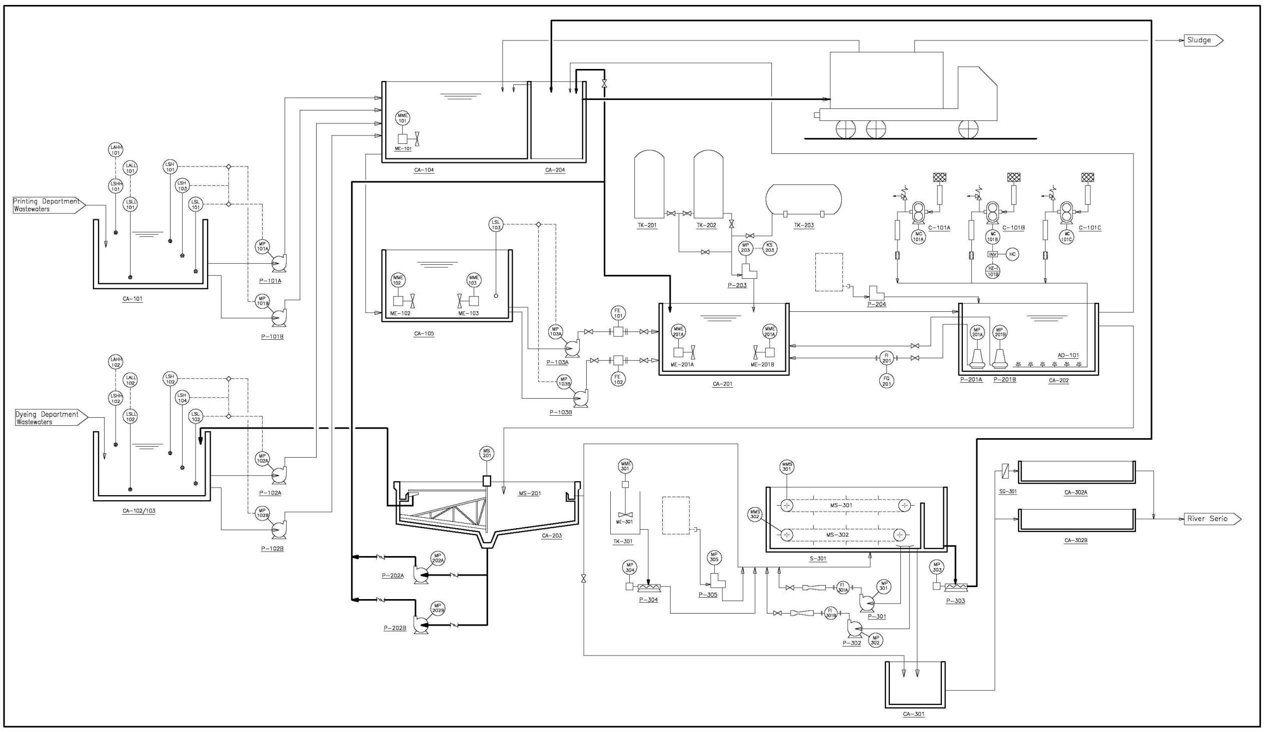



*Figure.7.4 - Wastewater treatment plant of Stamperia di Martinengo*

Wastewater generated by the production departments is stored in a homogenisation tank and successively pumped to the denitrification tank. To enable the removal of all nitrates, a feeder product is constantly added. Wastewaters flow to the oxidation-nitrification tank where air is supplied by means of three lobes compressors, through the micro-pore-membrane diffusers carpet. A portion of mixed liquor is continuously recycled to the denitrification tank. From nitrification the wastewater is conveyed to the circular decanter. Clarified water is conveyed to the air flotation unit. To optimize the process a solution of cationic polyelectrolyte and a decolorizer are dosed into the wastewater flow continuously. Final clarified water is discharged into Serio river. Waste sludge from the treatment plant is collected in a tank and monthly removed by a mobile dewatering station and finally outplaced as “special waste”.

Table 7.1: WWTP hydraulic and process parameters

| | |
|---|---|
| Daily volume $V_d$ ($m^3$/d): | 1.700 |
| Average flow rate $Q_{24}$ ($m^3$/h): | 71 |
| Average retention time in equalization tank | 72,68 |
| Mixed liquor recirculation ratio ($Q_{ricNO3}/Q_{24}$): | 14,08 |
| Sludge recirculation ratio ($Q_{ricSL}/Q_{24}$): | 2,11 |
| Average biomass concentration in oxidation tank (mg/l): | 9.100 |
| Organic load (estimated) (kgCOD/kgSS*d): | 0,062 |
| Sludge retention time (estimated) (d): | 25,45 |
| Sludge quantity (kg/yr) | 869.620 |
| Dewatered sludge solid content (%): | 21 |

The planned deliverables of this action have been issued.
No problems or delays have been highlighted.

*Action B.4: Characterisation of the company effluents*

Data from the chemical characterisation (Action B4 by SdM supported by ENEA and CIDA) of the effluents were elaborated with the aim of identifying an useful division in potentially reusable and not. This was done with the aim of realising a full scale “waste water design”, an efficient separation of effluents based on their final destination (reclamation and reuse o treatment and discharge).

Effluents from printing belt washing (carpet washing) were found very diverse in pollution level and their quality is in strict connection with the textiles permeability to printing paste. Printing paste density and viscosity are sensibly higher than water, therefore effluent with quite dense texture do not allow its passage. This effect can be verified by looking at the back side of printed fabrics where the colours applied are almost undetectable in case of impermeable textiles. On the contrary, if the texture is loose colour can pass through the fibres and reach the printing belt where it will be washed, therefore reaching and polluting the process effluents. Therefore effluents from textile printing were classified high and low in reuse potential respectively “R” and NR”, based on the permeability of the printed textile.

Effluents from washing machines have been also divided in two groups. In this case it was not possible to find any relation between the effluent contamination and any textile or dye property. The division between effluent with high and low reuse potential on values of absorbance

measured in the effluents. Other effluents, mainly from printing operation were grouped in a fifth category.
The sixth category, other discharges, grouped all the diverse effluents that were not taken into consideration for reuse due to impracticability of their collection mainly due to logistic reason. In Figure 7.5 the results of such classification is reported with data concerning the overall annual volume of each category and the resulting average contamination resulted from the characterisation.

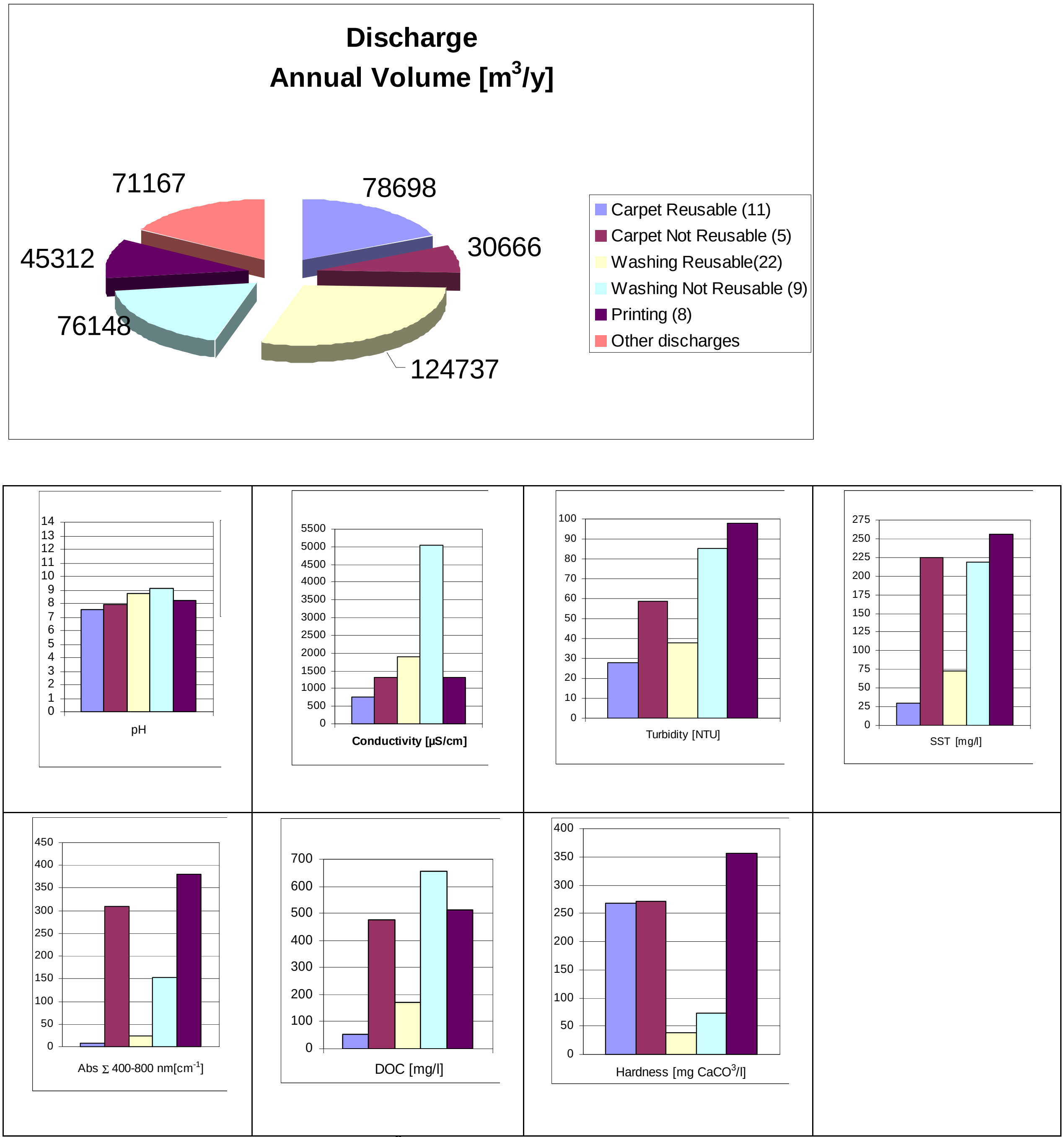



*Figure.7.5 - Overall annual volume (m$^3$) evaluated for each category of process effluents and average concentration of the main parameters (pH, conductivity, turbidity, SST, absorbance, DOC and hardness*

The pH values were generally in the basic range and in some cases they higher than 12, therefore evidencing the necessity to control monitor this parameter for water to be reused. Hardness is high in effluents from the printing department where hard water is used and

normally low in washing operations it appears to be never critical for reuse. Turbidity and suspended solids are high in effluents from textile washing and very high in effluents from other printing operation, confirming the necessity of excluding the latter from reuse.
Colour and DOC were quite correlated suggesting that using colour for effluent selection could prevent high DOC effluents to be reused.
Effluent classified as “reusable” categories evidenced chemical characterisation potentially compatible with water reuse with the exception of the high values in suspended solids, turbidity and, in few cases, colour.

*Task C: Operational data collection and preliminary evaluations to design the BAT demonstration plant*

| Task start / end date | Action | Expected results | Achieved results |
|---|---|---|---|
| *Task C:* *Operational data collection and preliminary evaluations* **1.04.2006 / 31.01.2007*** *end date was postponed to 31.03.2007 | **C.1-** Effluents treatability evaluation | - Selection of the optimal treatment technologies for the company effluents<br>- Operational data for technical and economical feasibility evaluations of effluents treatment | Action C.1 expected results have been achieved according to the proposal |
| | **C.2**- Evaluation of treated effluents reusability | - Definition of the target quality for the reuse in the company<br>- Assessment of the effluent reusability | Action C.2 expected results have been achieved with a two months delay with respect to the proposal |
| | **C.3**- Evaluation of biodegradability and toxicity of effluents | - Assessment of the effluents biological treatability<br>- Identification of streams representing a potential concern for the WWTP | Action C.3 expected results have been achieved with a two months delay with respect to the proposal |
| | **C.4**- Simulation of the water reuse scenario | - Preliminary design of water networks and reuse facilities<br>- Operational data for the scale-up | Action C.4 expected results have been achieved according to the proposal |
| | **C.5**- Expert system design | Expert System prototype for the automatic management of the BATTLE processes | Action C.5 expected results have been achieved with a two months delay with respect to the proposal |

*Action C.1: Effluents treatability evaluation*
All the effluents characterised were tested according to the procedure described in the previous paragraph (Action C.1 by ENEA supported by SdM and UNIFI). The data collected indicated good filterability for most of them from printing carpet washing and textile washing operations, while worse results were found for other printing operations.
As evidenced by Figure 7.6, the ultrafiltration treatment had no effect on the salt content of the water, therefore an effluent containing a high salt content results in a permeate with a comparable concentration. Since salts regulate the speed and the depth of reactive and direct dyeing of cotton and an higher concentration can affect on the colour of the dyed cotton, effluent segregation needs to guarantee that effluents with a high conductivity are excluded from reuse. Turbidity values confirmed the expected almost complete removal of suspended material and colloids. Colour and dissolved organics removal resulted very variable and unpredictable.

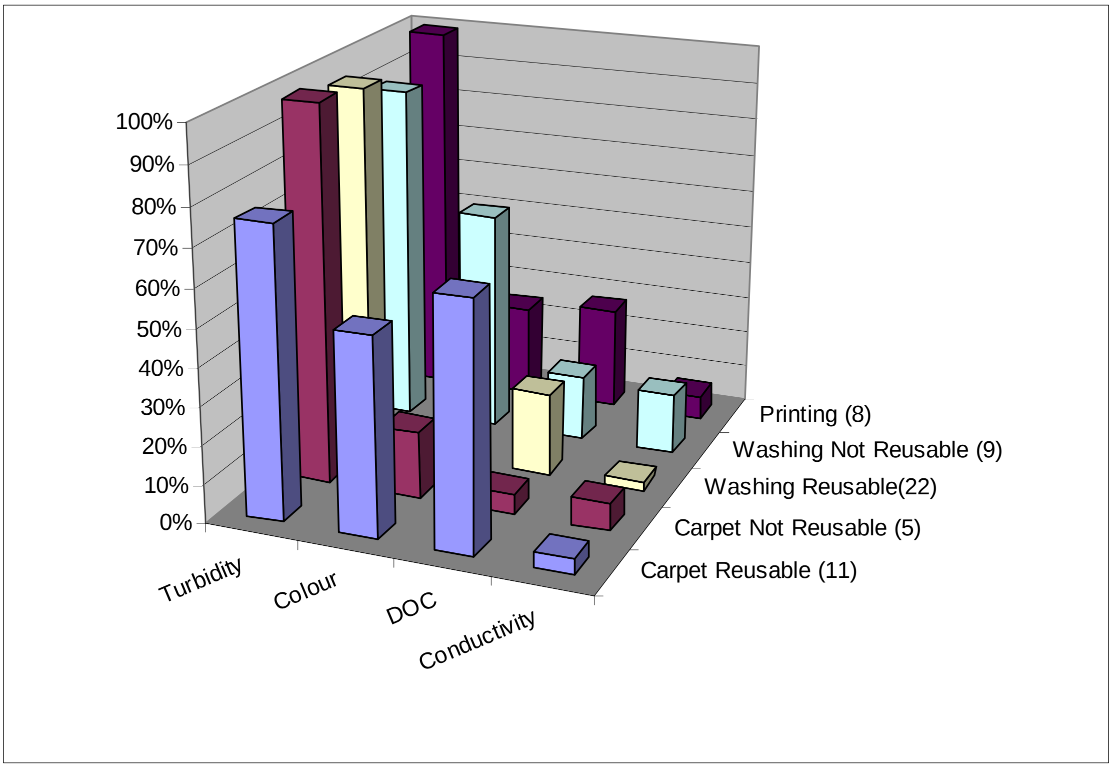



*Figure.7.6 - UF filtration removal of the main parameters*

*Action C.2: Evaluation of treated effluents reusability*
The reuse tests results (Action C.2 by CENTEXBEL supported by SdM and ENEA) can be summarised as follows:

- Dyeing tests: the results were not completely satisfactory in case of reactive exhaustion dyeing because of changes in the efficiency and colour differences.
- Washing tests of printed fabrics: all the tests gave good results except for the permeate of the WWTP effluent; in this case the tests evidenced difficulties in maintaining the white reserve of the non printed zones of the textiles and the hand feeling of polyester printed textile was not soft enough.
- Washing tests of printing belt: the quality of the treated textile material was always as good as the reference.
- Bleaching tests: the quality of the treated textile material was always as good as the reference.

Based on the results the different permeate streams, water reuse schemes were designed that gave priority to water reuse in the less quality demanding printing processes over the dyeing-washing departments and that considered the reuse of WWTP effluent only in absence of other suitable effluents.

*Action C.3: Evaluation of biodegradability and toxicity of effluents*
The results concerning of the evaluation of biodegradability and toxicity of effluents (Action C3 by UNIFI supported by ENEA and SdM) can be summarised as follows:

From the wastewater COD fractionation procedures, results obtained are showed in figure 7.7

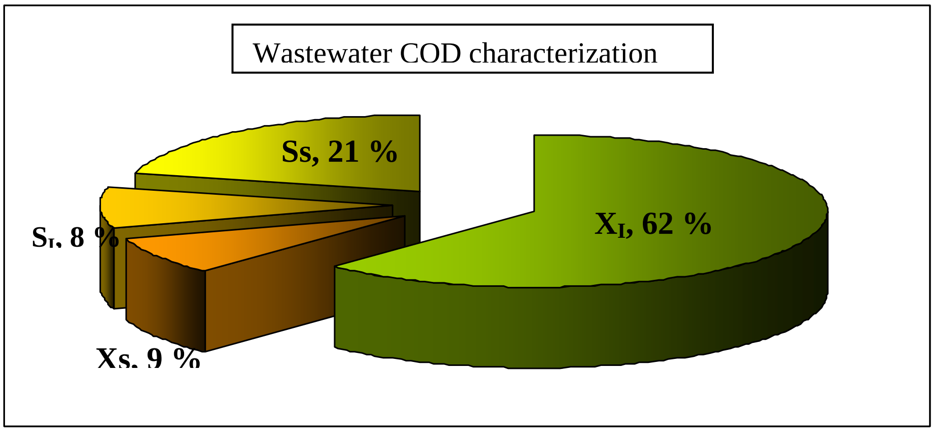



*Figure.7.7 - COD fractionation*

Table 7.2 summarizes the average concentration of total COD and the average concentration and percentage of different COD components.

Table 7.2

| Parameter | Average concentration (mg/l) | Percentage (%) |
|---|---|---|
| COD | 987 | 100 |
| $S_S$ | 207 | 20.8 |
| $X_S$ | 89 | 8.9 |
| $S_I$ | 79 | 8.0 |
| $X_I$ | 612 | 62.3 |

In figure 7.8 a titrimetric test, performed in order to assess the inhibition of nitrifying biomass, is showed as example.

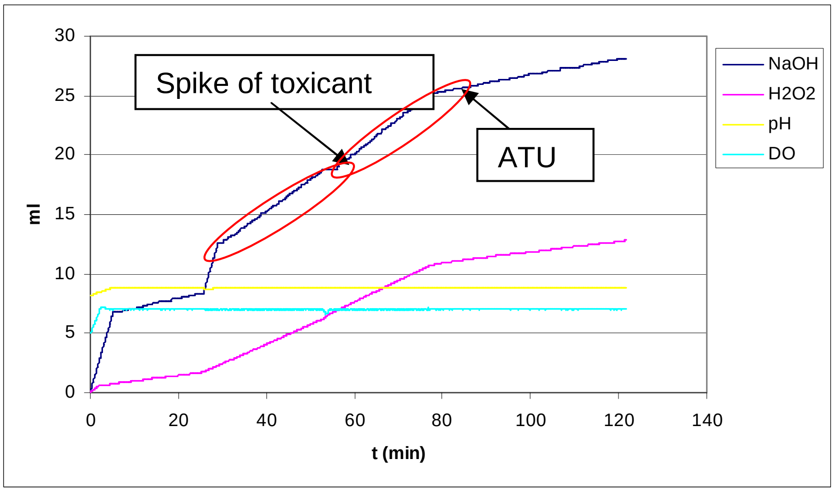



*Figure.7.8 - Example of titrimetric test*

As shown in figure 17 the NaOH dosage rate (regulated by the stoichiometric relationship between ammonium oxidation and acidity production) is not changed after the spike of potential toxicant as demonstration of no negative action on nitrifying biomass. As a matter of fact the slope of the line representing the volume of NaOH dosed (that means the rate of NaOH dosage) is constant until allylthiourea (ATU) was added with the consequent inhibition of nitrifying biomass.

The analysis of all the tests carried out proved that the increasing of both biodegradable and not biodegradable compounds in the WWTP is not inhibitory for nitrifying biomass. In the second case a particular attention should be paid in order to control interferences due to the oxygen consumption for the biodegradable substrate removal by growth of heterotrophic bacteria and to concentrate the wastewater (using a heater) rich in organic compound some of which inclined to volatilize.

The parameters used (taken from specific test and simulation and literature) for the simulation and relative sources are listed in Table 7.3

Table 7.3: Parameters used for the simulation

| Parameter | Unit | Value (20°C) | Source |
|---|---|---|---|
| $b_{A\_20}$ | $d^{-1}$ | 0,05 | Estimated by Aquasim |
| $b_{H\_20}$ | $d^{-1}$ | 0,16 | Respirometric tests |
| $f_p$ | Adimesional | 0,08 | Henze et al.(ASM1), 2000 |
| $i_{XB}$ | mgN/mgCOD biomass | 0,086 | Henze et al.(ASM1), 2000 |
| $i_{XE}$ | mgN/mgCOD biomass(endogeno) | 0,06 | Henze et al.(ASM1), 2000 |
| $k_a$ | L/(mgCOD d) | 0,08 | Henze et al.(ASM1), 2000 |

| | | | |
|---|---|---|---|
| $K_{NO}$ | $gNO_3^-/gN* m^{-3}$ | 0,5 | Henze et al.(ASM1), 2000 |
| $K_{0,H}$ | $gO_2/m^3$ | 0,20 | Henze et al.(ASM1), 2000 |
| $K_X$ | mgCOD/mgCODcell | 0,8 | Estimated by Aquasim |
| $K_s$ | mgCOD/L | 170 | Estimated by Aquasim |
| $K_{nh}$ | $mgN\text{-}NH_3/L$ | 0,45 | Estimated by Aquasim |
| $\mu_{A\_20}$ | $d^{-1}$ | 0,21 | Estimated by Aquasim |
| $\mu_{B\_20}$ | $d^{-1}$ | 6,8 | Estimated by Aquasim |
| $\theta_{bA}$ | Adimesional | 1,08 | Metcalf & Eddy, 2003 |
| $\theta_{bH}$ | Adimesional | 1,07 | Metcalf & Eddy, 2003 |
| $\theta_{\mu A}$ | Adimesional | 1,07 | Metcalf & Eddy, 2003 |
| $\theta_{\mu H}$ | Adimesional | 1,07 | Metcalf & Eddy, 2003 |
| $\theta_{kh}$ | Adimesional | 1,1 | Metcalf & Eddy, 2003 |
| $Y_A$ | mgCODcell/mgNox | 0,24 | Henze et al.(ASM1), 2000 |
| $Y_H$ | mgCODcell/mgCODox. | 0,53 | Respirometric tests |

Figure 7.9 and 7.10 show the good agreement achieved between experimental data and simulation for total suspended solid in biological reactor and for the nitrate concentration in the effluent of biological sedimentation.

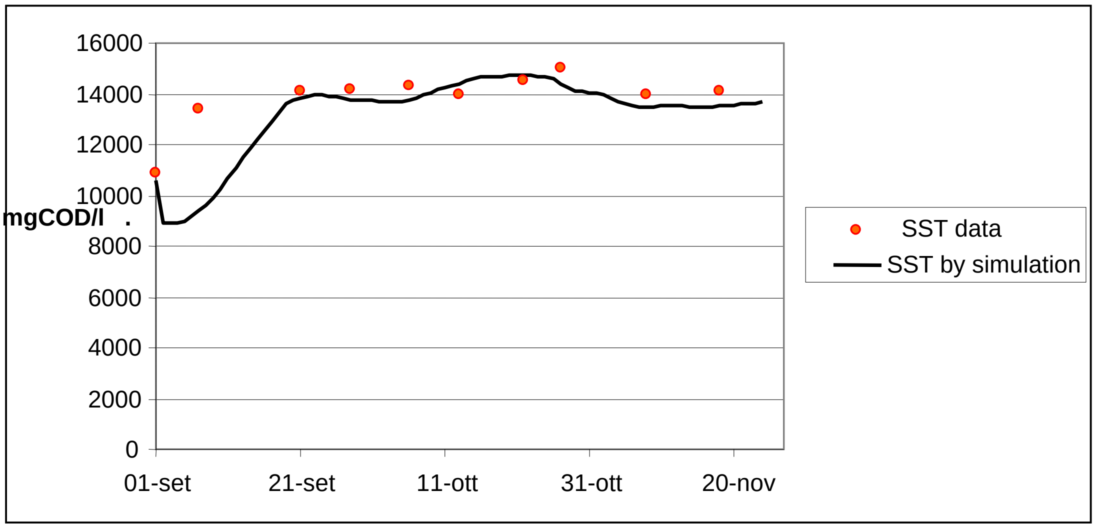



*Fig.7.9 - SST simulation*

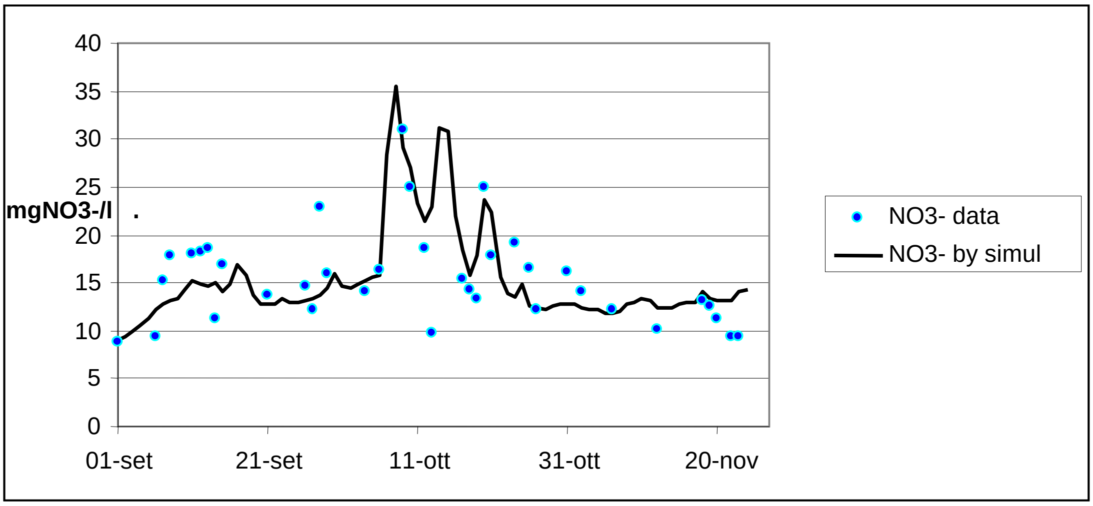



*Fig.7.10 - Nitrate simulation*

After the calibration was executed it was tried to apply the model in order to simulate potential problems when the reuse scenarios will be performed.
A steady state simulation was implemented and the following conclusions can be drawn:

- Results of titration tests indicated that both biodegradable and not biodegradable compounds did not exert any significant inhibitory effect on the nitrifying biomass performances of the WWTP, up to 60% recycling ratio.
- Autotrophic biomass appeared to have low kinetics but the capability of maintaining its activity in presence of high concentration of contaminants.
- The ASM1 well described the condition with not reuse and permitted a prediction of future scenarios, indicating that law limit for reclaimed wastewater discharge are not exceeded up to 50% as recycling ratio.
- The results obtained were used in the following part in order to estimate the wastewater quality effluent according to the proposed scenarios.

The actual cost and objects purchased differ slightly from those projected. During the experimental activity, it was necessary to change some expenses with regards to the projected goods.
The two projected samplers were found at SdM and used to collect WWTP samples therefore these purchases were replaced with two PCs fundamental for the data captures and processing and a cryothermostat in order to control the temperature during the tests.
A contract for two persons with specific skill was made to carry out the respirometric/titrimetric tests.
In addition modelling of the WWTP and integration of the model with the results of respirometric/titrimetric test required much more time than expected causing a rise for personnel costs.
Costs for travel was less than expected because of optimization of schedule for titrimetric tests and sampling. In addition an intensive communication by e-mail and on the telephone reduced the meeting needed to achieve the objective of our tasks.

*Action C.4: Simulation of the water reuse scenario*
Four reuse scenarios (Action C4 by CIDA, supported by ENEA and UNIFI) were elaborated trough mass balances of the main contaminants expected on the basis of the experimental results.
The first scenario elaborated is based on the key idea behind the project BATTLE, an efficient separation of effluents based on their final destination (reclamation and reuse o treatment and discharge). The scheme is provided in Figure 7.11 The production processes generating effluents with suitable characteristics are connected to a dual wastewater collection pipelines. The potentially reusable ones are collected separately and diverted to a membrane treatment

station for subsequent reuse. The effluents not potentially reusable and the concentrates produced by the membrane plant are treated in the existing WWTP.

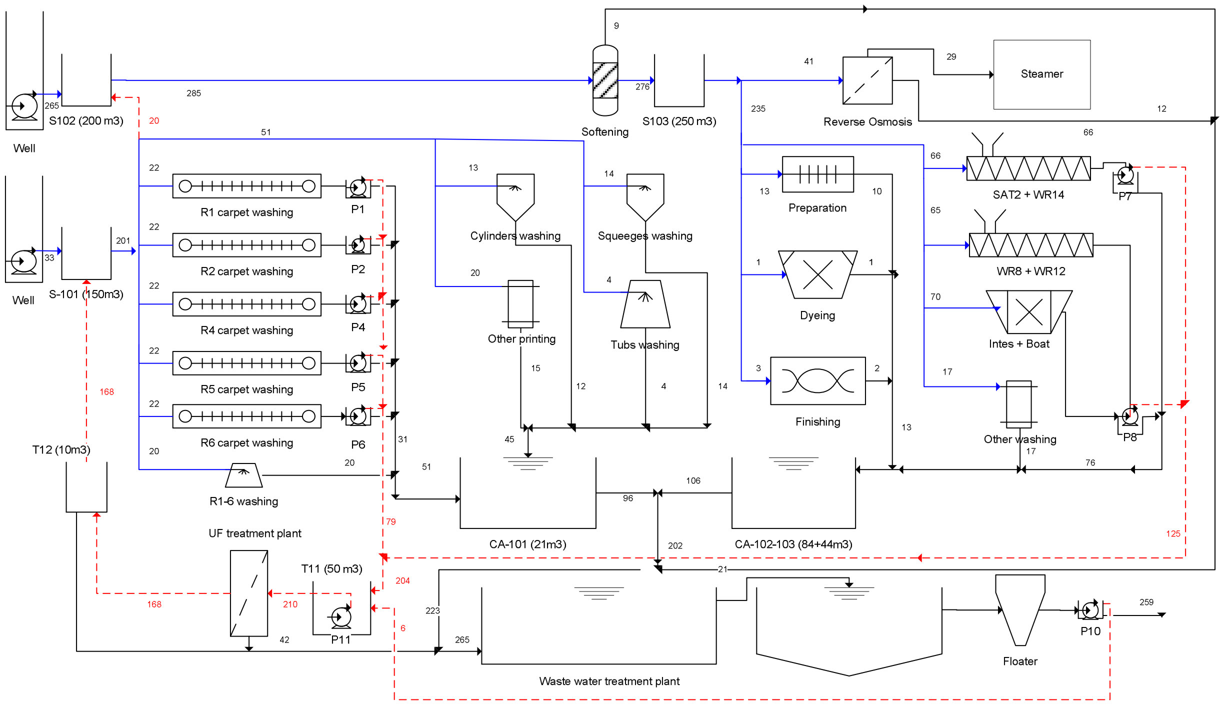



*Fig. 7.11 - Water and wastewater flows scheme of the company – reuse Scenario 1*

Scenario 1 was compared with three less complex reuse scenarios. Scenario 2 implements effluents segregation and separate collection in the printing department while the rest of the effluents for treatment and reuse is pumped from the WWTP discharge
Scenario 3 is the complementary of Scenario 2 implements segregation and separate effluents collection in the washing department, while the rest of the effluents for treatment and reuse is pumped from the WWTP discharge. Finally Scenario 4 is the classic end of pipe treatment and reuse.

**Water reuse flow chart and pollutants mass balance**
The water reuse scenario mass balance is calculated starting from the present mass balance (Scenario 0) and applying the experimental results of the first part of the project for the calculation of the expected characteristics of segregated effluents, permeates and concentrates. A synthesis of the calculated result are reported in the following Table 7.4 and 7.5.

Table 7.4 - Scenarios water balances

| | SCENARIO 0 | SCENARIO 1 | SCENARIO 2 | SCENARIO 3 | SCENARIO 4 |
|---|---|---|---|---|---|
| | [$m^3$/y] | [$m^3$/y] | [$m^3$/y] | [$m^3$/y] | [$m^3$/y] |
| Water consumption (departments) | *465.642* | *465.642* | *465.642* | *465.642* | *465.642* |
| Wells water | *465.642* | 273.797 | 273.797 | 273.797 | 273.797 |
| Recovered water | 0 | 191.845 | 191.845 | 191.845 | 191.845 |
| Waste water (WWTP inlet) | 426.255 | 266.185 | 377.577 | 334.388 | 447.568 |

Table 7.5 - Scenarios recovered water characteristics and mass balances

| | SCENARIO 1 | | SCENARIO 2 | | SCENARIO 3 | | SCENARIO 4 | |
|---|---|---|---|---|---|---|---|---|
| | Water [$m^3$/y] | COD [kg/y] | Water [$m^3$/y] | COD [kg/y] | Water [$m^3$/y] | COD [kg/y] | Water [$m^3$/y] | COD [kg/y] |
| **WW to Reuse water treatment plant – departments apportionment** | | | | | | | | |
| General Facilities | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Preparation | 15.013 | 1.595 | 0 | 0 | 7.327 | 370 | 0 | 0 |
| Dyeing | 3.079 | 616 | 0 | 0 | 3.639 | 1.281 | 0 | 0 |
| Printing | 78.327 | 15.665 | 69.991 | 21.979 | 0 | 0 | 0 | 0 |
| Steaming | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fabric washing | 84.964 | 13.392 | 0 | 0 | 102.214 | 69.203 | 0 | 0 |
| Finishing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **181.383** | **31.268** | **69.991** | **21.979** | **113.181** | **70.854** | **0** | **0** |
| | | | | | | | | |
| **Reuse treatment plant concentrate and permeate** | | | | | | | | |
| Concentrate | 21.313 | 22.043 | 21.313 | 21.594 | 21.313 | 40.829 | 21.313 | 7.886 |
| Permeate | 191.815 | 12.399 | 191.815 | 14.698 | 191.815 | 40.020 | 191.815 | 13.427 |
| **Total** | **213.128** | **34.443** | **213.128** | **36.292** | **213.128** | **80.849** | **213.128** | **21.313** |
| | | | | | | | | |
| ***WWTP* (Process WW discharge + WWrtP concentrate)** | | | | | | | | |
| WWTP inlet | 266.185 | 427.310 | 377.577 | 438.450 | 334.388 | 434.131 | 447.568 | 445.449 |
| | | | | | | | | |

**Technical feasibility assessment**
According to the test results, the selected reuse scenarios are technically feasible:

- process wastewater may be collected start of pipe and treated directly in membrane plant;
- WWTP effluent may integrate the process wastewater to reach the target as water volume to reusing;
- the membrane permeate characteristics are suitable for using in textile process;
- the effluent of WWTP doesn't exceed the regulatory limits in any scenario simulated.

Scenario 1 allows the higher recovered volume of process effluents than other scenarios and the lower recovered volume of WWTP outlet. It enables a significant reduction of the hydraulic load of the existing WWTP with respect to all other scenarios.

**Economic feasibility assessment**
The economic feasibility assessment was carried out to compare the present state (Scenario 0) with each defined water reuse scenarios (Scenario 1, 2, 3, 4).
The discount rate of 5,02 % is used for application of the NPV method and a period of 10 years was assumed for the economic feasibility assessment calculation.
The water reuse treatment plant cost is considered as investment cost. For each scenario the investment cost is reported in Table 7.6. For the specific project, no cost recovery was considered.

Table 7.6 - Investment cost

| | SCENARIO 0 | SCENARIO 1 | SCENARIO 2 | SCENARIO 3 | SCENARIO 4 |
|---|---|---|---|---|---|
| | Cost [€ $y^{-1}$] | Cost [€ $y^{-1}$] | Cost [€ $y^{-1}$] | Cost [€ $y^{-1}$] | Cost [€ $y^{-1}$] |
| Water reuse treatment plant | 0 | 294.480 | 277.756 | 276.364 | 248.640 |

The cash flows are the following running costs:

- Raw water supply cost: the raw water cost of Stamperia of Martinengo consists in a yearly fee and electric energy cost for pumping water; the total cost is about 12.000 €/y in Scenario 0 and 7.065 €/y in Scenario 1, 2, 3, 4; the specific raw water cost is about 0,0258 €/$m^3$ which is very low comparing with:
    - the cost of water (pumped from the lake) in the textile district of Como: 0,30 €/$m^3$ (2007);
    - the average water supply cost in Italy: 0,49 €/$m^3$ (2004);
    - the water supply cost in France, Germany, Great Britain, Netherlands: 0,8 ÷ 2,1 €/$m^3$ (OECD 2002);
- Electric energy cost of waste water reuse treatment plant (WWrTP) – water network and membrane plant;
- Membrane cost: the plant is equipped by a first membrane set (100.000 €/y) which is totally replaced each 5 years with a yearly charge of 20.000 €/y;
- Spare parts cost of waste water reuse treatment plant (WWrTP);
- Chemicals cost of waste water reuse treatment plant (WWrTP);
- Operating and maintenance labour cost of waste water reuse treatment plant (WWrTP);
- Total cost of company's waste water treatment plant (WWTP): it concerns energy, chemicals, sludge disposal, operating and maintenance costs.

For each scenario the running cost is reported in Table 7.7.

Table 7.7 - Running cost

| | SCENARIO 0 | SCENARIO 1 | SCENARIO 2 | SCENARIO 3 | SCENARIO 4 |
|---|---|---|---|---|---|
| | Cost [€ $y^{-1}$] | Cost [€ $y^{-1}$] | Cost [€ $y^{-1}$] | Cost [€ $y^{-1}$] | Cost [€ $y^{-1}$] |
| Raw water supply | 12.000 | 7.065 | 7.065 | 7.065 | 7.065 |
| WWrTP running cost | 0 | 194.640 | 201.001 | 198.808 | 205.168 |
| Total cost WWTP | 306.646 | 301.705 | 308.066 | 305.873 | 312.233 |

The calculated NPV of the project is negative for each reuse scenario as reported in Table 7.8.

Table 7.8 - Net Present Value

| | SCENARIO 1<br>SCENARIO 0 | SCENARIO 2<br>SCENARIO 0 | SCENARIO 3<br>SCENARIO 0 | SCENARIO 4<br>SCENARIO 0 |
|---|---|---|---|---|
| | [€] | [€] | [€] | [€] |
| Net present value (10 years – r = 5,02%) | -803.193 | -791.560 | -772.927 | -787.847 |

Payback period and IRR methods are not applicable being NPV negative.
Setting NPV = 0 and solving the equation (1) for raw water cost, the breaking point of NPV curve is evaluated. Breaking point cost are reported in Table 7.9 for each scenario.
The evaluated raw water specific cost is close to the average cost in Italy and lower than cost in main European countries: it means that the treatment and reuse textile waste water start of pipe is a feasibility option for textile firms.

Table 7.9 - Raw water specific cost for NPV = 0

| | SCENARIO 1<br>SCENARIO 0 | SCENARIO 2<br>SCENARIO 0 | SCENARIO 3<br>SCENARIO 0 | SCENARIO 4<br>SCENARIO 0 |
|---|---|---|---|---|
| | [€/$m^3$] | [€/$m^3$] | [€/$m^3$] | [€/$m^3$] |
| Raw water specific cost (10 years – r = 5,02%) | 0,57 | 0,56 | 0,55 | 0,56 |

Increasing the supplied water cost to 0,8 €/$m^3$ close to the low cost of supplied water in France, Germany, Great Britain and Netherlands, NPV is positive (€ +376.969 ÷ +407.235) and payback period is 4 ÷5 years.

The planned deliverable of this action has been issued.
No problems or delays have been highlighted.

*Action C.5: Expert system design*

Design and validation of the Expert System for the on-line management of the ruse plant was the next activity (Action C.5 by ANOVA supported by ENEA). After a preliminary analysis on textile process plant lay-out about check-points for wastewater drawing of monitoring samples and plant control interfacing (Pumps Valves, UF, Tanks), it has been chosen to install and characterise the Expert System with the following distributed components:

<u>REMOTE CONTROL EXPERT NODES (Kb and SCn modules):</u>

- SCn Module (SCn601, SCn602, SCn603, SCn604, SCn605, SCn606, SCn607) with I/O Remote Controller modules installed in the Printing Department for Rotative (R1, R2, R4, R5, R6) wastewater process control and in the Washing Department for Washing Units (WR6 - WR7).

The Printing Department, the five rotative printing machines (R1, R2, R4, R5,R6), using the most common dyes, produce a continuous effluent discharge due to printing belt washing and a batch stream due to the final washing operations of the equipment.

In the Washing Department water demand is almost 50% of total company. Two continuous washing lines (WR6 -WR7), continuous rope washing and several batch equipment, are used for textile washing of printed, dyed, prepared or raw fabrics. They produce a continuous effluent discharge during operations and a batch stream due to the equipment draining.

- Kb Module (Kb601, Kb602, Kb603) with I/O Remote Controller modules installed as Remote Control Expert Nodes for Water Quality Analysis (Color Index, pH, Conductibility) and as Color Index Multistream Detection Units.

<u>PC/EXPERT SYSTEM - SERVER STATION (BTL)</u> with central Process Monitoring Expert System (XBASE) software + basic software applications - to be running diagnostic processing and learning modules and decision-supporting tools;

- PC/Station (case, monitor, keyboard, mouse, USB-WiFi, USB -Switch), S.O. Windows2003 server with XBASE SwTool and DB SQL-server 2005, HMI software (SCADA);

- N.1 Router and N.3 Extender

- Pocket PC, UPS, I/O Modules, Interface and Control Devices, etc.

In particular, the PC/Expert System performs and gives available:

- Field data/signals detecting and controlling, as well as the working state of each textile machine /equipment;

- Knowledge Base exploitation and trends tracing about the dynamics of target processes, regarding water quality discharged from each one of textile departments;

- Inferring on water balancing and matching between printing/washing water requirements and Ultra-Filtration (UF) operative performance, as well as WWTP potentiality, in reference to storage water tanks and to the low water quality limits;

- Data validation and Knowledge Base up-grading (auto-learning) through a redouble data matching/fitness between PC/Server XBASE and each one KB Nodes;

- Software Operational Dashboard/Scheduling and a Decisional Support System for water recovery real-time management, reporting functionality enclosed.

ELECTRONIC EQUIPMENTS and electrical material for the installation of the whole Prototype System:

- WiFi Network Data Communication: performs and gives available Wireless/redouble data transmitting to the nodes Kb "Remote Control Export Node", that will identify through the "macro-descriptor" (WPR) the most suitable water outflows to the recovering;

- N.1 Router and N.3 Extender

- Pocket PC, UPS-Riello, I/O Modules, Interface and Control Devices, etc.

Expert System functional architecture consists of electronic devices and software modules which have to be connected (and interfaced) to the electrical and mechanical equipments of textile plants.

The all ES prototype will be constituted by the following (see Table) Hw/Sw components:

- 9 SCn/RWI – "Remote Wireless I/O Node" Hw & Firmware Aitron Producer
- 3 KB/RCN – Hw/Sw "Remote Control Expert Node" Hw & Firmware Aitron Producer
- 1 PC -Station /SQL Server and Peripherals Units Hw/Sw & OS Various Producers
- 1 XBASE (eXpert Based Advisor System for Enterprise) Sw- Middleware Aitron Producer
- Equipments and Spare Parts (for the installation) Hw/Sw Various Producers

The SCn I/O Nodes were interfaced within water recovery pump switchboards, related to finishing and washing textile departments, as well as to the effluent from the WWTP. At this purpose, it was necessary to derive On/Off/Anomaly state signals from each referred operative textile equipment, in each of the pump switchboards (QCP), by predisposing a right supplementary switching circuit and a "clean contacts" bench of input/output relays (n.6DO/n.2DI). The last one has to be equipped by a manual/automatic/remote switching, so that it will be able to operate (for instance, in case of maintenance) within/without wireless connection to the PC/Server Expert System station: in particular, in case of lack of network wireless signal, but with a switching state on "remote control", for safety and rightness, each recovery pump must to remain in off state. Another point of interfacing to textile target equipments, is about the local control system (PLC) on the Ultra filtration Plant (UF): in this case there will be preset a "clean contacts" bench of input/output relays to derive the UF operating functional signals, or rather a direct PLC serial connection, so that it will be possible to derive anagogic inputs on tank levels, water flow measurements, and so on. In other words, the ES interfacing with textile equipments it will be located (see Fig.1):

1) near Printing Equipment (R1, R2, R4, R5, R6): with n.5 SCn I/O unit, to detect and transmit "on/off" state of machine and water recovery pumps (P1, P2, P4, P5, P6), as well as data/info about textiles characteristic as Textile thickness and Textile Permeability;

2) near Washing Equipment (SAT2 + WR14" and "WR 8 + WR 12): with n.2 SCn I/O unit, to detect and transmit "on/off" state of machine and water recovery pumps (P7, P8);

3) out of WWTP: with n.1 SCn I/O unit, to detect and transmit "on/off" state of machine and water recovery pump (P10);

4) before UF (Tank T11) and integrated with UF/PLC switchboards: with n.1 SCn I/O unit, to detect and transmit "UF Functionality", "water level index" and "on/off" state of water recovery pump (P11).

The real-time Expert System water quality and recovery control will be operated by the following functionalities (see Fig.21):

a) selection from Printing Department which of P1, P2, P4, P5, P6 water recovery stream is acceptable to be recovered on the base of WPR on-line measurement (pH, conductibility);

b) selection from Washing Department which of P7-P8 water recovery stream is acceptable to be recovered on the base of WPR on-line measurement (pH, conductibility, colour);

c) monitoring of UF plant by if P11 water recovery stream is acceptable to be treated by UF on the base of WPR on-line measurement (pH, conductibility, colour). fFor instance, high values of pH could damages membranes, ad so on;

d) monitoring of effluent from WWTP plant by if P10 water recovery stream is acceptable to be treated by UF on the base of WPR on-line measurement (pH, conductibility, colour);

e) monitoring of Water Balance in the tank T11 so that, if necessary, ES can operates with the start of the related WWTP P10 pump;

f) monitoring of Water Balance in the tank T11 so that, in the case of water recovered overflow, ES can operates with a more higher water quality limits

The functional Expert System scheme and its basic devices and components are in the following figure:

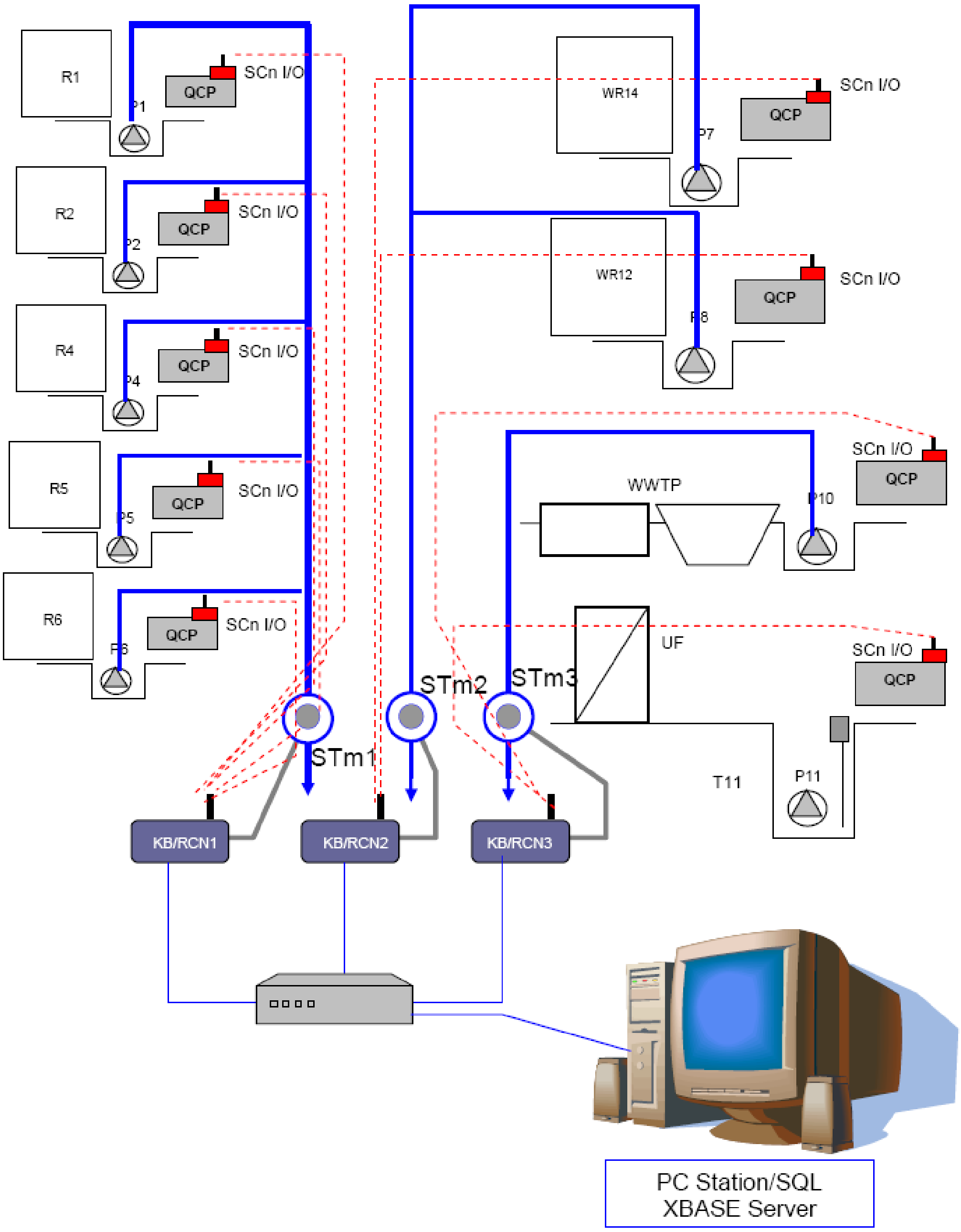



*Fig. 7.12 - Functional Expert System scheme and its basic devices and components*

*Task D: Water reuse demonstrative plant design and build-up*

<table>
<tr><th>Task start/end date</th><th>Action</th><th>Expected results</th><th>Achieved results</th></tr>
<tr><td rowspan="5">Task D:<br>Water reuse demonstrative plant design and build-up<br>1.12.2006*/31.03.2008<br>*Start date was postponed to 1.02.2007</td><td>D.1- Plant lay-out</td><td>Preliminary design</td><td rowspan="5">All of the task expected results have been achieved according to the proposal</td></tr>
<tr><td>D.2- Equipment data sheets identification</td><td>Equipment data sheets</td></tr>
<tr><td>D.3- Final design</td><td>- Final detailed design<br>- Operative handbook</td></tr>
<tr><td>D.4- Plant building-up</td><td>Complete wastewater treatment and reuse plant properly integrated in the company lay-out</td></tr>
<tr><td>D.5- Interface between the Expert System and the plant</td><td>Complete interface of the E.S. with the plant</td></tr>
</table>

*Actions D.1 and D.2: Plant lay-out - Equipment data sheets identification*

According to the Scenario 1, preliminary lay-out and simplified process and instruments diagram of the reuse treatment plant were defined considering the company constrains (Action D.1 by ENEA supported by ANOVA, SdM and CIDA).
Each electromechanical component (including machinery, piping and online monitoring device) was defined in its main features to comply the plant functionality according to the lay-out defined. The equipment datasheets were detailed enough to enable the purchasing and the correct installation based also on operational data gained by pilot trials. (Action D.2 by CIDA supported by ENEA, ANOVA, SdM).

The equipment datasheets list is reported in the following table (Table 7.10):

| | |
|---|---|
| SDM.N.JS.A.101 | Descrizione opere civili |
| SDM.N.JS.A.102 | Capitolato tecnico opere civili |
| SDM.N.JS.C.101 | Specifica generale tubazioni |
| SDM.N.JS.C.102 | Valvola a farafalla pneumatica |
| SDM.N.JS.C.103 | Valvola a sfera pneumatica |
| SDM.N.JS.C.104 | Descrizione lavori meccanici |
| SDM.N.JS.C.105 | Capitolato tecnico impianto meccanico |
| SDM.N.JS.C.106 | Specifica tecnica tubazioni metalliche |
| SDM.N.JS.C.107 | Descrizione lavori di modifica serbatoi |
| SDM.N.JS.K.101 | Interruttore di livello a conducibilità |
| SDM.N.JS.K.102 | Misura di livello ad ultrasuoni TK-601 |
| SDM.N.JS.K.103 | Misura di livello ad ultrasuoni TK-603 |
| SDM.N.JS.K.104 | Misura pH rotativa |
| SDM.N.JS.K.105 | Misura pH WR |
| SDM.N.JS.K.106 | Misura pH alimento e permeato |
| SDM.N.JS.K.107 | Misura conducibilità rotativa |
| SDM.N.JS.K.108 | Misura conducibilità WR |
| SDM.N.JS.K.109 | Misura conducibilità alimento e permeato |
| SDM.N.JS.K.110 | Termostato |
| SDM.N.JS.K.111 | Misura colore WR |
| SDM.N.JS.K.112 | Misura colore alimento e permeato |
| SDM.N.JS.K.113 | Interruttore di livello a fine corsa |
| SDM.N.JS.N.101 | Descrizione lavori elettrici |
| SDM.N.JS.N.102 | Quadri bassa tensione |
| SDM.N.JS.N.103 | Sistema di automazione / supervisione / sistema esperto |
| SDM.N.JS.N.104 | Logica di funzionamento |
| SDM.N.JS.N.105 | Capitolato tecnico impianto elettrico |
| SDM.N.JS.N.106 | Capitolato tecnico impianto strumentale |
| SDM.N.JS.N.107 | Capitolato tecnico impianto automazione / supervisione / sistema esperto |
| SDM.N.JS.N.108 | Lista ingressi e uscite |
| SDM.N.JS.P.101 | Pompe sommergibile per rotative |
| SDM.N.JS.P.102 | Pompe sommergibile per WR |
| SDM.N.JS.P.103 | Pompa centrifuga alimentazione serbatoi |

| | |
|---|---|
| SDM.N.JS.P.104 | Pompa centrifuga alimentazione impianto riuso |
| SDM.N.JS.Q.101 | Impianto membrane |
| SDM.N.JS.T.101 | Serbatoio alimento |
| SDM.N.JS.T.102 | Serbatoio permeato |

The planned deliverables of this two actions have been issued.
No problems or delays have been highlighted.

*Action D.3: Final design*

Final design (Action D3 by CIDA supported by ENEA, SdM) was released with constructive detailed design of all the facilities and equipment including necessary installation details (sketch). Start-up manual and Operative handbook. The main characteristics of the plant are reported in Table 7.11.

The water reuse treatment plant lay-out and process and instruments diagram are reported in Figure 7.13 and Figure 7.14.

The production processes producing effluents with suitable characteristics are connected to a dual wastewater collection pipelines. Suitable ones are collected separately and pumped to the storage tank where different process effluents are mixed and the resulting stream is diverted to a membrane treatment station for subsequent reuse. Before reuse membrane permeates are stored in existing tanks and mixed with an amount of primary water, they are sent to the company water distribution network. The effluents not suitable for reuse, mixed with the concentrates produced by the membrane plant, constitute the inlet of the existing WWTP.

The treatment technology is UF on hollow fibres membranes ZeeWeed® 500d by GE Zenon.

The extreme variability of the production processes in a textile SME, and consequently in its effluents, requires implementation of on-line control. For this purpose, a prototype Expert System was developed and programmed. The ES, fed by a continuous on-line analytical control (e.g., colour, conductivity, pH) on the different process effluents, perform the selection of the most suitable effluent streams for the next treatment and the reuse.

Table 7.11: WWrTP characteristics and process parameters

| | |
|---|---|
| Total filtering surface ($m^2$) | 2.402 |
| Feed Flow rate ($m^3/h$): | 50 |
| Recovery factor (%) | 85 |
| Working cycle (h/d) | 12 |

*Fig. 7.13 - Wastewater reuse treatment plant lay-out*

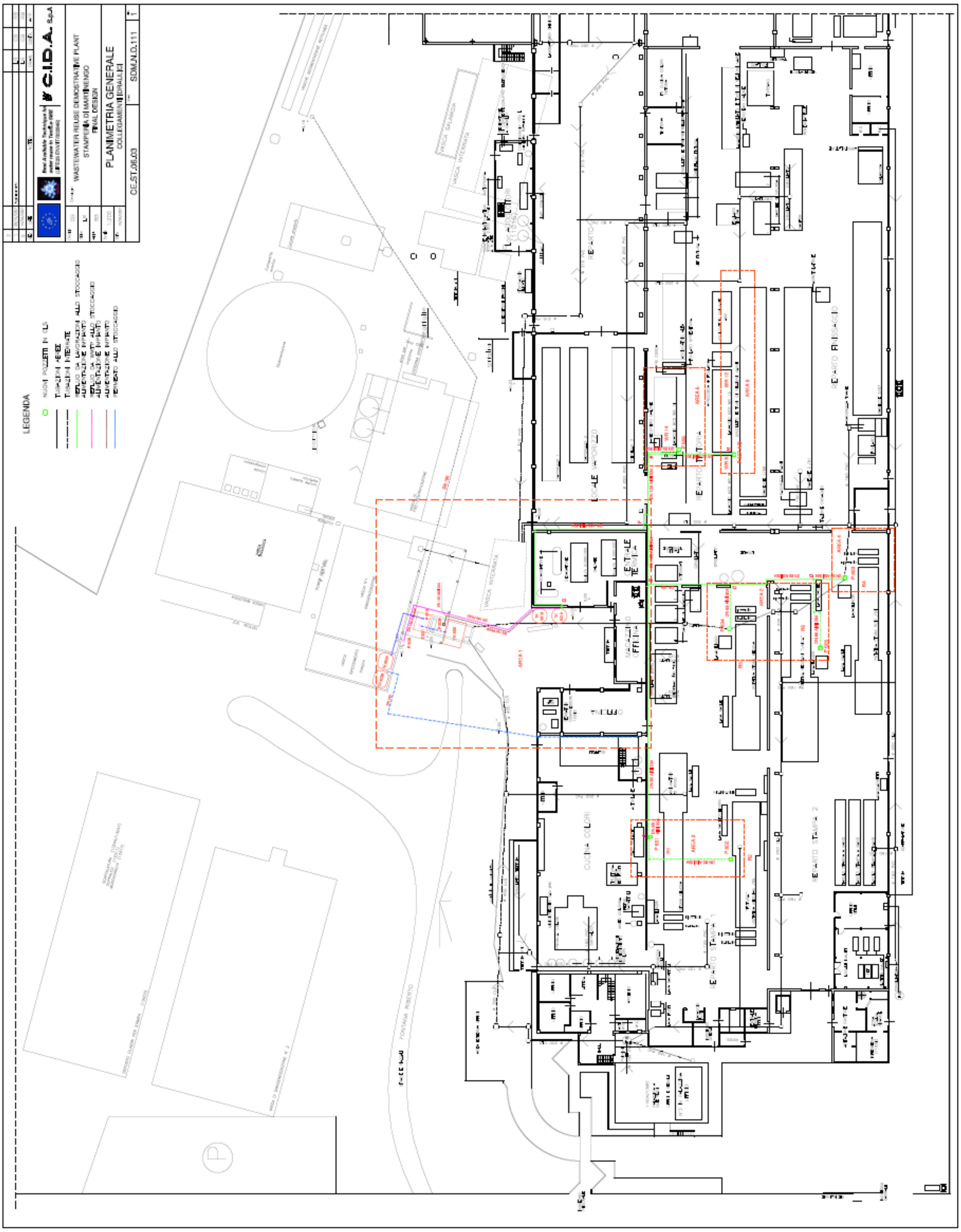
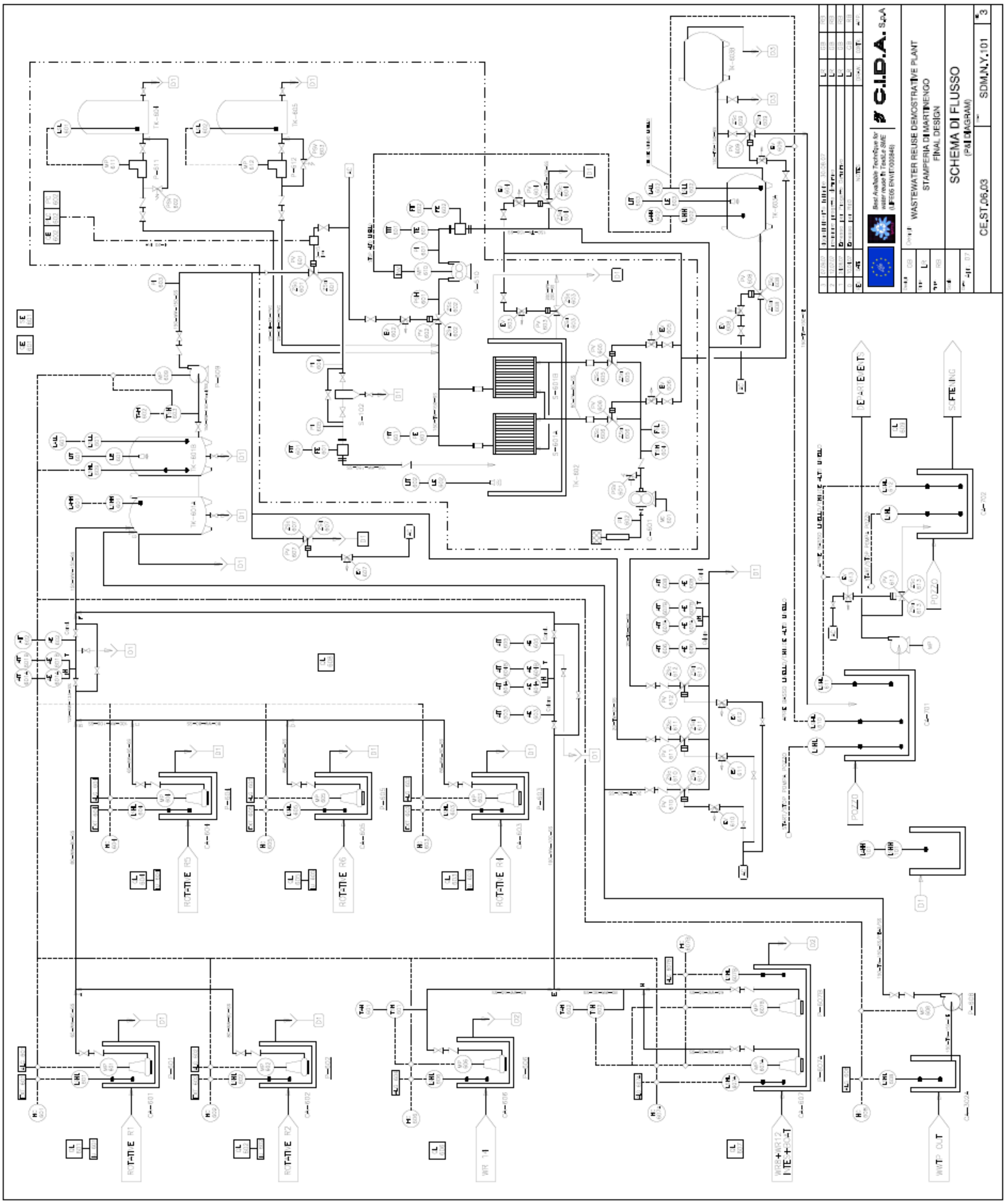


*Fig. 7.14 - Wastewater reuse treatment plant process and instruments diagram*




The planned deliverables of this action have been issued.

No problems have been highlighted; a delay in issuing of the deliverable: “Operative handbook of the plant” D3.002 has been reported as a consequence of suppliers delay in providing equipment and plant final documents. The final version of this document will be submitted with the present report in paper and digital format (Annex n.o: 1).

*Action D.4: Plant building-up*

According to the final design all the plant components were set-up and linked together and with the existing equipments (Action D4 by SdM supported by ANOVA and ENEA). The deliverable “Complete wastewater treatment and reuse plant” which is annexed to the present report, describes with a series of photos each section of the plant (Annex n.o: 2).

*Action D.5: Interface between the Expert System and the plant*

The implementation of the interface between the Expert System (ES) and the plant (Action D5 ANOVA supported by SdM, UNIFI and ENEA) was achieved completely, according to the proposal all the signals from the plant devices (on line measures, functional status of the machines, etc, etc) were identified and provided to the ES through proper hardware and software connections as inputs for its elaboration and decision making. The deliverable "Complete interface of the E.S. with the plant " (annexed to the present report, n.o: 3) contains details about how each Expert System component interfaces the SdM textile plant, both from a hardware and control logic point of view.
Starting from the plant lay-out and main obvious interface points, like power supply and electrical input/output signals from sensors transmitters, this documentation outlines how:

1) the data acquisition and SCn control node unit works, related to the on-line water quality measuring stations KB601/KB602, to allow derivation of collections of water streams from the rotative and washing machines textile areas. It is reported the input/output list of parameters (start/stop of pumps, color index IC on-line detection, electrochemical measurements like, pH, temperature and conductivity) and their logistic roles in water quality monitoring and process control for each of interfacing points like electrical switchboards and human interface (push-button panels);
2) the on-line measuring station KB603 works regarding final check related to water pollution rate WPR on Ultra-Filtration Unit, the water recovered storage management, the possible WWTP water contribute management;
3) the wireless network of data communication units (Wi-Fi transmitters and repeaters) works with reference to different distributed node units SCn and KB;
4) Expert System Server Station BTL works about the characteristics of the process effluents, their treatability and reusability (limits, constraints, etc.) and the evaluation of water treatment and reuse option. It is described about E.S: Knowledge Base (HMI/XBASE) and the opportunity to use evolutive programming (self-learning and optimization by Genetic Algorithms) to semi-automatically up-dating KB control nodes when a concrete dis-matching between WPR on-line detected and WPR expected happened.

*Task E: Plant operation and evaluation of the BAT on water use optimisation*

| Task start/end date | Action | Expected results | Achieved results |
|---|---|---|---|
| ***Task E:*** *Plant Operation and evaluation of the BAT on water use optimization* **1.03.2008 / 30.11.2008*** *End date was postponed to 31.03.2009 | **E.1**- Functional tests and check of the plant | Report on the functionality tests results recommendations and integrations to the operative handbook | Action E.1 expected results have been achieved according to the proposal |
| | **E.2**- Start-up and provisional operation of the plant aimed at the E.S. training | - Plant operation in "human supervisor" modality<br>- Complete training of the E.S. | Action E.2 expected results have been achieved with a two months delay with respect to the proposal |
| | **E.3**- Operation of the integrated demonstrative plant | - Four months of continuous operation<br>- Collection of all the data to characterise the advantages and the drawbacks of the proposed BAT | Action E.3 expected results have been achieved with a four months delay with respect to the proposal because of the plant breakdown.<br>For the same reason the plant operated continuously for three months only. |
| | **E.4** -Report of the results and BAT definition | Final Report and manual for the BAT | Action E.4 expected results have been achieved with a four months delay with respect to the proposal |

*Action E.1: Functional tests and check of the plant*

Task E first objectives was the start-up of fully automated Expert System operation of the plant. Preliminary to this action, at first all the operative simulations to check the functionality of the plant parts (Action E.1 by ENEA supported by SdM) were carried out, including simulation of machines dysfunction. Check procedures were that released by the suppliers and complying the start-up manual included in the final design. Alarm signals and monitoring devices were also verified and calibrated. Finally the overall plant functionality was tested verifying the integration of all the parts. For details relative to this action see the deliverable "Report on functionality tests" which will be submitted with the present report (Annex n.o: 4).

*Action E.2: Start-up and provisional operation of the plant aimed at the E.S. training*

Successively, it was operated the start up of the overall plant in semi-automatic mode with real effluents (Action E.2 by ENEA supported by SdM, ANOVA and UNIFI). In this phase the plant operation was supervised by process experts with the aim of instructing the E.S. and verifying its decisions concerning the selection of the most suitable effluent streams for the next treatment and the reuse. For details concerning the "Expert System completely instructed for the management of the plant" see the relative deliverable, which will be submitted with the present report (Annex n.o: 5).

According to task B experimentation, the contamination of the effluents generated by belt washing of machineries R1-R6 was assessed by online measure of pH and conductivity as well as the detection of data/info about textiles characteristic like *Textile thickness* and *Textile*

*Permeability* set on the single machines by the equipment operators. This device was conceived as an alternative to the colour sensor and allowed the selection of the effluent before the ES monitoring process. It is based on the parameter WR, which can be considered as a combination parameter of the fabrics characteristic such as its weight and thickness. When the fabrics involved in the printing process has an high WR (low weight and thickness), the dye is not completely retained by the fabrics so that the resulting wastewater has an high colour and it is excluded a priori from the monitored stream for the reuse selection. In these effluents the combination of conductivity and WR parameter was found to be a good predictor of the effluents general contamination. The pH needs to be monitored to avoid membrane damaging.
The reusability of the effluents from washing department (SAT2 + WR14 and WR8 + WR12) is online monitored trough colour, pH and conductivity measure. For these effluents conductivity alone is not a good predictor of effluent contamination and an additional parameter (i.e. colour) needs to be monitored. In this way the E.S. is able to on-line characterize the quality of wastewater streams and it is "instructed" during the training procedures in order to be able to better control the selected streams.
During the E.S. training procedures parallel to the start up of the plant in semi-automatic mode, the ES performances were constantly monitored by a collection of samples and analytical investigations in order to compare results and verify its decision whether the effluent was to be discarded or not. The target of this operations was the good correspondence between the E.S. decisions and the expert technicians ones.
In this period unexpected inconveniences emerged and some procedures affecting the plant functionality has been reviewed, consequently the transition from semi-automatic to fully automated Expert system operation of the plant required more time than it was expected.
Due to the extreme variability of the different company manufacturing, the contamination of the effluents generated by carpet washing of machineries R1-R6 could not be always assessed correctly by online measures of pH, conductivity and WR machine settings. As a consequence it was discussed the possibility to install also a colour sensor in the printing department, in order to a better evaluation of the quality of these effluent.
A series of tests were carried out with the additional sensor installed off-line, in order to evaluate the correlation between the measures of colour and the respective values of conductivity and pH. The option of installing the colour sensor on-line was discussed, but providing the signal of this additional sensor proper hardware and software connections to the ES, was not a simple operation, requiring a complete reconfiguration of the same ES; as a consequence this option was soon rejected to avoid a major delay.
Another unexpected inconvenience was identified in the monitoring procedures of the effluents segregation from printing and washing departments. A fast worsening of the quality of the water in the storage tank was observed in correspondence of high colour or conductivity in one of the process effluents.
During the measure of pH, conductivity and colour for the time necessary for completing the measurement, the monitored wastewater flows into the storage tanks independently from its quality. This was considered acceptable in the final design after carrying out proper mass balances, based on the results of the experimental activity. This mass balances showed that the effluent contamination due to the discharge of these "undesired" effluents was below the limits of concern. Furthermore, in case of concentrations in the storage tanks higher than the limit values for acceptability in the UF unit, the procedure stops the flow to the UF and discharges the tanks content.
This problem can be solved definitely by introducing a bypass valve just after the measure point. This valve should be directly linked to the online monitoring instruments, causing an immediate discharge of the effluents to the WWTP, every time the quality requirements are not matched. This solution was plenary discussed, but it was decided to postpone it after the project end, because its realisation would have caused a long stop of the plant operation. As a consequence in order to avoid a major delay two different actions were taken to deal with this inconvenience: firstly, in order to prevent unsuitable effluent to reach the storage tank, the frequency of the monitoring tests was decreased from one every five minutes, to one every thirty minutes. Secondly the kb603 node limit values of acceptability of the UF influent was set to more restrictive values, in order to prevent the possible damage of the UF membranes.

As a result of all of these circumstances, the start-up of fully automated ES operation of the plant was completed only at the end of September 08 and sub-action E.2.7 ended with a two months delay.

*Action E.3: Operation of the integrated demonstrative plant*

The subsequent activities (action E.3 by ENEA supported by SdM, CENTEXBEL and UNIFI) regarding the operation of the integrated demonstrative plant fully automatic operation conditions, were performed and maintained continuously for about two weeks. Then suddenly, one of the Knowledge based remote control PC/Nodes KB-RCN which controls the on line monitoring of the effluents, crashed and caused a total blockage of the Expert system. In particular KB-RCN 603 node turned in an emergency situation, and stopped sending water to UF plant.

The event was promptly reported to the external monitoring team and to the EC which agreed with the request of a three month delay in order to enable to perform some extra experimentation; it was proposed to use the three months period usually devoted to the compilation of the final report. Obviously all the expenses made beyond the date of 30/11/08, such as the ones relative to the organization of the final conference, were not included in the final financial report. The final report was submitted with a delay of about one month, to allow inserting all the reuse plant performances data of three months of continuous operation and the new BAT.

With regard to the plant breakdown, it was then verified that it was caused by a total blockage of the communication among the Knowledge based remote control PC/Nodes KB-RCN. In fact, the Expert System is a “pyramidal” system where the kb603 acts as supervisor on all the nodes Kb and Sc; the acquisition of wrong or missing data place the system in emergency shutdown procedure, and the reuse plant is stopped in order to prevent irreversible damage of the UF membranes.

In these cases the following controls becomes necessary:

1.Checking all the data sent to the PC/Server for being able to give a first hypothesis of what has happened.

2.Checking all firmware (that is the software in all the nodes) in order to exclude eventual programming errors

3.Checking all digital and analogic modules in order to exclude eventual anomalies deriving from jolts of voltage.

4.Checking all voltage levels in and out and the total wireless network.

It took more than one month to restore the full functionality of the Expert system and repair the damage by replacing some electronic accessories of the wireless communication among the KB-RCN nodes. In particular, it was upgraded the wireless signal through high gain antennas and dislocated in various way the router wireless in order to make forehead the structural modification of the system of Martinengo.

After that, it was necessary to do again all the preliminary tests to check the functionality of all the plant parts (action E.1) and then the plant start-up in semi-automatic mode was performed again (action E.2.1) in December 08. In a document annexed to the present report (Annex n.o: 6) are showed the results of the off-line laboratory analytical determination of the process effluents coming from Rotary and Washing sections, the WWTP treated wastewater and the influent and effluent of the UF treatment plant (UF in, UF out). These data, are relative to various campaign of sample collection from December 08 to February 09.

During this phase of demonstrative scale operation, the water recovered from the printing department was almost constantly scarce so the opportunity of including these effluents in the stream of the different process ones monitored for the reuse selection, was discussed. In fact, during almost three months of on-line and off-line analysis of the printing effluents characteristics, it was evident that their quality was most of the time poor and unsuitable for reuse due to the particular company manufacturing at the time, which frequently involved disperse dyes (see annex 6).

In addition, sometimes this fact caused also the worsening of the quality of the water in the storage tanks at every monitoring cycle (lack of the by-pass valve, see above), unless an

equipment operator was present to block the printing department flow, after a visual test of its chemo-physical parameters at the kb602 node. In the absence of the operator, it was assessed that it was too risky to carry out the reuse of these effluents in automatic mode, in fact in case of very contaminated wastewater the quality of the water in the storage tanks resulted completely spoiled and forced to discard it.
In conclusion, it was decided to exclude temporarily the printing effluents from the reuse process in order to collect data and conclude positively action E.4. This way, the reuse scenario was shifted from the first one to the third one (fig.7.15), which implements segregation and separate effluents collection in the washing department, while the rest of the effluents for treatment and reuse is pumped from the WWTP discharge. Obviously the total amount of water recovered from the process effluent is less than that of the first scenario but it is possible to maintain the same total quantities by pumping more effluent from the WWTP discharge. However in case it is available the presence of an equipment operator who performs the visual control, effluents from the printing department could enter the reuse cycle and the reuse scenario change again to the first one.

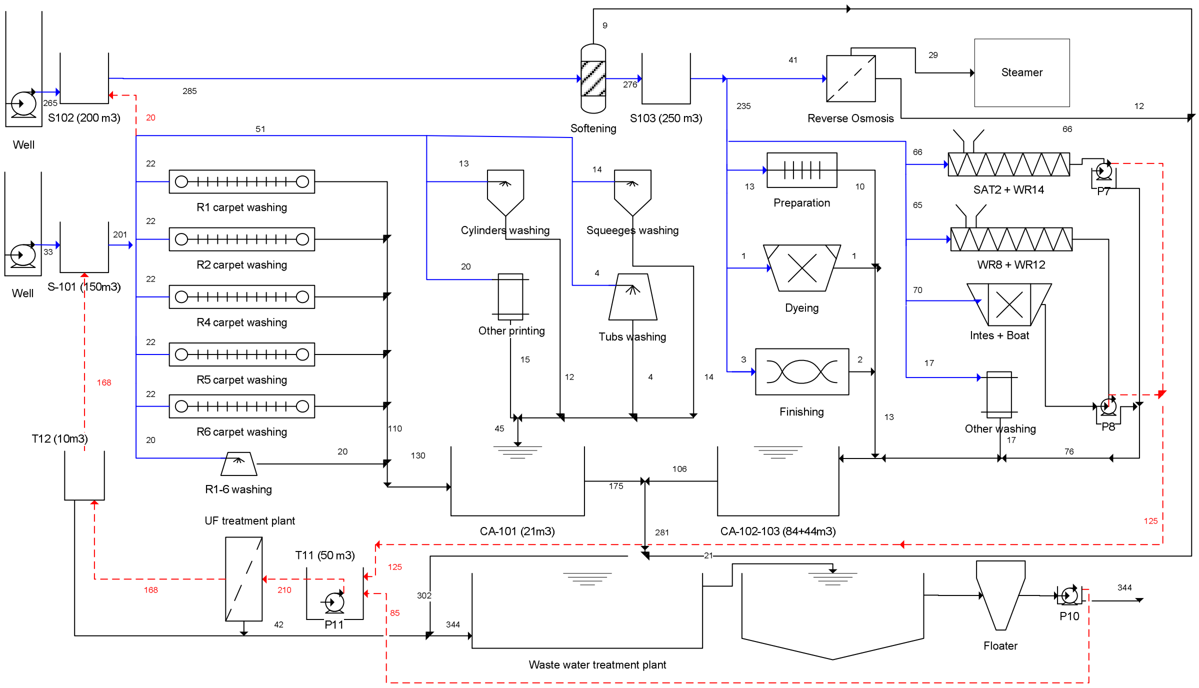



*Fig. 7.15 - Water and wastewater flows scheme of the company –reuse Scenario 3*

In this context, the additional start-up of fully automatic operation of the integrated demonstrative plant (action E.2.7) was performed in January 09 and maintained continuously for about three months until the end of the project.
During this period, the treated effluents was used in the company production lines and control of the quality of textile produced was performed with a series of test which are described in details in a document submitted with the present report (Annex n.o: 7).
The performances of the overall system was monitored including the quality of the final discharge with the continual calculation of water and contaminants mass balances.
In addition, after the start up of the water recycling plant, its effects on the WWTP where evaluated both in terms of WWTP influent and effluent quality and nitrification activity (E.2.5 and E.2.6).

As far as the WWTP influent quality is concerned, it is important to highlight that water recycling reduces the consumption of fresh water without a corresponding reduction of contaminants leading to an increase of the latter in the WWTP influent.
The followings were chosen as main parameter in order to check the effect of water recycling on WWTP influent: chemical oxygen demand (COD) and ammonium nitrogen ($N-NH_4^+$).
As far as the WWTP effluent quality is concerned, the followings were chosen as main parameter in order to check the effect of water recycling on WWTP effluent: chemical oxygen demand (COD), total suspended solids (SST), nitrite nitrogen ($N-NO_2^-$) and ammonium nitrogen ($N-NH_4^+$).
The monitoring of the WWTP was carried out taking and analyzing several samples in the different sections of the plant according to the monitoring plan used in the preliminary characterization. The data collected during this monitoring plan (from January 8$^{th}$ until February 20$^{th}$) were compared with those collected during the year 2008, before the start up of the water recycling.
In spite of an increase of the WWTP influent COD due to the water recycling plant (from 640 to 799 mg/l on average) the effluent COD was constantly under the limit of 160 mgCOD/l set by law for discharge in receiving water body. The limit was exceeded just one time but it was rarely observed before the start of the water recycling plant, as well.
During the operation of the water recycling plant, a slightly decrease in the WWTP influent nitrogen ammonium concentration was observed on average in comparison to the mean of the year 2008. It is not surprising because the concentration of ammonium nitrogen is strongly linked with the type of fabric in process. Nevertheless the concentration of ammonium nitrogen was around 120 mg N/l which is a still high concentration. As far as the nitrification process is concerned, data from monitoring show that it is still quite satisfactory in spite of the start of the recycling water plant. In fact, the ammonium nitrogen concentration was almost constantly below 1 mg $NH_4^+$/l accordingly with the results before the start of the water recycling plant.
The concentration of nitrite, as well, was not affected by the water recycling plant and few data available show that the concentration in the WWTP effluent carries on staying below 0,01 mg $N-NO_2^-$/l.
The concentrations of WWTP effluent TSS were well under the limit of 80 mg/l with the exception of one data. The limit set by law for TSS was exceeded just a couple of times. The limit was exceeded with a similar frequency before the start of the water recycling plant, as well. It means that the sedimentability of the activated sludge was not affected by the water recycling so far.
Finally, results of the monitoring carried out after the start of the water recycling plant show that none remarkable negative effect due to the water recycling plant has been detected so far.
In addition to the monitoring of the of the WWTP (action E.2.5), some titrimetric tests were carried out in order to check the nitrification activity (amount of ammonia oxidized per unit time by the unit amount of biomass or solid in the activated sludge).
In fact, the nitrification activity was used in the previous action for the assessment of potential inhibitory effects on nitrifying micro-organisms due to the higher concentration of biodegradable and not biodegradable compounds in wastewater due to the water recycling. Preliminary tests showed that the water recycling had no effect on nitrifying biomass activity and this action was put on in order to confirm such result.
The tests for the evaluation of nitrification activity were carried out according to the same procedure used in the action C.3.
Results of the titrimetric tests showed none remarkable effect of the water recycling on nitrifiers. In fact the sludge of the WWTP showed the same activity as in the preliminary tests carried out before the start of water recycling with similar WWTP operating conditions.
The model of WWTP developed in the first part of the project showed that none problem was expected in terms of WWTP functionality in the case of water recycling as experienced so far. The results of both WWTP and nitrifiers activity monitoring confirm the model prediction.

The performances of the reuse treatment plant are summarised in tables 7.12, 7.13 and 7.14 where the total volumes of effluents suitable for reuse treated by UF plant (UF feed) and recovered water (UF outlet) in three months of operation, January, February and March ’09, are showed day per day. Recovered water comes from the UF membrane filtration of the selected

effluents plus WWTP effluent stored in the TK601A and TK601B tanks. For details regarding the “Complete data set referring to the period of continuous operation” see the relative deliverable submitted with the present report (Annex n.o: 08)
Table 7.15 shows the total reuse plant performances of the monthly periods: January (fifteen days), February (twenty days) and March (twenty-two days ); the data included refer to the actual daily hours of plant functioning. The daily average recovered water data have been calculated both considering the actual days of plant functioning and considering only the days of regular functioning (more than 8 hours), when no stop of the plant for control or membrane maintenance was performed.
Data show a positive trend of the plant performances with the transition from the start up phase to the full regime status of operation of the reuse plant. In fact, in March the reuse plant treated totally about 500m$^3$/d of process and WWTP effluents, according to the project objectives, and produced on average 374m$^3$ of recovered water. This datum improves greatly if we consider only the days in which the plant operated regularly without any stop, in fact it was constantly more than 500m$^3$, according to the project objectives.
Furthermore, the company plans to increase the plant capacity up to 1000 m$^3$/day, 50% of its total fresh water use. With this full scale plant in operation the company productive processes will use a mix of primary water and reclaimed wastewater in equal proportions.
The quality of the recovered water, in this period of plant full functioning, has been always conform to the project objectives. In addition all company manufacturing (about 1000 l.m./month) were produced with a mix of primary and recovered water in various proportion till to 50%.
Moreover all the controls of the quality of textile produced were performed and it was always conform to the company requirements (see annex n.o 7); no problems or notes were communicated by the persons responsible for the company production.

Tabella 7.12: January '09

| Day Jan | Selected effluents (TK601A and TK601B) ($m^3$) | | Total daily UF feed ($m^3$) | Total daily UF outlet ($m^3$) | UF feed ($m^3$/h) | UF outlet ($m^3$/h) | Printed fabrics (l.m.) |
|---|---|---|---|---|---|---|---|
| | Textile process wastewater ($m^3$) | WWTP outlet ($m^3$) | | | | | |
| *08* | 30,5 | 10,5 | 41,0 | 13,0 | 33 | 10 | 32.330 |
| *09* | 195,0 | 74,0 | 269,0 | 192,0 | 32 | 23 | 33.930 |
| *12* | 141,0 | 93,0 | 234,0 | 173,0 | 29 | 22 | 32.569 |
| *13* | 160,0 | 6,0 | 166,0 | 109,0 | 29 | 19 | 27.431 |
| *14* | 200,0 | 55,0 | 255,0 | 177,0 | 30 | 21 | 42.102 |
| *15* | 211,3 | 49,7 | 261,0 | 201,0 | 30 | 23 | 42.765 |
| *16* | 205,0 | 13,0 | 218,0 | 161,0 | 26 | 20 | 40.540 |
| *19* | 360,0 | 338,0 | 698,0 | 512,0 | 29 | 21 | 40.843 |
| *20* | 360,0 | 322,0 | 682,0 | 468,0 | 30 | 20 | 50.569 |
| *21* | 200,0 | 60,0 | 260,0 | 158,0 | 25 | 15 | 47.123 |
| *22* | 360,0 | 87,0 | 447,0 | 316,0 | 33 | 23 | 67.739 |
| *23* | 162,0 | 94,0 | 256,0 | 189,0 | 32 | 24 | 65.729 |
| *28* | 360,0 | 217,0 | 577,0 | 426,0 | 34 | 25 | 50.863 |
| *29* | 270,0 | 55,0 | 325,0 | 234,0 | 34 | 25 | 48.184 |
| *30* | 227,0 | 6,0 | 233,0 | 159,0 | 39 | 27 | 46.854 |

Tabella 7.13: February '09

| Day Feb | Selected effluents (TK601A and TK601B) ($m^3$) | | Total daily UF feed ($m^3$) | Total daily UF outlet ($m^3$) | UF feed ($m^3/h$) | UF outlet ($m^3/h$) | Printed fabrics (l.m.) |
|---|---|---|---|---|---|---|---|
| | Textile process wastewater ($m^3$) | WWTP outlet ($m^3$) | | | | | |
| *02* | 200,0 | 111,0 | 311,0 | 233,0 | 41 | 31 | 52.731 |
| *03* | 205,0 | 88,0 | 293,0 | 221,0 | 33 | 25 | 79.236 |
| *04* | 360,0 | 314,0 | 674,0 | 506,0 | 37 | 28 | 50.235 |
| *05* | 200,0 | 55,0 | 255,0 | 199,0 | 27 | 21 | 56.063 |
| *06* | 38,0 | 50,0 | 88,0 | 16,0 | 88 | 16 | 35.591 |
| *09* | 360,0 | 340,0 | 700,0 | 516,0 | 37 | 27 | 52.330 |
| *10* | 141,0 | 212,0 | 353,0 | 254,0 | 29 | 21 | 67.413 |
| *11* | 360,0 | 373,0 | 733,0 | 507,0 | 35 | 24 | 86.275 |
| *12* | 360,0 | 526,0 | 886,0 | 660,0 | 37 | 28 | 52.420 |
| *13* | 205,0 | 12,0 | 217,0 | 143,0 | 43 | 29 | 35.695 |
| *16* | 360,0 | 243,0 | 603,0 | 434,0 | 39 | 28 | 49.806 |
| *17* | 144,0 | 58,0 | 202,0 | 141,0 | 40 | 28 | 57.009 |
| *18* | 360,0 | 534,0 | 894,0 | 606,0 | 37 | 25 | 62.473 |
| *19* | 360,0 | 552,0 | 912,0 | 628,0 | 42 | 29 | 85.770 |
| *20* | 306,0 | 42,0 | 348,0 | 254,0 | 44 | 32 | 58.078 |
| *23* | 360,0 | 578,0 | 938,0 | 691,0 | 44 | 32 | 58.598 |
| *24* | 360,0 | 124,0 | 484,0 | 371,0 | 43 | 33 | 33.241 |
| *25* | 306,0 | 46,0 | 352,0 | 311,0 | 38 | 34 | 61.011 |
| *26* | 141,0 | 11,0 | 152,0 | 62,0 | 38 | 16 | 61.317 |
| *27* | 160,0 | 38,0 | 198,0 | 139,0 | 47 | 33 | 55.507 |

Tabella 7.14: March ‘09

| Day<br>Mar | Selected effluents (TK601A and TK601B) ($m^3$) | | Total daily UF feed ($m^3$) | Total daily UF outlet ($m^3$) | UF feed ($m^3/h$) | UF outlet ($m^3/h$) | Printed fabrics (l.m.) |
|---|---|---|---|---|---|---|---|
| | Textile process wastewater ($m^3$) | WWTP oulet ($m^3$) | | | | | |
| 02 | 360,0 | 29,0 | 389,0 | 312,0 | 41 | 33 | 63.716 |
| 03 | 360,0 | 433,0 | 793,0 | 585,0 | 43 | 32 | 65.826 |
| 04 | 38,0 | 56,0 | 94,0 | 75,0 | 42 | 33 | 84.651 |
| 05 | 141,0 | 62,0 | 203,0 | 163,0 | 43 | 34 | 71.942 |
| 06 | 36,0 | 51,0 | 87,0 | 65,0 | 35 | 26 | 53.778 |
| 09 | 360,0 | 282,0 | 642,0 | 507,0 | 43 | 34 | 71.468 |
| 10 | 360,0 | 497,0 | 857,0 | 615,0 | 41 | 29 | 62.870 |
| 11 | 360,0 | 545,0 | 905,0 | 657,0 | 44 | 32 | 80.849 |
| 12 | 144,0 | 62,0 | 206,0 | 132,0 | 43 | 28 | 85.808 |
| 13 | 205,0 | 49,0 | 254,0 | 196,0 | 32 | 25 | 44.574 |
| 16 | 360,0 | 67,0 | 427,0 | 332,0 | 43 | 33 | 35.168 |
| 17 | 360,0 | 456,0 | 816,0 | 606,0 | 44 | 33 | 34.353 |
| 18 | 360,0 | 513,0 | 873,0 | 642,0 | 44 | 32 | 64.321 |
| 19 | 360,0 | 606,0 | 966,0 | 719,0 | 44 | 33 | 74.706 |
| 20 | 205,0 | 61,0 | 266,0 | 187,0 | 44 | 31 | 64.250 |
| 23 | 360,0 | 670,0 | 1030,0 | 780,0 | 43 | 33 | 64.532 |
| 24 | 360,0 | 56,0 | 416,0 | 284,0 | 46 | 32 | 49.180 |
| 25 | 141,0 | 90,0 | 231,0 | 176,0 | 42 | 32 | 58.522 |
| 26 | 200,0 | 51,0 | 251,0 | 177,0 | 47 | 33 | 47.936 |
| 27 | 306,0 | 19,0 | 325,0 | 248,0 | 41 | 31 | 19.640 |
| 30 | 360,0 | 361,0 | 721,0 | 512,0 | 39 | 28 | 70.681 |
| 31 | 360,0 | 4,0 | 364,0 | 253,0 | 40 | 28 | 41.993 |

Table 7.15: total results

| Reuse plant performances | January | February | March |
|---|---|---|---|
| Total recovered water (UF outlet) ($m^3$) | 3488 | 6892 | 7691 |
| Daily average recovered water (UF outlet) ($m^3/d$) | 232 | 345 | 374 |
| Daily average recovered water (UF outlet) in days of regular plant functioning ($m^3/d$) | 270 | 408 | 503 |
| Hourly average treated water (UF feed) ($m^3/h$) | 31 | 40 | 42 |
| UF recovery factor | 0,7 | 0,7 | 0,7 |
| Total Printed Fabrics (l.m.) | 669.571 | 1.150.799 | 1.310.764 |

*Action E.4: Report of the results and BAT definition*

The last project activity (action E.4 by ENEA supported by UNIFI), regarded the report of the results and BAT definition on water use optimisation. Although the period of continuous operation of the plant was shorter than foreseen, the data collected was considered sufficient to conclude positively this action. In fact, all the data related to the performances of the reuse plant were enough to characterise the advantages and the drawbacks of the proposed BAT and to demonstrate the feasibility and reliability of the technique proposed.

Reports of the results was produced both in a technical scientific form and in a dissemination form. The innovation of the technique was assessed together with the reliability and the technical and economical feasibility. The report includes all the mass and energy balances and the evaluation of the environmental impacts. A manual for the BAT was defined containing the guidelines for the application in other textile SMEs all over Europe. For details concerning the handbook of the BAT see the deliverable submitted with the present report (Annex n.o: 9).

## 8. DISSEMINATION ACTIVITIES AND DELIVERABLES

*Dissemination*

| Task start/end date | Action | Expected results | Achieved results |
|---|---|---|---|
| *Task F:* *Dissemination* **1.12.2005 / 30.11.2008*** *End date was postponed to 31.03.2009 | **F.1-** Development of a Web Site | Disseminate info on the project to end-users and the general public | Action F.1 expected results have been achieved according to the proposal |
| | **F.2-** Organisation of an International Workshop | Agreement on the proposed new BAT | Action C.2 expected results have been achieved with a six months delay with respect to the proposal |
| | **F.3-** Organisation of two Info-days | To involve SMEs, to identify at least two textile districts and to set up at local level a pool of SMEs to duplicate the project | Not done.<br>To be done in the after LIFE communication plan |
| | **F.4-** Organisation of site visits to the plant | To help demonstrating the feasibility of the implemented integrated expert system for wastewater recovery | Not done completely.<br>To be done in the after LIFE communication plan |
| | **F.5-** Publication of short technical articles and brochures; participation to the relevant international Conferences and Congresses | - Technical papers will be published in selected national and international Bullettins and Reviews<br>- One brochure will be done<br>- Presentations and posters will be given at the relevant international Conferences and Congresses | Action F.5 expected results have been achieved according to the proposal |
| | **F.6-** Organisation of a Final meeting | Scope of the final meeting will be the presentation of the final results of the project | Not done.<br>To be done in the after LIFE communication plan |
| | **F.7-** After LIFE communication plant | - Maintenance of the web site<br>- Networking | - |

Due to its features and scopes, Task F started in due time and followed the implementation of the other tasks except for task E. The general objectives of this task has been pursued along with the development of the other project tasks.
With regards to task F single activities:

- Action F.1 – Implementation of the Project Web Site.

The technical functionalities of the Web Site were prepared by the Beneficiary and shared with the partners for comments and agreement.
The Web Site has been implemented through the first six months and launched, as scheduled, the first week on June 2006.

The Web Site has two different areas:

1. A public area, where general information on the Project, main project official documents, major European events, major links to the partners Web Site, to the EC Web Sites (including the LIFE Web Site) and other relevant Sites in the textile sector are included. By this part, it is possible to apply for receiving the newsletter of the project.

2. A (username and password) restricted area, where documents and info specifically devoted to the implementation of the activities of the project and the consortium have been downloaded and therefore shared in the various stages.

The Web Site manager is within the Beneficiary organisation; all the partners and the External Monitoring Team Timesis have access to both areas and can upload and download files, though with different level of hierarchy among administrators.
The site has been regularly updated by all the partners during the Project, a lot of documents/info/links have been uploaded into the Site.
The maintenance and enrichment of the project website in all its sections, the identification of all the items for uploading into the web page, as well as the approval and uploading of the draft and final deliverables as expected output of the actions and tasks, has been regularly performed by all the partners during the Project.
All news about the project were reported in the website, as much as possible in real time. As a result, a large number of consultations by several SMES and public institutions (figures provided by the counter) shows the increasing interest in the project expectations raised by the general alarm on the water scarcity and quality.
The Web Site is both in Italian and English languages.
The Web Site address is www.life-battle.bologna.enea.it

- Action F.2 - Organisation of an International Workshop

The scope of the Workshop was meant to be the presentation and discussion of applicability of productive BATs reported in the textile BREF for SMEs as well as the proposed new BAT on optimisation of water use feasible for SMEs, to integrate the BREF indications. Since the latter aspect was tightly related to the results of the activities of task D, due to the strategic relevance of such international workshop and the level of participants we intended to invite, the event was postponed until the complete plant building up and its interface with the Expert system was completed. This way it has been possible to present a detailed description of the reuse plant, preliminary results and a photographic report of all the plant sections, such as: the membrane treatment station and the ultrafiltration modules, the Expert System with the two Smart Sensing Cluster Node (XBase) and the various sensors (pH, conductivity and colour) which monitor the quality of the different process effluents.
Such timing, furthermore, allowed the Workshop to be held as a special session of SIDISA (International Symposium on Sanitary and Environmental Engineering, (http://www.andistoscana.it/sidisa08/index.php)) in Florence, June 24/27, 2008.
SIDISA is the annual conference of the ANDIS (Italian Association on Sanitary and Environmental Engineering), and was organized in 2008 in collaboration with the Department of Civil and Environmental Engineering of the University of Florence, partner of the BATTLE project. This event, which hosted the BATTLE beneficiary and the partners participation and presentations with extensive lectures and information on the project, is an important international and national meeting and involves also the ABES (Associacão Brasileira de Engenharia Sanitaria e Ambiental) and AIDIS (Inter-American Association of Sanitary and Environmental Engineering).
Furthermore, in the 2008 edition a special session dedicated to the theme of "Modelling and Automation of Water and Wastewater Treatment Processes" was included.
Finally the choice of SIDISA was found to be suitable for the BATTLE project also because of the wide range of participants and selected audience it usually attracts: Public Administration, Companies (which are the end-users of the BATTLE project), Professionals in the field,

Universities and Research Institutes. Moreover the Congress is an important opportunity to outline the state of the art and current national and international trends on the general theme of environmental protection, management, and monitoring.
During the event a brochure with general information about the BATTLE project (annexed to this report, n.o: 10) was distributed among the participants, together with a questionnaire in which were asked personal data as well as some notes on the workshop.
The Workshop agenda, a list of the participants as well as the proceedings of the workshop have been included in the progress report n.o 4.

- Action F.3 - Organisation of two Info-days

Not done

- Action F.4 - Organisation of site visits to the plant

The first site visit to the reuse plant site in SdM, took place on 21 April 09, during the period of continuous operation of the demonstrative reuse plant. The visit was very important to inform SMEs on the usefulness of the BATTLE implemented integrated expert system for wastewater recovery. In fact, the participants were: Mr. Vanzi from Confindustria Bergamo (Confederation of Italian Industry), Mr. Paolo Belluschi from SIAD International Group (Development of application in wastewater treatment) and Mr. Giancarlo Merisio from SERVITEC (Services for Technology Innovation, one of the most important firms in the gases sector: industrial, specialty and medical gases, technology, plants and services all gas-related) whose main activity is the management of the technological industrial pole of the Bergamo district and the support of the local SMEs.
During the visit all the reuse plant facilities have been showed and its performances in terms of recovered water have been reported with the aim of demonstrating the feasibility of the applied technology and to set up at local level (in the local textile district and other industrial district) a pool of SMEs who can be interested to adopt the implemented integrated technology to duplicate the project.
In addition the possibility of organizing an info-day on the BATTLE project in the Confindustria headquarters of Bergamo has been discussed.

Another event of dissemination that may be cited as a site visit to the industrial site of the BATTLE demonstrative treatment and reuse plant (Martinengo, BG), has been organized in the context of the EMWATER (Efficient Management of Wastewater, its Treatment and Reuse in the Mediterranean Countries) Project. The EMWATER aims to create awareness of innovative solutions in wastewater treatment and its reuse and support the installation of new technologies of wastewater management. The primary outcome of the EMWATER project is to increase efficiency and effectiveness in the management of wastewater, its treatment and reuse in Turkey, Jordan, Lebanon and Palestine.
The event was related to a training course for professionals in wastewater management and treatment from various Mediterranean Countries and took place on June 19, 2007. Although the reuse plant was not completely built-up yet, the event included also a field visit to SdM printing company where some preliminary reuse plant infrastructure were showed and presentations and brochures were given with the aim of demonstrating the feasibility of the BATTLE proposed reuse strategy (BAT) and of the implemented integrated expert system for wastewater recovery.

- Action F.5 – Brochures, Articles, participation in International Conferences

The BATTLE project has been presented during some national and international events, often linked to the PROWATER EU project, according to the EC recommendations. In fact, the project partners have been participating in meetings and contexts sensitive to the culture of the “industrial water recycle and reuse” as environmental but also socio-economic issue. In these events, lectures and info papers have been presented on the project, the promoted technology and the BREF field of action. A list of all attended events by the project is provided below and annexed with the present report is a cd with all the relevant input such as presentation and abstract (Annex n.o: 11).

1. Brussels - June 7th-8th, 2006 – **Annual Conference of the European Technology Platform for the Future of Textiles and Clothing** - Wastewater Recycling in Textile Finishing. Attendance and information on BATTLE and the wider theme of the water reuse and recycle were provided by dedicated lecture: The LIFE-ENV BATTLE Project, BAT for water reuse in TextiLE SMEs

2. Amman, Giordania October 30th-November 1th, 2006 - **Emwater Regional Conference** "Efficient Management of Wastewater, its Treatment and Reuse in the Mediterranean Countries",

3. Rimini - November 6-9th, 2006 - **Thematic Workshop in ECOMONDO 2006**, **the International Trade Fair of Material and Energy Recovery and Sustainable Development.** The workshop was aimed at reaching small European enterprises potentially interested in water recovery and recycling and its main issue was the Sustainable management of water resources in the textile sector: treatment and recycling wastewater. Attendance and information on BATTLE and the wider theme of the water reuse and recycle were provided by dedicated lectures: BAT for water reuse in textile SMEs - The BATTLE Project, brief description and achieved results –Submerged membrane system for water reuse- General overview on the water reuse and recycling in the most water demanding European industrial sector.

4. Gent, Centexbel Headquarters, Belgium - February 6th, 2007 - **PROWATER and BATTLE Joint International Conference on the “Industrial Water Management: results and opportunities of European Research Projects”** . This International workshop was supported by Centexbel and the BATTLE project and was aimed at offering an overview on innovative wastewater treatment and eco-friendly technologies for textile industry. Attendance and information on BATTLE and the wider theme of the water reuse and recycle were provided by dedicated lectures such as “Results of BREF screening in European textile companies- LIFE ENV Project BATTLE”
5. Antwerp, October 9th-12th, 2007 - **6th IWA Conference on Wastewater Reclamation and. Reuse for Sustainability**. Attendance and information on BATTLE project and the wider theme of the water reuse and recycle were provided by dedicated lectures: “Water recycling in textile industries: Effects on biological treatment plants” (procedure aimed at evaluating the compatibility of a recycling system with an existing wastewater treatment plant, an objective of BATTLE) and “Implementation of Best Available Techniques as a prerequisite for sustainable water reuse in textile industry”.

6. Rimini –November 6-9th, 2007 - **ECOMONDO 2007, the International Trade Fair of Material and Energy Recovery and Sustainable Development**. Attendance and information on BATTLE and the wider theme of the water reuse and recycle were provided by a series of slides presenting BATTLE project objectives, progress and expected results plus some project features such as the membrane filtration technology (as a reliable and feasible option in the treatment and reuse of various industrial effluents), and an innovative on-line monitoring instrument for color and suspended

solids (such sensors are necessary to define the treatability and reusability of the effluents for the demonstrative reuse plant). The slides (available on the web site section News) have been aired exhaustively on Friday November 9th with particular reference to the BATTLE project objectives, progress and expected results.

7. Rimini –November 5-8th, 2008 - **ECOMONDO 2008, the International Trade Fair of Material and Energy Recovery and Sustainable Development**. Two different lectures were presented: one within the 3rd Session: "The water heritage in the textile and tanning industries: problems of disposal of wastewater and integrated strategies for its treatment and water recycling". In the context of sustainable wastewater management, which requires that after purification water can also be re-used in factories to achieve the fundamental objective of the IPPC regulations, the lecture presented the BATTLE project objectives and preliminary results. The second lecture presented within the session: "Means for automatic control and management of the wastewater treatment plants" gave an exhaustive insight of the automation and remote control of the BATTLE project which enables to observe the status of the plants operation from a distance, thus enabling to take action in the shortest possible time to handle any problems of incorrect operation that may occur. In addition, a new instrument for the on-line monitoring of the colour effluents has been described which fed an innovative measurement systems for process control.

The dissemination activity has been performed also by means of scientific publications and on newspaper and technical magazines:

1. A preliminary brochure had been prepared and presented at the Monitoring Team Timesis info-day about the 2005 LIFE Approved projects (Dec. 1st, Pisa – Italy). It has been regularly updated and modified in order either to be used as a poster and to provide recipients with complete information on the project and further widespread during some events the Partners took part in. The brochure illustrates the main objective of the Project and contains a short description of the Partner expertises (Annex n.o: 12).

2. An article was published on Belgian Textile Review "MILIEUFAX - Centexbel/Febeltex 2006" Nr 1 - Jan. 15, 2006 , page 15-16 (Annex n.o: 13).

3. Article on the SMI-ATI (the Italian Textile and Fashion Industry Federation) Review "TINCTORIA" (http://www.asstex.it/tinctoria/index.html), vol.6 -giugno 2006 (Annex n.o: 14).

4. Announcement of PROWATER - BATTLE Joint Workshop of Feb. 6, 2007, on the EURATEX Newsletter "EUROPEAN APPAREL AND TEXTILE ORGANISATION" of Jan.2007

5. Article on "DESALINATION - The International Journal on the Science and Technology of Desalting and Water Purification", edited by Elsevier, http://www.elsevier.com. "Best available technique for water reuse in textile SMEs (BATTLE LIFE Project)- Desalination 206 (2007) 614–619 (Annex n.o: 15).

6. Article on the "Eco di Bergamo" Italian newspaper, Jan. 19. 2007 (Annex n.o: 16).

7. PhD thesis in Civil and Environmental Engineering (Università degli studi di Firenze) with the title “ Combination of respirometric and titrimetric techniques for the determination of the inhibiting potential of a textile effluent” (Annex n.o: 17).

For what concerns a comparison with the planned output, it has to be noted that as the technical activities of task E were subjected to a series of inconveniences until the final breakdown of the reuse plant, the dissemination activities suffered in the same way.
In fact, the organization of the two info-days, were planned to take place after the demonstrative plant start up with real effluent during the period of continuous operation of the reuse plant, which actually started in January 2009, after the official end of the project. As a consequence the info-days have been postponed. The project beneficiary and partners are planning to organize an event which will be held approximately in May 2009 in SdM, and will include a final conference together with an info day to present the final results, to involve other SMEs and duplicate the project and finally to demonstrate the feasibility of the BATTLE methodology. In this contest a final brochure and poster will be distributed and showed (annex n.o 18 and 19).
Since the project has already ended, economic difficulties may arise in organizing the event.

*<u>Deliverables</u>*

In the following table there is a list of all the deliverables produced, the project activities they refer to, the report they were submitted with and the format they were delivered.

| Activity | Organisation AL - Executor | Expected output/deliverable | Annexed to Progress Report n.o: | Format |
|---|---|---|---|---|
| **B.1**<br>Analysis of BAT reported in the textile BREF. | **CENTEXBEL** | **Report on BAT application in the textile industry** | **Interim report** | **paper** |
| **B.2**<br>Identification of BATs feasible in SMEs | | **Report on BATs applicability in SMEs** | **Interim report** | **paper** |
| **B.3**<br>Audit of an SME aimed at defining the new BAT: company characterisation | **CIDA** | **Characterisation of a textile SME - identification of the main processes and their impacts** | **Progress report 2** | **paper** |
| **B.4**<br>Characterisation of the company effluents | **ENEA** | **Characterisation of a textile SME - quality and quantity of the effluents produced** | **Interim report** | **paper** |
| **C.1**<br>Effluents treatability evaluation | **ENEA** | **Operational data for technical and economical feasibility evaluations of effluents treatment** | **Interim report** | **paper** |
| **C.2**<br>Evaluation of treated effluents reusability | **CENTEXBEL** | **Report on assessment of the effluent reusability** | **Interim report** | **paper** |

| | | | | |
|---|---|---|---|---|
| **C.3**<br>Evaluation of biodegradability and toxicity of effluents | **UNIFI** | **Assessment of the effluents biological treatability** | **Progress report 2** | **paper** |
| **C.4**<br>Simulation of the water reuse scenario | **CIDA** | **Preliminary design of water reuse schemes and their evaluation** | **Interim report** | **paper** |
| **C.5**<br>Expert system design | **ANOVA** | **E.S. specification** | **Interim report** | **paper** |
| **D.1**<br>Plant lay-out | **ENEA** | **Preliminary design** | **Interim report** | **paper** |
| **D.2**<br>Equipment data sheets identification | **CIDA** | **Equipment data sheets** | **Progress report 4** | |
| **D.3**<br>Final design | **CIDA** | **Final detailed design** | **Progress report 4** | |
| | **CIDA** | **Operative handbook of the plant** | **Final report** | **paper and digital** |
| **D.4**<br>Plant building-up | **SdM** | **Complete wastewater treatment and reuse plant** | **Final report** | **digital** |
| **D.5**<br>Interface between the Expert System and the plant | **ANOVA** | **Complete interface of the E.S. with the plant** | **Final report** | **paper** |
| **E.1**<br>Functional tests and check of the plant | **ENEA** | **Report on functionality tests** | **Final report** | **paper** |
| **E.2**<br>Start-up and provisional operation of the plant aimed at the E.S. training | **ANOVA** | **Expert System completely instructed for the management of the plant** | **Final report** | |
| **E.3**<br>Operation of the integrated demonstrative plant | **ENEA** | **Complete data set referring to the period of continuous operation** | **Final report** | **paper and digital** |
| **E.4**<br>Report of the results and BAT definition | | **Handbook of the BAT** | **Final report** | **paper** |
| | | **Final report** | **Final report** | **paper** |
| **F.1**<br>Development of a Web Site | **ENEA** | **Web Site** | **-** | **digital** |
| **F.2**<br>Organisation of an International Workshop | | **Proceedings of the International Workshop** | **Progress report 4** | **paper and digital** |
| **F.3**<br>Organisation of two Info-days<br>**(not done)** | | **Proceedings of the Info-days** | **-** | **-** |

| | | | | |
|---|---|---|---|---|
| **F.5**<br>Publication of short technical articles and brochures; participation to the relevant international Conferences and Congresses | | **Presentation given at other Conferences and Workshops**<br><br>***Proceedings of the Regional Workshop****** | **Web site**<br>**Final report** | **paper and digital** |
| | | **Three short technical articles** | **Progress report 1**<br><br>**Final report** | **paper and digital** |
| | | **A brochure and a poster of the project** | | |

**please note that the regional workshop was not included in the project proposal dissemination activities, and appears erroneously only on the list of the planned deliverables of task F*

## 9. Evaluation and Conclusions

### ***Project implementation***

a. **The process**:

The demonstrative part of the BATTLE project is the build up of a complete water reuse plant within the textile SME, Stamperia di Martinengo. This is aimed at demonstrating the technical economical feasibility of water reuse in the textile industrial sector, by allowing the evaluation of the impacts occurring when treated wastewater is used instead of high quality primary water.

The demonstrative plant was dimensioned for a peak treatment capacity of 50 $m^3$/h and flow rates up to 40 $m^3$/h were reached after the start up, which means an average daily permeate production of 500 $m^3$ according to the project objectives.

For details concerning the plant characteristics see the deliverables: "Final detailed design" and "Complete wastewater treatment and reuse plant"; for information about its performances see the deliverable "Complete data set referring to the period of continuous operation".

**b. The project management, the problems encountered, the partnerships and their added value:**

With regards to the project management, the beneficiary and co-ordinator of the project, namely the ENEA, was in charge for the overall management of the project. The project management centred around the steering group consisting of one member from each of the partners and the core team set up by representatives from the beneficiary. At the beginning of the project, a Collaboration Agreement was prepared laying down the project rules and guidelines for organisation, management, internal and external communication. These agreements at an early stage clarified many issues and facilitated the management of the project.

The difficulties encountered (see task E), have been successfully overcome. The regular meetings among the partners, as well as their constant communication has promoted the exchange of experiences and it has aided them to effectively deal with the problems that have risen during the various phases of the project. There have been no major delays to the project, until the unexpected event of the plant breakdown caused by a crash of one of the Knowledge based remote control PC/Nodes KB-RCN which controls the on line monitoring of the effluents. The situation was finally recovered by extending the data collection period beyond the planned project end with only a small delay in the final report delivery. The partners consortium of the BATTLE project has proved to be well assorted. The matching of the different scientific backgrounds, experience and skills was productive and efficient concerning the achievement of the scheduled project targets.

**c. Technical and commercial application:**

The technology developed in this project is conceived to be proposed for its possible inclusion in the textile BREF. The BREF at present contains several BATs (Best Available Techniques) to prevent pollution and reduce the impact in the production processes, but only general advices on wastewater treatment and reuse.

The methodology and the technology developed in the partner company Stamperia di Martinengo can be extended and applied in other companies with similar characteristics all over Europe. Thanks to the techno-economic feasibility of water reuse in the partner company (a SME with production capacity close to the threshold of applicability of the IPPC Directive), the proposed BAT will be applicable both in small-medium companies and in big ones.

The methodology as it is and specific technology with adaptations, can be successfully applied in other industrial sectors (tanneries, agro-industries and certain chemical industries), characterized by a high water consumption and by a significant variability of the quality of the process effluents.

The key idea behind the project BATTLE, is the efficient separation of the different process effluents based on their final destination (reclamation and reuse o treatment and discharge). This concept can only be implemented in companies where the process effluents are characterised by a considerable variability.

In companies with machinery characterised by process effluents constant in time, the application of the BATTLE methodology will be easier. In this case the different machinery could be connected to one destination only (reuse /discharge) without the necessity of continuously monitoring effluents characteristics.

The treatment technology needs to be adapted to the specific effluent contamination and water quality demands of the different companies. UF membrane filtration is not expected to fit the needs of all companies. As a consequence different treatment technologies, such us nano–filtration, activated carbon adsorption or advanced oxidation process need to be investigated and in case used in combination or in substitution of UF.

**d. Comparison against the project-objectives:**

The implementation of the BATTLE project was in accordance with the initially proposed objectives except for task E which was submitted to a postponement of the final results because of the plant breakdown, and task F which suffered for the technical inconveniences as well.

**e. Effectiveness of dissemination activities:**

The dissemination activities implemented during the BATTLE project had an impact on a wide audience of stakeholders. Several presentations in scientific papers and congresses were done. Awareness has been created for the problems of environmental impact of a textile SME. Dissemination activities also included the construction of a web site with descriptions of the project, providing an access point to interested parties worldwide; the preparation of publications and brochures for dissemination to stakeholders and the general public; as well as the organisation of a international conference attended by various interested stakeholders who were invited to learn about the project and its achievements. The project Coordinator has been contacted by interested parties who would like to learn more about the project and its activities.

**f. The future: continuation of the project + remaining threats**

The demonstrative reuse plant is continuously operating at the Stamperia di Martinengo processing various effluents in order to explore its applicability and effectiveness to different types of wastewater, which always varies with the different company manufacturing. At the moment, the reuse plant is dimensioned for a treatment capacity of 500 $m^3$/d. However, the company SdM is planning to upgrade it to 1000 $m^3$/day. With this full scale plant in operation the company productive processes will use a mix of primary water and reclaimed wastewater in equal proportions.

In addition, at least two modification are planned to optimise the performances and the automation of the reuse plant; these modification were not accomplished during the project duration because its realisation would have caused a long stop of the plant operation, that is further possible delays in the achievements of the project objectives. The proposed modifications are:

1. Installation of an additional colour sensor in the printing department and its interfacing with the expert system
2. Installation of a bypass valve just after the measure point of the printing and washing departments. This valve should be directly linked to the online monitoring instruments, causing an immediate discharge if the effluents to the WWTP, every time the quality requirements are not matched.

***<u>Analysis of long-term benefits</u>***

**a. Environmental benefits**

**1. Direct / quantitative environmental benefits:**

The environmental benefits derived by the application of the proposed wastewater treatment and reuse technology are mainly related to the lower consumption of high quality water through the maximisation of water re-use. The plant will be maintained in operation by the company therefore allowing an average daily permeate production of more than 500$m^3$/day. This means a reduction of groundwater uptake by the company of the same amount. Furthermore the company plans to increase the plant capacity up to 1000 $m^3$/day, 50% of its total fresh water use.

Water reuse by treatment of segregated effluents has also reduced the hydraulic load of the company WWTP, a plant that was highly loaded. This represented a significant environmental benefit, by allowing a better treatment and removal of contaminants before wastewater discharge

**2. Relevance for environmentally significant issues or policy areas:**

The project results are in accordance to the fundamentals of the IPPC directive and can give an effective contribution to the IPPC application. In fact, the European Directive CE 61/96 "Integrated Pollution Prevention and Control" (IPPC) requires that the industrial sectors change their production techniques according to Best Available Techniques (BAT), defined with the objective to reduce the impacts on the environment as a whole.

The BATTLE project has proposed a technique for consideration in the definition of BATs, for the textile industry. The reclaimed wastewater is a technically feasible alternative to fresh water. The project results can push the implementation of reuse in an industrial sector where it is still an uncommon practice.

In accordance with the Water Framework Directive 2000/60/EC, BATTLE promotes the sustainable use of water, reinforcing and providing integrated water management. The methodology developed enables lower consumption of high quality water, such as groundwater by textile industries, through efficient water re-use and recycling.

## b. Long-term sustainability

### 1. **Long-term qualitative environmental benefits**:

The full-scale application of the treatment process developed within the BATTLE project can have interesting effects in terms of environmental impact. The saving of freshwater, which can be obtained through the reuse of the treated wastewater, represents the most important result of the project. In fact, development and pollution are worldwide both increasing, while the supply of water is not. These days, there are more and more demands being put on our limited water supplies by people, agriculture and industry and the problem is more severe in water scarce regions such as the Middle East and North Africa.

Water scarcity is a shortage in freshwater availability from renewable resources to meet the essential demand in various water consumption sectors. Essential demand includes domestic demand and agricultural demand needed to ensure food security for the nation, while industrial demand can be met, to a great extent, by recycled water. Therefore, to alleviate water shortages serious consideration must be given to wastewater reclamation and reuse, hence wastewater has to be reclassified as a renewable water resource rather than as waste. This helps in augmenting water availability, and at the same time in preventing environmental pollution.

In fact, the recycle of treated effluents will reduce the freshwater needs, meeting the European policy for the conservation of natural resources and biodiversity. In particular lower consumption of high quality water, through water re-use and recycling, can preserve valuable resources for potable use and decrease the problems of subsidence related to groundwater overexploitation.

At the same time, the total volume of effluents either sent to centralized treatment plants or directly discharged in surface basins will be reduced, and this will contribute to the protection of recipient water bodies and therefore amelioration of the quality of life of the citizens and spread an aware use of the water resources.

### 2. Long-term qualitative economic benefits:

Textile companies represent an important industrial sector in the European Union. The development of systems for the treatment of textile effluents which can be then re-used in the production activities surely contributes to improve the competitiveness and the environmental sustainability of this sector.

Even though in Italy, where the price of industrial water is very low, the wastewater reuse may not be so advantageous, in other countries characterised by severe water scarcity or where the water supply costs are bigger, such as in France, Germany, Great Britain, Netherlands ( 0,8 ÷ 2,1 €/$m^3$ ) the methodology proposed may be very useful for the textile company productivity or any other highly water demanding industry.

In addition, the companies involved in water reuse may also strengthen their competitiveness by the ISO 14000 or EMAS certification and distinguish themselves from the competitors which are less attentive to the environmental policy.

### 3. Long-term qualitative social benefits:

The major impetus for reusing wastewater comes from the increasing pressure on natural water resources, as evidenced by the effects of climate change and shifting weather

patterns. Wastewater reuse can help conserve the supply of freshwater, and this presents clear advantages with respect to environmental protection.
On the other hand, wastewater reuse tends also to arise from the potential savings in related supply and discharge costs that can be achieved. In fact, water supply and discharge costs are constantly increasing so that the economic motivation for reuse of industrial wastewater may be a major driving force because many industries like the textile ones, consume large volumes of water. Reuse of wastewater is particularly attractive in cases where the quality of the supplied freshwater, predominantly of potable standard, either exceeds that demanded by the industrial process or else demands further processing.
Obviously in arid regions wastewater reuse become more important and in some cases the only possible solution to assure the sustainability of water demanding companies. Here the development of systems for the reuse of wastewater effluents contributes to improve the competitiveness of the companies, therefore helping in preservation of job opportunities.

## c. Replicability, demonstration, transferability, cooperation

### 1. Transferability & Potential for Commercialisation

The BATTLE integrated methodology may give an effective contribution to the application of the IPPC directive and, enabling a sustainable use of the water in critical industrial sites, represents a good methodology for similar approaches in other industrial sectors.
European Directive CE 61/96 “Integrated Pollution Prevention and Control” (IPPC) requires that the industrial sectors change their production techniques according to Best Available Techniques (BAT), defined with the objective to reduce the impacts on the environment as a whole. The elaboration of an integrated and coherent methodology to support the implementation of sustainable water reuse is therefore a priority in all the industrial sectors.
The BATTLE results targeted end users are textile companies but the methodology, enabling a sustainable use of the water in crucial industrial sites, can be useful for similar approaches in other industrial sectors which are highly water-demanding.

## d. Innovation

### 1. Level of innovation on (inter)national level

The project innovation is related mainly to two different features:

- the separation of the process effluents approach as opposed to the end of pipe one
- high level of automation of the plant performed by the Expert System

On-Line/Real-time monitoring of wastewater quality remains a scarcely resolved problem into the wastewater treatment industry. In spite of a deep changeability of textile segregated wastewater stream quality, there are only a few chances (instrumentation technologies) to on-line detect water quality parameters and, no one of them, is directly correlated to a specific pollutant.
To be able to solve the problem regarding on-line/real-time monitoring of textile wastewater quality, having only a few sustainable chances versus constraints satisfaction conditions, we suggest to resort to a multi-clustering on-line measurement technology (not multiparameter only), based on WPR indexes inferred to an appropriate Knowledge Base

(network designed). In fact, to better detect and learn from the on-line measurements and process data-input, to decide if an effluent has to be sent to the reuse plant or to the WWTP, an appropriate water pollution rate index has been defined, called WPR. This index is able to on-line characterize the quality of wastewater streams and is “instructed” in order to better control the selected streams. The Remote Control Nodes that are involved in the functionality of self-learning contains a base of knowledge through which it is possible to calculate the index WPR, to assess the quality of the inlet effluent. This knowledge base is codified so that it can be altered simply by defining a vector of indices. In particular, the knowledge base is formalized through functions that represent the relations existing between the inputs received from sensors (pH, temperature, conductivity, color, etc.etc.) and quality (WPR). The learning algorithms are introduced in this project to obtain the K vectors of indices that make the foundations of knowledge, contained in the node, the closest to real conditions in the given range of time.

The principal distinction between the Expert System and traditional problem solving programs is the way in which the problem related expertise is coded. In traditional applications, problem expertise is encoded in both program and data structures. In the ES approach all of the problem related expertise is encoded in data structures only; none is in programs. This organization has several benefits. Determining what type of information is captured, and where that information resides in a knowledge base is something that is determined by the processes that support the system. A robust process structure is the backbone of any successful knowledge base.

Some knowledge bases have an artificial intelligence component. These kinds of knowledge bases can suggest solutions to problems sometimes based on feedback provided by the user, and are capable of learning from experience (Expert System). Knowledge representation, automated reasoning and argumentation are active areas of research at the forefront of artificial intelligence.

## 10. AFTER-LIFE COMMUNICATION PLAN

Even though the project is formally ended its results will to some extent continue to be disseminated by the partners and the Beneficiary in the future.

The most important dissemination methods are direct contacts with experts, seminars and conference, newspaper articles, radio, television, Internet.

- **Internet**

The project web site www.life-battle.bologna.enea.it introduces the project results, reports, publication in media and presentations during conferences, workshop and special events. Reports and presentations are available in pdf format and can be downloaded by visitors.

The use of the Internet site has proceeded according to the project proposal and it will be available for at least 2-3 years after the end of the project. After this, the most part of the information will continue to be available on the partners web sites.

- **Presentations in international meetings/ conferences**

A group of experts working in the project will be presenting the project results in various seminars etc. meetings. Dissemination of the project results will be also achieved by the distribution among the participants of a project brochure and Layman report.

At the moment two abstracts have been submitted to be reviewed to the referees of the First International Conference on "Advances in Wastewater Treatment and Reuse" to be hold in

University of Tehran, Tehran, Iran, 30 June -2 July, 2009. This conference will be organized by College of Engineering of the University of Tehran in collaboration with other universities, national and international authorities and would be a nice opportunity to spread and share our experiences and results of the BATTLE project outside Europe.
In addition the project was recently proposed to be included as one of the environmental technologies in the context of the ACT CLEAN project (CENTRAL EUROPE programme), where ENEA is one of the partners.

- **Info-days and final conference**

The Info days which were not held during the project duration will become one of the activities of the after-LIFE communication plan, useful to the dissemination of the project final results. In fact, one info –day is planned to take place in concomitance with the final conference which the partners are planning to organize to be held approximately in May 2009.
The organisation of the two technical events, for the presentation of the project results and connected themes, is of large importance for the dissemination of results. The aim of the events will be to gather different subjects involved in the industrial wastewater management which are targets of this dissemination. The aim of the final conference will be to show the applicability, reliability and reproducibility of the reuse plant, in particular to those subjects that could be interested to implement such a system in other landfills or other possible applications.

- **Layman report**

The layman's report (Annex n.o: 20) will be distributed widely during the final conference, the info-days as well as all the meetings and conferences the partners will participate in the near future. In addition it will be available on the LIFE-BATTLE web-site.

- **Continuing projects**

It is planned that cooperation between project partners will continue after the end of the BATTLE project. In particular the Stamperia di Martinengo company is very interested in improving the efficiency of the reuse treatment plant. ENEA can provide the recommendations and technologies for the modification and improvement of the existing system (see paragraph 9.1.f -The future: continuation of the project) as well as for the upscaling of the plant to full scale. This will assure that the reuse plant will continue to be operative for the next years.
Obviously, the reuse plant is accessible anytime for a visit to interested stakeholders.

## 11. COMMENTS ON FINANCIAL REPORT

Motivation and justification for each cost-item with a deviation of more than 10% (over or under expenditure).

1. Personnel Costs:

   The personnel cost, was subjected to a significant deviation (more than 10%) if compared to the initial proposal, due in particular to a major commitment of personnel of two partner companies: ANOVA and SdM.

   For what concerns ANOVA, the excess of the amount declared for staff is due to a bigger number of working hours than planned which were dedicated to:

   - Installation in SdM of a network of wireless data transmission, instead of the more traditional transmission network cable which was planned in the proposal

   - Repair works related to the crash of the plant that occurred in the second half of 2008 and restoration of the full functionality of the Expert system .

For the partner SdM, the higher cost declared for personnel was caused by installation, checking and operation activities of the reuse plant, which have involved a significant commitment in terms of personnel.

2. Travel and subsistence costs.

The costs declared are much lower than expected because travels were made only when they were absolutely necessary. In other circumstances it was preferred to use technological methods with low environmental impact, such as teleconferencing, web-cam, telephone or e-mail.

Furthermore, the non-execution of the final events of dissemination, in particular the final international conference (scheduled in Seville), led to significant savings in terms of travel abroad

3. Durable goods: Equipment

The cost of durable goods declared is much higher than expected. This is partly due to increased costs , because the project was conceived, written and then submitted nearly a year and a half before its presentation.

In any case, some electrical and hydraulic components were added during the engineering design of the plant and some other parts were replaced due to malfunctioning or damage occurred during the plant start-up.

**PROJECT COSTS INCURRED**

| | **Cost category** | **Total cost**<br><br>**according to the Commision's decision** | **Costs incurred from the start date to 01/12/05** | **%** |
|---|---|---|---|---|
| 1. | Personnel | € 1.183.745 | € 1.614.863,82 | 136,42 |
| 2. | Travel | € 155.390 | € 85.432,95 | 54,97 |
| 3. | Outside assistance | € 45.000 | € 37.178,00 | 82.61 |
| 4. | Durables: total <u>non-depreciated</u> cost | | | |
| | *- Infrastructure sub-tot.* | 0 | € 21.949,26 | |
| | *- Equipment sub-tot.* | € 202.000 | € 417.214,35 | 206 |

| | | | | |
|---|---|---|---|---|
| | *- Prototypes sub-tot.* | € 180.000 | € 190.940,58 | 106 |
| 5. | Consumables | € 142.500 | € 153.722,04 | 107.8 |
| 6. | Other costs | € 20.000 | € 24.510,65 | 122.5 |
| 7. | Overheads | € 126.709 | € 152.123,78 | 120 |
| | **SUM TOTAL** | € 2.055.344 | € 2.697.935,42 | 131 |

## 12. APPENDICES

List of all the technical final report annexes:

1. Deliverable: "Operative handbook of the plant" (Introductive part in paper format, all the technical annexes in digital format)
2. Deliverable "Complete wastewater treatment and reuse plant" (paper and digital format)
3. Deliverable " Complete interface of the E.S. with the plant " (paper and digital format)
4. Deliverable "Report on functionality tests" (paper format)
5. Deliverable "Expert System completely instructed for the management of the plant" (paper and digital format)
6. Technical report "Verification of reuse treatment functionality" " (paper format)
7. Technical report "Verification of produced textiles compliance to production quality standards" (paper and digital format)
8. Deliverable "Complete data set referring to the period of continuous operation" (paper and digital format)
9. Deliverable "Handbook of the BAT (paper and digital format)

Annexes concerning the project dissemination:

10. BATTLE International workshop brochure (paper and digital format)
11. Presentation and abstracts relative to the participation in International Conferences (digital format)
12. BATTLE preliminary brochure (paper and digital format)

13. Article on Belgian Textile Review “MILIEUFAX (paper and digital format)
14. Article on the SMI-ATI (the Italian Textile and Fashion Industry Federation) Review “TINCTORIA”  (paper and digital format)
15. Article on “DESALINATION - The International Journal on the Science and Technology of Desalting and Water Purification” (paper and digital format)
16. Article on the “Eco di Bergamo” Italian newspaper (paper and digital format)
17. BATTLE final brochure (paper and digital format)
18. BATTLE final poster (paper and digital format)
19. PhD thesis in Civil and Environmental Engineering (Università degli studi di Firenze) with the title “ Combination of respirometric and titrimetric techniques for the determination of the inhibiting potential of a textile effluent”
20. Layman’s report

LIFE Project Number

# <LIFE05 ENV/IT/000846>

# FINANCIAL FINAL REPORT

Reporting Date

## 31/03/2009

LIFE PROJECT NAME

## <BATTLE>

Data Project

| | |
|---|---|
| **Project location** | Rome, Italy |
| **Project start date:** | <01/12/05> |
| **Project end date:** | <30/11/08> **Extension date:** |
| **Total Project duration (in months)** | <36> months **Extension months** |
| **Total budget** | € 2.055.344 |
| **EC contribution:** | € 965.902 |
| **(%) of total costs** | 46.99% |
| **(%) of elibible costs** | 49.42% |

Data Beneficiary

| | |
|---|---|
| **Name Beneficiary** | ENEA |
| **Contact person** | Mr. Maurizio Casarci |
| **Postal address** | Via Anguillarese 301, 00060 S.M. di Galeria (Rome, Italty) |
| **Visit address** | Via Anguillarese 301, 00060 S.M. di Galeria (Rome, Italty) |
| **Telephone** | +39.06.3048 + 3263 |
| **Fax:** | +39.06.3048 + 3294 |
| **E-mail** | Maurizio.casarci@enea.it |
| **Project Website** | www.life-battle.bologna.enea.it |

## A. CONTENTS

THE STANDARD STATEMENT OF EXPENDITURE ATTACHED TO THE COMMISSION DECISION / GRANT AGREEMENT SHOULD BE USED

1. Standard statement of expenditure and income
2. Beneficiary Certificate
3. Project consolidated statement of expenditure
4. Project statement of income
5. Participant statement of expenditure
6. Form F1: Personnel costs
7. Form F2: Travel & Subsistence costs
8. Form F3 : External Assistance
9. Form F4.1 : Infrastructure
10. Form F4.2: Equipment
11. Form F4.3 : Prototype
12. Form F6 : Consumable Material
13. Form F7 : Other Costs
14. Form F8 : Overheads (part 1)
15. Form F8 : Overheads (part 2)

## B. AUDITOR DATA

- Final Report**:**

**As for interim <u>plus Auditor's Report/Declaration if required by the SAP / CP article 27 (use the standard audit report available on the LIFE website).</u>**

## C. MOTIVATION AND JUSTIFICATION FOR EACH COST-ITEM WITH A DEVIATION OF MORE THAN 10 % (OVER- OR UNDER EXPENDITURE).

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