Summary
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.

In the context described, LIFE funded project BATTLE (05 ENV/IT/000846) aims at promoting and supporting full implementation of the IPPC Directive, demonstrating the technical–economical feasibility of a water recycling technique, viable for the overall sector. In fact the 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.

Riassunto
Il settore industriale tessile è tradizionalmente caratterizzato da un forte consumo di acqua e il suo maggiore impatto ambientale è quindi relativo al consumo di acqua primaria (80-100 m$^3$/ton of finished textile). Secondo la direttiva IPPC (Integrated Pollution Prevention and Control – 96/61/EC) della UE, le linee guida contenute nel documento di riferimento BREF per il tessile dovrebbero essere applicate dalle grandi industrie e da quelle PMI con una capacità produttiva al di sopra della soglia, indicata dalla direttiva, di 10 tonnellate al giorno. Il BREF per il tessile contiene numerose BAT - Best Available Techniques indicate dall’Unione Europea per l’industria - sui processi di produzione, ma pochi e generici suggerimenti sul trattamento delle acque reflue e sul loro riutilizzo. Il riciclo dell’acqua, benché consigliato, non è trattato in modo esaustivo ed inoltre non vengono fornite indicazioni ad hoc sull’esistenza di tecnologie disponibili. In tale contesto la nuova tecnologia proposta dal progetto BATTLE tende a promuovere e supportare l’attuazione della direttiva IPPC, dimostrando la fattibilità tecnico-economica di una nuova tecnica per il riciclo dell’acqua adatta per l’intero settore tessile. Il progetto BATTLE, finanziato dal programma LIFE e coordinato dall’ENEA, da un lato, fornirà le basi per l’applicabilità delle BAT anche presso le PMI del settore tessile di rifinitura, raggiungendo spazi di applicazione legislativa mancanti. Dall’altro, contribuirà a configurare ed applicare su scala dimostrativa una nuova BAT, ovvero una tecnologia per la gestione idrica a basso impatto all’interno dell’industria tessile. La fattibilità e l’efficienza di questa nuova tecnologia saranno dimostrate applicandola all’interno di una azienda di rifinitura tessile di taglio medio, la Stamperia di Martinengo, di Bergamo.

1. Introduzione
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,
According to the IPPC Directive 96/91/CE, the textile BREF [1] (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 LIFE funded project BATTLE (05 ENV/IT/000846) aims at configuring and applying on demonstrative scale a new BAT for low impact water management in textile industry with the development and prototypical 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 prototypical multicriteria methodology built up within the EU funded RTD project TOWEF0 [2] (Toward effluents Zero – EVK1-CT-2000-00063). Feasibility and efficiency of the BAT will be shown by its demonstrative application in a representative textile finishing medium enterprise, Stamperia di Martinengo (Bergamo, Italy), it will imply evidence of feasibility in larger companies where lower unitary costs are expected.

The new BAT proposed methodology generates start of pipe (as opposite of end of pipe) effluent treatment. 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 BAT proposed in the present project is in fact meant to minimize the environmental impact related to water use and discharge. As a scarcely renewable resource, water 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.

In addition, changes in composition of the final effluent due to the reuse option have to be analysed in reference to the evaluation of impact of the final effluent in the recipient water body. Namely, reduction in volume and increase in concentration is expected leaving the global polluting load to the WWTP at the same level. The capability of the existing WWTP to treat such different effluent will be evaluated on simulation/pilot scale. The treatment efficiency is expected to increase in these conditions obtaining therefore better environmental performances.

Furthermore in the specific situation of the partner company Stamperia di Martinengo, the final discharge is diverted to a torrential river, river Serio. In dry season the impact of the discharge is very evident and negatively accepted by the community, therefore improving the environmental performance is a priority of the factory which carries out a biological treatment on the effluent without succeeding in obtaining a harmless discharge.

1.1 BATTLE objectives
In the context described, the BATTLE project aims at overcoming the obstacles for full implementation of the IPPC Directive, demonstrating the technical–economical feasibility of a water recycling technique, viable for the overall sector.

Specific targets are therefore:
- Evaluation of applicability of the BATs - such as those described in the textile reference documents (BREFs) for the implementation of the European Directive IPPC 96/91/CE - in the small-medium enterprises (SMEs) of the textile finishing sector
- Development and prototypical application of a clean technology for the water reuse, at present not envisaged in the BREFs, to be proposed as reference BAT for SMEs as well for large enterprises.
- Raised awareness on benefits and opportunities for the European SMEs and decision makers of textile and side sectors from the implementation of the new BAT.

2. Methods

2.1 BATTLE activities
The project develops following four principal activities:

Action 1: Textile BATs assessment and Company audit
- Analysis on the BATs as reported in the textile BREF in order to evaluate their possible applicability on SMEs, through a survey and data collection of European companies implementing the BATs.
- Characterization of a SME, the partner company Stamperia di Martinengo (SdM), by an auditing procedure to assure a complete and objective evaluation of the techniques implemented and, at the same time, a complete characterization of the produced effluents.

Action 2: Operational data collection and preliminary evaluations to design the BAT demonstration plant
- Selection of the effluents to be diverted for reuse after on-site treatment, through evaluation of the effluents treatability for reuse and assessment of both the change in composition of the final effluents and the effects on the functionality of the existing final treatment facility.
Action 3: Water reuse demonstrative plant design and build-up
- Design and build-up of a demonstrative treatment plant by employment of available treatment technologies such as commercial membranes or equivalent (about 500 m³/day of wastewater treated). Design and development of a prototypal Expert System (E.S.) for the automatic operation of both the plant and the existing facilities.

Action 4: Plant operation and evaluation of the BAT on water use optimisation
- Validation of the E.S. by adaptative runs during the start-up phase.
- Functioning of the new plant in a sufficient time-span, to assess the effects of reused waters on production quality.
- Proposal of a new BAT and the relative handbook on the basis of the above actions results.

Action 5: Dissemination
- Dissemination of information on the project activities and its results carried out throughout the whole duration by means of a website set-up, the participation of both partners and the general public in conferences, workshops and info-days. Back to back to these events, arrangement of on-site visits to the demonstrative plant.

3. Conclusions

3.1 BATTLE expected results
The expected results of the above mentioned activities are:
- BATs applicability in SMEs
- Identification and analysis of BAT on water (use and discharge) in the BREF
- Questionnaire dissemination and collection in IPPC companies
- Audits/interviews in IPPC companies
- Identification of BATs feasible in SMEs and assessment of applicability
- Proposal of modification and/or substitution to comply with different needs and constrains of SMEs

- BAT for optimisation of water cycle in textile SMEs (to be submitted to the IPPC bureau for the inclusion in the BREF)
- Definition of the targets for a new BAT for the optimisation of water use and reuse. (The textile BREF contains only general advices on wastewater treatment and reuse)
- The proposed BAT will integrate the BREF indications with the results of the EU project TOWEF0.
- The proposed BAT is conceived to be included in the sector BREFs. It has the characteristics to be considered “best” and “available” according to the requirements of the IPPC Directive
- The techno-economic feasibility of the proposed BAT will be assessed in the Stamperia di Martinengo (a SME close to the threshold of the IPPC Directive)
- A manual for the BAT will be issued with guidelines for the application in other textile SMEs all over Europe

Water reuse demonstrative plant design and build-up
Demonstration of the new BAT in Stamperia di Martinengo: water reuse plant reducing at least 50% of fresh water consumed and the same amount of wastewater discharged in the environment by a fully reliable, innovative, totally automated, reclamation system, based on the combination of membrane technology for effluents treatment and an Expert System for plant control and operation. The plant is at demonstrative scale (500 m³/day of wastewater treated) assuring the production of
treated water of constant good quality for the textile processes. A start of pipe effluent treatment and reuse scheme is provided, following the layout reported in figure 1.

Fig.1 - The general start of pipe effluent treatment and reuse scheme proposed

The process effluents with suitable characteristics (E1...E4), coming from the different production processes (M1…M4), are mixed and the resulting stream (E5) is diverted to a treatment station for subsequent reuse (W4) after mixing with required amount of primary water (W2). The effluents not suitable for reuse (D1), mixed with the concentrates produced by the membrane plant (D5, D6) constitute the inlet of the existing WWTP, whose operation need to be verified, monitored and in case adapted to the treatment of smaller volumes of more concentrated effluents.

Specific membrane treatment and reuse facilities (firstly UF + NF scheme, but suitable alternatives are under investigation) have been designed specifically for the partner company for on-site treatment and recovery of suitable process effluents.

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 (ES) has been developed and instructed. The ES, fed by a continuous on-line analytical control (e.g. TOC, colour, conductivity and flow-rate) on the different process effluents, performs the selection of the most suitable effluents streams for the next treatment and the reuse. The ES communicates with the plant through sensors and devices for on-line monitoring and it has been instructed during the start-up phase to be able to adapt to different production conditions, allowing for a reliable automatic mode operation of the prototype plant. It also indicates how much fresh water has to be mixed with the permeate, with the purpose of water reuse maximisation not hindering the production quality standards.

Dissemination

Expected results of this action include:
-toreach most of the European companies in view of implementation of the technique in their factories, with the full support of the Textile Associations,
- to demonstrate the advantages and benefits of the implemented integrated expert system for wastewater recovery in a textile processing industries, especially in SMEs;
- to increase the awareness of SMEs on the environmental aspects related to their activities (namely the environmental impacts and risks due to the textile processing industries and the new environment technologies available to overcome those impacts);
- to set up at local level (in selected textile districts all over Europe) a pool of SMEs who can be interested in adopting the implemented integrated expert system;
- to inform the end-users and the general public on the BAT reported in the textile BREF for the wastewater recovery in the textile sector.

3.2 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:
- 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.
- 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.
- CENTRO IMPRESE DEPURAZIONE ACQUE s.r.l., Fino Mornasco (COMO) Italy. CIDA is a private consulting company for the textile sector waste minimisation, design, upgrading of the centralised wastewater treatment plants, restructuring of the industrial aqueduct, upgrading sludge treatment and disposal plants.
- 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.

Bibliography
[1] IPPC Directive 96/91/CE, the textile BREF (Best available techniques REFerence document)
[2] EU funded RTD project TOWEF0 (Toward effluents Zero – EVK1-CT-2000-00063)