"Capacity Building and Strengthening Institutional Arrangement"

Workshop: "Best Available Techniques (BAT)

BAT on Textile and Weaving Industries

Ms. Margherita Secci, Mr. Giorgio Grimaldi

APAT

Agency for Environmental Protection and Technical Services

Index

1. Introduction
2. Flow chart of the textile cycle
3. Environmental issues and consumption and emission levels
4. General BAT
5. Specific BAT
6. Final considerations
7. Glossary
8. Reference documents

1.Introduction

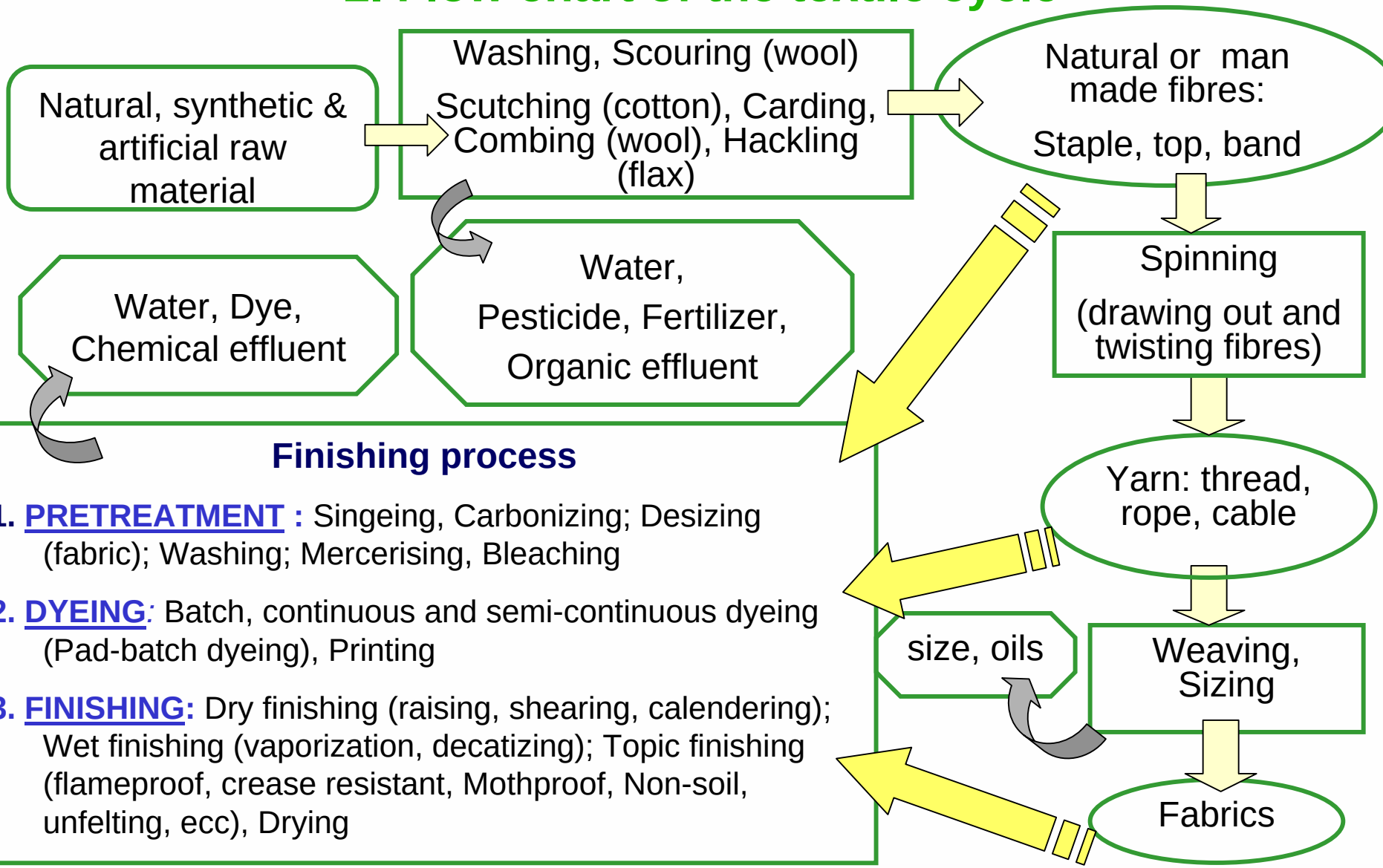
Textile & Weaving in brief

The Textile industry is one of the longest and most complicated industrial chains in manufacturing industry. It is a fragmented and heterogeneous sector dominated by SMEs, with a demand mainly driven by three main end-uses: clothing, home furnishing and industrial use.

It is composed of a wide number of sub-sectors, covering the entire production cycle from the production of raw materials (man-made fibres) to semi-processed (yarn, woven and knitted fabrics with their finishing processes) and final products (carpets, home textiles, clothing and industrial use textiles).

Weaving is an ancient textile art and craft that involves placing two threads or yarn made of fibre onto a warp and weft of a loom and turning them into cloth. This cloth can be plain (in one color or a simple pattern), or it can be woven in decorative or artistic designs, including tapestries.

2. Flow chart of the textile cycle



Finishing process

1. **PRETREATMENT :** Singeing, Carbonizing; Desizing (fabric); Washing; Mercerising, Bleaching
2. **DYEING:** Batch, continuous and semi-continuous dyeing (Pad-batch dyeing), Printing
3. **FINISHING:** Dry finishing (raising, shearing, calendering); Wet finishing (vaporization, decatizing); Topic finishing (flameproof, crease resistant, Mothproof, Non-soil, unfelting, ecc), Drying

3. Environmental issues and consumption and emission levels (1/10)

General

- The main environmental concern in the textile industry is about the amount of **water discharged** and the **chemical load** it carries. Other important issues are **energy and water consumption**, **air emissions**, **solid wastes** and **odours**, which can be a significant nuisance in certain treatments.
- Data on liquid effluents very poor and needing to be more specifically analysed.

3. Environmental issues and consumption and emission levels (2/10)

PRETREATMENT

Substances on the raw material (e.g. impurities and associated materials on natural fibres, preparation agents, spinning lubricants, sizing agents, must be removed from the fibre before colouring and finishing.

- DRY PROCESS (heat-setting): the auxiliaries present on the substrate become airborne (emission factors of 10-16 g C/kg are typical of mineral oil-based compounds).

- WET TREATMENT (i.e. washing): typical COD loads 40-80 g/kg fibre, by the removal of auxiliaries such as spinning lubricants, knitting oils and preparation agents.

Wool scouring with water leads to the discharge of an effluent with a high organic content and significant amounts of micro-pollutants resulting from the pesticides applied on the sheep.

3. Environmental issues and consumption and emission levels (3/10)

The washing water from the **DESIZING** of cotton and cotton-blend fabrics may contain 70% of the total COD load in the final effluent.

MERCERISING: A strong alkaline effluent (40-50 g NaOH/l) is produced if the rinsing water after is not recovered or re-used.

3. Environmental issues and consumption and emission levels(4/10)

BLEACHING

- Sodium hypochlorite bleaching gives rise to secondary reactions that form organic halogen compounds commonly measured as AOX (trichloromethane). For the combined application of hypochlorite (1st step) and hydrogen peroxide (2nd step) values of 90-100 mg Cl/l of AOX have been observed from the exhausted NaClO-bleaching bath. Concentrations up to 6 mg Cl/l can still be found in the spent H_2O_2-bleaching bath, due to the carry over of the substrate from the previous bath.
- The amount of AOX formed during chlorite bleaching is much lower, if compared to sodium hypochlorite. Per contra, the handling and storage of sodium chlorite needs particular attention because of toxicity, corrosion and explosion risks.

3. Environmental issues and consumption and emission levels(5/10)

DYEING PROCESS

Consumption and emission levels are strongly related to the type of fibre, the make-up, the dyeing technique and the machinery employed.

Most of the emissions are into water, originate from:

- the dyes themselves (e.g. aquatic toxicity, metals, colour)
- auxiliaries contained in the dye formulation (e.g. dispersing agents, anti-foaming agents, etc.)
- basic chemicals and auxiliaries used in dyeing processes (e.g. alkali, salts, reducing and oxidising agents, etc.)
- residual contaminants present on the fibre (e.g. residues of pesticides on wool, spin finishes on synthetic fibres).

3. Environmental issues and consumption and emission levels(6/10)

BATCH DYEING

- Spent dye baths have the highest concentration levels (values well above 5.000 mg COD/l are common).
- The contribution of dyeing auxiliaries (e.g. dispersing and levelling agents) to the COD load is especially noticeable when dyeing with vat or disperse dyes. Operations like soaping, reductive after treatment and softening are also associated with high values of COD.
- Rinsing baths show concentrations 10-100 times lower than the exhausted dyeing bath and water consumption 2-5 times higher than for the dyeing process itself.

3. Environmental issues and consumption and emission levels(7/10)

CONTINUOUS AND SEMI-CONTINUOUS DYEING:

Water consumption is lower than the one in batch dyeing processe, but the discharge of highly concentrated residual dyeing-liquors can result in higher pollution load when short runs of material are processed (COD due to the dyestuffs may be in the order of 2-200 g/l).

The ***padding technique*** is still the most commonly applied. The quantity of liquor in the padder can range from 10-15 litres for modern designs to 100 litres for conventional padders. The residual amount in the preparation tank can range from a few litres under optimised control conditions to up to 150-200 l. See the following web site for details:

http://www.swastiktextile.com/dyeing_range.htm

3. Environmental issues and consumption and emission levels(8/10)

PRINTING PROCESSES

Typical emission sources include

- printing paste residues
- waste water from wash-off and cleaning operations
- volatile organic compounds from drying and fixing.

- *Losses* of printing pastes are particularly noticeable in rotary screen printing (losses of 6.5-8.5 kg per colour applied are common for textiles).
- *Water consumption* levels for cleaning of the equipment at the end of each run are in the order of about **500 l** (excluding water for cleaning the printing belt).
- Printing pastes contain substances with high air emission potential (e.g. ammonia, formaldehyde, methanol and other alcohols, esters, aliphatic hydrocarbons, monomers such as, acrylates, vinylacetate, styrene, acrylonitrile, etc.).

3. Environmental issues and consumption and emission levels(9/10)

CONTINUOUS FINISHING PROCESSES

Water emissions due to the system losses and to the water used to clean the equipment. The amount of residual liquors is in the range of **0.5-35 % of the total** amount of finishing liquor prepared (the lower value for integrated mills, higher values for textile mills processing small lots and different types of substrates). The COD concentration can easily be in the range of **130-200 g/l**.

Often the ingredients of the finishing formulations are non-biodegradable, non-bioeliminable and sometimes also toxic.

In the drying and curing operations, air emissions are associated with the volatility of the ingredients used in the formulations and with the carry-over from upstream processes.

3. Environmental issues and consumption and emission levels(10/10)

WATER WASHING PROCESSES

High water and energy consumption. Polluting load related to the pollutants carried (e.g. impurities removed from the fabric, chemicals from previous processes, detergents and other auxiliaries used during washing).

The use of organic halogenated solvents (persistent substances) for dry cleaning may give rise to diffuse emissions, resulting in groundwater and soil pollution and may also have negative effects on the air emissions from high-temperature downstream processes.

4. General BAT

Dosing and dispensing of chemicals (excluding dyes)

- Install automated dosing and dispensing systems, which meter the exact amounts of chemicals and auxiliaries required
- and deliver them directly to the various machines through pipework, without human contact.

4. General BAT

Selection and use of chemicals

- Follow predefined general principles in selecting and managing chemicals:
- Avoid the use of chemicals wherever possible
- If not, adopt a risk-based approach (to ensure the lowest overall risk) to select chemicals and their utilisation mode.
- Adopt modes of operation that ensure the lowest overall risk, including techniques such as closed-loops and the in-loop destruction of pollutants.

4. General BAT

Selection of incoming fiber raw material

- **man-made fiber:** Select material treated with low-emission and biodegradable/bioeliminable preparation agents
- **cotton:** Select material sized with low add-on techniques and high-efficiency bioeliminable sizing agents. Preference should be given to organically grown cotton
- **wool:** Avoid processing wool contaminated with OC (organochlorine) pesticides (select certified suppliers, encourage collaboration initiatives among competent bodies in order to minimise the risk at the source). Select wool yarn spun with biodegradable spinning agents instead of formulations based on mineral oils and/or containing APEO (**alkylphenolethoxylate**).
- Establish collaboration with upstream partners in the textile chain to exchange information on the type and load of chemicals that are added and remain on the fiber at each stage of the product's life cycle.

4. General BAT

Management

- Implementation of a EMS (*Environmental Management System*),
- Training and retraining courses
- Implementation of a monitoring system to process input and output for identifying priority areas and options for improving environmental performance.

4. General BAT

Water and energy saving

- Monitor water consumption and improve control of process parameters
- Recycle cooling water in the dyeing bath (save water in a tank and use it again in the same process)
- Reduce dyeing washing ratio for tops (wool) and bobbins (recommended 8/10 lt for each Kg of fiber)

- Thermally insulate pipes (i. e. in the stenter-frame phase)
- Isolate warm/cold water flows
- Save energy from cooling water (i.e. heat exchanger on the hot discharge line of the dyeing bath)
- Save energy from the exhaust effluents

5. Specific BAT

Pretreatment of "Finishing process" (1/4)

•**Removing knitting lubricants from fabric**

· Select knitted fabric that were processed using water-soluble and biodegradable lubricants, instead of the conventional mineral oil-based lubricants. Remove them by water washing.

· Carry out the thermofixation step before washing and treat the air emissions generated from the stenter-frame by dry electrofiltration systems that allow energy recovery and separate collection of the oil. This will reduce the contamination of the effluent.

· Remove the non-water soluble oils using organic solvent washing. This will avoid any possible contamination of groundwater arising from diffuse pollution and accidents. This technique is convenient when other non water-soluble preparation agents, such as silicone oils, are present on the fabric.

5. Specific BAT

Pretreatment of "Finishing process" (2/4)

- **Desizing**

· Select raw material processed with low add-on techniques (e.g. pre-wetting of the warp yarn) and more effective bioeliminable sizing agents combined with the use of efficient washing systems for desizing and low F/M (food-to-mass ratio) waste water treatment techniques, to improve the bioeliminability of the sizing agents.

· Adopt the oxidative route when it is not possible to control the source of the raw material.

· Combine desizing/scouring and bleaching in one single step, as described in Section 4.5.3.

· Recover and re-use the sizing agents by ultrafiltration.

5. Specific BAT

Pretreatment of “Finishing process” (3/4)

- **<u>Mercerising</u>**
- Recover and re-use alkali from mercerising rinsing water.
- Re-use the alkali-containing effluent in other preparation treatments.

5. Specific BAT

Pretreatment of “Finishing process” (4/4)

- **Bleaching**
  - Use hydrogen peroxide bleaching (H2O2).
  - Use two-step hydrogen peroxide-chlorine dioxide (see previous slide on issues).
  - Use sodium hypochlorite only when high whiteness is needed or for fragile fabrics, that would suffer depolymerisation.

5. Specific BAT

Dyeing (1/8)

- **<u>Dosage and dispensing of dye formulations</u>**

· Reduce the number of dyes (i.e. using trichromatic systems)

· Use automated systems for dosage and dispensing of dyes

· In long continuous lines, give preference to decentralised automated stations, that do not premix the different chemicals with the dyes before the process, and that are fully automatically cleaned.

5. Specific BAT

Dyeing (2a/8)

- **General BAT for batch dyeing processes**
  - Use machinery equipped with: automatic controllers of fill volume, temperature and other process parameters, indirect heating & cooling systems, hoods and doors to minimise vapour losses
  - Choose the machinery that is most fitted to the size of the lot to be processed, to allow its operation in the range of nominal liquor ratios for which it is designed. Modern machines can be operated at approximately constant liquor ratio, whilst being loaded at a level as low as 60 % of their nominal capacity (or even 30 % of their nominal capacity with yarn dyeing machines)

5. Specific BAT

Dyeing (2b/8)

- Select new machinery according as far as possible to the requirements described in Section 4.6.19:
  - low- or ultra-low liquor ratio
  - in-process separation of the bath from the substrate
  - internal separation of process liquor from the washing liquor
  - mechanical liquor extraction, to reduce carry-over and improve washing efficiency
  - reduced duration of the cycle.
- Substitute overflow-flood rinsing method in favour of drain and fill or other methods (smart rinsing for fabric) as described in Section 4.9.1

5. Specific BAT

Dyeing (2c/8)

- Re-use rinse water for the next dyeing or reconstitute and re-use the dye bath when technical considerations allow.
- The fibre carrier can be removed from the dyeing machine without draining the bath. Modern batch dyeing machines are equipped with built-in holding tanks allowing for uninterrupted automatic separation of concentrates from rinsing water.

5. Specific BAT

Dyeing (3/8)

• **BAT for continuous dyeing processes**

They consume less water than batch dyeing, but highly concentrated residues are produced.

BAT is to reduce losses of concentrated liquor by:

· using low add-on liquor application systems

· adopting dispensing systems as separate streams, being mixed only immediately before being fed to the applicator

· using one of the systems for dosing the padding liquor, based on measurement of the pick up (see 4.6.7)

· increase washing efficiency according to the principles of counter-current washing and reduction of carry-over described in Section 4.9.2.

5. Specific BAT

Dyeing (4/8)

- **PES [poly(ether-sulfone)] & PES blends dyeing with disperse dyes**
- Avoid the use of hazardous carriers (section 4.6.1 & 4.6.2)
- Substitute sodium dithionite in PES aftertreatment, by applying one of the 2 proposed techniques (section 4.6.5)
- Use dispersing agents with high degree of bioeliminability (Section 4.6.3.)

5. Specific BAT

Dyeing (5/8)

- **<u>Dyeing with sulphur dyes (section 4.6.6)</u>**
- Replace conventional powder and liquid sulphur dyes with stabilised non-pre-reduced sulphide-free dyestuffs
- Replace sodium sulphide with sulphur-free reducing agents or sodium dithionite
- Adopt measures to ensure that only the strict amount of reducing agent needed to reduce the dyestuff is consumed (e.g. by using nitrogen to remove oxygen from the liquor and from the air in the machine)
- Use hydrogen peroxide as preferred oxidant.

5. Specific BAT

Dyeing (6/8)

- **Batch dyeing with reactive dyes**
- Use high-fixation, low-salt reactive dyes (Sections 4.6.10 and 4.6.11)
- Avoid the use of detergents and complexing agents in the rinsing and neutralisation steps after dyeing, by applying hot rinsing integrated with recovery of the thermal energy from the rinsing effluent (Section 4.6.12).

5. Specific BAT

Dyeing (7/8)

- **Pad-batch dyeing with reactive dyes**

This technique permit to avoid the use of urea and to use silicate-free fixation methods (see Section 4.6.9).

The initial capital investment in switching to this new technology is significant. Then only new installations are expected to adopt it.

5. Specific BAT

Dyeing (8/8)

Wool Dyeing

- Substitude chrome dyes with reactive dyes
- Ensure minimum discharge of heavy metals in the waste water when dyeing wool with metal complex dyes
- Give preference to a pH-controlled process, so that level dyeing is obtained with maximum exhaustion of dyes and insect resist agents and minimum use of organic levelling agents

5. Specific BAT

Printing (1/3)

- **Process in general**
- Reduce printing paste losses in rotary screen printing (Section 4.7.4, 4.7.5 and 4.7.6)
- Reduce water consumption in cleaning operations by a combination of the techniques described in Section 4.7.7
- Use digital ink-jet printing machines for the production of short runs (less than 100 m) for flat fabrics, when product market considerations allow.
- *It is not considered BAT to flush with solvent to prevent blocking while the printer is not in use.*
- Use digital jet printing machines described in Section 4.7.8 for printing carpet and bulky fabrics.

5. Specific BAT

Printing (2/3)

- **Reactive printing**

Avoid the use of urea by the one-step or two-steps techniques, described in Sections 4.7.1 and 4.7.2.

5. Specific BAT

Printing (3/3)

- **Pigment printing**

Use optimised printing pastes that fulfil the following requirements (see 4.7.3):

- Thickeners with low-emission of volatile organic carbon and formaldehyde-poor binders.
- APEO-free (alkylphenol ethoxylates free) and high degree of bioeliminability
- Reduced ammonia content.

5. Specific BAT

Finishing (1/3)

- **Process in general**

❖minimise residual liquor by:

- using minimal application techniques (e.g. foam application, spraying) or reducing volume of padding devices
- re-using padding liquors if quality is not affected

❖minimise energy consumption in stenter frames by (see Section 4.8.1):

- using mechanical dewatering equipment
- optimising exhaust airflow through the oven, automatically maintaining exhaust humidity between 0.1 and 0.15 kg water/kg dry air,
- installing heat recovery systems
- fitting insulating systems
- ensuring optimal maintenance of the burners in directly heated stenters

❖use low air emission optimised recipes, described in Section 4.3.2.

5. Specific BAT

Finishing (2/3)

•**Easy-care treatment**

BAT is to use formaldehyde-free cross-linking agents in the carpet sector, and formaldehyde-free or formaldehyde-poor (<0.1 % formaldehyde content in the formulation) cross-linking agents in the textile industry (see 4.8.2).

5. Specific BAT

Finishing (3/3)

- **Mothproofing treatments** (process in general)
  - Adopt appropriate measures for material handling (Section 4.8.4.1)
  - Ensure that 98 % efficiency (transfer of insect resist agent to the fibre) is achieved
  - Adopt the following additional measures when the insect resist agent is applied from a dye bath:

➢ensure that a pH<4.5 is reached at the end of the process and if this is not possible, apply the insect resist agent in a separate step with re-use of the bath;

➢add the insect resist agent after dye bath expansion in order to avoid overflow spillages;

➢select dyeing auxiliaries that do not exert a retarding action on the uptake of the insect-resist agent during the dyeing process (see Section 4.8.4.1).

5. Specific BAT

Washing

- Substitute overflow washing/rinsing with drain/fill methods or “smart rinsing” techniques (Section 4.9.1)
- Reduce water & energy consumption in continuous processes by:
  - -installing high-efficiency washing machinery (Section 4.9.2).
  - -introducing heat recovery equipment
- When halogenated organic solvent cannot be avoided (e.g. with fabrics loaded with preparations by silicone oils), use fully closed-loop equipment.

5. Specific BAT

Waste water treatment (1/2)

- Waste water treatment follows at least three different strategies:

  · central treatment in a biological waste water treatment plant on site

  · central treatment off site in a municipal waste water treatment plant

  · decentralised treatment on site (or off site) of selected, segregated single waste water streams

5. Specific BAT

Waste water treatment (2/2)

- BAT for the treatment of waste water from the textile finishing and carpet industry:
- Treatment of waste water in an activated sludge system at low food-to-micro organisms ratio as described in Section 4.10.1 (concentrated streams containing non-biodegradable compounds have to be pretreated separately).
- Pretreatment of highly-loaded (COD>5000 mg/l) selected and segregated single waste water streams containing non-biodegradable compounds by chemical oxidation. Candidate waste water streams are padding liquors from semi-continuous or continuous dyeing and finishing, desizing baths, printing pastes, residues from carpet backing, exhaust dyeing and finishing baths.

5. Specific BAT

Sludge disposal

- For sludge from waste water treatment of **wool scouring** effluent:

- Use sludge in brick-making (see 4.10.12) or adopt any other appropriate recycling routes.

- Incinerate the sludge with heat recovery, provided that measures are taken to control emissions of SO_x, NO_x and dust and to avoid emissions of dioxins and furans arising from organically bound chlorine from pesticides potentially contained in the sludge.

6. Some final considerations

- The textile industry is a very complex and variegated sector. The impact of the implementation of the BAT identified will depend on the characteristics of each mill.
- A Quality Assurance system is necessary, particularly for incoming textile material (many companies have difficulty in controlling/ selecting the source of the fiber raw material).
- A collaboration system with upstream partners in the textile chain is envisaged, in order to create a chain of environmental responsibility for textiles.

7. Recommendations for future work

- A more systematic collection of data is needed on the current consumption and emission levels and on the performance of techniques to be considered in the determination of BAT, especially for water effluents.
- A more detailed assessment of the costs and savings associated with techniques is needed to further assist the determination of BAT.
- Collection of further information on areas not properly covered by the BREF due to a lack of information.

Future EC projects

- Clean technologies.
- Emerging effluent treatment.
- Recycling technologies and management strategies.

8. Glossary

(http://www.apparelsearch.com/Definitions/Definition_List_Clothes.htm)

Bleaching: Whiten by hypochlorite
Calendering: material is passed between several pairs of rollers, to give a shiny surface
Carbonizing: Cellulose residues removel, by sulphuric acid bath
Carding: The processing of brushing raw or washed fibers to prepare them as textiles
Combing: Between carding and spinning, lays the fibers parallel, and removes short fibers
Crease resistant, Flameproof, Mothproof: Resistant to fold, flame,moth
Decatizing: Technique to give stable colours to yarn or fabric
Dyeing: To give an uniform colour to a fibre, yarn or fabric
Fabrics: Flexible natural or artificial material made up of a network (Warp &Wert) of fibres
Finishing: Surface process intended to give to yarn or fabric the desired final aspect
Hackling: To comb flax or hemp with a hackle
Knitting: one of several ways to turn thread or yarn (i.e. wool) into cloth (cf weaving, crochet)
Mercerising: makes the surface glossier, increases strength and improves dye absorption
Raising: Raising (putting up) the fibers of cloth to produce a pilelike (gauze) surface
Scouring: To remove dirt or grease from fibres or cloth, by means of a detergent
Scutching: To separate the valuable fibers of (i.e. flax) from the woody parts, by beating
Shearing: Clipping of surface fibres
Singeing is the burning off of loose fibers sticking out of textiles goods
Sizing: Coating yarn surface by natural or artificial agents, aimed to give specific proprerties
Spinning: Separate fibers are twisted together to bind them into a stronger, long yarn
Yarn: a long continuous length of interlocked fibers, used to produce textiles, ropemaking,
Weaving, To make cloth by interlacing the threads of the weft and the warp on a loom.

9. Reference documents

- BREF: Reference Document on Best Available Techniques for the Textiles Industry – July 2003:

Applied Processes and techniques(chapter 2), Best Available Techniques (chapter 5), Emerging Techniques (chapter 6)
http://eippcb.jrc.es/pages/Fmembers.htm

- Methodology for the environmental analysis of a production cycle – APAT 36/2006 *(Italian language)*

http://www.apat.gov.it/Media/cicli_produttivi/Avvio.htm

- Analysis of the textile industry (wool) in the “Piemonte” region - ARPA Piemonte, 2007 *(Italian language)*