Cleaner Production Training for EPD Punjab

Promotion of Sustainability in the Textile and Garment Industry in Asia-FABRIC

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

FABRIC Asia

Day 1: Monday, 19/9/2022

1. Resource Consumption Profiling Textile Factories

10:00 – 11:00

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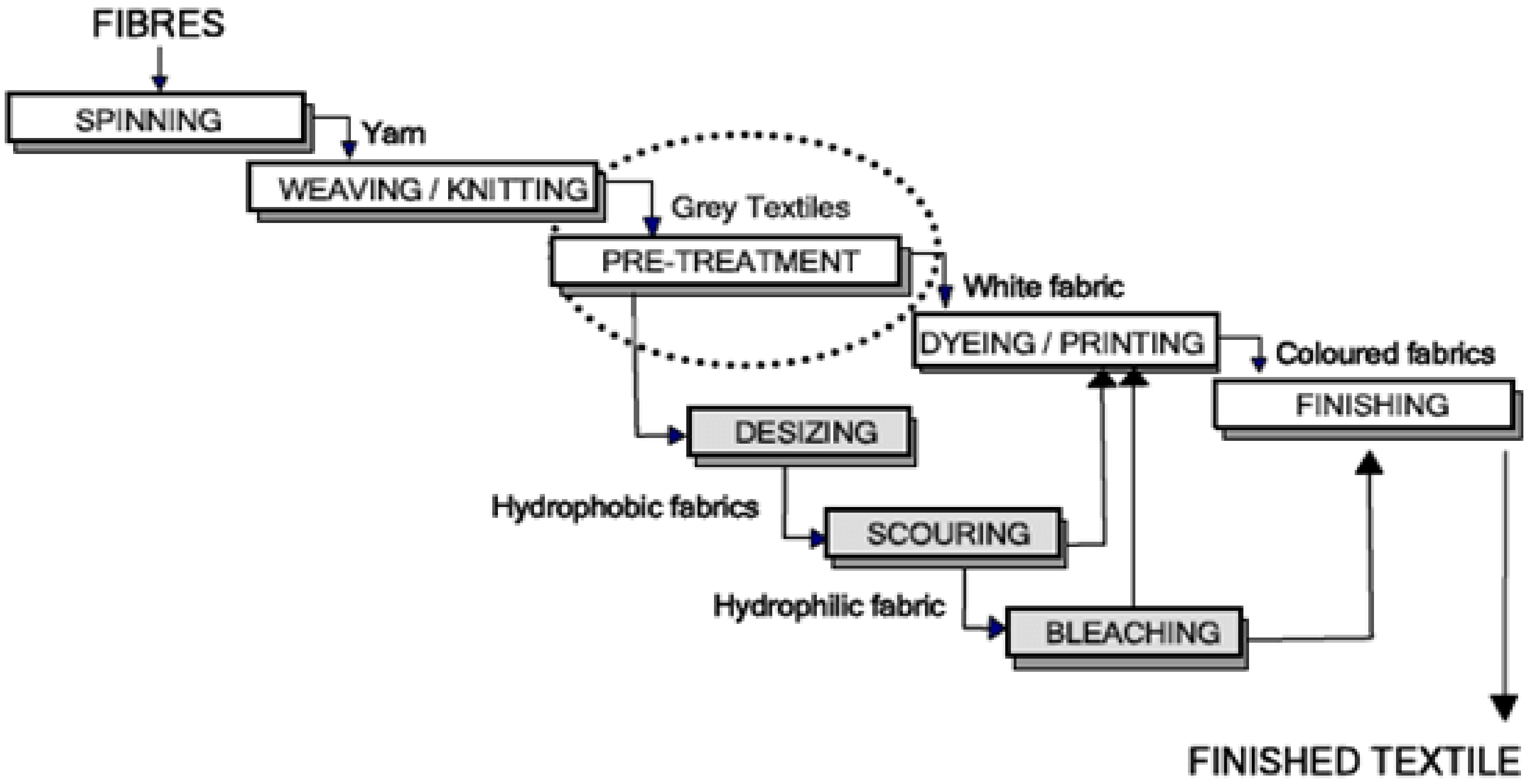
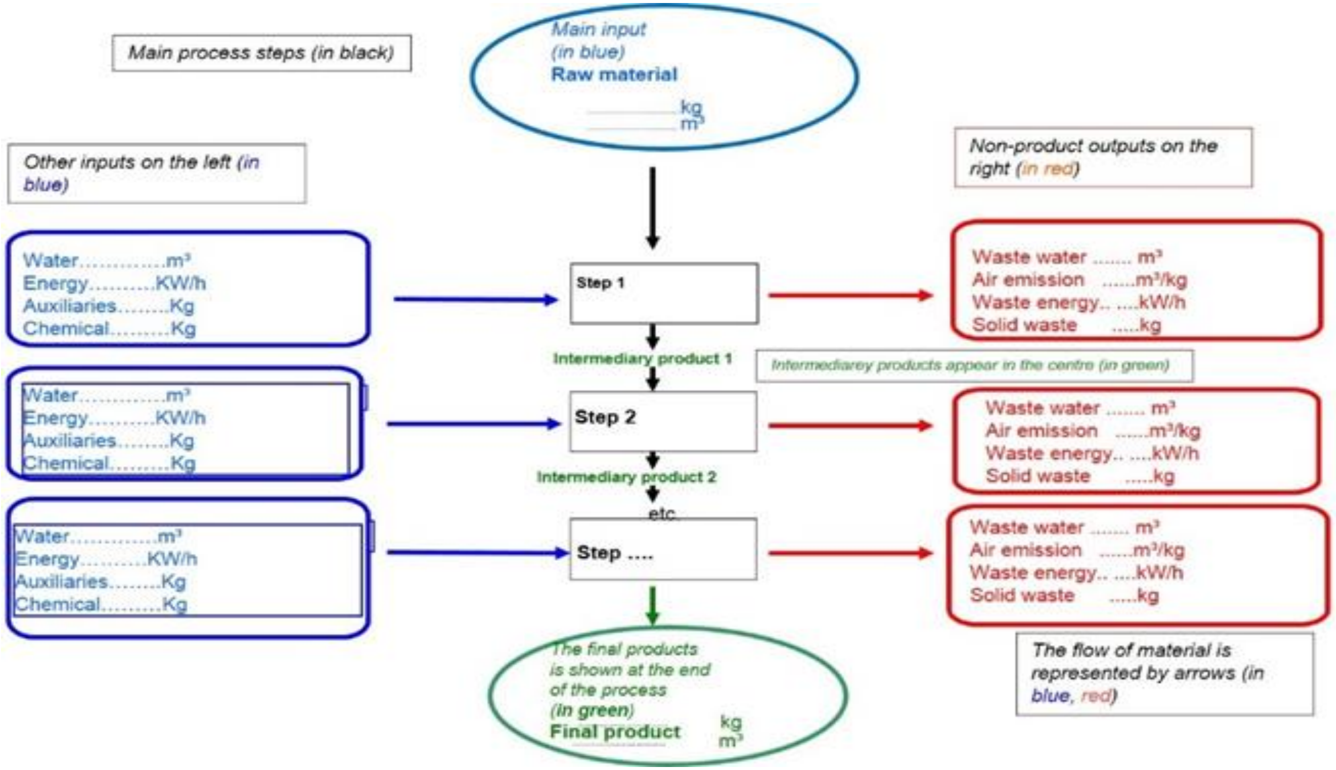
Agenda

- Textile Supply Chain targeting Wet Processing
- Typical Wet Processing
- Typical water supplies and Water Consumption
- Typical energy supplies and Energy Consumption
- Typical Chemical Used in Bulk
- Ranges and benchmarks of Resource consumption per kg of Product (l/kg, kWh/kg)

Wet-pretreatment process for the cotton textiles

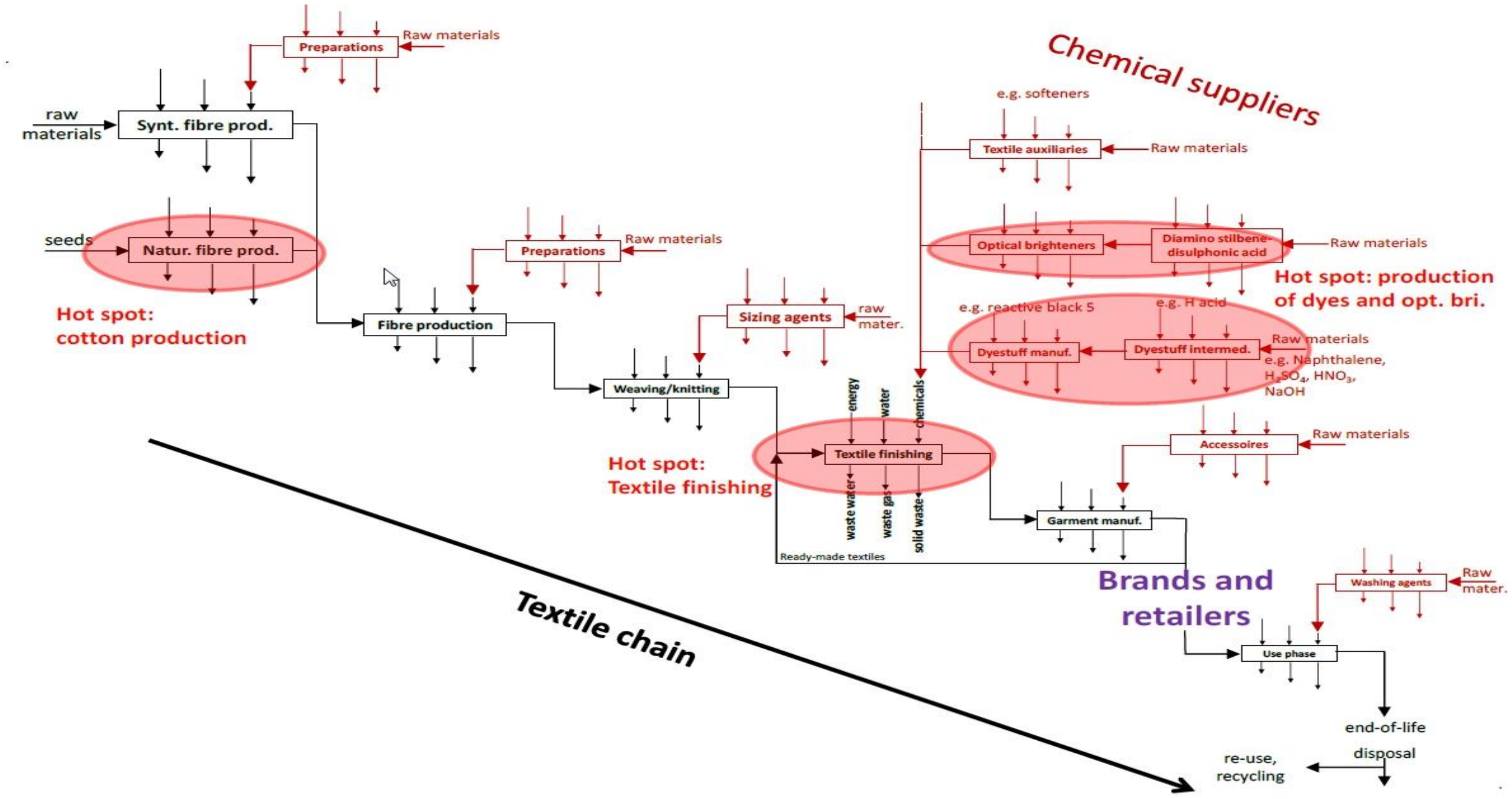


Concept of Process Flow Mapping



Source: e-REMC toolkit by Deutsche Gesellschaf für Internationale Zusammenarbeit (GIZ)

Hotspots in the textile chain



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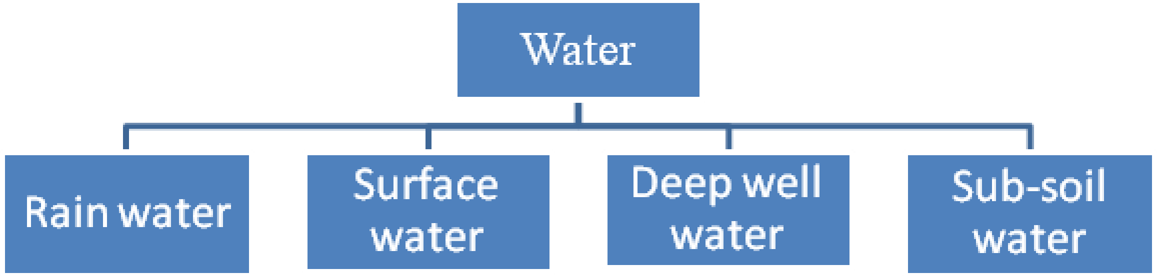
Typical water supplies and Water Consumption

The textile industry uses a significant volume of **freshwater** throughout all processing operations (e.g., dyeing, bleaching, washing), while it contributes to freshwater pollution during the thorough washing of the fabrics to remove chemicals.



The water supplies for textile industries are the

- Use of groundwater extracted by wells
- Canal water
- Piped water from water utilities
- Rainwater

In most cases the process water need a pre-treatment before use (MF,UF or RO)

Quality of Water Used in Textile Wet Processing:

The process water for textile wet processes must meet quality requirements

The following qualities of water used in wet processing must be fulfilled.

- The water should be free of bicarbonate of metals like calcium (Ca), magnesium (Mg), aluminum (Al), iron (Fe) etc. and sulfate and chloride of calcium, magnesium and aluminum.
- Water should be free of ammonia and ammonium compounds.
- The water must be free of dissolved compounds.
- The water used for textile wet processing should be mild or soft.
- It must be free of insoluble or floating matter.
- At normal temperature water should be pure, colorless, odorless and tasteless liquid.
- Water must be free of hydrogen sulfide, carbon dioxide and other dissolved gases.

Wastewater Quantity Benchmarks	L/kg
Wool scouring	2 - 6
Yarn finishing (wool)	35 - 45
Yarn finishing (cotton)	100 - 120
Yarn finishing (synthetic fibres)	65 - 85
Finishing of knitted fabrics (wool)	60 - 70
Finishing of knitted fabrics (cotton)	60 - 136
Finishing of knitted fabrics (synthetic fibres)	35 - 80
Finishing of woven fabric (wool)	70 - 140
Finishing of woven fabric (cotton)	50 - 70
Finishing of woven fabric (synthetic fibres)	100 – 180
Bovine leather (from raw to finished)	12 -30
Pig skin leather (from raw to finished)	32 - 69
Sheep/goat skin leather (from raw to finished)	110 – 265 per skin

Specific water consumption when applying water-saving measures

Specific process(es)	Specfic water consumption (Yearly average) (m^3/t)
Bleaching	3–48 (Batch) 3-8 (Continuous)
Scouring of cellulosic materials	2-43 (Batch) 2-20 (Continuous)
Desizing of cellulosic materials	2–20
Mercerisation	2–13
Washing of synthetic material	5–20
Batch dyeing Fabric Fabric Yarn Loose fibre	10-175 3-140 13-62
Continuous dyeing	2–16

Reduced water consumption results in a high concentration of pollutants and requires corresponding waste water treatment.

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The use of countercurrent washing may also lead to a water consumption reduction of between 41 % and 62 %.

Cross-media effects

Highly intensive and efficient washing techniques with low water consumption require intensive mechanical washing conditions such as spraying and sucking, which may cause require somewhat higher electricity consumption. However, this is largely offset by energy savings achievable by implementing thermal energy recovery measures that are also part of the measures described.

Economics

The achievement of performances typical of highly efficient washing machines requires investment in new equipment. However, the application of low-technology measures such as flow control devices, automatic valves, etc. can also produce some reduction in water and energy consumption.

Driving force for implementation

The main driving forces for the implementation of the techniques described are the increasing cost of water supplies and waste water treatment, and the desire to increase productivity (in the case of new highly efficient washing machinery).

Example Capital costs and annual savings related to water reuse techniques

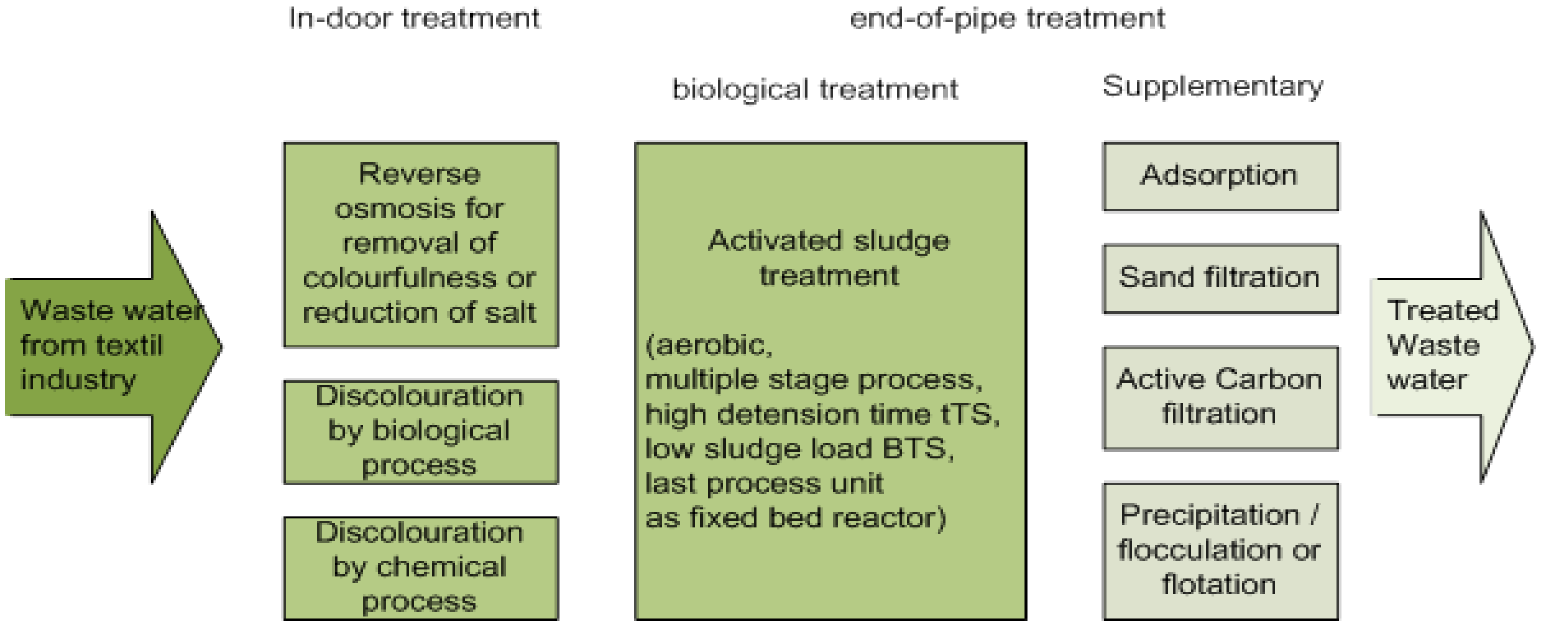
Measure	Bleach bath recovery	Reuse of cooling water and condensate
Capital cost	USD 80 000 to USD 246 000	USD 143 000 to USD 212 000
Net annual operating savings	USD 38 500 to USD 118 400	USD 82 900 to USD 161 500
Payback period	2.1 years	1.3 to 1.7 years

Environmental performance and operational data
'Drain and fill' and 'smart rinsing' are both more efficient in terms of water consumption than conventional overflow rinsing.

As far as the 'drain and fill' method is concerned, by replacing each overflow rinse by two to four 'drain and fill' cycles a reduction of 50-75 % water consumption can be achieved.

Reduced water consumption also means reduced energy consumption, since hot and warm rinsing steps are often required. In addition, energy savings are obtained with combined cooling and rinsing techniques.
One fundamental feature of both 'smart rinsing' and 'drain and fill' compared to the conventional overflow method is that it is possible to keep the exhausted concentrated dye liquor and the rinsing waters as separate streams. This means that they can be reused or at least treated separately, and thermal energy can thus be recovered.

Scheme of the common treatment of waste water from textile industries



Mixed waste from textile industries are generally characterized by organic carbon-containing substances, which concentrations are slightly higher concentrated than in municipal waste water, but are more difficultly to degrade. The concentrations of nitrogen and phosphorous containing substances are lower than in municipal water.

Scheme of the common treatment of waste water from textile industries

Main process	Waste water treatment process
Pre-treatment	Equalization of flow streams + concentration neutralization
Separation of solids Mechanical or physical	Grids, sizes Sedimentation Flotation filtration
Separation of solids Chemical or and physical	Adsorption Precipitation and Flocculation Ion exchange
Degradation of substances (oxygen demanding) Biological	Aerobic Anaerobic
Degradation (reduction) of substances Chemical	Oxidation Reduction

Waste water Sludge Treatment

As per ZDHC your company is expected to follow generally-accepted process engineering best practices with respect to wastewater treatment and overall facility water efficiency management.

In addition to the treatment of all waste water and discharge as per established discharge limits/standards, special attention needs to be paid to the management of the treatment sludge.

Textile waste water treatment generates about 1.5 kg per m^3 of waste water.

Waste water Sludge Treatment

Depending on the concentration of certain chemicals in the sludge the same be considered as hazardous waste, requiring the further removal and disposal of the sludge by licensed/permitted and qualified third parties that have appropriate facilities to properly dispose of the sludge wastes to ensure that sludge and leachates from the sludge do not adversely impact the environment.

Substitution of hazardous chemicals and application of Best Available Techniques (BAT) will help to reduced the hazard levels of treatment sludge and waste, reducing the cost for their treatment and disposal.

Recovery of chemicals

Many chemicals can be recovered from effluents, if the respective streams are separated before mixing with other wastewater streams.

- This leads to a lower loaded wastewater and cost savings due to the recovered chemicals.

Examples for this practice are:

- Caustic soda recovery through destillation
- Acetic acid recovery through extraction
- Precious metal recovery through electrolysis

Reuse of the treated wastewater

- As the groundwater table is falling in many industrial areas of the producing countries, pumping the water to the surface and its pretreatment becomes more expensive.
- In some areas, companies have begun on site wastewater treatment with the goal of reusing the majority of their effluent as raw water for their processes.
- In many cases, treating and reusing some low-loaded wastewater streams can already lead to a significant reduction in water consumption and wastewater production.

Processes for reuse of the treated wastewater

ANAEROBIC TREATMENT OF DESIZING WASTEWATER

- Desizing
- Bleaching/ Scouring
- Mercerization Dyeing Printing Finishing
- Drain towards Effluent Treatment Plant
- Over 50% of the total organic load is released in the wastewater system from the desizing process. However, the wastewater volume from desizing only represents about 5 % of the total wastewater volume. The combined treatment of this stream with the other wastewater streams from the textile finishing (mixed wastewater) is associated with considerable energy demand for aerobic biodegradation and high amounts of biomass produced

Possible usefull corrective actions 1

1. Management Techniques

- Water monitoring of individual machines or processes and systematic use of the results to reduce water consumption
- Advanced monitoring of all relevant processes in order to establish a water balance of the whole wet processing unit
- Measurements of water consumption of individual finishing processes such as from roller washers or exhaust dyeing

2. Improvement of Installations

- Optimized reverse osmosis plants for the preparation of boiler feed water
- Optimization of water consumption for the continuous pre-treatment of cotton and blended cotton woven fabrics
- Substitution of roller washers by continuous counter-current washing
- Optimization of heat recovery from wastewater of individual machines or a group of machines
- Use of washing water from scouring and/or bleaching for the steam water lock in continuous pretreatment lines

Module 4: Wastewater- and Sludge Treatment

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Possible usefull corrective actions 2

3. Recycling of specific water streams

- Recycling of cooling water from singeing
- Recycling of cooling water from caustic soda recovery
- Recycling of steam condensate from caustic soda recovery
- Recycling of last rinsing water from mercerization
- Use of RO reject for scrubbing waste gas from coal combustion
- Recycling of cooling water from cylinder dryers

4. Improvement of recipes or usage of chemicals with better environmental properties

- Systematic listing of all chemical products used with all available environmental data and identification of the need of alternatives
- Substitution of liquid ammonia for pigment printing pastes

Module 4: Wastewater- and Sludge Treatment

Possible usefull corrective actions 3

5. Pre-treatment of segregated waste water streams and end-of-pipe waste water

- Anaerobic pre-treatment of desizing liquors from the pre-treatment of cotton or blended cotton woven fabrics
- Adjustment of optimum conditions for biological wastewater treatment such as maximum temperature of 37°C, food-to-microorganism ratio of less than 0.15 kg BOD5/kg MLSS x d and C:N:P ratio of 100:5:1, and plough flow reactors

Module 4: Wastewater- and Sludge Treatment

Specific water and energy consumption

Specific water consumption (i.e. cubic metre of water consumed per tonne of textile treated) the specific energy consumption (i.e. kWh of energy consumed per tonne of textile treated).

- Water consumption: between 100 and 350 liters / kg
- Energy consumption: 25 kWh / kg on average

Source:
http://textilelearner.blogspot.ch/2014/04/water-consumption-in-textile-industry.html
http://www.textileworld.com/Issues/2008/November-December/Features/Ecology_And_Economy_In_Textile_Finishing

Typical energy supplies and Energy Consumption

Coal – boilers, steam generation
Oil – boilers, steam generation, electricity generation
Gas – boilers, heating of processes
Electricity – from grid or self generated – machines like spinning and weaving …

Renewable energies
- Use of direct solar energy for fiber drying
- Use of solar energy for water heating in the textile industry

Energy is one of the main cost factor in textile production.

Rising energy prices are driving up costs and decreasing value added at the plant. Successful, cost-effective investment into energy-efficiency technologies and practices meets the challenge of maintaining the output of a high quality product despite reduced production costs. This is especially important in the current age, as energy-efficient technologies often include “additional” benefits, such as increasing the productivity of the company or reducing the water and/or materials consumption.

In spun yarn spinning, electricity is the dominant energy source, whereas in wet-processing the major energy source is fuels.

Studies showed that around 36% of the energy input to the textile industry is lost onsite (e.g. in boilers, motor system, distribution, etc.)

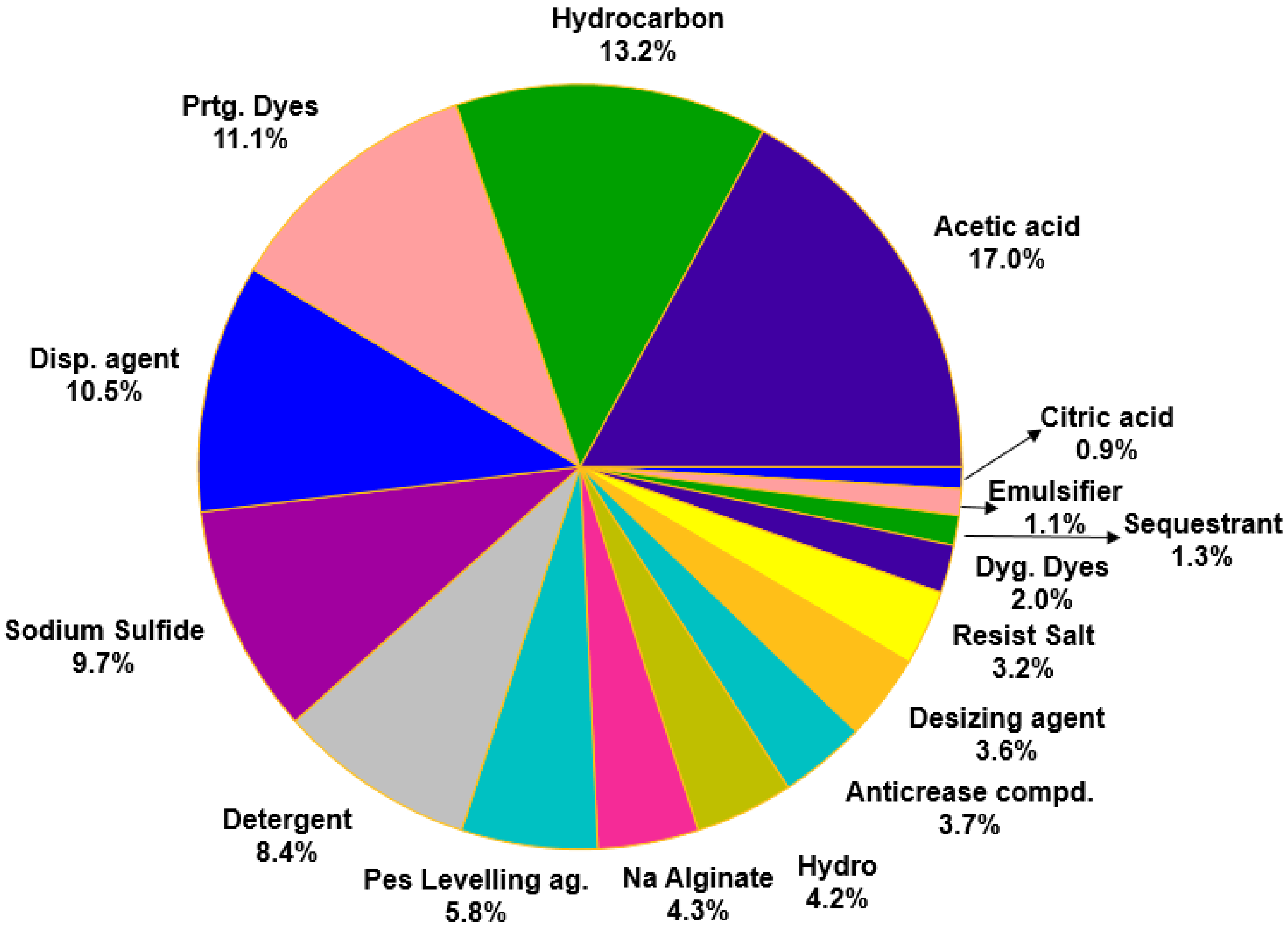
There are many energy efficiency improvement measures available, which can reduce the energy consumption on different levels of the processes and reduce costs as well emissions.

Typical Energy Requirements for Textile Wet- Processes, by Product Form, Machine Type and Process

Product form/machine type	Process	Energy requirement (GJ/tonne output)
Desize unit	Desizing	1.0 - 3.5
Kier	Scouring/bleaching	6.0 - 7.5
J-box	Scouring	6.5 - 10.0
Open width range	Scouring/bleaching	3.0 - 7.0
Low energy steam purge	Scouring/bleaching	1.5 - 5.0
Jig/winch	Scouring	5.0 - 7.0
Jig/winch	Bleaching	3.0 - 6.5
Jig	Dyeing	1.5 - 7.0
Winch	Dyeing	6.0 - 17.0
Jet	Dyeing	3.5 - 16.0
Beam	Dyeing	7.5 - 12.5
Pad/batch	Dyeing	1.5 - 4.5
Continuous/thermosol	Dyeing	7.0 - 20.0
Rotary Screen	Printing	2.5 - 8.5
Steam cylinders	Drying	2.5 - 4.5
Stenter	Drying	2.5 - 7.5
Stenter	Heat setting	4.0 - 9.0
Package/yarn	Preparation/dyeing (cotton)	5.0 - 18.0
Package/yarn	Preparation/dyeing (polyester)	9.0 - 12.5
Continuous hank	Scouring	3.0 - 5.0
Hank	Dyeing	10.0 - 16.0
Hank	Drying	4.5 - 6.5

1 GJ = 277 KWh

Typical Process Loads



Oxidising agents and reducing agents

Oxidising agents are mainly used for **bleaching** and reducing agents are mainly used for vat dyeing in textile wet processes. These agents are often strong chemicals and need to be handled with care. The assay of these agents is almost always based on the redox titration. In a redox reaction, an oxidising agent (oxidant) is reduced (it gains electrons) and a reducing agent (reductant) is oxidised (it loses electrons).

Oxidising Agents:

Hydrogen peroxide

Hydrogen peroxide (H_2O_2) can be titrated with potassium permanganate ($KMnO_4$) in an acid medium. H_2O_2 is the reducing agent and $KMnO_4$ is the oxidising agent.

Sodium Hypochlorite

In hypochlorite bleaching of textiles, active chlorine is the species measured for the control of the **bleaching process**. Iodometry is the method used to determine the content of active chlorine.

Sodium perborate

Either sodium permanganate or potassium iodide can be used to titrate the sodium perborate ($NaBO_3 \cdot 4H_2O$). Dissolve 0.2 g of sample in 200 ml distilled water, add 40 ml 6 N H_2SO_4, titrate with 0.1 N sodium permanganate until a pink colour appears.

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Reducing Agents

Sodium hydrosulphite ($Na_2S_2O_4$)
It is the Dilute of 10 ml 40% formaldehyde with 50 ml distilled water.

Glucose
Glucose ($C_6H_{12}O_6$) can be used as a reducing agent in vat and **sulphur dye** applications. It can be analyzed by iodometry. Accurately prepare a 0.5% glucose solution.

Sodium thiosulphate
Sodium thiosulphate ($Na_2S_2O_3 \cdot 5H_2O$) can be titrated easily by iodometry. Accurately weigh a 5 g sample and dissolve it in 500 ml distilled water to make a 1% sample solution.

Acid

An acid (from the Latin acidus/acēre meaning sour) is a substance which reacts with a base. Commonly, acids can be identified as tasting sour, reacting with metals such as calcium, and reacting with bases such as sodium carbonate. Aqueous acids have a pH under 7, with acidity increasing the lower the pH. Chemicals or substances having the property of an acid are said to be acidic.

There are two types of acid:

1.Inorganic acid

2.Organic acid

1. Inorganic Acid:

Inorganic acid are Sulphuric acid (H_2SO_4), Hydrochloric acid (HCl), Nitric acid (HNO3), Phosphoric acid (H_3PO_4), etc.

Sulphuric Acid (H_2SO_4):

The concentration of sulphuric acid (H_2SO_4) can be determined by using Baume's (ºBé) hydrometer. The titration of sulphuric acid is carried out using sodium hydroxide in the presence of phenolphthalein as an indicator. The end point is reached when a faint pink color is persistent.

Acids

HCl

The concentration of hydrochloric acid (HCl) can be determined using a hydrometer, in a very similar manner to the determination of sulphuric acid concentration. Hydrochloric acid is a volatile acid at high concentration.

HNO_3

The concentration of nitric acid (HNO_3) can be determined using a hydrometer. If titration is used to determine the concentration, phenolphthalein is the indicator.

H_3PO_4

The concentration of phosphoric acid (H_3PO_4) can be determined in a similar manner to that discussed for H_2SO_4, HCl and HNO_3.

Organic Acids

2. Organic Acids:

Organic acids are HCOOH (formic acid), Acetic acid etc.

HCOOH

HCOOH (formic acid) is the simplest organic acid in terms of its organic structure. Concentrated HCOOH is usually 88% in strength. Since formic acid is a volatile acid, precautions should be taken to prevent loss of strength in the sample preparation stage. The concentration of formic acid can be determined by acid– base titration as well as by redox titration owing to the reduction power of formic acid.

CH_3COOH

Acetic acid is a weak acid. It is available at different concentrations. Highly concentrated acetic acid at 98% and above is called glacial acetic acid because its freezing point range is between 13.3ºC (98%) and 16.7ºC (100%). Glacial acetic acid is flammable. The concentration of acetic acid can easily be determined using acid–base titration with phenolphthalein as an indicator. The water used should be free from CO_2, prepared by boiling before use.

Salts

Function of Salt in the Textile Wet Processing

The textile substrate and dye molecule, not necessarily should have of homogeneous characteristics to combine with each other. In such case, we require some catalyst to facilitate dyeing action on fabric. Salt plays this crucial role of catalyst. Salt has an extremely high affinity for water.

Salt is necessary in three ways, firstly, to drive dye into textile during the **dyeing process in textile**. Secondly, use of salt leads to maximum exhaustion of dye molecules during dyeing process in textiles. Thirdly it is used as an electrolyte for migration, adsorption and fixation of the dyestuff to the cellulose material. The salt is used to attract dyes to the fiber before they become permanently fixed by the addition of alkali.

Salts plays important role in **reactive dyeing** by improving the affinity of the dyestuff towards the fiber and acceleration of the dyestuff's association and lowering its solubility. Normally, Glauber's salt or common salt/ vacuum salt (NaCl) is used for this purpose. While dyeing turquoise shade/royal blue shade, glauber salt must be used as an electrolyte (salt) for the dyeing process. The presence of chlorine ion in the common salt may cause corrosion of the equipment.

Glauber's salt is always preferred over common salt. Glauber's salt is a common name for sodium sulfate decahydrate, $Na_2SO_4.10H_2O$; it occurs as white or colorless monoclinic crystals. Upon exposure to fairly dry air it effloresces, forming powdery anhydrous sodium sulfate.

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Salts

Role of Inorganic Salt in Reactive Dyeing:

Inorganic salts have two main functions in exhaustion dyeing with **reactive dyestuffs**:

1. Improving the affinity of the dyestuff.
2. Acceleration of the dyestuff's association and lowering of its solubility.

Generally reactive dyes contains sulphonic acid (-SO_3H) group which is insoluble in water. During the manufacturing of the **reactive dyes** these sulphonic acid groups are converted into the sodium salt of sulphonic acid (-SO_3Na) which is soluble in water.

Reactive dye – $SO_3H + Na^+ \rightarrow$ Reactive dye SO_3Na

Function of Salt in the Dyeing Process:

1. The salt in the reactive dyeing increases the affinity of the dye towards the Cellulosic substrate.
2. Salt increases the exhaustion rate of reactive dyestuffs.
3. As reactive dyestuffs have a lower affinity, more inorganic salt is required when using reactive dyestuffs in order to accelerate absorption.
4. While the amount of inorganic salt used varies according to the type of dyestuff used, recently developed high-fixation dyestuffs with improved affinity allow the amount of inorganic salt to be reduced.

Sodium chloride

Industrial grade NaCl has a content of 92–98%. The precipitation titration can be conducted using 0.1 N $AgNO_3$ as the titrant and 5% K_2CrO_4 as the indicator (the Mohr method). The sample chloride solution should be buffered with calcium carbonate to a pH between 6.3 and 7.2 in order to avoid any interference from other ions present in the solution.

Sodium sulphate

Na_2SO_4 is available in two types, anhydrate and decahydrate. Its content analysis can be conducted based on the precipitation method using barium chloride ($BaCl_2$).

An excess amount of barium chloride is added into the sample solution which has been filtered beforehand to form $BaSO_4$ precipitate as indicated by the following reaction:

$Na_2SO_4 + BaCl_2 \rightarrow 2NaCl + BaSO_4\downarrow$

Bases (Caustic)

A base in chemistry is a substance that can accept hydrogen cations (protons) or more generally, donate a pair of valence electrons. A soluble base is referred to as an alkali if it contains and releases hydroxide ions (OH^-) quantitatively.

Bases are two types:

1. Inorganic and
2. Organic bases

1. Inorganic Bases:

Inorganic bases are Sodium hydroxide (NaOH), Sodium carbonate (Na_2CO_3), Ammonium hydroxide (NH_4OH) etc.

NaOH

Sodium hydroxide (NaOH) is also called caustic soda. It is available in solution at different concentrations or in solid form. Commercial NaOH often contains a little sodium carbonate (Na_2CO_3) as a by-product of the manufacturing process. This small amount of Na_2CO_3 will usually not influence its use in textile wet processes.

Owing to its strong alkalinity, NaOH can react with CO_2 in air easily. It can also absorb water very quickly.

Na_2CO_3

Sodium carbonate (Na_2CO_3) is also called soda ash. In textile wet processes, it is often available in anhydrous form. Its purity can be > 99% Na_2CO_3 (58% Na_2O).

If the concentration of a Na_2CO_3 solution needs to be determined, a titrimetric method identical to the ones listed for NaOH in this section can be used.

NH_4OH

Ammonium hydroxide (NH_4OH) is a water solution of ammonia gas (NH_3). It can also be called aqua ammonia or ammonia water. The concentration determination can be done using either a hydrometer or an acid–base titration. Since ammonia is volatile, the concentration determination should be done with care to avoid any loss of strength. If a hydrometer is used, the sample and the hydrometer should be cooled to 5–10ºC. Acid–base titration can also be used to determine the concentration of NH_4OH.

Organic Bases

Organic bases are Triethanolamine, $N(CH_2CH_2OH)_3$, Ethylenediamine $(H_2NCH_2)_2$ etc.

Triethanolamine
Triethanolamine, $N(CH_2CH_2OH)_3$, is a strong organic base miscible with water, methanol and acetone. The pH of its 0.1N aqueous solution is 10.5. Analytical grade $N(CH_2CH_2OH)_3$ is a highly hygroscopic and viscous liquid with a pale yellow or no colour. Its melting point is between 18 and 21ºC. Its density is about 1.12.

Ethylenediamine
Ethylenediamine, $(H_2NCH_2)_2$, is a strong organic base miscible with water and alcohol. It is a colourless and viscous liquid with a density of 0.898 and a melting point of 8ºC. The pH of a 25% aqueous solution is 11.5. Like triethanolamine, it is an aliphatic amine soluble in water and, therefore, can be determined by the acid–base titration with methyl orange as an indicator.

Chemicals inputs to wet processes

•**Sizing** Polyvinyl alcohol, Carboxymethyl Cellulose, Oils, Waxes,

Adhesives, Urea, Diethylene glycol, etc.
•**Desizing**Enzymes, Sulphuricacid, Detergents and Alkali
•**Scouring** Sodium hydroxide, Sodium Carbonate, surfactants, chlorinated

solvents
•**Bleaching** Hypochlorite, hydrogen peroxide, acetic acid.
•**Mercerization** Sodium hydroxide, surfactants, acid, liquid ammonium
•**Dyeing** Dyestuffs, auxiliaries, reductants, oxidants
•**Printing** Dyes (acids or alkalis), pigments, kerosene, binders, ammonia,

xylenes.
•**Chemical finishing** Formaldehyde, phosphorus, ammonia, silicone, fluorocarbon, resins, toluene, zircon salts etc.

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