Cleaner Production in Textile Wet Processing
Cleaner Production in Textile Wet Processing

A Workbook for Trainers

First Edition • March 1996
Acknowledgements

The first version of this trainers workbook was prepared in March 1996 by Dr Prasad Modak for UNEP IE and later edited by Fritz Balkau.

It was subsequently trialled in workshops and courses in several places, leading to subsequent revisions to produce this current document.

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United Nations Publication

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Users Guide

This is a trainers support package, not a reference book. It does not give a systematic, comprehensive overview (there is not enough room to do this); rather, it focuses on some selected aspects that are central to the subject. The structure of the document allows further sections to be easily developed and added as additional modules.

The package is written for trainers to provide them with support material and ideas. It has not been intended as a study book for students. The average trainee will only ever see a few pages or exercises reproduced from this document.

One of the purposes of this package is to provide some case studies and situation scenarios that can be used as a basis for interactive training and simulated decision-making. The exercises only explore a small part of the potential of the case studies, and trainers are strongly encouraged to develop further exercises or tasks.

The package is oriented at developing insights and decision-making skills. It is not particularly suited to teaching the factual knowledge base of the subject. For this, trainers are referred to the reading lists in the bibliography.

Work exercises are predominantly based on interactive groupwork and a team approach to problem-solving. Such work needs to be guided by a tutor who is a recognized expert in the field. This method allows the full complexity of real decision-making to be explored.

Where calculations are required, the exercises are more oriented towards throwing light on useful approaches or management decisions than simply finding the ‘correct’ answer. Trainers are strongly urged not to see this package merely as a set of arithmetic exercises.

In some instances, answers are indicated. The ‘correct’ answer often depends on the context of the question. It is here that a tutor or external resource expert is useful.

Many trainers find this disturbing. They should remember that real decision-making depends on the wider circumstances surrounding the problem, and that a numerical answer which is politically or socially unacceptable, or administratively unworkable (even though accurate), is not in effect ‘correct’.

The simulation of real life situations and decision-making that is the basis of this package makes it most suitable for senior students and trainees, and especially for professional training (or retraining) courses.

Do not forget to also refer to the package on Cleaner Production for teaching the underlying concepts and approaches in this workbook.

Finally, we must stress again that this package does not cover all aspects of the subject. Its prime purpose is to lead trainers into this field, and to help and encourage them to develop their own material, appropriately tailored to their specific learning situation. UNEP is prepared to work further with trainers who wish to extend this package into new directions, or go into greater depths on some subjects.
How to start a training activity based on this workbook

1. **Remember that this is a starters kit**, not a complete recipe book. Remember also that the workbook aims to develop insights and decision-making skills, not to convey knowledge or facts.

2. **Understand the needs of your trainees.** What insights or skills do you intend to develop? Define your learning objectives.

3. **Refresh your memory** by reading some of the background papers and studying the overhead transparencies. Write your own notes in the spaces provided.

4. **Identify some expert resource persons** who could be invited as tutors to help you in discussion sessions.

5. **Select some of the exercises** you wish to present to trainees.

6. **Examine carefully the case study or scenario** on which they are based. Be sure that you have at least one solution to the exercise that you can explain and defend.

7. **Develop other exercises or questions yourself.**

8. **Develop your own local case study** if you can, and use this instead of the one in the package.

9. **Prepare some background questions** and preliminary exercises for trainers to carry out before they start the workshop/course.

10. **In session, summarize the issues** for trainees using the overheads given, and others you may have. Discuss the problems and difficulties decision-makers face. Discuss where factual information can be found to help in decision-making.

11. **Commence the work sessions**, preferably in small groups, and preferably guided by a tutor. Discuss and compare results. Be open to ideas and experiences from trainees, and discuss these.

12. **Return to the learning objectives**, and check that they have been achieved.

13. **Consider how to follow up and reinforce** the learning experience by establishing some ongoing projects, or periodic reunions.

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To facilitate using this workbook, the header of odd-numbered pages describes the contents of that particular section. This information is also repeated in the footer of even-numbered pages. You can track your progress through the workbook by referring to the calibrations on the bar across the bottom of odd-numbered pages:

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The shading shows your current position in the text.
This glossary contains some terms which are used in the background papers and exercises, or which you may come across when gathering information about the topic. You may want to add some terms to this list.

These terms have been taken from the Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites, the Code of Practice for the Investigation and Mitigation of Possible Petroleum-Based Land Contamination, the UNIDO training course on Ecologically Sustainable Development, some US EPA publications, and some UNEP IE publications.

Absorptivity The ability to absorb matter in bulk (e.g. water, dissolved chemicals, gases).
Aquifer An underground rock formation composed of materials such as sand, soil or gravel that can store and supply ground water to wells and springs.
Background levels Levels of substances or chemicals that are commonly found in the local environment.
Bioaccumulation The retention and concentration of a substance by an organism.
Biodegradation Decomposition of substances into more elementary compounds by the action of micro-organisms.
Biomagnification The serial accumulation of a chemical by organisms in the food chain, with higher concentrations of the substance in each succeeding trophic level.
Biological monitoring Measurement of a contaminant or metabolite in body tissue or fluid.
Clean-up The removal, treatment or containment of soil contaminated with chemicals at unacceptable concentrations.
Cleaner production The continuous application of an integrated preventive strategy to processes and products, in order to reduce environmental risks and impacts.
Contaminated A condition or state which represents or potentially represents an adverse health or environmental impact because of the presence of potentially hazardous substances.
Contaminated site A site where the level(s) of hazardous substances is (are) above response level(s): i.e. where the site specific assessment deems that a response is required to protect health or the environment.
Cradle-to-grave Term used to imply the whole life cycle of a product, from raw material to final disposal.
End-of-pipe treatment Treating pollutants at the end of a process (by, for example, filters, catalysts and scrubbers) instead of preventing their occurrence.
Environmental auditing The management tool comprising a systematic, documented, periodic and objective evaluation of how well environmental organization, management and equipment are performing. The aim is to help to safeguard the environment by: (i) facilitating management control of environmental practice; and (ii) assessing compliance with company policies, which would include regulatory requirements.
Environmental impact assessment An analysis to determine whether an action would significantly affect the environment.
Environmental risk assessment The process of estimating the potential impact of a chemical or physical agent on a specified ecological system under a specific set of conditions.
Exposure Contact with a chemical, physical or biological agent.
Exposure assessment The estimation (qualitative or quantitative) of the magnitude, frequency, duration, route and extent (for example, number of organisms) of exposure to a chemical substance or contaminant.
Hazard The capacity to produce a particular type of adverse health or environmental effect: e.g. one hazard associated with benzene is leukemia.

Health risk assessment The process of evaluating the potential impact of a chemical or physical agent on a specified human population system under a specific set of conditions.

Hydrology The science dealing with the properties, movement, and effects of water on the earth's surface, in the soil and rocks below, and in the atmosphere.

Incineration Burning of certain types of solid, liquid, or gaseous materials under controlled conditions to destroy hazardous waste.

Indicator analytes Readily measured chemicals that can indicate the probable presence of certain classes of chemicals or substances.

Investigation level The concentration level of a contaminant above which further appropriate investigation and evaluation will be required.

In-situ In the original place or location.

Leachate A contaminated liquid resulting when water percolates, or trickles, through waste materials and collects components of those wastes.

Life cycle analysis A quantitative assessment of the total environmental impacts caused by a particular process or product, from resource consumption to contamination, from the cradle to the grave.

Mass/material balance A precise account of all the inputs and outputs of a process, based on the law of conservation of mass.

Metabolite A substance produced or modified by metabolism in an organism.

Mobility The ability of particles and substances to move, either by random motion or under the influence of field forces.

Monitoring wells Special wells drilled at specific locations on or off a hazardous waste site where groundwater can be sampled at selected depths and studied to determine such things as the direction in which groundwater flows and the types and amounts of contaminants present.

Persistence The ability of a substance to remain unaltered for prolonged periods.

Phytotoxicity Toxicity of a substance for plants.

Pollution Degradation or impairment of the purity of the environment by causing a condition which is hazardous to public health, safety, aesthetics or welfare, or to animals, birds, wildlife, fish or aquatic life, or to plants.

Porosity Property of a solid which contains many small channels or open spaces.

Preliminary assessment The process of collecting and reviewing available information about a known or a suspected hazardous waste site or release. If further study is needed, a site inspection is undertaken.

Receptor An organism, plant or physical structure that receives, may receive or has received environmental exposure to a chemical.

Remediation The clean-up or mitigation of pollution/contamination of soil by various methods.

Response level Response levels apply to a specific site and site assessment and are levels at which some form of response to protect public health and/or the environment with a wide margin of safety is required.

Risk The probability that an adverse outcome will occur in a person, a group, or an ecological system that is exposed to a particular dose or concentration of a hazardous agent: i.e. it depends on both the level of toxicity of hazardous agent and the level of exposure.

Risk management The process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probabilities of occurrence.

Site inspection A technical phase that follows a preliminary assessment designed to collect more extensive information on a contaminated site.

Sustainable development Meeting the needs of the present generation without compromising the ability of future generations to meet their needs.

Technology assessment An analytical tool used to help understand the likely impact of the use of a new technology by an industry or society.

Toxicity The quality or degree of being poisonous or harmful to plants, animals or humans.
Part 1

Introduction

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1 Introduction

Many teaching institutions and individual trainers have difficulty in following the rapid evolution of environmental issues that are relevant to their courses.

This is particularly true when teaching subjects such as pollution and environmental management. And yet it is important that new graduates have a good knowledge of issues in which they may eventually provide consulting services or policy advice to governments and industry.

The fact that development and environment are interrelated means that it is more vital than ever that:

- all professionals have a basic environmental literacy that helps them to incorporate environmental priorities into their specialized work, whatever their profession;
- specialized environmental courses are relevant to today's environmental agenda.

In 1993, in response to these findings, UNEP, WHO, and ILO jointly initiated the programme on Training Approaches for Environmental Management in Industry. The programme aims to enhance the capacity of national institutions to offer local training on topics concerned with the prevention of industrial pollution.

In this context, trainers' packages have been prepared on different areas of environmental management. These packages are intended to help educators and trainers to develop their own workshops or curricula, or to integrate some of the ideas and information into already existing teaching programmes.

It is important to keep in mind that these training resource packages merely provide a first orientation to the topic.

In no way does the package constitute a 'course' in its own right.
1.1 This package

This package is a workbook that complements
the trainer's package on 'Cleaner
Production'. For best results, both should be used
together. In many cases, it would be useful to use
the Cleaner Production material as an
introduction to any curriculum-based material in
this workbook.

The workbook is balanced between curriculum-
based content (useful for technicians) and a more
management systems approach (useful for
supervisors and managers). In practice, both will
be needed, and the trainer is urged to develop a
balanced curriculum in response to the needs of
his/her audience. Any missing elements may be
found in one of the other UNEP manuals, to be
converted into training format based on the case
studies and scenario included here.

Thus, the package is not static.

As feedback is received from users and
technical specialists, the material will be
modified and enriched.

Users are encouraged to report on their
experiences in using this package, and to send in
suggestions for improvements.

1.2 Contents of this package

This package is conceived principally to
help trainers prepare a seminar,
workshop, or extended course. It is not a
course per se.

The package contains:
• suggestions and hints for effective training;
• a short background to the subject, drawn from
other existing publications;
• overhead transparencies to introduce and
illustrate the main ideas;
• case studies and situation reports and scenarios
drawn from actual experience;
• work exercises and questions;
• annexes containing supplementary technical
information to support some work exercises;
• appendices with further information about
UNEP and its programmes.

Trainers are encouraged to extend the package by
adding their own case studies and exercises, and
expanding the subject coverage into new topics.
For example, trainers in environmental health may
wish to add some modules on occupational safety
and ecotoxicity by building on the chemical
information already presented.
Part 2
Organizing Effective Training Activities

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2 Organizing Effective Training Activities

2.1 Introduction

Communication and organizational skills are just as important as a technical appreciation of the subject. Professional educators already understand this point, but teaching is a very individual matter, and interactive teaching can be very demanding on a busy person.

Here, we recall some of the key aspects of the learning process.

This text contains suggestions about:
- how to ensure maximum effectiveness as a trainer
- how to organize effective training activities and presentations.

We have provided this advice before consideration of the technical material, so that readers can remind themselves of the importance of the advice when choosing work exercises and training projects, later in this package.

Adults learn best when they are actively engaged. They remember 20% of what they hear, 40% of what they see, and 80% of what they discover for themselves.

Accordingly, this package relies on interactive teaching methods, using working exercises, case studies, and groupwork problem-solving, rather than on lecture format.

Interactive techniques are more complex to organize than simple lecture-giving, but they give better results. In particular, interactive methods are more likely to provide students with practical skills. This is important where skill development rather than factual knowledge is the objective.

Lectures are better at providing factual knowledge than at developing skills.

For example, a workshop format is very effective in providing training on the effective use of management tools such as Environmental Impact Assessment (EIA), or audits. For high level environmental management, both knowledge and skills are required, so the appropriate mixture of techniques should be used.

The notes in this Part are based on the experiences of UNEP IE and WHO in organizing workshops and other training sessions.

Personal advice on how to be an effective trainer is also given by several experienced trainers, who all use interactive training approaches.
2.2 Notes on interactive workshop organization

2.2.1 Workshops

Workshops provide a stimulating learning environment where people with a wide range of experiences and skills can join together to address practical problems beyond the ability of an individual to resolve.

Interactive workshops use a combination of several techniques to bring about a deeper and more pragmatic learning experience than is possible with a lecture-style format.

Workshops also provide excellent opportunities for exchanging personal experiences, problem-solving through panel sessions and direct consultations with experts, and discussing some of the complex situations which surround most environmental problems.

The UNEP/WHO workshop format incorporates the following elements:

- preparation of a country report by each participant before the workshop
- short introductory or overview lectures on key issues
- practical problem-solving work exercises on case studies
- feedback by experts and discussions on workshop exercises
- panel sessions (that is, question-answer dialogues) with experts
- individual study sessions, computer quizzes, and so on.
- structured oral presentations of country reports leading to a regional overview
- audiovisuals such as videos, films, and slides
- field visits where appropriate
- personal action planning by participants for follow-up activity.

2.2.2 Preparation

Sessions need to be carefully prepared, with participants knowing in advance what they will do or see. A proforma report form for country reports gives a common format to these sessions. Country reports should also try to link the issues with other sessions.

It cannot be overstressed how important it is that participants should be thoroughly prepared for the workshops, and that all the pre-workshop activities have been completed.

2.2.3 Organization

The organization of working group sessions also requires care. Groups should first meet informally, elect their own chairman, and then act as a permanent team in various workshop sessions. They are guided, but not instructed, by technical experts.

It is useful to finish the workshop by preparing personal action plans. Participants should develop and present their proposals for what they can initiate immediately on their return home. Such action includes:

- what they can achieve unassisted, and
- what else they could achieve if some assistance were available.

The role of resource experts as advisors is crucial. They should have sufficient experience to assist in all sessions and provide general advice on all subjects in workshops, discussion or panel sessions. They should not, however, dominate the workshops.

The five day format is ideal for covering all these requirements. If less than five days is taken, you can be sure that important issues will be left out. If more time is available, consider including social events and private study sessions, along with more extensive project work for the students.
2.3 Some ideas for more effective communication

If the training is to be successful, effective communication is essential – from recognition of the training need to the final evaluation of the event.

Without good communication, all manner of things can go wrong:
- the training is too early – or too late – to make any impact on performance
- trainees do not know what the training is about or what to expect
- the course is planned for a local public holiday
- trainees who are traditionally used to lectures are suddenly required to take part in discussion groups, which might feel alien to them.

Most of these issues can be anticipated and overcome by good communication between the course designers, writers, and event organizers and presenters on the one side, and the students and their organizations on the other.

Some simple communication considerations will help to improve outputs in training and avoid disasters.

Before the learning event
Find out:
- how the learners have been taught in the past
- the real needs and situation of the learners
- whether the facilities are adequate for the envisaged training
- whether the training has the support of senior people
- how success will be measured.

Make a project plan for the organizers, giving details of how the event will be organized. Send the plan to them, with details of the key dates and needs.

During the learning
- find out how relevant the topics are to the work situation of the participants
- start with the familiar oil can – not a video of an oil spill disaster
- communicate using topics, themes and issues in the local press
- store unanswered questions, and remember to answer them before the end
- keep notes for participants to bullet-point format
- ensure the participants keep notes for future reference – few read essays, or even articles
- if you are working in a foreign language, at least translate the slides.

After the learning event
- always communicate your thanks and best wishes
- inform participants on follow-up study procedures, and how the instructor can help to analyze the evaluations and inform the organizers of the results
- communicate to colleagues the results of the training and what can be learned from these results.
2.4 Some personal suggestions for effective training

The following suggestions come from four teachers with long experience in training. They are all different in character, and therefore in teaching approaches. However, they all believe in an enthusiasm for the subject which is critical when teaching students.

To be an effective educator/teacher:
- Provide an enjoyable learning situation that expands all of the participants' network.
- Model courses and teaching styles on examples that you think are outstanding. Ask yourself about the qualities of a good instructor or a good course, and follow the answers you come up with.
- Allow the subject matter to be discussed and discovered by students – not hammered in.
- Make courses relevant and interesting by understanding your audience. Ask them what they already know, and then plan for their needs.
- Incorporate ideas from the group in the course.
- Remember that no amount of style will substitute for a lack of substance.

Deborah Hanlon, Environmental Scientist
Office of Environmental Engineering and Technology Demonstration, US EPA

The outstanding educator/teacher:
- Is fully acquainted with, and believes in, the educational merit of the subject matter.
- Utilizes clear and graphic illustrations to inform and motivate the students to learn.
- Utilizes learning approaches including multimedia, projects, interviews, questionnaires, debates, and similar interactive approaches to ensure full involvement of the students.
- Reacts positively to all questions – there are no Stupid Questions, only Stupid Answers.
- Remembers that positive reinforcement is a better motivational approach than criticism.
- Is available for private discussions with individual students or groups of students.

Don Huisingh, Environmental Consultant and Professor at Erasmus University in Rotterdam, The Netherlands

To be efficient ('doing things right'), and effective ('doing the right things'):
- Think about helping people to learn, rather than teaching them.
- Seek learner feedback, and measure learning achieved with objective tests.
- Set learning time limits.
- Seek conscious and unconscious learning.
- Seek learning that endures, based on understanding and skills.

Bob Boland, Environmental Consultant, France

The best educator/teacher:
- Likes the learners, and has a true understanding of how they learn.
- Has the ability to communicate.
- Will change the training programme and the approach if necessary.
- Is still learning, and has recent applied experience of the subject being taught.
- Has the ability to organise events and to manage things.

Colin Sutherland, Educational Consultant, France

Cleaner Production in Textile Wet Processing: A Workbook for Trainers
Part 2 • Organizing Effective Training Activities
2.5 Resource persons guide

As this package relies heavily on interactive groupwork sessions, here are some guidelines on how to be an effective resource person.

In a case study-based training approach, the resource person serves more as a:
- facilitator of the group learning process
- technical adviser as needed,
  and a
- catalyst of learning
  rather than a:
  - lecturer
  - story-teller
  or
  - instructor.

Here are some guidelines on how to be an effective resource person.

1. Be sure that you have read and understood thoroughly the participant's notes before you meet your group. There's nothing like being prepared and more familiar with the case study scenario than the participants are!

2. Before every group work session, take time to visit your assigned meeting room and check the:
   - seating arrangements: There should be a large enough table surrounded by enough chairs for the participants and yourself
   - equipment and supplies: such as flipcharts, flipchart papers, marker pens, white/black board, board eraser, masking tape, transparency sheets, writing pads, ballpen/pencils, calculator, etc.
   - physical conditions of the room: There should be sufficient lighting, the room temperature should be comfortable, noise should be as low as possible, etc.

3. During the initial group meeting, it is important to set an informal and friendly atmosphere. It is suggested that you:
   - introduce yourself, preferably asking everyone to call you by your first name, and then let everybody introduce himself/herself in a similar manner. Do not waste time stating positions and respective organizations, etc., which should have been done on the first day anyway.
   - then ask if the objectives and purpose of the exercise, which have been previously discussed in the plenary session, are clear to them.

Sample objectives are:
- identify and understand the options that SMEs can employ in their pollution prevention program
- evaluate the feasibility and suitability of these options in view of technical, environmental, financial, organizational, and social criteria and constraints.

It will be useful to know whether the majority of the group members have actually read the text provided, which states the background and the problem.

If they have not, then you will need to direct them to focus their attention first on what needs to be accomplished by the end of each part.

4. If your group gets involved in diverse issues, try to steer them back on the right track by asking relevant questions, rather than telling them what to do.

5. Give technical assistance and supplementary information as needed,
without ‘spoon-feeding’ the participants. However, do not lecture or dominate the group discussion process.

6 Although you need not stay with your group for 100% of the time, it is expected that you:
• spend at least 80% of the time with them during regular sessions. The crucial times are at the beginning, middle, and near the end of each groupwork session.
• If they decide to work beyond the prescribed regular time, just make sure that they are on the right track; your presence during overtime is not mandatory, but voluntary.

7 There will be critical parts during the identification of options, followed by technical, environmental, and economic evaluation, where your technical advice will be most needed by your group.

The best way to assist the participants is by giving only the advantages and disadvantages of the options in question. Let them weigh these pros and cons and decide for themselves whether to take or drop the option.

8 If you encounter any question about the technical content of the material that you have not been briefed on, discuss it with the Team Leader and agree on how to tackle the situation. It may well be that the other resource persons need to be duly advised on the particular question.

9 See to it that you compare notes, exchange hints, and share strategies with other resource persons so that you can assist one another, as well as gauge your group’s progress in comparison with the others.

10 If tension or heated argument arises among your group members, try your best (with a sense of humor) to defuse it.

11 In the case of absenteeism, approach the person/persons in question and encourage them to participate.

12 If one or two group members are dominating the discussions or doing all the work, intervene and encourage everyone to get involved. In order to do this effectively, you need to be attuned to your group’s ‘culture’ and trend of discussion.

13 Although division of labor is a time saving group work strategy, you must ensure that it is not done to the extent that there is no peer learning and discussion occurring. It is counter-productive for group members to work individually on these exercises.

14 The most productive, meaningful and fulfilling group work is when they get to accomplish what they have to do as a team – and have fun in the process!
2.6 Suggestions for self study

Although this package was designed to provide resources for trainers, the potential for self-study should not be ignored. The package does not constitute a complete course on cleaner production in leather tanning, but can be seen as an introduction to be supplemented by further reading and additional training materials listed in the Appendices, and perhaps by site visits and discussions with professionals.

The following approach is suggested for individual study:

- Read the introduction, but avoid any sections on organizing training events.
- Seek out the section containing background papers or subject content. Read through the whole section as narrative.
- Work through the pages offered to the trainer for overhead projection, and ensure you can relate the key points of each overhead to the text you have read.
- Look at the section on exercises. Identify those which lend themselves to individual work, and tackle them. Those exercises clearly constructed for teamwork, or requiring research, may not be appropriate.
- Refer back to the narrative text as and when you need to, to complete the exercises.
- Check your answers against those given in this resource pack. Where there are discrepancies, check through your own working to understand why the discrepancies appeared.
- Use the Appendices to plan your own further development.
Part 3

Introduction
to Current Environmental Issues and Aspects of Textile Wet Processing

3.1 Introduction .......................................................... III:3
3.2 Understanding environmental problems.......................... III:4
3.3 Environmental aspects of the textile processing industry... III:6
3.4 Exercises ............................................................ III:9
3.5 Solutions .................................................................. III:11
3 Introduction

to Current Environmental Issues and Aspects of Textile Wet Processing

3.1 Introduction

This training resource package gives an introduction to cleaner production opportunities in textile wet processing. It is part of a larger interagency initiative to provide educators and institutional trainers with up-to-date teaching resource material on key environmental issues in sustainable industrial development. You will find a complete list of other available training resource package materials at the end of this publication.

This package is suitable for people who are active in the textile industry, as well as those who would like to acquire a better understanding of the cleaner production approach through interactive exercises, focusing on different unit processes of textile processing:

Part 3 contains a general introduction to current environmental issues and their significance to the textile industry.

Part 4 presents an introduction to textile wet processing processes.

Parts 5, 6 and 7 each provide data on major process steps, and are followed by specific problem solving exercises to optimize the process or find less polluting alternatives.

These exercises simulate actual situations that may be found in an average textile wet processing house. However, they require some understanding of the textile wet processes. The exercises can be done either through individual study or through interactive groupwork problem solving. Suggested answers to the problems are provided at the end of the exercises.

Annex 1 presents a section on the transpollution related issues which are of importance to the textile industry such as ecolabelling etc. This section also dwells on the areas of hazard management and workspace safety.

Annex 2 presents a comprehensive compilation on best environmental practices specific to the textile industry.

UNEP Technical Report No. 16, Textile Industry and the Environment, is expected to serve as the background reading on textile processing, including cleaner production options. The Audit and Reduction Manual for Industrial Emissions and Wastes Technical Report No. 7, developed by UNEP and UNIDO, also provides useful background information.

Note: This package may be used as a stand-alone. You may also want to include it as a supplement to the UNEP 1E training resource package on Cleaner Production. Nevertheless, the package does not function as a complete course on cleaner production in textile processing. For this, the trainer is encouraged to build further on the package and develop his/her own training tools and exercises.
3.2 Understanding environmental problems

This section and the associated reading excerpts are designed to acquaint you with the major environmental problems associated with industrial development. For those familiar with environmental problems, it may not be necessary to read this section. For others, the study materials will serve as an introduction, and the reading excerpts may be read at another time.

Readers are also referred to Chapter 3 of the UNEP Technical Report No. 16 The Textile Industry and the Environment. For in-depth reading on the environment, refer to Part 8 and Appendices I and II of this workbook.

3.2.1 Global climate change

The natural concentration of CO\textsubscript{2} in the atmosphere is controlled by the interactions between the atmosphere, the oceans and the biosphere in what is known as the biogeochemical carbon cycle. Human activities can disturb this cycle by injecting additional CO\textsubscript{2} into the atmosphere, thereby aggravating the natural greenhouse effect. Over the past 100 years, the global mean temperature has risen by 0.3° to 0.6°C. A doubling of atmospheric concentrations of CO\textsubscript{2} is expected to increase the global mean temperature in the range of 1.5° to 4.5°C.

Most CO\textsubscript{2} is generated from energy production and transport activities. Research over the last two decades has found that other gases such as nitrous oxide, methane, chlorofluorocarbons (CFCs) and tropospheric ozone are also greenhouse gases.

3.2.2 Ozone depletion

In contrast to the harmful ozone (tropospheric ozone) formed as a photochemical oxidant at ground level, ozone in the stratosphere (stratospheric ozone), between 25 and 40km above the earth’s surface, is a natural filter that absorbs and blocks the sun’s short-wavelength ultraviolet (UV-B) radiation, which is harmful to life.

CFCs are used as propellants and solvents in aerosol sprays; as fluids in refrigeration and air-conditioning equipment; as foam-blowing agents in plastic foam production; and as solvents, mainly in the electronics industry.

Studies in the 1980s showed that emissions of bromine can also lead to a significant reduction in stratospheric ozone. Bromofluorocarbons are widely used to extinguish fires, and ethylene dibromine and methyl bromide are used as fumigants.

3.2.3 Acidification

Acidification refers to the gradual increase in acidic conditions in soils, forests and lakes. Such an increase also occurs in urban environments, where it contributes to the deterioration of metal and stone.

Acid deposition may be absorbed, even in sensitive areas, by the natural buffering capacity of the environment. However, the onset of acidic conditions in an environment may occur long after an increase in acid deposition.

The main anthropogenic source of acid-forming gases, primarily SO\textsubscript{2} and NO\textsubscript{x}, is the burning of fossil fuels in power stations.

Additional sources include metal ore smelting, sulphuric acid manufacture and other industrial processes.
3.2.4 Toxic chemicals and hazardous wastes

All chemicals are toxic to some degree. The health risks from a chemical depend mainly on its dose/toxicity and on exposure. Just a few parts per billion of a highly toxic compound such as dioxin may constitute a threat to health after only brief exposure. In contrast, only high doses of compounds like iron oxide or magnesium carbonate pose problems after extended exposure.

An important development has been the shift from a focus on just the acute effects of chemicals to a focus on their chronic effects as well. These chronic effects include birth defects, genetic and neurological disorders and cancer.

Although the term ‘hazardous’ has different connotations in various countries, it is widely applied to wastes containing metallic compounds, halogenated organic solvents, organohalogen compounds, acids, asbestos, organophosphorus compounds, organic cyanides and phenols. Most hazardous wastes are produced by industry, but it is now recognized that there are hundreds of thousands of smaller sources of hazardous wastes that add to the problem. These include households, medical facilities, garages and auto-repair workshops, petrol stations and small-scale industries and businesses. Many hazardous wastes come from sludges in treatment plants.

3.2.5 Atmospheric pollution

Air pollution refers to gaseous or particulate contaminants in quantities, characteristics or durations that are injurious to humans, plant or animal life or to property.

The combustion of fossil fuels, both for power generation and transportation, is the major source of atmospheric pollution.

The previously known common air pollutants are SO₂, NOₓ, suspended particulate matter (SPM), hydrocarbons (HC), carbon monoxide (CO) and lead (Pb). More recently, research has demonstrated the adverse effects of volatile organic compounds generated from various sources, including solvents in industry.

3.2.6 Water pollution

The amount of fresh water available represents less than 0.01% of the earth’s water reserves. Of this amount, about half (approximately 4 000km²) is used by industry each year.

Some water pollutants, such as organic wastes from agro-industries and human settlements, are easily decomposed into substances that are normally harmless. However, at high concentrations, they may seriously disturb the ecosystem. Other pollutants, such as metals and persistent organic compounds, cannot be degraded; they usually remain absorbed in bottom sediments near the source of discharge.

Some organisms have a remarkable ability to accumulate such pollutants, even when they are present in extremely low concentrations.

Both the atmosphere and rivers contribute to marine pollution. The atmospheric pathway accounts for more than 90 per cent of the lead, cadmium, copper, iron, zinc, arsenic, nickel, PCBs, DDT and hexachlorofluorohexane found in untreated or inadequately treated wastewater from cities and industrial plants. Contaminants from agricultural lands, forests and roads can be significant in rural areas. Industrial effluents are a particularly significant source of water pollution.
3.3 Environmental aspects of the textile processing industry

The textile industry is among the largest industries in the world with regard to production and labour. It exhibits a typical variation in scale: e.g. from large scale mechanized to small scale traditional units. Broadly, this industry is classified into the cotton, woollen and synthetic fibre industries. The reader may refer to UNEP Technical Report No. 16 on the Textile Industry and the Environment (specifically Chapter 2.0) for an overview of textile wet processing operations.

The textile industry is characterized not only by the vast quantity of water required, but also by the variety of chemicals used. Generally, there is a long sequence of wet processing stages, and therefore many requirements for resource inputs and several sources of waste generation. Other features of this industry include variations in fabric production and profiles, and hence fluctuations in flow rates and waste concentration.

Amongst the contributions to wastes, liquid wastes tend to dominate over air emissions and solid wastes in terms of severity of environmental impact. Solid wastes generate from fabric rejects, containers and bags etc. Liquid wastes arising from the various washing operations contain a substantial pollution load in terms of organic matter and suspended matter, such as fibres and grease. These liquid wastes are generally hot and alkaline, with a strong smell and colour due to the consumption of a variety of chemicals in the dyeing processes. Some of the chemicals discharged can have toxic effects on the receiving environment. Discharge of such effluents into aquatic bodies can cause lowering of dissolved oxygen and threats to aquatic life and downstream water users, due to possible toxicity and deterioration in the aesthetic value of the water quality. Table 3.1 below provides a typical description of liquid wastes.

Apart from the problem of water pollution, aspects of air emissions – especially related to Volatile Organic Compounds (VOC), excessive noise, odor and work-space safety – have become equally important issues of concern. Environmental issues relevant to textile industry thus encompass the traditional issues of water pollution from discharge of untreated effluents.

<table>
<thead>
<tr>
<th>Unit process</th>
<th>Possible pollutants in the wastewater</th>
<th>Nature of the wastewater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desizing</td>
<td>Starch, glucose, carboxy methyl cellulose, polyvinyl alcohol, resins fats and waxes.</td>
<td>High BOD (34% to 50% of total). Carboxymethyl cellulose and polyvinyl alcohol do not exert a high BOD.</td>
</tr>
<tr>
<td>Scouring</td>
<td>Caustic soda, waxes and greases, soda ash, sodium silicate and fragments of fabric.</td>
<td>Strongly alkaline, dark colour, high BOD (30% of total).</td>
</tr>
<tr>
<td>Bleaching</td>
<td>Hypochlorite, chlorine compounds, caustic soda, AOX, acids etc.</td>
<td>Alkaline constitutes approximately 5% BOD.</td>
</tr>
<tr>
<td>Mercerizing</td>
<td>Caustic soda.</td>
<td>Strongly alkaline, low BOD (less than 1% of total)</td>
</tr>
<tr>
<td>Dyeing</td>
<td>Various dyes, mordants and reducing agents such as sulphides, hydrosulphide, acetic acid and soap.</td>
<td>Strongly coloured, fairly high BOD (6% of total).</td>
</tr>
<tr>
<td>Printing</td>
<td>Colours, starch, gums, oil, china clay, mordants, acids and metallic salt.</td>
<td>Highly coloured, fairly high BOD and oily appearance.</td>
</tr>
<tr>
<td>Finishing</td>
<td>Traces of starch, tallow, common-salt, glauber salt etc.</td>
<td>Slightly alkaline, low BOD.</td>
</tr>
</tbody>
</table>

Table 3.1 Characteristics of process waste streams of textile mills
Table 3.2 and Table 3.3 below show impacts of raw material production to health and the environment of natural and synthetic fibres in the textile industry.

### Table 3.2 Impacts of raw material production of natural fibres from plants on human health and the environment

<table>
<thead>
<tr>
<th>Process</th>
<th>Desired effect</th>
<th>Area of application</th>
<th>Chemicals employed</th>
<th>Possible impacts on health and the environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivation</td>
<td>Pesticides</td>
<td>Natural fibres: cotton • bast (flax, jute, hemp, ramie)</td>
<td>• Aldrin • Chlordane • DDT • Dieldrin • Endrin • HCH (including Lindane) • PCP • Toxaphene</td>
<td>• acute toxicity (oral and dermal) • local, acute effects • short-term toxicity • long-term toxicity • carcinogenicity • mutagenicity • reproduction toxicity • neurotoxicity</td>
</tr>
<tr>
<td>Harvesting</td>
<td>Defoliation</td>
<td>Natural fibres: cotton • bast (flax, jute, hemp, ramie)</td>
<td>• 2, 4-d • 2, 4, 5-t (agent orange)</td>
<td>see above</td>
</tr>
</tbody>
</table>

### Table 3.3 Impacts of raw material production of synthetic fibres on human health and the environment

<table>
<thead>
<tr>
<th>Process</th>
<th>Desired effect</th>
<th>Area of application</th>
<th>Chemicals employed</th>
<th>Possible impacts on health and environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material synthesis</td>
<td>Fibre material</td>
<td>Regenerated cellulose fibres: viscose acetate</td>
<td>• Solvents • Other substances</td>
<td></td>
</tr>
<tr>
<td>Raw material synthesis</td>
<td>Fibre material</td>
<td>Synthetic fibres: polyamide polyester polyacrylic polyvinylchloride</td>
<td>• Fossil fuels</td>
<td>• Non-renewable energy resource</td>
</tr>
<tr>
<td>e.g. Polyester synthesis</td>
<td>Catalysis of polymerisation</td>
<td>Polyester</td>
<td>Heavy metals containing catalysts: antimony trioxide antimony pentoxide germanium dioxide</td>
<td>• Toxic effects to human health</td>
</tr>
</tbody>
</table>
As the environmental issues have become more complex, a comprehensive integrated approach is required to tackle the problem of pollution control. Avoidance of waste generation and reduction whenever and wherever possible should become the strategy of first priority. This would imply that utilization of all types of resources - water, chemicals, heat, and so on - should be optimal. This could be done in many instances by the implementation of simple measures, such as good housekeeping or reuse of resources.

In a few situations, a review of the existing process technology may also be needed with respect to the choice of process, processing sequence and equipment. Examples of such options include:

- water conservation by counter-current washing
- recovery of chemicals such as size, caustic, dyes and grease
- substitution of low BOD (Biochemical Oxygen Demand) chemicals for high BOD ones
- heat recovery from effluents, etc.

Textile equipment manufacturers are becoming more and more aware of the need to conserve water, chemicals and energy. In fact, many new production technologies have (at least in part) been spawned by that awareness, and have thus influenced the design of textile manufacturing equipment without impairing the product quality. Examples of such process and equipment changes include modifications in equipment for washing and drying and for dyeing and printing of fabric.

Having explored the production processes so as to generate only the smallest possible amount of waste, it then becomes necessary to select the treatment strategy. If pollution avoidance, recycling and treatment are carefully chosen, then there should be little residue requiring treatment and disposal. Nevertheless, this must be carried out, keeping in mind the possible environmental impacts as well as safety to the workers and neighbouring community.

Nowadays, textile products - in particular, garments - have attained a significant environmental focus. Garments represent protection, but their contact with the skin can cause irritation or even disease, deriving from the following principal causes:

- content of metals
- content of organic substances or chemical elements
- pH.

This being the case, the first steps towards establishing standards for textiles have been made in Europe with the MST standards, Eco-Tex, which serve as worldwide references and are the only premises of international legislation.

Moreover, new man-made 'ecological' fibres (such as Tencel, Lyocell, Newcell, etc.) have recently come onto the market. Their 'ecological' character is derived partly from their manufacture, which does not involve any chemical reaction, and partly from the total recovery of the solvents used in manufacture.

Parallel to this, a new subsidiary market with an immense potential is developing, based on ecological disposal of waste textiles, such as re-use, recycling and destruction.
3.4 Exercises

1. (i) Which of the impacts mentioned earlier are the most important to the textile industry overall? Why are they the most important?

(ii) Which are most important to local people? Try to rank them in order:

(iii) Which issues are addressed in a typical factory permit? How are the others addressed?

(iv) What does the textile association do to address these issues?
Listed in Table 3.4 are several different groups of chemicals/products generally encountered in the textile wet processing industry. These groups may be characterized in terms of the difficulty in treatment/control according to the following categories:

1. Relatively harmless
2. Moderate to high organic load (in terms of BOD)
3. Difficult to biodegrade
4. Not suitable for biological treatment

Assign the appropriate pollution category against each chemical/product group:

### Table 3.4 Pollution capability of chemicals and products used in the chemical processing of textiles

<table>
<thead>
<tr>
<th>Chemicals/Products</th>
<th>Difficulty of treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formaldehyde</td>
<td>N-methylol resins</td>
</tr>
<tr>
<td>Chlorinated solvents and carriers</td>
<td>Cationic retarders and softeners</td>
</tr>
<tr>
<td>Biocides</td>
<td>Sequestering agents</td>
</tr>
<tr>
<td>Heavy metal salts</td>
<td></td>
</tr>
<tr>
<td>Wool grease</td>
<td>Dyes and brighteners</td>
</tr>
<tr>
<td>Polyacrylate size such as polyvinyl alcohol</td>
<td></td>
</tr>
<tr>
<td>Polymer finishes</td>
<td></td>
</tr>
<tr>
<td>Starch size</td>
<td>Biodegradable surfactant</td>
</tr>
<tr>
<td>Organic acids</td>
<td>Reducing agents</td>
</tr>
<tr>
<td>Alkalis</td>
<td>Mineral acids</td>
</tr>
<tr>
<td>Neutral salts</td>
<td>Oxidizing agents</td>
</tr>
</tbody>
</table>
Question 1

(i) The most important impacts are the depletion and contamination of water resources and the impacts of energy consumption. Issues of contamination of soil, water and natural ecosystems are also important from a long term global scale, but are difficult to isolate and quantify.

(ii) At the local level, the order of impacts could be:

- depletion and contamination of water resources
- impacts due to energy consumption (including associated air pollution)
- impacts on the health of factory workers due to air emissions and noise.

(iii) Typically, a factory permit addresses issues such as water and energy consumption during licensing, wastewater and air emissions released during permits from the environment department, worker safety and health issues in terms of noise insulation, ventilation and work space during safety related and architectural/design related clearances. Additional issues are addressed through the process of Environmental Impact Assessment, if needed, depending on the size and location of the textile factory.

Question 2

<table>
<thead>
<tr>
<th>Chemicals/Products</th>
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</table>

A Workbook for Trainers: Cleaner Production in Textile Wet Processing
Part 4
Environmental Aspects of Preparatory Processing

4.1 Sizing (slashing) ........................................ IV:3
4.2 Desizing ................................................ IV:4
4.3 Scouring ................................................ IV:6
4.4 Bleaching .............................................. IV:8
4.5 Mercerizing ............................................ IV:10
4.6 Exercises ............................................. IV:12
4.7 Questions ............................................. IV:15
4.8 Solutions ............................................. IV:17
4 Environmental Aspects of Preparatory Processing

As part of the multi-stage operations involved in the chemical processing of textiles, preparatory processing covers the following areas:

- sizing
- scouring
- bleaching
- desizing

and

- mercerizing

These areas will now be considered in turn.

4.1 Sizing (slashing)

In sizing, the warp threads are coated with size (either starch or synthetic) to facilitate weaving by giving the threads tensile strength and smoothness. The compound is then dried on the threads and remains a part of the cloth until it is removed in the subsequent processes.

Although the sizing (slashing) compounds used most often are natural starches, other compounds — such as polyvinyl alcohol (PVA), resins, alkali-soluble cellulose derivatives, and gelatine glue — have been used. One of these, sodium-carboxymethyl-cellulose or CMC, has found some acceptance, mostly in the sizing of polyester blends.

Other chemicals, such as lubricants, agents, and fillers, are often added to impart additional properties to a fabric.

The grey goods thus prepared usually contain about 10-15% add-on.
4.2 Desizing

The purpose of desizing is to remove sizing ingredients, mainly starches, gums, PVA etc. The gums and PVA are removed by a simple hot wash but starch has to be degraded first into small molecules. These molecules, being soluble in water, are then removed through a hot wash. The desizing process is important, because presence of starch on the fabric hampers the penetration of other chemicals in the subsequent processes.

The process is commonly carried out either by acid desizing or enzymatic desizing.

4.2.1 Enzymatic desizing

Enzymatic desizing is a widely used desizing method, as it is most economical and safe.

The enzymes are bio-catalysts. There are three types of enzymes: bacterial, malt and pancreatic. Enzyme activity is affected by the presence of salt - for full activity, sodium chloride must be present. Malt and bacterial enzymes require the presence of calcium for full activation.

In the enzymatic desizing process, three important steps are involved:
- saturation of the fabric
- reaction of the fabric
- washing of the degraded size.

The process is considerably fast, but involves the risk of dry cellulose formation and high desizing cost. Normally, fabric is padded with 1.5 to 2 g/l enzyme at a temperature of 60°C and pH levels of between 5.5 and 6.5, along with 1 to 2 g/l common salt and 1 to 2 g/l wetting agent. The wet pick-up is normally between 85 to 100%, and is stored for eight to ten hours before thorough washing.

For continuous processes, Rapidase (a heat resisting enzyme) is used at temperatures up to 95°C.

4.2.2 Acid desizing

The fabric is padded with dilute hydrochloric acid or sulphuric acid and stored for an hour. It subsequently undergoes hot washes, cold washes and neutralization. Many units in developing countries have adopted this technology in order to make the desizing process faster.
4.2.3 Desizing method

Pad-steep is the general method used for all the above mentioned techniques.
The fabric is padded with chemicals with the help of a two-bowl padding mangle and a batching machine. A batch of the fabric roll is made for storing. The washing is done either on a washing range or on a simple jigger.
For the continuous method, desizing is done on the continuous range. The process can be carried out using different chemicals, but the machinery used (an impregnation/padding trough) remains the same.

In the pad-steep-batch process, open width fabric is guided through a starch dissolving solution. Excess solution is squeezed out by squeeze rollers.
The impregnated fabric is stored for a predetermined time, allowing chemical reactions to take place, and then washed.
Polyvinyl alcohol (PVA) and carboxymethyl cellulose (CMC) are directly soluble in water; therefore, no decomposition is required during desizing and the goods are merely washed with water to remove sizing agents.

4.2.4 Desizing pollution loads

Desizing operations are typically large contributors (of between 40-50%) to the pollution load arising out of the preparatory sequence. During desizing, size materials leach out of fabrics. In addition, commonly used assistants in the size mix (such as glycerine, waxes, urea and surfactants) are released. However, synthetic sizes do not normally contribute much to the organic load. Furthermore, synthetic sizes can be recovered from liquid effluents.
The pollution generated in desizing depends mainly on the selection of size material, work practices, recovery and reuse. In order to minimize the pollution load at source, it is essential that unused portions of size mixes containing starches are not disposed of down the drain. Replacement of starches which have a high BOD by other synthetic film-forming polymers – such as polyvinyl alcohol (PVA) or carboxymethyl-cellulose (CMC) – is another option to reduce the organic load. However, PVA or CMC need to be recovered from the effluents as their cost is generally much higher than that of starch.
4.3 Scouring

Cotton, being a natural fibre, contains about 2 to 3% of different impurities such as waxes, fatty acids, proteins,pectins, and mineral matter.

Scouring removes natural impurities other than colouring matter, particularly from cotton fibres. The process is performed under highly alkaline conditions at temperatures conventionally above 100°C. The mechanism of the scouring action is as follows.

Fatty acids present in the fibre are saponified in the presence of alkali and soluble soaps. These soluble soaps act as emulsifiers for unsaponified oils and cotton wax, and help in their removal. Proteins are hydrolysed into water soluble amino acids, whereas pectic substances present as calcium, magnesium and iron salts are solubilized in the presence of alkali. Hemi-cellulose also becomes soluble in alkaline solution, and is thus removed.

The scouring liquor contains alkali (caustic soda), a wetting agent and a sequestering agent. Sometimes, however, sodium carbonate, sodium silicate, sodium sulphate etc. are also added. Sodium sulphate, a reducing agent, improves the efficiency of the system, but sodium silicate often creates problems in dyeing, as it is difficult to remove traces in the subsequent processes.

The scouring is normally done either on a Kier, a J Box, or an open width pad roll system, or on open width continuous plant.

The three widely used scouring machines mentioned above are as follows.

4.3.1 Kier

This is a cylindrical vessel equipped with a circulation pump and multitubular heater. The capacity of the Kier varies from one ton to three tons of fabric.

In a Kier, fabric is treated in a rope form. Loading of the fabric is done either manually or by autopilers. Autopilers help in avoiding the channelling of the liquor.

Both open (atmospheric pressure) and close (pressure) type Kiers are in use. In pressure boil, the Kier is loaded to about 90% of its capacity, and air is expelled from it. The fabric is treated at between 25°C and 130°C for six to eight hours with continuous liquor circulation.

On completion, the pressure is released, the liquor is drained, and then washing is done in the Kier itself before unloading.

The whole process takes about 16 to 20 hours. A material-liquor ratio of 1:4 is kept for the Kier.

Kiers may now be considered as fairly outdated for a modern processing house.

4.3.2 J Box

This equipment looks like the English letter ‘J’, and so is known as a ‘J Box’. The equipment is available in different sizes, and the speed of the machine depends on the equipment capacity and steaming time.

Fabric is treated in a J Box in rope form. The fabric is first saturated with scouring liquor and steamed at atmospheric pressure for between one and two hours, depending on the fabric quality.

The J Box normally requires a 4% higher alkali concentration than the Kier.

The fabric enters from one end, and comes out the other end continuously. After a predetermined residence time, it is washed and then taken for further treatments.

For continuous operation, three units of J Boxes are installed in tandem. The first unit is used for scouring, the second is for chemicking and the third for hydrogen peroxide treatment.

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4.3.3 Pad-roll-batch reaction system

The fabric is impregnated with chemicals (up to 5% of caustic soda), and is then batched in a reaction chamber which rotates slowly. Live steam is injected into the chamber to keep the temperature at around 100°C.

After steaming, the fabric is washed and sent for subsequent processing. This system is suitable for open width scouring of heavy goods, and is also used for continuous operation as it has more than one reaction chamber. Steaming time is between 90 to 150 minutes.

4.3.4 Jigger or jumbo jiggers

Here, fabric is scoured in an open width. First, the fabric is batched on to a roller which is mounted on the jigger machine. It is threaded through guide rolls for impregnation, and then wound onto another roller.

The fabric is run from one roll end to another and vice-versa. The number of ends (number of runs) depends on the product quality and the process parameters.

This is basically a batch process. Jiggers are equipped with differential gear systems for simultaneous drive of the two main rollers. These give an almost uniform speed for the fabric and very little longitudinal tension. The jiggers are also fitted with an automatic reversing device, passage counters and an oscillating expanding device for crease removal. Desizing, scouring and bleaching can be done in the same machine if the number of units is increased as required.

4.3.5 Continuous scouring range

The fabric is treated in open width in a continuous scouring range. Fabric enters the chamber and passes through a saturator containing the required chemicals, a reaction chamber where reaction takes place, and a washing compartment where it is washed. Desizing, scouring and bleaching can be done in the same machine if the number of units is increased as required for each process.

4.3.6 Scouring and combined desize-scour

Cutting down the stages of preparatory processing — from three to two, or even to a single stage — is another attractive possibility. This process reduces both energy and water consumption. The consequences of lower energy consumption include less steam raising and reduced air emissions, leading to reduced atmospheric pollution. However, this process is not yet popular in the industry, but is expected to become more important in the near future. Several early attempts to reduce processing stages under pad-steam conditions were not successful because of inadequate seed and size removal. Early attempts included combining the stages of scouring and desizing in what is termed oxidative desizing.

A highly successful process is to add hydrogen peroxide or a persulphate to the scouring liquor, forming an unstable bleaching system. This unstable system favours desizing over bleaching; therefore, oxidatively desized fabric requires a bleaching stage in order to achieve the optimum degree of whiteness. Combined desize-scour, which can be carried out hot or cold, with or without the addition of stabilizers such as silicates or phosphates, has been quite successful. However, both silicate and phosphate types of stabilizer have been found to be non-biodegradable, and their use in peroxide bleaching has been banned in several countries. A stabilizer called Di-ethylene-triamine-penta-acetate (DTPA), identified for peroxide bleaching, is free from silica or phosphorous containing compounds. DTPA has been found not only to prevent accelerated decomposition of peroxide due to presence of metallic contaminants, but also to prevent the premature oxidation of peroxide, probably by retarding the formation of peroxy or perhydroxy free radicals.
4.4 Bleaching

Bleaching is basically a process to destroy the natural colouring matters present in cotton. There are three typical technologies available for bleaching:

- **sodium chlorite** bleaching
- **sodium hypochlorite** bleaching (chemicking), and
- **hydrogen peroxide** bleaching.

*Sodium chlorite* bleaching is an old method, now outdated because of the harmful chlorine gas which is generated. However, this process is still in use in some hand processing units.

4.4.1 Chemicking

Sodium hypochlorite bleaching (also known as chemicking) is carried out with NaOCl. The strength of the NaOCl is expressed in terms of the available chlorine. Conventionally, the fabric is treated in a cistern with chemick liquor containing two to three g/l of available chlorine.

After piling the fabric in false-bottomed pits, the liquor is circulated for 15 to 45 minutes. During the operation, a pH level of between 9.5 to 10.5 is maintained, and if necessary, 0.5 g/l sodium carbonate is added.

The chemical reactions involved are as follows:

\[
\text{NaOCl} + \text{H}_{2}\text{O} = \text{NaOH} + \text{HOCl}
\]

\[
\text{HOCl} = \text{HCl} + \{\text{O}\} \text{ [nascent oxygen]}
\]

The process needs to be performed with utmost care, to avoid tendering by acid. After chemicking, a thorough wash is required to remove the traces of chlorine, and a scouring treatment is normally carried out, using 2g/l HCl to remove the traces of chlorine and surface deposits from the fabric.

Chemicking machineries

The chemicking is preferably done in the cistern. However, some processors not equipped with cisterns use a rope washing machine for the purpose, and store the treated fabric for 60 to 90 minutes.

However, in this case, the process does not give uniform treatment.

Some of the processors use PVC J Boxes for continuous or semi-continuous chemicking treatment.

4.4.2 Hydrogen peroxide bleaching

Hydrogen peroxide bleaching offers permanent whiteness, while chemicking gives better, but non-permanent, whiteness. Hence, for white goods or pale shade dyed goods, peroxide bleaching is preferred. With hydrogen peroxide bleaching, the reaction is as shown:

\[
\text{H}_2\text{O}_2 = \text{H}_2\text{O} + \{\text{O}\} \text{ [nascent oxygen]}
\]

Open kiers or jiggers are normally used for hydrogen peroxide bleaching.

However, for continuous plant, hydrogen peroxide bleaching is done in a J Box.
4.4.3 Bleaching pollution loads

The bleaching process contributes the lowest BOD to the total plant load, but relatively high TDS and toxic substance loads.

Chlorine-containing bleaching agents are regarded as highly toxic, and several countries have prescribed strict limits or banned their use in preparatory processing. Legislation is now being implemented throughout the European Community which will have serious implications all over the world.

Chlorine-containing bleaching agents such as sodium hypochlorite or sodium chlorite are the main source of absorbable organohalogen compounds (AOX). Compared to chlorine-containing bleaching systems, hydrogen peroxide – whether in the presence or absence of salt – gives rise to a negligible increase in AOX.

It has been observed that increasing the purity of the material to be bleached decreases the AOX content of the effluent. Knitted fabrics made with less clean combed cotton and loose stock with a high content of vegetable matter have shown high AOX content. In the wool textile industry, sources of AOX have been identified due to the use of chlorine compounds which form part of shrink-resist processes. These chlorination agents have now been replaced with peroxy compounds: magnesium mono-peroxy-phthalate or potassium mono-peroxy-sulphate, alone or in combination with certain resins.
4.5 Mercerizing

The mercerisation process is basically an alkali (NaOH) treatment given to cotton yarn or fabric so that the cotton fibres swell and attain a rod-like structure from their original convoluted form.

The axial ratio of the cross section of fibre is reduced due to rounding. When performed under tension for 40 to 45 seconds with caustic soda of 52 to 56 TW, this process improves lustre, strength and dye uptake. It also removes the immature fibres. Mercerisation can be done in both hot and cold conditions. Different processors prefer mercerisation at different stages as per the end use requirements, i.e. grey mercerisation or scour mercerisation. Normally, mercerisation is carried out on dry fabric. Wet mercerisation reduces the steam consumption, but requires stringent control of the operational parameters, such as the concentration of caustic soda.

Generally, the caustic soda dragged out by the cloth is recovered and reused for scouring or mercerization. The mercerizing rinse wastes are alkaline, high in inorganic solids and caustic alkalinity, and low in BOD. With the increasing trend toward cotton-polyester blends, much less mercerizing is being done. It is estimated that less than 30% of cotton is now mercerized or causticized.

Combined mercerizing, where scouring is carried out simultaneously with the mercerization in hot conditions, is now becoming popular. Hot mercerisation increases the rate of scouring. Scouring is done after saturation with hot caustic and before the stability wash. This combined process reduces capital cost, space requirements, energy costs, labor requirement and chemical costs.

4.5.1 Mercerizing machines

Basically, two types of mercerisation machines are used: a chain type and a chainless type.

The chain type of mercerizing machine runs at about 40 m/minute, while chainless machines run at 18 to 20 m/minute. In the latter, however, two to four ends of fabric can be run simultaneously, thus giving equivalent or higher productivity. Speed can also be accelerated by increasing the impregnation time of the fabric in caustic soda.

In the case of the chain merceriser, the width of the fabric is controlled through two divergent running chains which hold the fabric tightly across its width when it passes. The angle between these two running chains controls the width of the fabric.

In the case of chainless mercerisers, the weft-way stretch is ensured by positioning and designing of the guide rollers, thereby controlling width shrinkage.

Other than width control, all other functions are identical to those carried out by the chain merceriser. The advantage over the chain merceriser is that one fabric can be processed over another, or two narrow width fabrics side by side.

This gives more flexibility and proves to be economical.

Against this advantage, the width loss after finishing is increased in the case of the chainless merceriser.
Part 4

Environmental Aspects of Preparatory Processing

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4.2 Desizing ............................................................... IV:4
4.3 Scouring ............................................................... IV:6
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4.7 Questions ............................................................... IV:15
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4 Environmental Aspects of Preparatory Processing

As part of the multi-stage operations involved in the chemical processing of textiles, preparatory processing covers the following areas:

- sizing
- scouring
- bleaching
- desizing
  and
- mercerizing

These areas will now be considered in turn.

4.1 Sizing (slashing)

In sizing, the warp threads are coated with size (either starch or synthetic) to facilitate weaving by giving the threads tensile strength and smoothness. The compound is then dried on the threads and remains a part of the cloth until it is removed in the subsequent processes.

Although the sizing (slashing) compounds used most often are natural starches, other compounds – such as polyvinyl alcohol (PVA), resins, alkali-soluble cellulose derivatives, and gelatine glue – have been used. One of these, sodium-carboxyl-methyl-cellulose or CMC, has found some acceptance, mostly in the sizing of polyester blends.

Other chemicals, such as lubricants, agents, and fillers, are often added to impart additional properties to a fabric.

The grey goods thus prepared usually contain about 10-15% add-on.
In the desizing operation, all the residual starch is discharged into the wastewater. Due to the relatively low cost of the chemical, one-stage sodium hypochlorite bleaching (chemicking) with antichloring with hydrogen peroxide is performed. Table 4.3 on page iv.12 shows the summary of specifications and chemical/additives for the jumbo jigger.

The quality control section of the process house has noticed that, on an average day, around 5% of the dyed fabric needs to be stripped and re-prepared. If two-stage peroxide bleach is used, then the stripping could virtually be eliminated, saving the incremental costs of re-preparation.

However, hydrogen peroxide is an expensive chemical and costs much more than sodium hypochlorite.

Figure 4.1 shows the processing sequence and the operational details of the jumbo jigger, and a suggested preparatory sequence using peroxide bleach is described in.

---

**Figure 4.1 Processing sequence in jumbo jigger**

(1500 kg/10000 m) (1:1.5 MLR)

- **Load 1500 kg Greige fabric**
- Freshwater → Hot wash 1 end → Discharge
- Chemicals, Freshwater → Enzyme desizing @ 60°C 4 ends → Desize → Discharge
- Chemicals, Acid, Freshwater → Hot wash 1 end → Desize → Discharge
- Chemicals, Freshwater → Caustic scour @ 80°C 4 ends → Scour → Discharge
- Freshwater → Hot wash 2 ends → Scour → Discharge
- Freshwater → Cold wash 2 ends → Scour → Discharge
- Chemicals, Freshwater → Chemick 4 ends → Bleach → Discharge
- Freshwater → Cold wash 2 ends → Bleach → Discharge
- Chemicals, Freshwater → Peroxide boil (antichlor) 2 ends → Bleach → Discharge
- Freshwater → Hot wash 1 end → Bleach → Discharge
- Freshwater → Cold wash 1 end → Bleach → Discharge

To mercerizer / dryer
Table 4.4 Preparatory sequence on atmospheric jumbo jigger
(using hydrogen peroxide bleaching)

<table>
<thead>
<tr>
<th>Operation</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Loading</strong></td>
<td></td>
</tr>
<tr>
<td>Pre-hot wash</td>
<td>1 end</td>
</tr>
<tr>
<td>Enzyme desizing @ 60°C</td>
<td>4 ends</td>
</tr>
<tr>
<td>Hot wash</td>
<td>1 end</td>
</tr>
<tr>
<td>Caustic scouring @ 85°C</td>
<td>4 ends</td>
</tr>
<tr>
<td>Hot wash</td>
<td>2 ends</td>
</tr>
<tr>
<td>Cold wash</td>
<td>2 ends</td>
</tr>
<tr>
<td>Hydrogen peroxide bleaching</td>
<td>4 ends</td>
</tr>
<tr>
<td>Hot wash</td>
<td>1 end</td>
</tr>
<tr>
<td>Cold wash</td>
<td>1 end</td>
</tr>
<tr>
<td><strong>Unloading</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.5 Summary of specifications and chemical/additives
for the preparatory stage in the atmospheric jumbo jigger (desize-scour-bleach using peroxide bleaching)

<table>
<thead>
<tr>
<th>Process</th>
<th>Chemicals/additives</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Desizing</strong></td>
<td>Enzyme desizing</td>
</tr>
<tr>
<td></td>
<td>Enzyme</td>
</tr>
<tr>
<td></td>
<td>Wetting agent</td>
</tr>
<tr>
<td></td>
<td>Common salt</td>
</tr>
<tr>
<td><strong>Scouring</strong></td>
<td>Caustic</td>
</tr>
<tr>
<td></td>
<td>Wetting agent</td>
</tr>
<tr>
<td><strong>Bleaching</strong></td>
<td>Peroxide bleach</td>
</tr>
<tr>
<td></td>
<td>Peroxide</td>
</tr>
<tr>
<td></td>
<td>Caustic soda</td>
</tr>
<tr>
<td></td>
<td>Sodium silicate</td>
</tr>
<tr>
<td></td>
<td>or DTPA</td>
</tr>
<tr>
<td></td>
<td>Wetting agent</td>
</tr>
</tbody>
</table>
4.7 Questions

1 Estimate the effluent volume generated from the preparatory sequence and the concentrations of BOD, COD and Total Dissolved Solids (TDS), using the information on the production-pollution coefficients listed in Table 2.1:

The answer to this question is on page IV:17

2 Examine the process flow diagram. Can you find any ways of minimizing the preparatory sequence? What information would you want to check before suggesting an optimization strategy to the management?

The answer to this question is on page IV:18
3 Calculate the reduction in the effluent load if PVA is used instead of enzyme starch in the sizing process. What are the environmental, economic and managerial implications of such substitutions?

The answer to this question is on page IV:18

4 Are there any 'objectionable' additives in the size recipe? Give reasons for your answer:

The answer to this question is on page IV:19

5 Explain your strategy for making the bleaching process environmentally friendly, and list the pros and cons of the proposal:

The answer to this question is on page IV:20
4.8 Solutions

**Question 1**

*Estimation of the effluent load in a cycle for jumbo jiggers*

Calculations of effluent loads for the production of 6000 kg/day:

*a* Corrected production, accounting for 5% of stripping,

\[ 6000 \text{ kg/day} \times 1.05 = 6300 \text{ kg/day} \]

*b* Fabric handled at each jumbo jigger 6300/4 = 1575 kg

*c* Water required in the jigger compartment on the basis of MLR of 1.5

\[ = 1575 \times 1.5 = 2362.5 \text{ kg} \]

\[ \quad \text{Total} \quad 2.362 \text{ m}^3 \]

*d* Total number of drainings 11

\[ \text{Volume of effluent drained from jumbo jigger} = 2.362 \text{ m}^3/\text{draining} \times 11 \text{ (drainings)} \times 4 \text{ (machines)} \times 1 \text{ (batch/day)} = 103.93 \text{ m}^3/\text{day} \]

*e* Estimation of BOD for 6300 kg/day

\[ \begin{align*}
\text{i} & \quad \text{Enzyme starch desizing} \quad = 45.5 \text{ kg/1000 kg} \quad = 286.65 \text{ kg} \\
\text{ii} & \quad \text{For scouring} \quad = 21.5 \text{ kg/1000 kg} \quad = 135.45 \text{ kg} \\
\text{iii} & \quad \text{For bleaching} \quad = 1.0 \text{ kg/1000 kg} \quad = 6.30 \text{ kg}
\end{align*} \]

\[ \text{Total BOD load from preparatory stage} = 428.40 \text{ kg/day} \]

*f* Estimation of COD for 6300 kg/day

\[ \begin{align*}
\text{i} & \quad \text{Enzyme starch desizing} \quad = 91.0 \text{ kg/1000 kg} \quad = 573.30 \text{ kg} \\
\text{ii} & \quad \text{For scouring} \quad = 64.5 \text{ kg/1000 kg} \quad = 406.35 \text{ kg} \\
\text{iii} & \quad \text{For bleaching} \quad = 4.0 \text{ kg/1000 kg} \quad = 25.20 \text{ kg}
\end{align*} \]

\[ \text{Total COD load from preparation stage} = 1004.85 \text{ kg/day} \]

*g* Estimation of TDS for 6300 kg/day

\[ \begin{align*}
\text{i} & \quad \text{Enzyme starch desizing} \quad = 5.0 \text{ kg/1000 kg} \quad = 31.50 \text{ kg} \\
\text{ii} & \quad \text{From scouring} \quad = 50 \text{ kg/1000 kg} \quad = 315.00 \text{ kg} \\
\text{iii} & \quad \text{From bleaching} \quad = 55 \text{ kg/1000 kg} \quad = 346.50 \text{ kg}
\end{align*} \]

\[ \text{Total TDS load from preparation stage} = 693 \text{ kg/day} \]

*h* Concentrations in the effluents from the preparatory section

for parameters such as BOD, COD and TDS are:

\[ \begin{align*}
\text{BOD} & \quad 428.4 / 103.93 \quad = 4.12 \text{ kg/m}^3 \quad \text{..................} \quad 412 \text{ mg/l} \\
\text{COD} & \quad 1004.85 / 103.93 \quad = 9.67 \text{ kg/m}^3 \quad \text{..................} \quad 967 \text{ mg/l} \\
\text{TDS} & \quad 693 / 103.93 \quad = 6.67 \text{ kg/m}^3 \quad \text{..................} \quad 667 \text{ mg/l}
\end{align*} \]
Question 2

An examination of the preparatory sequence indicates water reuse at two distinct phases:

- before chemicking

and

- after chemicking.

Technically, all cold washes could be considered as potential streams, as these are expected to be a little less polluted. Out of the three cold washes, only the one after caustic scour – i.e. before chemicking (the sixth stage of the preparatory sequence) – may be considered, as it is expected to have least impact on fabric quality on reuse. The cold wash after chemicking is less attractive as it is bound to have some AOX contamination, and the last cold wash, after anti-chlor, is expected to contain some sodium silicate (refer to Table 4.3 on the recipes), which can cause interference during both preparation and dyeing.

For reusing the cold wash after scouring, the management would need to use/construct a sump with a pump, necessary piping and gates/valves etc., with instructions on which drain is to be sent to the reuse tank. The quality of the cold washwater and the economics of the investment need to be ascertained prior any implementation.

An evaluation would be needed to ascertain the feasibility of reusing the last two washes after the antichlor. Normally, the batch exercise would be required on different lots (dark and light shades) and the quality of preparation and dyeing would need to be assessed because of the water reuse policy.

Question 3

If PVA is used as the sizing agent, then we should use different pollution load generation factors as provided in Table 4.1.

\[ a \text{ Estimation of BOD for 6300 kg/day} \]

- Enzyme starch desizing = 2.5 kg/1000 kg = 15.75 kg
- For scouring = 21.5 kg/1000 kg = 135.45 kg
- For bleaching = 1.0 kg/1000 kg = 6.30 kg

Total BOD load from preparatory stage = 157.50 kg/day

\[ b \text{ Estimation of COD for 6300 kg/day} \]

- Enzyme starch desizing = 5.0 kg/1000 kg = 31.50 kg
- For scouring = 64.5 kg/1000 kg = 406.35 kg
- For bleaching = 4.0 kg/1000 kg = 25.20 kg

Total COD load from preparation stage = 463.05 kg/day

\[ c \text{ Estimation of TDS for 6300 kg/day} \]

- Enzyme starch desizing = 48 kg/1000 kg = 302.4 kg
- From scouring = 50 kg/1000 kg = 315.0 kg
- From bleaching = 55 kg/1000 kg = 346.5 kg

Total TDS load from preparation stage = 963.9 kg/day

\[ d \text{ Concentrations in the effluents from the preparatory section for parameters such as BOD, COD and TDS are:} \]

- \( BOD \) = 157.5 / 103.93 = 1.52 kg/m³ \( \ldots \) \[ \ldots \] 152 mg/l
- \( COD \) = 463.05 / 103.93 = 4.46 kg/m³ \( \ldots \) \[ \ldots \] 446 mg/l
- \( TTDS \) = 963.9 / 103.93 = 9.27 kg/m³ \( \ldots \) \[ \ldots \] 927 mg/l

Table 4.6 below shows a comparison of the ‘before’ and ‘after’ situation.
Question 3 continued...

<table>
<thead>
<tr>
<th>Case</th>
<th>BOD (mg/l)</th>
<th>COD (mg/l)</th>
<th>TDS (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
<td>412</td>
<td>967</td>
<td>667</td>
</tr>
<tr>
<td>PVA</td>
<td>152</td>
<td>446</td>
<td>927</td>
</tr>
</tbody>
</table>

Clearly, there is a substantial reduction in the pollution load due to size substitution. We have to evaluate the economics of the proposal, taking into consideration:
- the savings in effluent treatment (note, however, that although the organic load is decreased after size substitution, the PVA-laden effluents have slower biodegradability, and hence require longer residence times)
- increased cost of size recipe, as PVA is more expensive than starch.
- difficulty in practising PVA recovery as, in this case, sizing is done by Company A and desizing by Company B!

**Question 4**

*Pentachlorophenol is not acceptable.*

The size recipe contains the Pentachlorophenol (PCP) antimildew agent, used as a preservative. During scouring/bleaching of the fabrics, as well as during dyeing and printing, PCP is removed from the fabric and discharged into the environment. However, PCP is toxic due to its relative stability against natural degradation processes, and it bioaccumulates in the human body. PCP is therefore listed as an environmentally unfriendly chemical and cited in the red list of compounds issued by European Community (EC).

The concentration limit for PCP on textile fabric is listed as 0.5mg/kg, to comply with the various eco-standards. Presence of PCP above this threshold will not lead to an award of a typical EC ecolabel. In many cases, it is required that the fabric processor obtains a ‘NO PCP’ certificate from the fabric supplier and forwards this to the purchasing company.

Previously, substitutes for PCP have been proposed such as sodium silico-fluoride and zinc organic complexes. These have been withdrawn due to problems of limited solubility, toxicity in inhalation and tendency to cause damage to the drying cylinders and metal parts coming into contact with sized fabric.

Currently, few acceptable commercial substitutes have been proposed which do not possess any of the above disadvantages.

The company cited in this exercise should therefore conduct a discussion with the grey fabric supplier and urge them to substitute PCP and produce an appropriate certificate. This would be necessary if the company wishes to enter into the international market, particularly to Japan, EC countries and the United States of America.
**Question 5**

**Qualitative evaluation**

Changeover from hypochlorite bleaching and hydrogen peroxide antichlor to two stage hydrogen peroxide bleaching:

<table>
<thead>
<tr>
<th>+ Improved whiteness of fabric.</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ Reduced water consumption due to elimination of two drainings: one of hypochlorite bleaching and the other, cold wash after the bleaching stage.</td>
</tr>
<tr>
<td>+ Reduced energy consumption.</td>
</tr>
<tr>
<td>+ Reduced pollution load in terms of flow, BOD, COD and AOX.</td>
</tr>
<tr>
<td>+ Decrease in redyeing for shade adjustment during jet dyeing from 30% to 10%, due to improved permanent whiteness quality of the fabric.</td>
</tr>
<tr>
<td>+ Reduced preparatory stage batch time from 24 hours to 20 hours, leading to additional production capacity.</td>
</tr>
<tr>
<td>+ Increased potential for export by falling in line with eco-labelling requirements.</td>
</tr>
<tr>
<td>- High cost of bleaching, due to high cost of hydrogen peroxide as compared to sodium hypochlorite.</td>
</tr>
<tr>
<td>- Increased TDS load in the effluent.</td>
</tr>
</tbody>
</table>
Part 5

Environmental Aspects of the Dyeing Process

5.1 Dyeing.......................................................... V:3
5.2 Dyes and their applicability................................V:4
5.3 Dyeing machineries.........................................V:6
5.4 Dyeing pollution loads.....................................V:9
5.5 Exercises......................................................V:11
5.7 Solutions.....................................................V:17
5 Environmental Aspects of the Dyeing Process

5.1 Dyeing

Dyeing is a process or combination of processes which is performed to give a reasonably permanent coloration to textile fabric. The dyeing should offer a reasonable fastness to:

- household washing and laundering
- light
- rubbing
- oxidation and sublimation
- perspiration.

Obviously, the fastness depends upon various factors such as the use of dyestuff, the process carried out, after-treatment of the dyed goods, etc.

The uniformity is equally important, which is in turn dependent on preparatory processes, equipment, dye liquor preparation and dyeing conditions.

All dyestuffs are not suitable for all types of fibres and end use patterns.
5.2 Dyes and their applicability

All classes of dyestuffs are chemically different, and applicable for different fibres with different application methods. The major classes of dyestuffs commonly used in the industry are presented below, with information on their applicability.

5.2.1 Vat dyes

Vat dyes are characterized by all-round features as they are water insoluble and cover an almost full range of shades.

The first step in the application of vat dyes is to convert the dyes to their water soluble form. This is achieved by reducing the dye with a reducing agent (sodium hydrosulphate) in a strong alkaline medium created by caustic soda. This mixture is popularly known as leuco dye, which is water soluble and has great affinity with cellulosic fibre.

On exhaustion, oxidation is carried out to convert the dyes back to their original insoluble form. Vat dyes are available in different forms, including paste, powder, fine powder, ultradisperse, highly concentrated, superfine, microfine, etc. Vat dyeing is normally done using the following methods:

- exhaust dyeing in a jigger
- pad – jig – develop
- continuous dyeing

5.2.2 Azoic dyes

Azoics are also known as naphthols, and are produced on the fibre by the reaction of two components – naphthols and bases – during the dyeing process.

The azoics are used to economically produce deep shades such as blue, violet, yellow, orange and scarlet. Except for rubbing fastness, the other fastnesses with this type of dye are satisfactory. Azoic dyeing involves two distinct steps:

- naphtholation (jigger/padding)
- diazotation and coupling (wooden vellel and jigger/padding).

5.2.3 Reactive dyes

The technology of reactive dyes is different from other dye types. When using reactive dyes, the dye reacts chemically in the presence of alkali with the hydroxy group of cellulose, which forms the covalent linkage between the two.

The molecules of reactive dyes have a simple structure and are of low molecular weight, resulting in three distinct features:

- a low affinity of the dyes towards cellulose
- production of bright shades
- outstanding levelling and diffusion properties.

Reactive dyeing takes place between 40°C to 70°C, depending on whether the type of dyestuff is cold or hot. For reactive dyeing, the addition of common salt and alkali to the dyebath is mandatory.

Reactive dyes are mostly applied using the following methods:

- exhaust in jigger or in winch
- jet dyeing
- pad – dry – jig develop
- pad – jig develop (wet on wet)
- pad – batch
- pad – dry – chemical pad – steam (continuous process).

Occasionally, the following methods are also used:

- pad – dry
- pad – dry – steam
- pad – dry – bake.
5.2.4 Pigments

Pigments are not dyes in the true sense, as they do not contain chromophore and auxochromes – the qualification for an organic compound to be known as a dye. Therefore, pigments do not possess affinities for textile fibres, but are held on the fibre mechanically.

Pigments are extensively used for printing all cellulosic and polyester-blended textiles. However, their use in dyeing is confined to pastel and light shades, and not for quality fabrics. The pigments are held on the surface by a polymeric film which is strong but at the same time resilient.

The essential ingredients of the pigment coloration system are pigment, binder, catalyst – an acid liberating agent – and acetic acid to maintain the pH level. The coloration process involves three steps: pad, dry, and cure.

The padding liquor is prepared as follows:
- dilute the pigment emulsion, filter it, and slowly add the dilute binder to it, combining the mixture by stirring it.
- add an acid liberating agent – the catalyst, predissolved in water – followed by acetic acid (2–3 g/l)
- finally, make up the volume with water at room temperature.

Sometimes, anti-migrant is also added to the liquor.

The concentration of binder ranges from 10 to 20 g/l and that of catalyst around 0.5 to 1.0 g/l, depending upon the depth of colour required. The padding is normally done on a two-bowl mangle with wet pick-up of not more than 70%.

Drying is carried out either on hot air equipment (a float dryer, a hot fine dryer) or on a cylinder drying range. Curing is done at about 150°C for two to three minutes in a polymeriser.

5.2.5 Acid dyes

Acid dyes find their main application on wool, silk, polyamide, modified acrylic and regenerated protein fibres. They are applied by a dye liquor containing sulphuric, formic or acetic acid or ammonium sulphate. The pH value of the dyebath is kept to between 2 to 7, depending on the type of material dyed, the colour depth required and the acid used. Acid dyes give very bright colour and have a wide range of fastness properties, from very poor to very good.

5.2.6 Disperse dyes

Disperse dyes are applied to cellulosic, polyamide and polyester fibres. They are coloured organic substances with very low solubility in water which, during the course of dyeing, are transferred from dispersion via a monomolecular solution to the fibre.

In the trade, the dyestuff is referred to as low, medium or high energy. The difference from one disperse dye to another one depends on molecular size, structure or both.

Dyeing is carried out at 50°C and pH 4.5-5.0, in the presence of a dispersing agent and a suitable carrier. The high temperature exhaust method of dyeing is most prevalent since it is much faster and more economical than atmospheric dyeing.

The basic procedure remains the same, whether dyeing proceeds on a HTHP beam dyeing machine, a jet machine, or a package dyeing machine. However, no carrier (or a much reduced amount of carrier) is used.

The continuous dyeing method is more suitable for polyester cotton blends. Disperse dye is padded on to the fabric, along with a suitable thickener to prevent migration. The fabric is pre-dried by air drying or cylinder drying, and then thermosoled for 90 minutes at 100-200°C to fix the disperse dyestuff. In the continuous process, speeds of up to 90 meters/minute can be achieved.
5.3 Dyeing machineries

5.3.1 Jigger

This is the most universal dyeing equipment for woven fabrics. The fabric is dyed in open width under tension. The liquor ratio varies from 1:3 to 1:4.

The jiggers are available in various sizes to cope with fabrics of different widths. Variations of jiggers are available such as non-auto, semi-automatic and automatic. Automation allows control of end-change (reversing the movement of fabric from one roll to another).

Jumbo jiggers are also available, which can process larger batches at a time.

5.3.2 Padding mangle

Padding mangles are mostly used for dyeing with reactive dyes and pigment padding with vat dyes. Variations such as two-bowl or three-bowl padding mangles are available. However, two-bowl padding mangles are generally favoured.

To maintain a low liquor ratio, the trough should be of the smallest size possible.

The mangles should be pneumatically loaded, to control the uniformity and amount of pressure.

5.3.3 Continuous dyeing range (CDR)

This is a tandem arrangement of machines, such as a padding mangle, float dryer, chemical padder, steamer, soaper and can dryer. A CDR ensures higher productivity, low manpower requirement, and less material handling.

Dyeing of longer lengths with one colour necessitates the use of an CDR to achieve quality and cost effectiveness.

5.3.4 Jet dyeing machine

Jet dyeing facilitates faster dyeing in rope form with a low liquor ratio. The machine is used to dye polyester fabric. The speed of the fabric rope is between 250 and 600 m/minute. Due to the continuous fast movement of fabric, dyeing defects (such as uneven colour, patches, and tailing) are avoided. The liquor level is maintained automatically through controllers, and the dye liquor is circulated continuously. The temperature of the dye liquor is also controlled.

The liquor ratio is the ratio of the amount of water in litres to kilograms of fabric in the dyebath. This may cause pump cavitation or poor fabric movement through the dye chamber.

Modifications to the process are generally required in order to employ lower liquor ratio dyeing.

The advantages of low liquor ratio dyeing include:
- reduced usage of ratio dependent chemicals
- reduced water usage, benefiting the company not only in terms of purchased water savings, but also in a reduction of effluent volume and treatment costs and
- reduced cycle times due to quicker drains and fills.
In addition, the reduced volume in the dyebath results in a decrease in energy consumption for heating the dyebath which, in turn, leads to reduced steam usage, less boiler usage, reduced fuel consumption, and less emissions to the atmosphere from combustion. 

Jet dyeing is one of the piece dyeing methods that can be used in low ratio dyeing. Jet dyeing takes place in a closed system, where a jet emits a high pressure stream of dye which penetrates the fabric. The stream of dye also moves the fabric along the tube, as the fluid moves faster than the fabric. The turbulence aids in dye penetration and prevents the fabric from touching the walls of the tube. Jet dyeing machines with an air transport medium are also available.

Most fabrics, including 100% cotton, are dyed satisfactorily at a 6:1 ratio. Many fabrics can be dyed at an even lower ratio of 5:1.

5.3.5 Winch

A winch allows tensionless dyeing of the fabric, so it is most suitable for very fine knitted and terry fabrics. The disadvantage of this machine is that it requires a high material to liquor ratio of 1:20 to 25. The fabric is dyed in a rope form, and hence is not suitable for light shades as the probability of dyeing streaks is increased.

5.3.6 HT-HP beam dyeing machine

This high temperature and high pressure (HT-HP) beam dyeing machine is used for dyeing polyester and polyester-blended fabrics. Dyeing is carried out in open width form. Meticulous batching of fabric on a perforated beam is carried out. HT-HP beam dyeing machines have the disadvantage of a high liquor to material ratio. In newer machines, this disadvantage is eliminated by incorporating dummy space filler cylinders. Dye liquor is circulated continuously from the inside of the fabric beam, through the perforated beam and the fabric.

A temperature of between 125°C and 135°C is maintained, according to the type of the dye, shade required and fabric type.

Due to high temperature and pressure, the dye-exhaustion achieved is higher in comparison to other processes.

5.3.7 Pad batch dyeing machine

The pad-dyeing method is now commonly used for dyeing cellulosic fabric.

Excellent results have been obtained with the pad batch (cold) system utilizing high reactivity dyes. Dyers have experienced many benefits:

- reduction in waste loads in effluent
- low capital outlay
- low energy requirements
- high production speed
- reduced labor requirement
- high colour yield
- outstanding reproducibility
- excellent penetration and levelling characteristics
- rapid fixation

- substantial overall cost savings (dyes, chemicals, labor, water, etc.)

Pad batch dyeing is a cold method of dyeing cellulosics. The prepared fabric is saturated with the premixed dye liquor, and passed through rollers which squeeze out the excess and force the dyestuff inside the fabric for greater penetration. The fabric is then stored or batched on rolls or in boxes covered with a plastic film to prevent carbon dioxide absorption and water evaporation, for two to twelve hours. The dyestuff reacts and penetrates the fabric while in batching, resulting in even and consistent colour. After the reaction is complete, the fabric is washed.
There are many benefits to this method of dyeing. Salt and specialty chemicals for the dyebath such as antimigrants, levelling agents, and fixatives are virtually eliminated. The efficient use of dye and the elimination of specialty chemicals reduces chemical costs and waste loads in the effluent, which in turn saves money on wastewater treatment. Pad batch dyeing reduces water consumption and energy consumption. Consistent dye quality is another benefit to this method of dyeing.

Pad batch dyeing results in even colour absorbency and colour fastness, and produces much lower defect levels when the fabric is properly prepared than in rope dyeing. The high reactivity dyes have rapid fixation and stability resulting in shade reliability and repeatability.

The pad batch method offers simplicity, speed, and flexibility. It can be used on wovens or knits in many constructions.

The water soluble reactives allow easy clean-up and frequent shade changes.

The simplicity and flexibility of the system allow the use of available equipment, such as becks, beams, and continuous equipment for washing.
5.4 Dyeing pollution loads

The extent to which dyes are lost in exhaust and wash liquors varies, depending on the class of dyestuff applied to different fibres. In the case of reactive dyes, heavy loss is significant during cotton dyeing, while lower wastage figures of 3-10% have been reported for the reactive dyeing of wool. Normally, losses are considered to be about 10% for deep shades, 2% for medium shades, and of no consequence when dyeing pale shades.

It has been observed that dyeing wastes contribute to only 10-30% of BOD of the total.

With respect to COD, the contribution of dyes themselves is around 2-5%, while that of dyebath chemicals is as high as 25-35%. Acetic acid (used in disperse dyes on polyester, cationic dyes on acrylic fibres and acid dyes on wool, silk and nylon) exert a high BOD and can account for 50-90% of dye house BOD. In addition to the high BOD and COD values for dyes, toxicity to aquatic organisms also has to be considered. Out of the 3 000 dyes commonly used, 98% have an LC₅₀ value in excess of 1 mg/l. Amongst the different dyes examined, fish toxicity levels vary from less than 1 to more than 500 mg/l LC₅₀ value.

Table 5.1 Chemicals present in cotton and wool dyebaths

<table>
<thead>
<tr>
<th>Dye Type</th>
<th>Chemicals Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aniline Black</td>
<td>Aniline hydrochloride, sodium ferrocyanide, sodium chlorate, pigment, soap, sodium di-chromate.</td>
</tr>
<tr>
<td>Developed</td>
<td>Dye, penetrant, sodium chloride, sodium nitrite, hydrochloric acid or sulphuric acid, developer (beta naphthol), soap or sulphated soap or fatty alcohol.</td>
</tr>
<tr>
<td>Direct</td>
<td>Dye, sodium carbonate, sodium chloride, hydrochloric acid, wetting agent or soluble oil or sodium sulfate.</td>
</tr>
<tr>
<td>Naphthol</td>
<td>Dye, caustic soda, soluble oil alcohol, soap, soda ash, sodium chloride, base, sodium nitrate, sodium acetate.</td>
</tr>
<tr>
<td>Sulphur</td>
<td>Dye, sodium sulphide, sodium carbonate, sodium chloride, sodium di-chromate, hydrogen peroxide.</td>
</tr>
<tr>
<td>Vat</td>
<td>Dye, caustic soda, sodium hydrosulphite, soluble oil, gelatin, perborate or hydrogen peroxide.</td>
</tr>
</tbody>
</table>

Aquatic toxicity is expressed as LC₅₀ which is a concentration expressed in mg/l of the product which, when administered by the respiratory route, is expected to kill 50% of the population of the experimental fish during an exposure of 48 hours. Table 5.2 shows a compilation of LC₅₀ of the population of the experimental fish, during a 48-hour exposure for some dyes and chemicals.
Many add-ons in dyeing – namely carriers, dye-fixing agents, cationic retarders and heavy metal salts – are difficult to biodegrade. The most obvious source of non-metallic dyebath agents are additives to the dyebath used for pre- or after-treatments. These products pose a greater pollution threat than dyes themselves. Carriers used in the dyeing of polyester, insect-proofing agents applied to wool in the dyebath and some classes of dyes all give rise to high AOX.

The toxic effects of heavy metals on animal and aquatic life are dependent on their physicochemical form. In dyehouse effluent, heavy metals arise as a consequence of the heavy metal salts used in dyeing, the use of metal-complex dyes, or from the presence of impurities in dyestuffs.

Metal-complex dyes contain copper, chromium, nickel or cobalt. Strict limits on copper are being imposed, and these will become more rigid in future. Dichromate – used in the oxidation of vat dyes in cotton dyeing – is now being replaced by hydrogen peroxide or 1,3-di-nitro-benzenosulphonic acid.

### Table 5.2 LC₅₀ values of some dyes/substances

<table>
<thead>
<tr>
<th>Dye / Substance</th>
<th>LC₅₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Red 52</td>
<td>&gt; 500</td>
</tr>
<tr>
<td>Acid Yellow 17</td>
<td>180</td>
</tr>
<tr>
<td>Acid Blue 7</td>
<td>1-100</td>
</tr>
<tr>
<td>Acid Black 52</td>
<td>7</td>
</tr>
<tr>
<td>Copper sulphate</td>
<td>1.8</td>
</tr>
<tr>
<td>DDT</td>
<td>0.006</td>
</tr>
</tbody>
</table>

### Table 5.3 Pollution loads for dyeing operations

<table>
<thead>
<tr>
<th>Process</th>
<th>pH</th>
<th>BOD</th>
<th>COD</th>
<th>TSS</th>
<th>TDS</th>
<th>kg per 1000kg of product</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>50 / 50% Polyester / Cotton</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dyeing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct and disperse dyeing (woven goods)</td>
<td>6-8</td>
<td>10.7</td>
<td>32</td>
<td>–</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>Vat and disperse dyeing (woven goods)</td>
<td>12</td>
<td>22.8</td>
<td>68</td>
<td>–</td>
<td>122</td>
<td></td>
</tr>
<tr>
<td>Sulphur and disperse dyeing (woven goods)</td>
<td>11</td>
<td>22.8</td>
<td>68</td>
<td>–</td>
<td>69.7</td>
<td></td>
</tr>
<tr>
<td>Naphthol and disperse dyeing (woven goods)</td>
<td>11</td>
<td>13.8</td>
<td>41</td>
<td>–</td>
<td>57.2</td>
<td></td>
</tr>
<tr>
<td>Fibre reactive and dispersive dyeing (woven goods)</td>
<td>12</td>
<td>13.8</td>
<td>41</td>
<td>–</td>
<td>192</td>
<td></td>
</tr>
<tr>
<td><strong>100% Cotton</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibre reactive HE dyes (woven goods)</td>
<td>12</td>
<td>6.0</td>
<td>24</td>
<td>–</td>
<td>180</td>
<td></td>
</tr>
</tbody>
</table>
5.5 Exercises

5.5.1 Background to the problem

A textile dyeing and printing house processes fabric for shirting materials at a rate of 6000 kg/day. After preparation, the fabric undergoes a dyeing sequence on a jet dyeing machine, operating at 1:10 MLR. There are eight such jet dyeing machines, with a 250 kg capacity each per batch. Each batch is expected to take a total of around six hours – i.e. approximately one batch per shift for the entire operation (including loading and unloading operations).

Dyeing is done with fibre reactive dyes. The present market condition is such that the Company uses depths of shades varying from 0.5%–4%, with an average depth of shade of around 2%. Procion H-E (high temperature high exhaust) type of dyes are preferred for economic reasons. Generally, a dye fixation of 70% is expected.

Table 5.4 below provides the dye recipe of H-E colours for the jet dyeing machine at a shade of 2%.

<table>
<thead>
<tr>
<th>Additives &amp; Auxiliaries</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-E Dye</td>
<td>2% by weight of fabric</td>
</tr>
<tr>
<td>Common salt</td>
<td>60 gpl</td>
</tr>
<tr>
<td>TSP</td>
<td>20 gpl</td>
</tr>
<tr>
<td>Soda ash</td>
<td>20 gpl</td>
</tr>
<tr>
<td>Detergent</td>
<td>5 gpl</td>
</tr>
</tbody>
</table>

* gpl = gm/litre

An increase in the actual time required in the jet dyeing machine may be in the range of 30 to 90 minutes, depending on the reshading adjustments (corrections) required. For re-shading, the dyeing process is repeated after draining half of the contents and adding fresh water, with appropriately reduced dye and chemicals to half of its original amount (for 2% shade, 1% of H-E dye will be added, while the amount of other additives will also be halved).

For the kind of preparation and processing sequence adopted, it is felt that approximately 30% of the fabric may have to go through one or two shading additions. There are no instances of re-stripping.

Better housekeeping, training of operators and hiring of an experienced production manager or dye-master is expected to lead to a reduction in re-shading over a long run.

In practice, it is usually found that replacing hypochlorite bleaching with peroxide bleaching
will reduce the reshading adjustments from 30% to approximately 15%.
Changing the dye type, from H-E fibre reactive to M-E type fibre reactive dye alone, will help to reduce the reshading adjustments from 30% to 20%, since the temperature required for dyeing is lower and better control of the dyeing operation is achieved.

For each operation, the jet dyeing machine is emptied, refilled and reheated to the prescribed temperature. Cooling water utilization is once-through at the rate of 2300 litres/batch.

Table 5.5 below shows a typical jet dyeing machine (MLR 1:10) operating sequence.

<table>
<thead>
<tr>
<th>Operation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading</td>
<td></td>
</tr>
<tr>
<td>Hot wash @ 50°C</td>
<td></td>
</tr>
<tr>
<td>Raise temp to 95°C of dye-water solution and add salt (for exhaustion) and alkali for fixation</td>
<td></td>
</tr>
<tr>
<td>Dyeing</td>
<td></td>
</tr>
<tr>
<td>Hot wash 60°C</td>
<td></td>
</tr>
<tr>
<td>Hot wash 60°C</td>
<td></td>
</tr>
<tr>
<td>Hot wash 60°C</td>
<td></td>
</tr>
<tr>
<td>Soap using neutral detergents at 98°C</td>
<td></td>
</tr>
<tr>
<td>Hot rinse 60°C</td>
<td></td>
</tr>
<tr>
<td>Cold rinse 20°C</td>
<td></td>
</tr>
<tr>
<td>Unloading</td>
<td></td>
</tr>
</tbody>
</table>
Figure 5.1 Dyeing sequence in jet dyeing machines (250kg, 1:10MLR)

- **Fabric in rope form (250kg)**
- **Hot wash at 50°C**
- **Raise temperature to 95°C**
- **Salt addition for exhaustion**
- **Alkali addition for fixation**
- **Dyeing for 60 min (stabilize dye solution for 30 min)**
- **Check for shading correction**
  - **Drain**
  - **Fabric with half of the liquor**
  - **Hot wash at 60°C**
  - **Dyeing for 60 min after stabilization of dye solution for 30 min**
  - **Check for shading correction**
  - **Hot wash at 60°C**
  - **Cold rinse at 20°C**
  - **Hot rinse at 60°C**
  - **Soaping at 98°C**
  - **Freshwater**
  - **Discharge**
  - **Discharge**
  - **Discharge**
  - **Discharge**
  - **Discharge**

- **H-E dye 2%; TSP 20gpl; freshwater**
- **Common salt 60gpl**
- **Soda ash 20gpl**

If shading correction is required:
- **Discharge half of the liquor**

If no shading correction is required:
- **H-E dye 2%; TSP (as required); freshwater**
- **Common salt**
- **Soda ash**

Completion of dyeing with colour shade check **Discharge**
5.6 Questions

1. What are the key environmental issues attached to the dyeing process?

Suggested responses to this question are on page v: 17

2. Estimate the effluent volume being generated from the dyeing sequence, using the information on the dyeing equipment and operational sequence followed:

The answer to this question is on page v: 17
3 Write down the parameters you would propose to measure the pollution potential of the effluent, and justify their selection.

Would you propose to handle and treat the dyeing effluents separately, or blend them with the effluents from the preparatory section? What are the pros and cons of segregation vs. blending strategies?

Suggested responses to this question are on page v:17

4 For the dye recipe provided, prepare a table of inputs and outputs indicating material consumed and the material escaping in the effluent, on the basis of production over a month.

List any additional assumptions you would need to make, especially regarding the fixation of chemicals other than dyes:

Suggested responses to this question are on page v:18
5 Estimate the BOD, COD, TDS and colour concentrations in ADMI units of the dye house effluent. (Assume 1 mg/l of dye = 20 ADMI. This approximation is based on actual data reported in the literature of similar plants. ADMI is the colour unit prescribed by the American Dye Manufacturers Institute):

The answer to this question is on page v:19

6 Examine the process flow diagram. Can you find any ways to minimize water consumption in the dyeing sequence? Are there any reuse possibilities? What information would you like to check before suggesting such an optimization strategy to the management?

Suggested answers to this question are on page v:19

7 Jet dyeing machines are also available at lower material to liquor ratios (MLR) of 1:6 or even lower. List the pros and cons of these machines. For an existing plant, is such a machine replacement strategy economical or practical?

The answer to this question is on page v:20
5.7 Solutions

Question 1
The key environmental issues are:
• type of dye used (e.g. reactive, disperse etc.) and its
toxicological and biodegradability related characteristics
• metal content of the dyes
• its extent of fixation
• dye recipe in terms of auxiliaries used and their
toxicological and biodegradability related characteristics
• extent of resources such as water and heat consumed
• form of dye: e.g. powder, liquid
• any occupational issues related to handling of the dye.

Question 2
Estimation of effluent volume
(Note that we should now be considering production of 6000 kg/day from the
preparation section, and not 6300 kg/day as considered in Part II. This is because re-stripping is considered to be minimal or negligible)

a  Water discharged per batch per machine
   \[ = \frac{250}{1000} \]  \[ \text{...} \]  \[ = 2.5 m^3 \]
Water discharged in 8 drainings
   \[ = 8 \text{ (drainings)} \times 2.5 \text{ m}^3/\text{batch} \times 8 \text{ (machines)} \times 3 \text{ (batches)} \]
   \[ \text{...} \]  \[ = 480 \text{ m}^3/\text{day} \]

b  For a 30% shade adjustment, the additional fabric processed is:
   \[ = 6000 \times 0.3 \]  \[ \text{...} \]  \[ = 1800 \text{ kgs/day} \]

Reshading is possible to manage in the existing system as the normal batch takes
only 6 hours. Each machine can manage 30 to 90 minutes of reshading in the total
batch time of 8 hours.

In other words, each machine would undergo an extended reshading cycle of, say,
one hour at the end of a six hour normal batch. Note, however, that the less the
reshading, the lower the costs of chemicals, water and energy, and there are greater
opportunities to increase production.

Additional water consumption for shade adjustment:
   \[ = (2.5 \text{ m}^3/\text{batch} \times 0.5) \times (1800/250\text{kg}) \]
   \[ \text{...} \]  \[ = 9.00 \text{ m}^3/\text{day} \]

A factor of 0.5 is used, since only half of the fresh water consumption per batch is
used during shade adjustment, mainly as a make-up water since half of the liquor in
the previous dyeing operation is drained and the ratio of 1800/250 gives the number of
batches required for re-processing 1800kg of cloth.

c  In addition to the process water, cooling water is also drained:
   \[ = 2.3 \text{ m}^3/\text{batch (data supplied)} \times 8 \text{ (machines)} \times 3 \text{ (batches)} \]
   \[ = 55.20 \text{ m}^3/\text{day} \]

d  Total volume of effluent from dyeing stage
   \[ = 480 + 9 + 55.2 \]
   \[ \text{...} \]  \[ = 544.2 \text{ m}^3/\text{day} \]

Question 3
Pollution parameters
• Biochemical Oxygen Demand
• Chemical Oxygen Demand
• Concentration of metals such as copper and zinc
  (because the reactive dyestuff contains metals)

• Total Dissolved Solids
• Colour
Advantages of segregation

Colour removal is easier and more economical. Blending with effluents from the preparatory process can lead to interference and increased handling of effluents.

Heat recovery and dye-bath re-use can be explored at source before blending.

Pretreatment may be given before blending if biological treatment is to be used, especially when the dyes exhibit difficult to degrade or toxic properties.

Question 4

Calculation for the dye

a) Total weight of dye used for 250 kg of batch at 2% of the application by weight of the fabric:

   = 250 * 0.02 ................................................................. 5kgs

b) Dye used for reshading at 30% of the production
   (for reshading only 50% of extra dye is used)

   = 250 * 0.3 * 0.02 * 0.5 ........................................... 0.75kgs

c) Total dye consumption = 5.0 + 0.75 .................................. 5.75kgs

d) Dye loss in the effluent at 70% fixation = 5.75 * 0.3 .............. 1.725kgs

e) The volume of the dye liquor in the jet dyeing machine for each batch:
   Since the MLR is 1:10, the liquor volume is
   250 * 10kgs or 2500/1000m³ ........................................... 2500 litres

Calculation for other dye ingredients

f) Assumptions about fixation:

<table>
<thead>
<tr>
<th>Material</th>
<th>Fixation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common salt</td>
<td>5%</td>
</tr>
<tr>
<td>Trisodium phosphate (TSP)</td>
<td>60%</td>
</tr>
<tr>
<td>Soda ash</td>
<td>60%</td>
</tr>
<tr>
<td>Detergent</td>
<td>5%</td>
</tr>
</tbody>
</table>

g) Common salt at concentration of 60 g/l = 2500 * 60/1000 .. 150kgs

Common salt in the effluent = 150 * 0.95 ....................... 142.5kgs

h) TSP at concentration of 20g/l = 2500 * 20 / 1000 ........... 50kgs

TSP in the effluent = 50 * 0.40 .................................. 20kgs

i) Soda ash at concentration of 20g/l = 2500 * 20 / 1000 ........ 50kgs

Soda ash in the effluent = 50 * 0.40 ............................. 20kgs

j) Detergent at concentration of 5g/l = 2500 * 5 / 1000 ........ 12.5kgs

Detergent in the effluent = 12.5 * 0.95 ....................... 11.875kgs

k) Estimate of number of batches in a month:
   3 in a day * 25 (assuming 25 working days) .................... 75

The above calculations are thus multiplied by a factor 75. The results are provided in the table below:

<table>
<thead>
<tr>
<th>Material</th>
<th>Input/month (kg)</th>
<th>Output/month (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dye</td>
<td>431.25</td>
<td>129.375</td>
</tr>
<tr>
<td>Common salt</td>
<td>11250</td>
<td>10687.5</td>
</tr>
<tr>
<td>TSP</td>
<td>3750</td>
<td>1500</td>
</tr>
<tr>
<td>Soda ash</td>
<td>3750</td>
<td>1500</td>
</tr>
<tr>
<td>Detergent</td>
<td>937.5</td>
<td>890.625</td>
</tr>
</tbody>
</table>

Cleaner Production in Textile Wet Processing: A Workbook for Trainers
Part 5: Environmental Aspects of the Dyeing Process
Question 5

Estimation of effluent loads (using data from Table 5.3)

a  Estimation of BOD load:

BOD load from jet dyeing sequence = 6.0kg/1000kg * 6000 .................. 36kg/day
Additional BOD due to shade adjustment = 6kg/1000kg * 1800 * 0.5 ...... 5.4kg/day

Total BOD load from jet dyeing sequence = 36 + 5.4 ......................... 41.4kg/day
Hence BOD concentration = 41.4kg/544.2m² = 0.0761kg/m² .................. 76.1mg/l

b  Estimation of COD:

COD load from jet dyeing sequence = 24kg/1000kg * 6000 .................. 144kg/day
Additional COD due to shade adjustment = 24kg/1000kg * 1800 * 0.5 ...... 21.6kg/day

Total COD load from jet dyeing sequence = 144 + 21.6 .................. 165.6kg/day
Hence COD concentration = 165.6kg/544.2m² = 0.3043kg/m² ............ 304.3 mg/l

c  Estimation of TDS:

TDS load from jet dyeing process = 180kg/1000kg * 6000 .................. 1080kg/day
Additional TDS in the effluent due to readjustment:

= 180kg/1000kg * 1800 * 0.5 ................................................. 162kg/day

TDS from jet dyeing sequence = 1080 + 162 .......................... 1242kg/day
Hence TDS concentration = 1242kg/544.2m² = 2.282kg/m² ............. 2282mg/l

d  Estimation of dye in the effluent:

Assuming dye exhaust at 70% (i.e. 30% remaining in the effluent)
and average depth of shade as 2%, dye remaining in wastewater

= 6000kg * 0.02 * 0.3kg/day .... 36kg/day for Right First Time quality dyeing

Dye remaining in wastewater due to redyeing for shade adjustment
(assuming only half of the fresh dye is used during shade adjustment)

= 1800 * 0.02 * 0.3 * 0.5 ................................................. 5.4kg/day

Total dye remaining in wastewater = 36 + 5.4 ......................... 41.4kg/day

e  Conversion of dye concentration to approximate ADMI colour units

The total volume of wastewater generated in the dyeing process is 544.2m³/day.
The 41.4kg of unfixed dye will be thus diluted in 544.2m³ of flow.
This will correspond to the dye concentration (in mg/l)
of 41.4 (kg/day)/544.2 (m³/day) = 0.0761kg/m³ .................. 76.1mg/l
Since 1mg/l of dye = 20 ADMI units, the colour of the dye effluent
in ADMI units is 76.1 * 20 .............................. 1522 ADMI units

Question 6

One good possibility to reduce water consumption is by eliminating and/or reusing some of the washing steps in the dyeing cycle. In this case, the possibilities are:

1 Eliminate one of the three hot washes before dyeing
2 Reuse the washwaters from the dyeing process:
   • the first hot wash before dyeing
   • the last two hot washes from the three hot washes (Stages 10 and 11) after the dyeing process
   • the last cold wash after soaping.
Before introducing these changes, detailed analysis of the water quality of the washes under consideration should be done (especially in terms of suspended solids, pH, total dissolved solids, residual chlorine, iron and manganese concentrations), and compared with the minimum desirable water quality for the washing sequence. Any corrections needed would have to be engineered by designing a system consisting of isolation, conveyance and storage with an adequate facility for correction of water quality. Initially, batch work may be done on small lots consisting of both dark and light shades, and an evaluation carried out on the results of dyeing: especially checks for levelness, fastness, bronzeness etc., as well as any influence on the percentage of reshading. Once the results have been found to be satisfactory, then the entire batch may be tried, followed by full scale engineering work (pipework, valves, storage and treatment system with a pump) and issuing of new worker instructions (training).

Question 7
Effects of changing liquor ratio (MLR) from 1:10 to 1:6 by using a new jet dyeing machine

Qualitative evaluation:

| + | Reduction in water consumption for the processing of the same quantity of fabric due to change in MLR. |
| + | Reduced energy and steam consumption. |
| + | Reduced chemicals and dye consumption. |
| - | Reduction in effluent volume and hence costs of effluent treatment. |
| - | Increased pollution concentration and colour concentration in effluent due to reduced dilution. There may be difficulty in meeting the colour standards. |
| - | Low returns while selling the existing jet dyeing machines and added costs of purchases of the new units. |
| - | Retraining of workers needed for operation of new machines. |
Part 6
Environmental Aspects of the Printing and Finishing Processes

6.1 Printing .................................................................IV:3
6.2 Finishing ..............................................................IV:4
6.3 Printing and finishing pollution loads ........................IV:7
6.4 Exercises .............................................................IV:8
6.5 Solutions ..............................................................IV:9
Environmental Aspects of the Printing and Finishing Processes

6.1 Printing

Washing the fabric after printing results in coloured effluents which carry the unfixed print paste with its ingredients. Some of the hard-to-treat printing wastes include colour residues, phosphate and nitrogen-containing chemicals, and non-biodegradable organic materials such as surfactants and solvents. These products can resist effluent treatments, causing subsequent environmental problems.

Nowadays alkylphenol-ethylene oxide products are being replaced by eco-friendly surfactants and white spirit, with water emulsion thickening by aqueous thickeners in pigment printing. More serious problems arise in printing with reactive dyes where large quantities of urea are used to swell cellulosic fibres, bringing about the disaggregation of dyes, an increased solubility of dyes, retarded evaporation of water during drying, and increased condensation of water on prints during steaming.

Some approaches to eliminate or replace urea in cellulose printing have been suggested:
• adoption of two-phase flash printing
• complete or partial substitution of urea with an alternative chemical Metaxyl FN-T and
• the mechanical application of moisture to printed fabric prior to entering the steamer.

In the flash-ageing process, highly reactive dyes are printed from a paste free of alkali and urea, and then overpadded with high concentrations of caustic soda and electrolyte followed by flash-steaming. However, it is observed that adoption of this technique may not solve effluent problems, because the flash-age process involves use of high salt and high pH liquors.

Moisture spraying systems have been found to be useful in conditioning viscose fabrics after printing and drying but before steaming. These systems eliminate the use of urea totally by printing from a urea-free print paste followed by applying moisture of up to 30% prior to steaming.
6.2 Finishing

The finishing process imparts the final aesthetic, chemical and mechanical properties to the fabric as per the end use requirements. Several finishing methods have been developed to improve the feel, drape, antistatic, antisoiling, anti shrinking, anti-crease, water repelling and flame retardancy properties of the fabric.

The finishing can be broadly classified into two categories: mechanical finishing and chemical finishing. In the case of mechanical finishing, the effect is produced mechanically, while for chemical finishing, chemicals are used.

The finishes can be further classified as permanent and nondurable finishes.

6.2.1 Resin finishing

The main objectives of resin finishing are to improve dry and wet crease recovery and sharp crease retention of the fabric. This finish is largely applied to cotton and its blends with manmade fibres.

There are three main types of resin finishing treatments:
- anti-crease finishing
- wash and wear finishing

Though the anti-crease finish and wash and wear finish methods are basically the same, the difference lies only in the type and level of crease recovery. In anti-crease finishing, a dry-crease recovery of about 230 (warp and weft) is regarded as satisfactory. However, in wash and wear fabrics, it is not only the dry crease recovery which is important but also the wet crease recovery. Dry and wet crease recovery of about 240 (warp and weft) each can be considered as satisfactory for wash and wear fabrics.

For anti-crease and 'wash and wear' finishing, two processes are mainly used: pad-dry-cure and wet cross linking. In the case of the pad-dry-cure method, the fabric is padded with the resin, dried on the stenter and cured in polymeriser. After curing, the fabric is washed with soap and soda ash to remove decomposed products from the cured fabric, whereas in the wet cross linking process, the chemical reaction is allowed to take place between a cross linking agent and cellulose in an acidic wet condition. The fabric is padded with (80% pick-up) a solution containing thermosetting resin with a highly acidic or alkaline catalyst and thermoplastic resin. After padding, the fabric is batched in wet conditions and left to react under rotation for 10 to 16 hours, depending on the amount of catalyst used.

Durable press treatment is based on different requirements. It gives high wrinkle recovery. However, in certain types of garments (such as men's suiting and shirts), creases are introduced deliberately. The creases should last as long as possible and should survive normal launderings, whilst at the same time, the rest of the garment should be wrinkle free.

Different methods, such as the post-cure process and garment treatment, are used for durable press treatment. Of these, the post-cure and pre-cure process are mainly used.

In the post-cure process, the fabric is impregnated with a solution containing thermosetting resin, acidic catalyst, softener etc., and dried under conditions which do not cause a complete reaction between the cotton and the cross-linking agent. At this stage, the fabric is said to be 'sensitised'. Garments are stitched from the 'sensitised fabric, lightly ironed to their proper shape, and then cured in a garment curing oven. In the pre-cure process, however, after the usual pad-dry-cure afterwash technique, the garment is manufactured from the crease resistant fabric. The creases are then heat-processed after local application of a small amounts of cross-linking agent, together with an acidic solution and an acidic catalyst. In the durable press treatment to cotton fabrics, the combination of high resin content and prolonged curing at high temperatures causes severe strength losses and reduces abrasion resistance below acceptable limits.
6.2.2 Anti-shrink finishing

The main objective of this finish is to overcome the problem of shrinkage of cotton and cotton-blended fabric during washing. The process was originally patented and treated fabric was known as 'Sanforised' fabric. The cloth is mechanically shrunk between a drum and a rubber belt. The sanforising machine consists of an entry roll, a cloth damping unit, a small clip stenter to adjust the width of the fabric, a cloth shrinking unit, and a felt palmer unit to impart the felt finish.

6.2.3 Stenter finishing

The main function of the stenter is to impart dimensional stability to the fabric. Fabric structure is stabilized by controlling the longitudinal and transverse tension and heat setting the fabric in tension. Length is controlled by positive overfeeding, whereas width is controlled by mounting the fabric on parallel running chains. Stentering is a critical process, and determines the dimension stability of the fabric and shrinkage during use.

These machines normally run at around 0-150m/min., depending on the type of machine, the process used, and the fabric. Overfeeding can be carried out between -15% and +60%. Heat setting is done in a long closed chamber, where the fabric is dried at a high temperature by means of hot air.

Amongst the different products used in the finishing of textiles, the most eco-friendly products are formaldehyde-based cross-linking agents which are applied to cellulosic textiles to impart crease-resistance and dimensional stability.

During their application, the evolution of free formaldehyde can arise due to unreacted formaldehyde in the product, liberation of formaldehyde during the cross-linking reaction, and slow generation of formaldehyde during the storage of resin-finished fabrics and garments.

Various countries have prescribed tolerance limits for free formaldehyde, depending on the end use of the treated fabrics and garments. The presence of formaldehyde in the atmosphere and in wastewater streams is considered as highly objectionable.

Two different approaches have been adopted to minimize the problems connected with free formaldehyde in textile wet processing:

- the development of formaldehyde-free cross-linking agents for cellulosic textiles and formaldehyde-free dye-fixing agents
- the use of formaldehyde scavengers during application and storage of resin finished goods.

A wide variety of products is used in textile finishing, depending on the characteristics to be imparted to the consultant fabric. Most of these products are either polymeric in nature or anionic, cationic or non-ionic compounds. In several cases, catalysts are used along with these products to bring about a chemical reaction between them and the fibre substance to make them more durable during use. Precise information is not readily available regarding biodegradability and toxicity of these products; it is therefore difficult to evaluate their impact on receiving streams.

In order to overcome the problems connected with non-ecofriendly products used in the chemical finishing of textiles, research is now concentrated in the mechanical finishing of textiles whereby desired properties - namely softness, stiffness, bulk, drape, smoothness, handle etc. - can be imparted to textiles by changing the morphology or surface characteristics of the fabrics by mechanical means. In turn, this completely obviates the use of chemical products, thereby reducing considerably the problems of toxicity and stream pollution.

Vacuum extraction has been utilized in many capacities. The technology has been used for lint removal, water removal, chemical finishing, dyeing, washing, and removal and recovery of chemicals. Vacuum extraction lint removal systems remove lint from fabric prior to printing, eliminating a potential unprinted spot where lint is attached to the fabric. In addition, by removing the lint prior to the printing process, lint does not become attached to the printing screen, thereby resulting in repeated unprinted spots along the length of the printed fabric. By removing lint before the fabric is printed, the quality,
consistency, and appearance of the printed fabric is improved.

One of the most common and simplest uses of vacuum extraction is for water removal prior to drying. Moisture removal before drying saves energy in the drying process, increases production speed by decreasing the overall drying time, and assists in washing the fabric.

In wet processing, it is critical that the fabric has the correct moisture level to prevent bath dilution from fabric which is too wet. Vacuum control is crucial to maintain consistent extraction rates for even chemical application. By applying reactive chemicals on wet fabric as opposed to dry fabric, savings are not only realized chemically, but drying is eliminated. The period of return on investment is extremely short.

Utilizing vacuum extraction technology in washing significantly increases the contaminant removal from fabric compared to water removal using a squeeze roll. Vacuum extraction equipment is space efficient, can be added to existing systems, and requires relatively low capital outlay.

Applications of these systems include water removal prior to drying fabric and chemical application, and as a means of improving the washing process. Some of the benefits of removing water prior to the drying of fabric include increased drying and process speed, reduced energy requirements for drying, a reduction of lint accumulation on rolls and dry cans, and elimination of a drying process for wet-on-wet chemical finishing. Water removal before chemical application removes fabric contaminants and assures uniform wet pick-up prior to chemical application. The washing process is improved by vacuuming out, not squeezing in, contaminants, and allows controlled counterflow and filtering of water in the wash line.
### 6.3 Printing and finishing pollution loads

Table 6.1 Pollution loads for printing and finishing operations (50/50 polyester/cotton)

<table>
<thead>
<tr>
<th>Process</th>
<th>pH</th>
<th>BOD</th>
<th>COD</th>
<th>TSS</th>
<th>TDS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kg per 1000kg of product</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Printing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pigment (woven goods)</td>
<td>6-8</td>
<td>1.26</td>
<td>5.0</td>
<td>0.13</td>
<td>2.5</td>
</tr>
<tr>
<td>Pigment (knot goods)</td>
<td>6-8</td>
<td>1.26</td>
<td>5.0</td>
<td>0.13</td>
<td>2.5</td>
</tr>
<tr>
<td>Vat dye (woven goods)</td>
<td>10.0</td>
<td>21.5</td>
<td>86</td>
<td>25</td>
<td>34</td>
</tr>
<tr>
<td>Vat dye (knit goods)</td>
<td>10.0</td>
<td>21.5</td>
<td>86</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td><strong>Finishing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resin finishing (woven goods)</td>
<td>6-8</td>
<td></td>
<td></td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>Resin finishing flat curing</td>
<td>6-8</td>
<td>6.32</td>
<td>25</td>
<td>12</td>
<td>17.3</td>
</tr>
</tbody>
</table>
6.4 Exercises

1. What are the key environmental considerations of the finishing and printing processes? What are the local environmental implications?

2. What are the environmental problems of using:
   
   [a] kerosene in pigment printing?

   [b] urea in the printing paste?

   [c] formaldehyde in finishing?
6.5 Solutions

Question 2

[a] At elevated temperatures, kerosene can lead to the release of hydrocarbons, which in turn leads to the generation of carcinogenic compounds and affects the health of workers.

[b] When washed-out or wasted, printing paste containing urea can reach the water bodies nearby. The escape of urea into water bodies can lead to an increase in nutrients promoting the growth of algae and subsequently eutrophication.

[c] When on the fabric, free formaldehyde can react with perspiration or rubbing skin, and can lead to skin diseases depending on skin sensitivity (especially in case of children).
Part 7
Application of Environmental Audit to identify Cleaner Production measures

7.1 Achieving cleaner production ........................................ VII:3
7.2 Cleaner Production audit ............................................. VII:5
7.3 Conducting a waste audit ............................................. VII:6
7.4 Phase 1 Pre-assessment .............................................. VII:7
7.5 Phase 2 Material balance: process inputs and outputs ...... VII:9
7.6 Economic and environmental evaluation ....................... VII:24
7.7 Solutions ..................................................................... VII:29
7 Application of Environmental Audit to identify Cleaner Production measures

7.1 Achieving cleaner production

Identification, evaluation and implementation of Cleaner Production measures is an important task. During the 1980s, the responsibilities of environmental engineers were limited to the design, maintenance and operation of end-of-pipe treatment systems, and liaising with the pollution control authorities. In the context of the Cleaner Production approach, the scope and expectations of both the environmental engineer and the production engineer are indeed more demanding. In fact, a truly professional managerial approach is required which takes advantage of the interface in production systems, environmental organizations, finance and public relations.

In such a changing climate, what should a Chief Executive Officer of the company do?

1 Appoint an environmental manager

First, the CEO will need to appoint an environmental manager and establish the environmental manager’s position at senior management level. A formal company policy should be issued, laying down the job profile and list of duties for an environmental manager.

These duties may include:
- monitoring new developments and products as part of a comprehensive environmentalist procurement policy
- providing convincing presentations of the company’s environment-related activities to the outside world, insofar as this is not done by other departments or partners/owners
- arranging for precautionary pollution measurements and making proposals for commissioning consultants to investigate ways of saving energy and water
- investigating the feasibility of allowing other companies to use spare capacity in the company’s plant (e.g. waste disposal or recycling plant) on a remunerative basis
- participating in training activities
- maintaining close liaison with pollution control authorities.

2 Provide comprehensive information within the company on the duties, purpose and objectives of the new post.

3 Draw up an establishment chart clearly showing responsibilities and functions.

4 Provide the environmental manager with active support.

5 Discuss and resolve conflicts between environmental and departmental objectives without delay.

6 Draw up a budget for environmental activities outside the company (e.g. support of associations for environmental protection).

7 Plan investment for environmental purposes separately within the overall investment programme and carry out a specific assessment of the extent to which objectives are met.
8 Ensure adequate liaison and discussion between departmental managers/directors/members of the executive board and the environmental manager.
9 Give the environmental manager the opportunity to draw attention to environmental problems and possible solution by meeting bodies of workers (workforce meetings, information tours), etc.
10 Set up a technical committee for environmental matters.
   The technical committee should deal with all environmental problems or questions which affect the company, such as:
   • materials
   • energy supplies
   • water supplies
   • waste disposal
   • disposal of special-category wastes
   • scope for recycling
   • environmental problems in the production process

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   • energy supplies
   • water supplies
   • waste disposal
   • disposal of special-category wastes
   • scope for recycling
   • environmental problems in the production process

7.1.1 What should an Environmental Manager do?

1 Plan environmental activities and assess progress
   Make a study of weaknesses in all departments, including subsidiaries and associated companies, and draw up a plan of action indicating what is to be done, by whom and by when. In order to identify shortcomings, a systematic audit will be required of all known and predictable environmental problems affecting the company, assessing their relative importance. More particularly, a systematic analysis will be needed of the likelihood and repercussions of incidents, so that preventive arrangements can be made.
2 Wherever possible, incorporate specific objectives in the action plan
   Such as:
   • undertaking prioritization of waste streams and identifying reuse, recovery and recycling potentials within one year.
   • aiming for a 20 per cent reduction in water consumption in washing and cooling operations by the end of the year.
   • ensuring optimum reuse of used oil within the next six months.

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   • aiming for a 20 per cent reduction in water consumption in washing and cooling operations by the end of the year.
   • ensuring optimum reuse of used oil within the next six months.

3 Ensure that the materials management department draws up a list of materials
   This list should contain at least the following information about the materials:
   • inventory number
   • name
   • ecological hazards
   • transport code
   • disposal
   • alternatives
   • unit price
   • supplier
   • chemical designation
   • dangerous reactions and toxicity
   • technical precautions
   • annual consumption.

4 Formulate an ecology-oriented purchasing strategy
   Collect information from suppliers, in particular details of production processes (e.g. whether the size used by the grieg supplier uses pentachlorophenol etc.).

5 Consult own R & D and engineering departments about the possibility of using alternative materials, processes and methods of operation.

6 Run a Cleaner Production Audit Programme.

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Part 7 • Application of Environmental Audit to Identify Cleaner Production measures
Chapter 7: Application of Environmental Audit to Identify Cleaner Production Measures

7.2 Cleaner Production audit

The Cleaner Production audit links the environmental manager with production processes, the waste generated, and the product itself. The Cleaner Production audit is not just a stocktaking of information or an opportunity to ask questions or conduct an evaluation. It should be viewed as an integral and essential process concerning the production systems, with technological, economic and human factor interfaces. In today’s competitive world, the cleaner production audit is a survival tool which will lend a competitive edge.

7.2.1 Waste auditing

A waste audit is the first step in an ongoing programme designed to achieve maximum resource optimization and improved process performance. It is a common sense approach to problem identification and problem solving. But remember, it is not a one-time job – it must be an ongoing process.

The waste audit should be later expanded to look into some of the product related issues, health and safety considerations etc. These areas are discussed in Part 6.

A waste audit enables you to take a comprehensive look at your site or process to facilitate your understanding of material flows and to focus your attention on areas where waste reduction – and therefore cost saving – is possible.

A good waste audit:
- defines sources, quantities and types of waste generated
- collates information on unit operations, raw materials, products, water usage and wastes
- highlights process inefficiencies and areas of poor management
- helps set targets for waste reduction
- permits the development of cost-effective waste management strategies
- raises awareness in the workforce regarding the benefits of waste reduction
- increases your knowledge of the process;
- helps to improve process efficiency.

A waste audit can succeed only if it enjoys the support and commitment of the top management.

A formal policy statement conveyed by the management to all employees is the program’s entry point into the organizational climate or value system, as well as into the company’s operating systems. The policy statement should include answers to questions such as:
- why pursue cleaner production?
- what will have to be done?
- who will do it?

Here is a typical policy statement.

7.2.2 A sample policy statement

Our Company is committed to excellence and leadership in protecting the environment. In keeping with this policy, our objective is to reduce wastes and emissions. We strive to minimize adverse impacts on air, water and soil through excellence in waste minimization. By successfully minimizing waste at the source, we can achieve cost savings, increased operational efficiencies, improvements in the quality of our products and services, and maintenance of a safe and healthy workplace for our employees.

Our Company’s environmental guidelines include the following:
- Environmental protection is everyone’s responsibility. It is part of our value system and displays commitment to our Company.
- Waste minimization at source is of prime consideration in research, process design and plant operations. Our Company is committed to identifying and implementing waste minimization opportunities with the encouragement and involvement of all employees.
- Technologies and methods which substitute non-hazardous materials and utilize source reduction approaches will be given top priority in addressing all environmental issues.
- Our Company seeks to demonstrate its corporate citizenship by adhering to all environmental regulations. We promote cooperation and coordination between industry, government and the public towards the shared goal of waste minimization at its source.
7.3 Conducting a waste audit

The Cleaner Production audit process may be divided into three distinct phases: Pre-assessment, Material Balance and Synthesis.


Please consult the description of each of the steps described and attempt to answer the questions which follow.

7.3.1 The Company Fabina

A medium scale textile dyehouse called Fabina processes 6000kg/day of dyed shirting material. The dyed fabric is later purchased by screen printers who make print designs based on the market demands.

There are 200 workers employed in each shift, and the factory operates three shifts a day for nearly 300 working days in a year.

The various processes employed are similar to those described in the earlier sections of preparation and dyeing. Stentor finishing is carried out after the dyeing process.

A steam boiler of 5T capacity is installed to provide hot water in preparation and dyeing as well as steam during finishing.

It is proposed to design and construct an Effluent Treatment Plant (ETP) facility.

After treatment, the effluents would be discharged into a river.

The information on average total water consumption and effluent characteristics as compiled at the unit is shown in the table below.

Average total effluent discharge = 830m³/day

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average concentration in mg/l</th>
<th>Required standard (into surface waters) mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>800</td>
<td>50</td>
</tr>
<tr>
<td>COD</td>
<td>2000</td>
<td>150</td>
</tr>
<tr>
<td>TDS</td>
<td>4500</td>
<td>1500</td>
</tr>
<tr>
<td>Colour in ADNI Units</td>
<td>1200</td>
<td>50</td>
</tr>
</tbody>
</table>

The proposed ETP consists of an equalization/neutralization tank, followed by an activated sludge process.

Cleaner Production in Textile Wet Processing: A Workbook for Trainers
Part 7: Application of Environmental Audit to Identify Cleaner Production measures
7.4 Phase 1 Pre-assessment

7.4.1 Step 1 Audit focus and preparation

1. What should be the major focus of conducting the Cleaner Production audit for Fabina? List points from the production and the environmental angles:

2. What should be the ideal number and composition of the audit team? List the areas of specialization and the responsibilities of the team members:
7.4.2 Step 2 Listing unit operations

3 List the various unit operations applicable to Company Fabina which need to be looked into for the purpose of auditing. Do not forget to include any related utility operations or related source of generation of waste.
7.4.3 Solutions to Step 1

Question 1  
From the production angle, the major focus is excessive water consumption. Meeting standards, especially for the colour requirements, is also necessary. High concentrations of colour with excessive use of water probably indicates poor dye fixation, excessive re-shading (i.e. less batches ‘right first time’), or poor housekeeping in the dye kitchen.

Generally, for the type of processes and processing sequence adopted at Fabina, a water consumption of the order of 100 litres/kg should be adequate. Most of the well operated textile dyehouses are close to such a norm. 100 l/kg indicates water consumption to the order of only 650 m³/day. Assuming dye loss of 30% at a 2% depth of shade, the dye discharged would be around 37.8 kg.

As the ADMI of effluent is 850, there is an indication – at least on a rough basis – that around 42.5 kg of dye is being lost in the effluent.

Question 2  
Proposed team members

- Plant Manager/Senior Plant Engineer
- Dye Master/Senior Laboratory Chemist
- Materials Manager/Storekeeper
- R & D Manager/Process Consultant
- Environmental Engineer/Consultant on Pollution Control
- Financial Planner/Senior Accountant

7.4.4 Solutions to Step 2

Question 3  
Unit operations

- Storage and preservation of grieege fabric
- Sizing
- Scouring
- Dyeing
- Desizing
- Bleaching
- Printing
- Inspection for quality control for the purpose of reshading
- Finishing
- Packing and storage
- Inspection for quality control
- Procurement and storage of processing chemicals
- Boiler operation
- Operation of the dye-house
- Washing and toilet facilities for workers.
Phase 2 Material balance: process inputs and outputs
Steps 4, 5 and 6 Determining inputs

1 Develop a list of inputs of resources (such as water, chemicals, energy, etc.) for every unit operation identified in the process flow diagram. For each item in your list, write down the method or probable sources of information or assumptions you propose to use for quantifying the resource use.

By the end, you should have a quantified list of all the items under the description of inputs. Extend the concept used for preparing input and output for jet dyeing operation (see the questions in Part 2 on dyeing).
7.5.2 Solution to Steps 4, 5 and 6

**PREPARATION**

**Hypochlorite bleaching**

- **Water consumption**
  - From the process flow diagram, the total number of drainings is 11. (note the use of 6300 here, as it is the base case having 5% restripping)
  - **Volume of water required for the jumbo jigger**
    \[ = 2.362 \text{m}^3/\text{draining} \times 11 \text{ (drainings)} \times 4 \text{ (machines)} \times 1 \text{ (batch/day)} \]
    \[ = 103.93 \text{m}^3/\text{day} \]

- **Chemical consumption**
  - **Chemicals required**
    - 2.5% hypochlorite (2.5% by weight) = 6300*0.025 = 157.5 kg/day
    - Soda ash (0.2%) = 6300*0.002 = 12.6 kg/day
    - Wetting agent (0.1%) = 6300*0.001 = 6.3 kg/day

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5% hypochlorite</td>
<td>157.5 kg/day</td>
</tr>
<tr>
<td>Soda ash</td>
<td>12.6 kg/day</td>
</tr>
<tr>
<td>Wetting agent</td>
<td>6.3 kg/day</td>
</tr>
</tbody>
</table>

*Water consumed in preparatory stage: 103.93 m³/day*

**DYEING**

**Jet dyeing in dyehouse**

- **Water consumption**
  - For H-E dyes and hypochlorite bleaching, considering extra for (30%) reshading of 1890 (6300*0.3) kgs (note the use of 6300 here, as it is the base case having 5% restripping)
    \[ = (2.5 \text{m}^3/\text{batch} \times 6300/250) \times 8 + ((2.5 \text{m}^3/\text{batch} \times 0.5) \times (1890/250)) \]
    \[ = 504 + 9.45 \text{m}^3/\text{day} \]
    \[ = 513.45 \text{m}^3/\text{day} \]
  - **Cooling water**
    \[ = 2.3 \text{m}^3/\text{batch} \text{ (typical for 250 kg jet dyeing machine)} \times 6300/250 \]
    \[ = 57.96 \text{m}^3/\text{day} \]
  - **Total water consumption for dyeing**
    \[ = 513.45 + 57.96 \]
    \[ = 571.41 \text{m}^3/\text{day} \]

- **Chemical consumption**
  - **Dye consumption**
    \[ = (6300*0.02 + 1890 kg*0.02*0.5) kg/day \]
    \[ = 144.9 kg/day \]
  - **TSP consumption**
    \[ = 20 g/lt*(6300/250)(batch)*(2500 litres/batch)/1000 + 20 g/lt*0.5 \]
    \[ = 1449 kg/day \]
  - **Common salt consumption**
    \[ = 60 g/lt*(6300/250)(batch)*(2500 litres/batch)/1000 + 60 g/lt*0.5 \]
    \[ = 4347 kg/day \]
  - **Soda ash consumption**
    \[ = 20 g/lt*(6300/250)(batch)*(2500 litres/batch)/1000 + 20 g/lt*0.5 \]
    \[ = 1449 kg/day \]
Jet dyeing in dyehouse continued

<table>
<thead>
<tr>
<th>Water consumed in dyeing process</th>
<th>571.41m³/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dye (H-E)</td>
<td>144.9kg/day</td>
</tr>
<tr>
<td>TSP</td>
<td>1449.0kg/day</td>
</tr>
<tr>
<td>Common salt</td>
<td>4347.0kg/day</td>
</tr>
<tr>
<td>Soda ash</td>
<td>1449.0kg/day</td>
</tr>
</tbody>
</table>

**FINISHING**

Water consumption

- **For stenter finishing**
  \[ \text{Water consumption} = 5 \text{liters/kg} \times 6300 \text{kg/1000} \] 31.5m³/day

- **Domestic consumption**
  - Assuming *per capita* water consumption of around 140 litres per capita per day (lpcd), the domestic water consumption
    \[ \text{Water consumption} = 200 \text{ (workers)} \times 140 \text{ lpcd/1000} \] 28m³/day
  - Assuming *lump sum* water consumption for floor washing and other miscellaneous uses
    \[ \text{Water consumption} = 25m³/day \]
  - Total *domestic effluent* = 28m³/day + 25m³/day
    \[ \text{Water consumption} = 53.0m³/day \]

- **Boiler**
  - Water consumed by 5 T boiler
    \[ \text{Water consumption} = 10m³/day \]
7.5.3 Steps 7, 8, 9 and 10 Quantifying process outputs

2 Prepare a list of output in terms of wastes or losses, indicating the media (i.e. air emission, effluent, solid wastes). Include in your list the likely characteristics of the wastes in qualitative form, such as high BOD, odorous, continuous/intermittent etc. Proceed with the quantification of each item using related sources of information.

At the end, you should have produced a quantified list of all the items under the description of inputs. Extend the concept used for preparing input and output for the jet dyeing operation (see the question in the exercises in Part 2 on dyeing).
### 7.5.4 Solution to Steps 7, 8, 9 and 10

**Pollution load**

<table>
<thead>
<tr>
<th>From preparatory stage</th>
<th>Effluent (neglecting losses)</th>
<th>103.93 m³/day</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BOD</strong></td>
<td>per 6300 kg/day</td>
<td></td>
</tr>
<tr>
<td>a Enzyme starch desizing</td>
<td>45.5 kg/1000 kg</td>
<td>286.65 kg/day</td>
</tr>
<tr>
<td>b For scouring</td>
<td>21.5 kg/1000 kg</td>
<td>135.45 kg/day</td>
</tr>
<tr>
<td>c For bleaching</td>
<td>1.0 kg/1000 kg</td>
<td>6.3 kg/day</td>
</tr>
<tr>
<td>d For mercerizing</td>
<td>2.0 kg/1000 kg</td>
<td>12.6 kg/day</td>
</tr>
<tr>
<td><strong>Total BOD load from preparatory stage</strong></td>
<td></td>
<td>441.0 kg/day</td>
</tr>
<tr>
<td><strong>COD</strong></td>
<td>per 6300 kg/day</td>
<td></td>
</tr>
<tr>
<td>a Enzyme starch desizing</td>
<td>91.0 kg/1000 kg</td>
<td>573.3 kg/day</td>
</tr>
<tr>
<td>b For scouring</td>
<td>64.5 kg/1000 kg</td>
<td>406.35 kg/day</td>
</tr>
<tr>
<td>c For bleaching</td>
<td>4.0 kg/1000 kg</td>
<td>25.2 kg/day</td>
</tr>
<tr>
<td>d For mercerizing</td>
<td>6.0 kg/1000 kg</td>
<td>37.8 kg/day</td>
</tr>
<tr>
<td><strong>Total COD load from fabric preparation stage</strong></td>
<td></td>
<td>1042.65 kg/day</td>
</tr>
<tr>
<td><strong>TDS</strong></td>
<td>per 6300 kg/day</td>
<td></td>
</tr>
<tr>
<td>a Enzyme starch desizing</td>
<td>5.0 kg/1000 kg</td>
<td>31.5 kg/day</td>
</tr>
<tr>
<td>b From scouring</td>
<td>50.0 kg/1000 kg</td>
<td>315.0 kg/day</td>
</tr>
<tr>
<td>c From bleaching</td>
<td>55.0 kg/1000 kg</td>
<td>346.5 kg/day</td>
</tr>
<tr>
<td>d From mercerizing</td>
<td>142.0 kg/1000 kg</td>
<td>894.6 kg/day</td>
</tr>
<tr>
<td><strong>Total TDS from the fabric preparation stage</strong></td>
<td></td>
<td>1587.6 kg/day</td>
</tr>
</tbody>
</table>

**From jet dyeing in dyehouse (considering additional load due to 30% shade adjustment)**

| Effluent (neglecting losses) | 571.41 m³/day |
| Dye in effluent              |               |
| Assuming dye exhaust at 70% (i.e. 30% remaining in the effluent) and average depth of shade as 2% |
| \( (6300\text{kg} \times 0.02 \times 0.3 + 1890\text{kg} \times 0.02 \times 0.5 \times 0.3) = 37.8\text{kg/day} + 5.67\text{kg/day} \) | 43.47 kg/day |
| **BOD**                      | (6.0 kg/1000 kg \times 6300) + (6.0 kg/1000 kg \times 1890 \times 0.5) |
|                             | 37.8 kg/day + 5.67 kg/day | 43.47 kg/day |
| **COD**                      | (6.0 kg/1000 kg \times 6300) + (6.0 kg/1000 kg \times 1890 \times 0.5) |
|                             | 151.2 kg/day + 22.6 kg/day | 173.8 kg/day |
| **TDS**                      | (6.0 kg/1000 kg \times 6300) + (6.0 kg/1000 kg \times 1890 \times 0.5) |
|                             | 1134 kg/day + 170.1 kg/day | 1304.1 kg/day |

**From finishing stage**

| Effluent (neglecting losses) | 31.5 m³/day |
| **BOD**                      | 4 kg/1000 kg \times 6300 |
| **COD**                      | 16 kg/1000 kg \times 6300 |
| **TDS**                      | 15 kg/1000 kg \times 6300 |

**From domestic use**

| Effluent (neglecting losses) | 53.0 m³/day |
| **BOD**                      | 100 mg/lit \times (53.0 m³/day) / 1000 |
| **COD**                      | 250 mg/lit \times (53.0 m³/day) / 1000 |
| **TDS**                      | 500 mg/lit \times (53.0 m³/day) / 1000 |

**From boiler**

| Effluent (neglecting losses) | 10 m³/day |
| **COD**                      | 500 mg/lit \times (10 m³/day) / 1000 |
| **TDS**                      | 3000 mg/lit \times (10 m³/day) / 1000 |
7.5.5 Steps 11, 12, 13 and 14 Assembling input and output information for unit operation

3 Prepare an overall statement of outputs for the entire production process.
   For this purpose, use the outputs from each of the unit processes derived earlier, and develop a plant level material balance with respect to effluent volume, effluent BOD, COD, TDS and colour:

4 Compare the calculated effluent characteristics with respect to those calculated above. List various reasons why the estimated outputs do not exactly match with those measured at the inlet of the ETP.
   What would be your strategies for sampling, additional material balances, new information/assumptions etc. to reconcile the differences? For example, an analysis of segregated effluents from preparation and dyeing section may help in setting up two additional material balances to lend a focus:
7.5.6 Solutions to Steps 11, 12, 13 and 14

Table 7.1 Overall statement of pollution loads to effluent treatment plant

<table>
<thead>
<tr>
<th>Process</th>
<th>Effluent volume m³/day</th>
<th>BOD kg/day</th>
<th>COD kg/day</th>
<th>TDS kg/day</th>
<th>Dye kg/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparatory</td>
<td>103.93</td>
<td>441.0</td>
<td>1004.85</td>
<td>1587.6</td>
<td></td>
</tr>
<tr>
<td>Dyeing</td>
<td>571.41</td>
<td>43.47</td>
<td>173.8</td>
<td>1304.1</td>
<td>43.47</td>
</tr>
<tr>
<td>Finishing</td>
<td>31.5</td>
<td>25.2</td>
<td>100.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic</td>
<td>53.0</td>
<td>5.3</td>
<td>13.25</td>
<td>26.5</td>
<td></td>
</tr>
<tr>
<td>Boiler</td>
<td>10.0</td>
<td></td>
<td>5.0</td>
<td>30.0</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>769.84</strong></td>
<td><strong>514.87</strong></td>
<td><strong>1297.7</strong></td>
<td><strong>3042.7</strong></td>
<td><strong>43.47</strong></td>
</tr>
</tbody>
</table>

A comparison of the theoretically estimated pollutant concentration and the actual average concentration shows a fair agreement, within 20%, as a first trial of material balance. As the production-pollution coefficients are empirical, we cannot expect a hundred percent (100%) agreement with theoretical calculations. However, detailed measurements of effluents from the domestic and boiler sections – and in particular the dyeing effluents – would help in refining the material balance further.
7.5.7 Step 15 Examining obvious waste reduction measures

Prepare a list of obvious waste reduction measures (including those pertaining to management practices, normal process operations and housekeeping) which would:

[a] require less capital investment
[b] offer ease of implementability without much production interruption
[c] reduce the resource usage while maintaining similar or better fabric quality.

Prioritize the measures identified for possible implementation.
### 7.5.8 Solution to Step 15

Having gone through the exercise, you may identify various waste reduction possibilities. Generally, the following ten options should be identified by the participants:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Elimination of one hot wash of the three hot washes after dyeing.</td>
</tr>
<tr>
<td>2</td>
<td>Reuse of cooling water.</td>
</tr>
<tr>
<td>3</td>
<td>Reuse of cold wash effluents after caustic scour (sixth stage of preparatory sequence).</td>
</tr>
<tr>
<td>4</td>
<td>Reuse of wash water from the following stages in the dyeing process:</td>
</tr>
<tr>
<td></td>
<td>i) first hot wash before dyeing</td>
</tr>
<tr>
<td></td>
<td>ii) last two hot washes from the three hot washes (stages 10 and 11) after the dyeing process</td>
</tr>
<tr>
<td></td>
<td>iii) last cold wash after soaping.</td>
</tr>
<tr>
<td>5</td>
<td>Changeover from sodium silicate in peroxide antichlor to DTPA and subsequent reuse of:</td>
</tr>
<tr>
<td></td>
<td>i) cold wash effluents after caustic scour (sixth stage of the preparatory sequence)</td>
</tr>
<tr>
<td></td>
<td>ii) three discharges from the antichlor stage i.e. both hot and cold washes after antichlor stage (i.e. stages 9-11).</td>
</tr>
<tr>
<td>6</td>
<td>Changeover from hypochlorite bleaching and hydrogen peroxide antichlor to two-stage hydrogen peroxide bleaching.</td>
</tr>
<tr>
<td>7</td>
<td>Change in the type of dye from H-E (high exhaust-high temperature) to M-E (high exhaust-medium temperature).</td>
</tr>
<tr>
<td>8</td>
<td>Replacing the open atmospheric type of jumbo jigger by a closed atmospheric type of jumbo jigger.</td>
</tr>
<tr>
<td>9</td>
<td>Reducing the material:liquor ratio (MLR) from 1:10 to 1:6 by using a new jet dyeing machine.</td>
</tr>
<tr>
<td>10</td>
<td>Change in dyeing equipment from conventional jet dyeing of MLR 1:10 to pad-batch dyeing.</td>
</tr>
</tbody>
</table>

These options have been sequenced in order of options with no capital investment to options with significant capital investment.
7.5.9 Step 16 Targeting and characterizing problem wastes

6 Which process leads to maximum water consumption? Why?

7 Which process produces the maximum BOD load? Why?

8 Which effluent stream is expected to have potential toxicity? Which parameters do you think are responsible?
9 Are there any areas in the process house pertaining to air pollution? Is air pollution a significant problem? Why? Can the tools of material balance be used to assess the level of air pollution?

10 Describe additional sampling and characterization of waste that might be necessary, involving more in-depth analysis to ascertain the exact concentrations of contaminants:

11 List the wastes in order of priority for reduction actions:
7.5.10 Solutions to Step 16

Question 6    The dyeing process tends to maximum water consumption as it has a high MLR and a number of washing sequences.

Question 7    The maximum BOD load arises from the preparatory process. In this process, most of the organic impurities and size (starch) is released into the effluent, leading to a high exertion of BOD.

Question 8    Dyeing effluents can exhibit toxicity, probably due to the presence of metals in the reactive dyestuff and the reactive dyestuff itself.

Question 9    Finishing in a stentor can lead to some generation of air pollutants because of the release of finishing chemicals and the subsequent contamination of the exhaust air.

Question 10   Detailed analysis of water quality of the washes under consideration should be done, especially in terms of suspended solids, pH, total dissolved solids, residual chlorine, free caustic, iron and manganese concentrations. If facilities permit, then analysis of select heavy metals such as copper, chromium etc. (depending on the reactive dye) and AOX would be useful.

Question 11   A possible order might be:
               • dyeing
               • preparation (including mercerizing)
               • printing and finishing.
7.5.11 Step 17 Segregation

12 Is there a potential in segregation of the various effluents?

13 Which effluent streams could perhaps be segregated? What are the probable benefits of segregation?

7.5.12 Step 18 Developing long-term waste reduction options

14 Prepare a list of long term waste reduction measures which may help in:
   
   [a] increasing or maintaining the production level and the product quality
   [b] decreasing the input resources consumption
   [c] decreasing the output emission loads to the environment by
      (i) process optimization
      (ii) process modification
      (iii) raw material substitution
      (iv) equipment modification
      (v) recycle and reuse etc.

   Rank the measures identified in terms of best expected profitability. Use qualitative judgements or frameworks such as the Weighted Sum method:
7.5.13 Step 19 Environmental and economic evaluation of waste reduction options

In order to decide the options to be developed in formulating a waste reduction action plan, each option should be considered in terms of environmental and economic benefits. Generally, ranking of options done on a screening basis in Step 18 helps in limiting to a few potential evaluations.
7.6 Economic and environmental evaluation

Consider now the application of the following two waste minimization projects at the preparatory section and at the dye house, and conduct an economic and environmental evaluation.

7.6.1 Project A

Changeover from hypochlorite bleaching and hydrogen peroxide antichlor to two-stage hydrogen peroxide bleaching.

7.6.2 Project B

Reuse of washwater from the following stages in the dyeing process:

i. First hot wash before dyeing

ii. Last two hot washes from the three hot washes (Stages 10 and 11) after the dyeing process and

iii. Last cold wash after soaping.

iv. Last cold wash after soaping.

Usually, a screening assessment of all the options on the basis of criteria such as capital investment, ease of implementation, operating costs, possible reduction in the pollution load etc. should be done to select the appropriate options. In this example, we assume that Projects A and B have been recommended by such a screening analysis.

Please note that in the evaluation of waste minimization options, generally more than one option is applied at one time as a synthesis of individual waste minimization strategies, and the options to be evaluated may have interactive effect, i.e.:

• when Project A is implemented, it is possible to eliminate stripping of the order of 5% post-dyeing operations and to reduce reshading from 30% to 10%. This can reduce the load on the dyeing section.

• previous export was 50% of total production, but when Project A is implemented, the improvement in quality of cloth processed will lead to an expected increase in the demand in export from 50% to 60%.

• the reduction on the load of effluent treatment plant.
7.6.3 Economic data

Table 7.2 Chemical costs

<table>
<thead>
<tr>
<th>Chemical names</th>
<th>Cost per kg in unit currency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Desizing</strong></td>
<td></td>
</tr>
<tr>
<td>Enzymes</td>
<td>317.00</td>
</tr>
<tr>
<td>Wetting agent</td>
<td>20.50</td>
</tr>
<tr>
<td>Common salt</td>
<td>1.25</td>
</tr>
<tr>
<td><strong>Scouring</strong></td>
<td></td>
</tr>
<tr>
<td>Caustic soda (100%)</td>
<td>10.00</td>
</tr>
<tr>
<td>Wetting agent</td>
<td>20.50</td>
</tr>
<tr>
<td><strong>Hypochlorite bleach</strong></td>
<td></td>
</tr>
<tr>
<td>Sodium hypochlorite (5%)</td>
<td>3.00</td>
</tr>
<tr>
<td>Soda ash</td>
<td>4.50</td>
</tr>
<tr>
<td>Wetting agent</td>
<td>20.50</td>
</tr>
<tr>
<td><strong>Peroxide bleach</strong></td>
<td></td>
</tr>
<tr>
<td>Hydrogen peroxide (35%)</td>
<td>16.50</td>
</tr>
<tr>
<td>Caustic soda (100%)</td>
<td>10.00</td>
</tr>
<tr>
<td>Sodium silicate</td>
<td>2.5</td>
</tr>
<tr>
<td>Wetting agent</td>
<td>20.50</td>
</tr>
<tr>
<td>DTPA</td>
<td>41.70</td>
</tr>
<tr>
<td><strong>Dyeing</strong></td>
<td></td>
</tr>
<tr>
<td>HE-Dye (average)</td>
<td>210.00 - 235.00</td>
</tr>
<tr>
<td>Common salt</td>
<td>1.25</td>
</tr>
<tr>
<td>TSP</td>
<td>15.00</td>
</tr>
<tr>
<td>Soda ash</td>
<td>4.50</td>
</tr>
<tr>
<td>ME-dye (average)</td>
<td>335.00 - 350.00</td>
</tr>
<tr>
<td>Glauber salt</td>
<td>6.70</td>
</tr>
<tr>
<td>TSP</td>
<td>15.00</td>
</tr>
<tr>
<td>Soda ash</td>
<td>4.50</td>
</tr>
<tr>
<td>Detergent</td>
<td>3.00</td>
</tr>
<tr>
<td><strong>Water by industrial development corporation</strong></td>
<td>12.50/m³</td>
</tr>
</tbody>
</table>

Table 7.3 Effluent treatment plant cost

<table>
<thead>
<tr>
<th>Cost in million Unit Currency</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETP: Primary and Secondary</td>
</tr>
<tr>
<td>ETP Operating Cost</td>
</tr>
</tbody>
</table>

Cost of sump, pump and piping for waste reuse = 2700 units/m³
Use the following format for the presentation of evaluations.

7.6.4 Sample format for conducting economic and environmental evaluation for Project A

<table>
<thead>
<tr>
<th>Title:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Reason for justification of the project:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Qualitative evaluation:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Quantitative evaluation:</th>
</tr>
</thead>
</table>

1. **Calculation of reduction in water consumption**
   Water consumption for hypochlorite bleaching during preparation stage:
   Note that now, instead of 6300kgs, only 6000kgs would be used, as 5% stripping is eliminated after dyeing due to better dyeing operation and reduced reshading adjustments. Hence, the fabric loaded on each jigger is now only 1500 instead of 1575kgs. So, based on 1:1.3 MLR, the volume of effluent is 2.25m³ per drain.

<table>
<thead>
<tr>
<th>Reduction in water consumption during shade adjustment in dye house:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Cost saving due to reduced water consumption in the process:</th>
</tr>
</thead>
</table>
2 Calculations for change in chemical consumption

[a] Hypochlorite bleaching:

[b] Peroxide bleaching:

Increase in cost due to the change in bleaching reagents:

[c] Re-dyeing for shade correction
   (For re-shading, the consumption of new dye is assumed to be 1% by weight and other chemicals at 50% of prescribed recipe.)
   i Extra cloth processed during redyeing:
   ii Dye consumption:
   iii TSP consumption:
   iv Common salt consumption:
   v Soda ash consumption:

Total savings in cost of chemicals:

Net saving (water cost and chemical costs):

4 Other economic benefits
   Increase in selling price of cloth:
5 Reduction in pollution load on ETP

Reduction in pollution load from preparatory stage
BOD reduction:

COD reduction:

TDS reduction:

Reduction in pollution load due to 30% to 10% reshading in dyeing
BOD reduction:

COD reduction:

TDS reduction:

Dye reduction in effluent:

Conclusions:

Environmental evaluation in terms:

Assessment of pollution loads due to combined effects of Project A and B:

<table>
<thead>
<tr>
<th>Item</th>
<th>Before implementation of waste minimization options (as estimated)</th>
<th>With implementation of waste minimization options (as estimated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effluent volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADMI</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 7.7 Solutions

#### 7.7.1 Project A

<table>
<thead>
<tr>
<th>Waste reduction option in the preparatory section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changeover from hypochlorite bleaching and hydrogen peroxide antichlor to two-stage hydrogen peroxide bleaching</td>
</tr>
</tbody>
</table>

**Reason**  Improved whiteness, and hence subsequent better dyeing quality.

**Qualitative evaluation**

+ Improved whiteness of fabric.
+ Reduced water consumption due to elimination of two drainings, one of hypochlorite bleaching and the other, cold wash after the bleaching stage.
+ Reduced energy consumption.
+ Reduced pollution load.
+ Decrease in percentage dyeing for shade adjustment during jet dyeing from 30% to 10%, due to improved permanent whiteness quality of the fabric.
+ Reduced preparatory stage batch time from 24 hours to 20 hours as peroxide bleach is a shorter cycle.
+ Increased potential for export, hence more profits.
- High cost of bleaching, due to the high cost of hydrogen peroxide when compared with sodium hypochlorite.
- Worker re-training would be needed in the operation of the process.

**Quantitative evaluation**

**Calculation of reduction in water consumption**

**Water consumption for hypochlorite bleaching during preparation stage**

- From the process flow diagram, total number of drainings is 11.
- **Volume of effluent drained from jumbo jigger**
  
  \[ 2.362 \text{m}^3/\text{draining} \times 11/\text{drainings} \times 4/\text{machines} \times 1/\text{batch/day} \]  
  
  \[ \text{Note that now, instead of 6300kgs, only 6000 kgs would be used, as 5% stripping is eliminated after dyeing due to better dyeing operation and reduced reshading adjustments. Hence, the fabric loaded on each jigger is now only 1500 instead of 1575 kgs. So based on 1:1.5 MLR, the volume of effluent is 2.25m}^3 \text{per drain.} \]

- From the process flow diagram, reduced number of drainings is 9.
- **Volume of effluent drained from jumbo jigger**
  
  \[ 2.25 \text{m}^3/\text{draining} \times 9/\text{drainings} \times 4/\text{machines} \times 1/\text{batch/day} \]

**Water saved due to the reduction in number of drainings**

\[ 103.93 \text{m}^3/\text{day} - 81 \text{m}^3/\text{day} \]

\[ 22.93 \text{m}^3/\text{day} \]
Reduction in water consumption during shade adjustment in dye house
There is a decrease in percentage dyeing for shade adjustment during jet dyeing from 30% to 10%, owing to the improved whiteness quality of the fabric. Hence, reduction in water consumption is achieved due to reduced shade adjustment.

- For H-E dyes and hypochlorite bleaching, considering extra for (30%) reshading of 1890 (6300*0.3) kgs (note use of 6300 here, as it is the base case having 5% restripping)
  \[ (2.5m^3/batch*6300/250)*8+(2.5m^3/batch*0.5)*(1890/250) \]  \[ = 513.45m^3/day \]

- For H-E dyes and peroxide bleaching, considering extra for (10%) reshading of 600 (6000*0.1) kgs (note use of 600 here as restripping is eliminated)
  \[ (2.5m^3/batch*6000/250)*8+2.5m^3/batch*0.5*(600/250)kg \]  \[ = 483m^3/day \]

Water saved due to the reduction in reshading adjustment
\[ = 513.45m^3/day - 483m^3/day \]  \[ = 30.45m^3/day \]

Hence total saving due to savings in water use = 22.93 + 30.45 \[ = 53.38m^3/day \]

Formula: water cost = water consumption m^3/day * price of water unit/m^3

Cost saving due to reduced water consumption in the process
\[ = 53.38m^3/day \times 12.5 \text{ Unit/m}^3 \]  \[ = 667.25 \text{ Unit/day} \]

---

**a Hypochlorite bleaching**

Formula: chemical cost = kg of cloth * chemical weight/kg * Unit/kg

Chemicals required for hypochlorite bleaching stage:

- 2.5% hypochlorite (2.5% by weight) = \[ 6300*0.025*3 \]  \[ = 472.5 \text{ Unit/day} \]
- Soda ash (0.2%) = \[ 6300*0.002*4.5 \]  \[ = 56.7 \text{ Unit/day} \]
- Wetting agent (0.1%) = \[ 6300*0.001*20.5 \]  \[ = 129.15 \text{ Unit/day} \]

For antichlor stage after hypochlorite bleaching:

- 35% peroxide (0.5%) = \[ 6300*0.005*16.5 \]  \[ = 519.75 \text{ Unit/day} \]
- Caustic soda (0.2%) = \[ 6300*0.002*10 \]  \[ = 126 \text{ Unit/day} \]
- Sodium silicate (0.4%) = \[ 6300*0.004*2.5 \]  \[ = 63 \text{ Unit/day} \]
- Wetting agent (0.1%) = \[ 6300*0.001*20.5 \]  \[ = 129.15 \text{ Unit/day} \]

Total cost of chemicals for hypochlorite bleaching \[ = 1496.25 \text{ Units/day} \]

**b Peroxide bleaching**

Chemicals required for peroxide bleaching:

- 35% Peroxide (4.0%) = \[ 6000*0.04*16.5 \]  \[ = 3960 \text{ Unit/day} \]
- Caustic soda (0.5%) = \[ 6000*0.005*10 \]  \[ = 300 \text{ Unit/day} \]
- Sodium silicate (0.4%) = \[ 6000*0.004*2.5 \]  \[ = 60 \text{ Unit/day} \]
- Wetting agent (0.1%) = \[ 6000*0.001*20.5 \]  \[ = 123 \text{ Unit/day} \]

Total cost of chemicals for peroxide bleaching \[ = 4443 \text{ Unit/day} \]

Increase in the cost due to change in the bleaching reagents
\[ = 4443 - 1496.25 \text{ Unit/day} \]  \[ = 2946.75 \text{ Unit/day} \]

**c Re-dyeing for shade correction**

There is a decrease in percentage redyeing for shade adjustment during jet dyeing from 30% to 10%, owing to the improved whiteness quality of the fabric. Hence, reduction in chemicals consumption due to reduced shade adjustment. (For re-shading, the consumption of new dye is assumed to be 1% by weight and other chemicals at 50% of prescribed recipe.)

---

Cleaner Production in Textile Wet Processing: A Workbook for Trainers
Part 7 • Application of Environmental Audit to identify Cleaner Production measures
Calculations for change in the costs of chemical consumption continued

i Extra cloth processed during redyeing edit:
   for hypochlorite bleaching (HB) = (say) 1890kg (30% of 6300kg)
   for peroxide bleaching = (say) 630kg (10% of 6300 kg)

ii Costs of dye consumption
   Considering base case and dye consumption for reshading with hypochlorite bleaching
   \[ = (6300 \times 0.02 + 1890 \times 0.02 \times 0.5) \times 235 \text{ Unit/kg} \] 
   \[ \times (1890/250) \times 2500 \text{ litres/batch} \times 15.0/1000 \text{kg} \] 
   \[ \approx 34051.5 \text{ Units/day} \]
   Considering new case and dye consumption for reduced reshading with peroxide bleaching
   \[ = (6000 \times 0.02 + 600 \times 0.02 \times 0.5) \times 235 \text{ Unit/kg} \] 
   \[ \times (600/250) \times 2500 \text{ litres/batch} \times 15.0/1000 \text{kg} \] 
   \[ \approx 29610 \text{ Units/day} \]
   \[ \text{Savings in cost of dye} = 34051.5 - 29610 \text{ Units/day} \approx 4441.5 \text{ Units/day} \]

iii Costs of TSP consumption
   Considering base case and dye consumption for reshading with hypochlorite bleaching
   \[ = 20 \text{g/lit} \times (6300/250) \times 2500 \text{ litres/batch} \times 15.0/1000 + 20 \text{g/lit} \times 0.5 \] 
   \[ \times (1890/250) \times 2500 \text{ litres/batch} \times 15.0/1000 \] 
   \[ \approx 21735 \text{ Units/day} \]
   Considering new case and dye consumption for reduced reshading with peroxide bleaching
   \[ = 20 \text{g/lit} \times (6000/250) \times 2500 \text{ litres/batch} \times 15.0/1000 + 20 \text{g/lit} \times 0.5 \] 
   \[ \times (600/250) \times 2500 \text{ litres/batch} \times 15.0/1000 \] 
   \[ \approx 18900 \text{ Units/day} \]
   \[ \text{Savings in cost of TSP} = 21735 - 18900 \text{ Units/day} \approx 2835 \text{ Units/day} \]

iv Costs of common salt consumption
   Considering base case and dye consumption for reshading with hypochlorite bleaching
   \[ = 60 \text{g/lit} \times (6300/250) \times 2500 \text{ litres/batch} \times 1.25/1000 + 60 \text{g/lit} \times 0.5 \] 
   \[ \times (1890/250) \times 2500 \text{ litres/batch} \times 1.25/1000 \] 
   \[ \approx 5433.75 \text{ Units/day} \]
   Considering new case and dye consumption for reduced reshading with peroxide bleaching
   \[ = 60 \text{g/lit} \times (6000/250) \times 2500 \text{ litres/batch} \times 1.25/1000 + 60 \text{g/lit} \times 0.5 \] 
   \[ \times (600/250) \times 2500 \text{ litres/batch} \times 1.25/1000 \] 
   \[ \approx 4725 \text{ Units/day} \]
   \[ \text{Savings in cost of salt} = 5433.75 - 4725 \text{ Units/day} \approx 708.75 \text{ Units/day} \]

v Costs of soda ash consumption
   Considering base case and dye consumption for reshading with hypochlorite bleaching
   \[ = 20 \text{g/lit} \times (6300/250) \times 2500 \text{ litres/batch} \times 4.50/1000 + 20 \text{g/lit} \] 
   \[ \times (1890/250) \times 2500 \text{ litres/batch} \times 4.50/1000 \] 
   \[ \approx 6520.5 \text{ Units/day} \]
   Considering new case and dye consumption for reduced reshading with peroxide bleaching
   \[ = 20 \text{g/lit} \times (6000/250) \times 2500 \text{ litres/batch} \times 4.50/1000 + 20 \text{g/lit} \times 0.5 \] 
   \[ \times (600/250) \times 2500 \text{ litres/batch} \times 4.50/1000 \] 
   \[ \approx 5670 \text{ Units/day} \]
   \[ \text{Savings in cost of soda ash} = 6520.5 - 5670 \text{ Units/day} \approx 850.5 \text{ Units/day} \]
Total savings in cost of chemicals \[ \approx 7134.75 \text{ Unit/day} \]
Net decrease in change in the cost of chemicals
\[ = 7134.75 - 2946.75 \text{ Units/day} \approx \text{net saving of 4188 Units/day} \]
Increase in selling price of cloth

Earlier, export was 50% of total production, but due to improvement in the quality of the cloth processed, the demand in export is expected to increase from 50% to 60%. 30 Units/meter is the market price for domestic consumption, while 30 Units/meter is the market price for exports.

Increase in sales earning

\[ \text{cost difference in Unit/m) \times (30-25) = 18000 Units/day} \]

Assuming 10% net profitability margin, then increase in profit

\[ 0.1 \times 18000 = 1800 \text{ Units/day} \]

Reduction in pollution load on ETP

**Reduction in pollution load from preparatory stage**

- BOD reduction = \((1.0 \times 6300 - 0.5 \times 6000)/1000\) kg/day \(\rightarrow\) 3.30 kg/day
- COD reduction = \((4.0 \times 6300 - 2.0 \times 6000)/1000\) kg/day \(\rightarrow\) 13.20 kg/day
- TDS reduction = \((55 \times 6300 - 22 \times 6000)/1000\) kg/day \(\rightarrow\) 214.5 kg/day

**Reduction in pollution load due to 30% to 10% reshading in dyeing**

**BOD reduction:**

For hypochlorite bleaching and considering additional load due to 30% shade adjustment

\[ \text{BOD reduction} = (6.0 \times 1000 + 6.0 \times 1890 \times 0.5) \]

\[ = 37.8 \text{ kg/day} + 5.67 \text{ kg/day} \rightarrow 43.47 \text{ kg/day} \]

For peroxide bleaching and considering additional load due to 10% shade adjustment

\[ \text{BOD reduction} = (6.0 \times 1000 + 6.0 \times 1890 \times 0.5) \]

\[ = 36 \text{ kg/day} + 1.8 \text{ kg/day} \rightarrow 37.8 \text{ kg/day} \]

BOD reduction from jet dyeing sequence = 43.47 - 37.8 \(\rightarrow\) 5.67 kg/day

**COD reduction:**

For hypochlorite bleaching and considering additional load due to 30% shade adjustment

\[ \text{COD reduction} = (6.0 \times 1000 + 6.0 \times 1890 \times 0.5) \]

\[ = 151.2 \text{ kg/day} + 22.6 \text{ kg/day} \rightarrow 173.8 \text{ kg/day} \]

For peroxide bleaching and considering additional load due to 10% shade adjustment

\[ \text{COD reduction} = (24 \times 1000 + 24 \times 1890 \times 0.5) \]

\[ = 144 \text{ kg/day} + 9.2 \text{ kg/day} \rightarrow 173.8 \text{ kg/day} \]

COD reduction from jet dyeing sequence = 173.8 - 151.2 \(\rightarrow\) 22.6 kg/day

**TDS reduction:**

For hypochlorite bleaching and considering additional load due to 30% shade adjustment

\[ \text{TDS reduction} = (6.0 \times 1000 + 6.0 \times 1890 \times 0.5) \]

\[ = 1134 \text{ kg/day} \rightarrow 1304 \text{ kg/day} \]

For peroxide bleaching and considering additional load due to 10% shade adjustment

\[ \text{TDS reduction} = (180 \times 1000 + 180 \times 1890 \times 0.5) \]

\[ = 1080 \text{ kg/day} + 54 \text{ kg/day} \rightarrow 1134 \text{ kg/day} \]

TDS reduction from jet dyeing sequence = 1304 - 1134 = 170.1 kg/day

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Cleaner Production in Textile Wet Processing: A Workbook for Trainers

Part 7 • Application of Environmental Audit to identify Cleaner Production measures
Dye reduction in effluent:
For hypochlorite bleaching and considering additional dye used
due to 30% shade adjustment, assuming dye exhaust at 70%
(i.e. 30% remaining in the effluent) and average depth of shade as 2%
\[(6300kg \times 0.02 \times 0.3) + (1890kg \times 0.02 \times 0.5 \times 0.3)\]
\[= 37.8kg/day + 5.67kg/day \quad \text{..................} \quad 43.47kg/day\]

For peroxide bleaching and considering additional dye used
due to 10% shade adjustment
\[(6000kg \times 0.02 \times 0.3) + (600kg \times 0.02 \times 0.5 \times 0.1)\]
\[= 36kg/day + 1.80kg/day \quad \text{..................} \quad 37.8kg/day\]

Dye reduction from jet dyeing sequence = 43.47 – 37.8 \quad \text{..................} \quad 5.67kg/day

Conclusions
The total savings generated per year by changing the bleaching chemicals from hypochlorite to
peroxide:

| Total savings in cost of water | 667.25 Units/day |
| Total savings in costs of chemicals | 4188 Units/day |
| Increase in profit due to export | 1800 Units/day |
| **Net total savings** | **6655.25 Units/day** |

*The actual savings would be little higher because they include savings due to reduced capital and operating costs of the ETP.*

### 7.7.2 Project B

**Waste reduction option in the dyehouse**

- Reuse of wash water from the following stages in the dyeing process:
  1. First hot wash before dyeing
  2. Last two hot washes from the three hot washes (Stages 9 and 10) after the dyeing process
  3. Last cold wash after soaping.

**Reason** Water consumption for the dyeing sequence was observed to be more than the available norms
on unit water consumption for dyeing. Also, if these stages are eliminated, the quality of the
finished fabric may not deteriorate much.

**Qualitative evaluation**

+ Reduced water consumption due to reuse of washwaters.
+ Reduction in the volume of the effluent.
- Increased pollution concentration and colour concentration in effluents reduced dilution.
- Extra cost for sump, pump, pipings etc. to store the water in ground water tank.
Quantitative evaluation

Calculation for reduction in water consumption

- Due to reuse of four discharges, reduction in water consumption... \(2.5\text{m}^3/\text{discharge}\)
- Assuming a loss of 20% of water, total actual saving in quantity of water/day
  \(= (2.5 \times 0.8) \times 4 \times \text{discharges} \times 3 \times \text{batches} \times 8 \times \text{machines}... \approx 192.0 \text{m}^3/\text{day}\)

Formula: water cost = water consumption \(\text{m}^3/\text{day}\) * price of water Unit/\(\text{m}^3\)

- Cost saving due to reduction in water consumption
  \(= 192.0 \text{m}^3/\text{day} \times 12.5 \text{ units/m}^3... \approx 2400 \text{ units/day}\)

Estimation of costs for sump, pump and pipings

- Cost increase in construction of sump and incorporating pump and pipings at 2700 Units/m\(^3\)
  \(= 192 \times 2700... \approx 518400 \text{ Units}\)
- Cost of operation of reuse system (0.15% of capital)
  \(\approx 777.60 \text{ Units/day}\)

Conclusions

The total savings generated per year from the reuse of washwaters is \((2400 - 777.6) = 1622.4 \text{ Units/day}\), including the extra costs of sump, pump and piping system etc. This will amount to savings of \(1622.4 \times 300 = 486720 \text{ Units/annum}\).

An additional important benefit will be the reduction in ETP cost (capital + operating).

For an existing situation, the payback is still good, within a period of 11.2 months.

### 7.7.3 Estimation of new pollution load due to combined effects of Projects A and B

<table>
<thead>
<tr>
<th>Item</th>
<th>Before implementation of waste minimization options (as estimated)</th>
<th>With implementation of waste minimization options (as estimated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effluent volume</td>
<td>769.84 (m(^3/\text{day}))</td>
<td>524.46 (m(^3/\text{day}))</td>
</tr>
<tr>
<td>BOD</td>
<td>514.87 (kg/day)</td>
<td>505.9 (kg/day)</td>
</tr>
<tr>
<td></td>
<td>668.8 (mg/l)</td>
<td>964.6 (mg/l)</td>
</tr>
<tr>
<td>COD</td>
<td>1297.7 (kg/day)</td>
<td>1261.9 (kg/day)</td>
</tr>
<tr>
<td></td>
<td>1685.7 mg/l</td>
<td>2406 (mg/l)</td>
</tr>
<tr>
<td>TDS</td>
<td>3042.7 (kg/day)</td>
<td>2658.1 (kg/day)</td>
</tr>
<tr>
<td></td>
<td>3952.4 mg/l</td>
<td>5068.3 (mg/l)</td>
</tr>
<tr>
<td>Dye</td>
<td>43.47 (kg/day)</td>
<td>37.8 (kg/day)</td>
</tr>
<tr>
<td></td>
<td>54.55 (mg/l)</td>
<td>72.07 (mg/l)</td>
</tr>
</tbody>
</table>

*equivalent to 1091 ADMI units*  *equivalent to 1441 ADMI units*
<table>
<thead>
<tr>
<th></th>
<th>Management guidelines for site inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prepare an agenda in advance that covers all points that require clarification.</td>
</tr>
<tr>
<td>2</td>
<td>Schedule the inspection to coincide with the particular operation of interest (e.g., chemical addition, bath dumping, start up, etc.).</td>
</tr>
<tr>
<td>3</td>
<td>Monitor the operation at different times during all shifts, especially when waste generation is highly dependent on employees.</td>
</tr>
<tr>
<td>4</td>
<td>Interview the operators, shift supervisors, and work leaders in the area. Discuss the waste generation aspects of the operation. Note their familiarity with the impacts their operations may have on other operations.</td>
</tr>
<tr>
<td>5</td>
<td>Photograph or videotape the area of interest, if warranted. Many details can be captured in pictures that otherwise could be forgotten or inaccurately recalled later.</td>
</tr>
<tr>
<td>6</td>
<td>Observe the ‘housekeeping’ aspects of the operation. Check for signs of spills or leaks. Ask about problems in keeping the equipment leak-free. Assess the overall cleanliness of the site. Pay attention to odours and fumes.</td>
</tr>
<tr>
<td>7</td>
<td>Assess the organizational structure and level of coordination of environmental activities between various departments.</td>
</tr>
<tr>
<td>8</td>
<td>Assess administrative controls, such as cost accounting procedures, material purchasing procedures, and waste collection procedures.</td>
</tr>
</tbody>
</table>
Table 7.5 Site inspection checklist

<table>
<thead>
<tr>
<th><strong>Areas for receiving material</strong> (i.e. loading docks, incoming pipelines, receiving areas) can generate wastes such as:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Packaging material</td>
<td>• Spill residue</td>
</tr>
<tr>
<td>• Damaged containers</td>
<td>• Transfer line leaking or dumping</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Raw material and storage areas</strong> for the final product (i.e. warehouses, drum storage yards, storerooms) can generate wastes in the form of:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Tank bottoms</td>
<td>• Leaking pumps, valves, and pipes</td>
</tr>
<tr>
<td>• Off-spec and excess materials</td>
<td>• Damaged containers</td>
</tr>
<tr>
<td>• Spill residue</td>
<td>• Empty containers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Production areas</strong> (i.e. bleaching, dyeing, washing, printing, finishing areas) can produce wastes such as:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Washwater</td>
<td>• Additives</td>
</tr>
<tr>
<td>• Solvents</td>
<td>• Oil</td>
</tr>
<tr>
<td>• Still bottoms</td>
<td>• Process solution dumps</td>
</tr>
<tr>
<td>• Off-spec products</td>
<td>• Rinsewater</td>
</tr>
<tr>
<td>• Catalysts</td>
<td>• Excess materials</td>
</tr>
<tr>
<td>• Empty containers</td>
<td>• Filters</td>
</tr>
<tr>
<td>• Sweepings</td>
<td>• Leaking process tanks</td>
</tr>
<tr>
<td>• Duct work clean-out</td>
<td>• Spill residue</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Support services</strong> can also add to the generation of waste:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• <em>Laboratories</em> can produce</td>
<td>• <em>Cooling towers</em> can produce</td>
</tr>
<tr>
<td>- reagents - off-spec chemicals - sample containers</td>
<td>- chemical additives - empty containers - cooling tower bottom sediment</td>
</tr>
<tr>
<td>• <em>Maintenance shops</em> can produce</td>
<td>• <em>Garages</em> can produce</td>
</tr>
<tr>
<td>- solvent-lubes, oils, and greases - cleaning agents - degreasing sludges - sand-blasting waste</td>
<td>- oils - caustics - filters - cleaning bath sludges - solvents - batteries - acids</td>
</tr>
<tr>
<td>• <em>Powerhouses and boilers</em> can produce</td>
<td></td>
</tr>
<tr>
<td>- fly ash - chemical additives - oil</td>
<td>- slag - empty containers</td>
</tr>
</tbody>
</table>
Part 8
References

8.1 Some background documents on the environment .......... VIII:3
8.2 Audiovisuals ........................................................................ VIII:5
8 References

8.1 Some background documents on the environment

This book analyses the changes that have occurred in the environment in the past two decades. It focuses not only on the state of the environment, but also on the interactions between development activities and the environment. It highlights the main responses since 1972 to protect the environment.
Published by: Chapman & Hall, 2-6 Boundary Row, London SE1 8HN, UK.

This report is updated biennially and provides the best available data and information on a wide range of environmental topics, including pollution, health, natural resources, population and settlements, energy, wastes and disasters.
Published by: Blackwell Publishers, 108 Cowley Road, Oxford OX4 1JF, UK.

This book overviews the origins and impacts of pollution around the world, caused by selected chemical pollutants and wastes.
Published by: UNEP, Nairobi.

This publication is aimed at facilitating access to the very important material contained in Agenda 21.
Published by: The Centre for Our Common Future, 52 rue des Paquis, 1201 Geneva, Switzerland.

Using World 3, a computer model, to project the future, and by varying the basic global policy assumptions, a range of possible outcomes is described. It is shown that a sustainable society is technically and economically feasible, if growth if material consumption and population are ceased down and there is an increase in the efficiency of our use of materials and energy.
Published by: Earthscan Publications Ltd., 120 Pentonville Road, London N1 9JN, UK.

This book provides an analysis of how the business community can adapt and contribute to the crucial goal of sustainable development, combining the objectives of environmental protection and economic growth.
Published by: Massachusetts Institute of Technology (MIT) Press, Cambridge, Massachusetts 02142, USA.

This book is a handbook of industrial ecology with numerous checklists for practical use and a concrete example of the Integrated System of Environmentalist Business Management (the so-called Winter Model), supported by the Commission of the European Communities.
Published by: McGraw-Hill Book Company (UK) Ltd.
Life Cycle Assessment: what it is and how to do it

[1996] UNEP IE

This report is in two parts. The first, *Life Cycle Assessment: what it is*, is concerned with the concept of LCA, how it is currently practised and how it is expected to develop. It also places LCA in the broader perspective of other tools for environmental analysis such as environmental impact assessment, risk analysis and technology assessment.

The second part of the volume, *Life Cycle Assessment: how to use it*, examines the several steps involved in making an LCA in a simplified but systematic manner. It illustrates the problems involved and the kind of results that can be produced by working through a real LCA that has been used to assess the environmental impact of different low fat spreads.

*Further information:* UNEP IE, Paris, France.
8.2 Audiovisuals

IChemE has an international reputation for providing high quality, effective safety and environmental training solutions using video, slide, open learning and computer-based techniques. We draw on experts throughout industry, the regulatory bodies, the legal profession and academia to ensure that our training packages are both high quality and relevant.

ENVIRONMENTAL PACKAGES

ENVIRONMENTAL AWARENESS
Package EO2 Understanding is the key to effective environmental improvements - both through certified standards and effective policy implementation. This package gives a thorough grounding in environmental awareness. The case studies cover: environmental law; global issues; corporate issues; and waste minimization.

AQUEOUS EFFLUENTS
Volume 1: awareness and treatment strategies
Package EO1 Engineers learn how to assess and deal with effluent problems; senior management gain a sound technical and legal grounding; and operators learn why compliance is important. Seven case studies demonstrate how effective treatment strategies save money whilst benefiting the environment. And the technical guidance covers: characterisation of effluents; treatment strategy; safety; unit operations; and costs.

Volume 2: measurement and monitoring
Package EO13 Trainees learn how to measure and monitor effluents, ensuring compliance and reducing treatment costs.

AIR EMISSIONS
Volume 1: key issues
Package EO3 This package provides comprehensive coverage of generic air pollution issues and technologies, backed up with detailed sections on sources and types of emissions, atmospheric chemistry, standards and legislation (UK and European).

Volume 2: monitoring and control
Package EO12 This package follows on from AE Vol. 1: key issues, and provides detailed information on measurement and monitoring and control techniques, illustrated with comprehensive case studies. Sections on ambient monitoring, meteorology and air dispersion modelling help to provide a thorough grounding in the technical issues associated with air emissions.

ENERGY MANAGEMENT
Package EO11 Energy efficiency affects the bottom line. Trainees learn the basic tools and techniques for effective energy management.

ENVIRONMENTAL AUDITING
Package E04 Trainees learn how to make audits more effective. In clearly defined sections, the package explains how to go about auditing a site, from defining the scope and objectives through on-site activities to reporting and follow-up work. Thirteen case studies and exercises, supported by over 120 slides, include: setting up an EMS; auditing for waste disposal; due diligence and effluence compliance; reporting audit findings; and discussion of photographs of bad practice.

ENVIRONMENTAL MANAGEMENT SYSTEMS
Package EO5 If you already have an environmental management system, this package will help you gain commitment from your staff. If you are just developing a system, not only will you benefit from the training, but also benchmarking from the detailed case studies will save you time. And if you have still not decided which system to go for (if any), this package will help you make an informed decision.

ENVIRONMENTAL IMPACT ASSESSMENT
Package EO13 Trainees learn how to measure and monitor effluents, ensuring compliance and reducing treatment costs.

WASTE MINIMIZATION
Package E07 Approaches in the package vary from good housekeeping to complex techniques such as life cycle analysis. This training package shows how to go about it, from defining a strategy through to making sure it happens.

CONTAMINATED LAND
Package E08 Trainees learn why contaminated land is important, how and why a company should avoid contamination, and the pros and cons of the key remediation techniques. You will also learn how to use this knowledge to get the most out of the consultants you use.

For order form contact:
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165-189 Railway Terrace • Rugby CV21 3HQ, UK
Tel +44 1788 578214 • Fax +44 1788 550833

A Workbook for Trainers : Cleaner Production in Textile Wet Processing
Annexes

I  Data related to Pollution Issues
   including Health and Safety Aspects ............................................. 3

II  A Compilation of the Best Environmental
    Practices in Textile Wet Processing ........................................... 13
Annex I

Data related to Pollution Issues including Health and Safety Aspects

A checklist for comprehensive assessment

The field trip may include four main areas of observation:

- Water pollution
- Air pollution
- Workers' health
- Solid waste disposal

The following lists items for inspection within each area.

All areas

1 Work process or flow of operation
2 Materials handling
   - inventories of hazardous substances
   - storage
     - segregation of incompatibles
     - use of appropriate containers
     - monitoring for leaks
     - use of covers on containers
     - proper labelling
   - transport
   - use
     - emission control
   - use of chemical substitution
   - disposal
     - segregation of different wastes
     - labelling
     - frequency of disposal
   - emergency response plans
     - presence of plan, spill kits, training
3 Safety
   - electric hazards
   - mechanical
   - fire safety
4 Housekeeping

Water (e.g. wastewater plant)

1 Identify source(s) of wastewater
2 Treatment process
3 Appearance/odour
4 Appropriateness of treatment to type of waste
5 Monitoring data (frequency)
6 Data on release or water quality

Air pollution

1 Types of contaminants released
2 Noxious qualities (odour, excessive particulates, toxic releases, etc.)
3 Controls available
4 Effectiveness of controls
5 Monitoring data
Workers' health

Be sure to interview workers during the field visit.

1 Administrative procedures
2 Training
3 Engineering controls in use
4 Protective clothing and equipment
   • availability
   • use
5 Unsafe work practices
6 Incidence of accidents and injuries
7 Medical monitoring

Solid waste disposal

1 See materials handling
2 Sources of waste in manufacturing process
3 Housekeeping
4 Waste collection system

5 Use of waste minimization techniques
   • source reduction
   • resource recovery
   • recycling
   • treatment

Hazard communication

Overview

In order to protect the workforce, general public and environment from hazards associated with chemicals, the European Directives 67/548/EEC (The Dangerous Substances Directive) (1) and 88/379/EEC (The Dangerous Preparations Directive) (2), together with all amendments and adaptations, place certain obligations upon suppliers of chemicals.

In particular, the supplier must:
   • identify the hazards associated with any chemicals supplied
   • communicate safety advice to the user
   • package products suitably for safe usage
   • consider storage and transport related risks.

Classification

Under the Directives, the supplier of a chemical substance or preparation has the duty to identify hazards associated with his products. This may be done in one of two ways:
   • by using the pre-determined classification derived for a substance by the EU Technical Progress Committee and listed in Annex 1 to the Dangerous Substances Directive
   • where a substance is not listed, by self-classification using all available information.

As a consequence, a product may not require classification or may be classified in one or more categories of danger covering physicochemical, toxicological and environmental effects.
Labeling

Once a product has been classified and assigned to a category of danger, there is a requirement that all containers are labelled to indicate these dangers.

For all dangerous chemicals, certain aspects of the label are obligatory.

Supplies must ensure that the container is correctly labelled with the following information:

- the name, address and telephone number of the supplier within the European Union responsible for placing the product on the market
- the chemical name (or names of the dangerous components in the case of preparations) as given in Annex 1 to the Dangerous Substances Directive or, where the chemicals do not appear in the Annex, an internationally recognised designation
- the category or categories of danger together with the corresponding symbols
- risk phrases which relate to the classification (note that although these phrases are styled risk phrases, in fact they describe the intrinsic hazard of the material)
- safety phrases which advise on correct use
- the EEC number (if allocated) for single substance dangerous products
- the words 'EEC label' if the substance appears in Annex 1 of the Dangerous Substances Directives.

Materials safety data sheets (MSDS)

Safety data sheets must be provided for all dangerous chemicals by the supplier to the recipient on or before first supply and irrespective of the mode of supply (3). Should further significant information become available, the supplier is also obliged to revise the MSDS and supply this update to all those who received the product within the last twelve months. Responsible suppliers provide MSDS for all products.

The information supplied in the MSDS must be sufficient for the user to ascertain how best to protect persons coming into contact with the dangerous chemical and to protect the environment.

Although there is no obligatory format for the materials safety data sheet, the required information must be given under specific headings, covering:

- identification of the chemical product and its supplier
- composition information
- hazard identification
- first aid measures
- handling and storage
- exposure control and personal protection
- physical and chemical properties
- stability and reactivity
- toxicological information
- ecotoxicological information
- disposal
- transport requirements
- regulatory information and any other information which might facilitate safe use of the product.

As with the label, the safety data sheet should be offered in the recipients' own language.
### Tables

**Table 1** Impacts of hazardous substances contained in effluents from textile production processes to water

<table>
<thead>
<tr>
<th>Process</th>
<th>Effect/purpose Description</th>
<th>Area of application</th>
<th>Chemicals employed</th>
<th>Possible impacts on health and environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washing process</td>
<td>Detergent</td>
<td>All fibres</td>
<td>Complexing agents</td>
<td>Mobilisation of heavy metals from the sediment waters</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>– EDTA</td>
<td></td>
</tr>
<tr>
<td>Washing process</td>
<td>Detergent</td>
<td>All fibres</td>
<td>Complexing agents</td>
<td>Danger of overfertilisation of waters, resulting in death of fish</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>– Phosphates</td>
<td></td>
</tr>
<tr>
<td>Sizing/desizing</td>
<td>Sizing agent</td>
<td>All fibres</td>
<td>– Starch and derivatives-</td>
<td>High concentration of organic substances (CSB)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Polyvinyl alcohol-Polyacrylate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>–</td>
<td>Difficult to degrade in sewage treatment plants</td>
</tr>
<tr>
<td>Sizing/desizing</td>
<td>Preparation of fibres for further processing; e.g. for weaving</td>
<td>All fibres</td>
<td>Mineral oil</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>–</td>
<td>Difficult to degrade</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>–</td>
<td>Concentration in sewage sludge</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>–</td>
<td>Formation of scum</td>
</tr>
<tr>
<td>Dyeing</td>
<td>Colour</td>
<td>All fibres</td>
<td>Synthetic dyestuff</td>
<td>Not readily degradable, concentration in sewage sludge</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>–</td>
<td>Colour of waters</td>
</tr>
<tr>
<td>Dyeing, auxiliary agents</td>
<td>Colour</td>
<td>All fibres</td>
<td>Heavy metals: e.g.</td>
<td>Concentration in sewage sludge</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>– Chromium</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>– Copper</td>
<td>Transfer via plants into the food chain, when sewage sludge is employed in agriculture</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>– Tin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>– Cadmium</td>
<td></td>
</tr>
<tr>
<td>Preservation, dyeing acceleration</td>
<td>Preservation (fungicide)</td>
<td>All fibres</td>
<td>Chloro-organic compounds</td>
<td>Usually difficult to degrade; in some cases, the decomposition of sewage sludge is impeded</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>– PCP</td>
<td>Dangerous toxic pollutants</td>
</tr>
<tr>
<td>Bleaching dyeing</td>
<td>Optical brightness</td>
<td>All fibres</td>
<td>– Sulphites</td>
<td>Disturbance of the biological stage at sewage treatment plants</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>– Hydrosulphite</td>
<td>In some cases conversion into sulphide, which is toxic for micro-organisms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>– Thiosulphate</td>
<td></td>
</tr>
<tr>
<td>Dressing</td>
<td>Dressing</td>
<td>All fibres</td>
<td>Synthetic polymers</td>
<td>Difficult to degrade, often high concentrations in sewage sludge</td>
</tr>
</tbody>
</table>
### Table 2 Impacts of hazardous substances on human health and environment from textile production processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Effect/purpose Description</th>
<th>Area of application</th>
<th>Chemicals employed</th>
<th>Possible impacts on health and environment</th>
</tr>
</thead>
</table>
| Bleaching              | Whitening                  | All fibres                                                                         | − Hydrogen peroxide  
− Sodium hypochloride                                                           | − Large quantities of effluent                                                   |
| Optical brightening    | Brilliant white            | All fibres (white and pastel coloured articles)                                    | − Organic substances                                                            | − Skin allergies  
− Pollution of waters                                                                  |
| Dyeing                 | Diverse range of colours   | All fibres                                                                         | − Diverse dyestuffs  
− Heavy metals  
− Carriers                                                                 | − Skin allergies  
− Carcinogenic (benzidine dyestuffs, carriers)  
− Environmental pollution  
− Large quantities of effluent                                                        |
| High-grade finishing   | Prevention of shrinking and creasing | − Cellulosic natural and man made fibres  
− Blends with synthetics                                                          | − Urea formaldehyde  
− Melamine formaldehyde                                                            | − Skin allergies  
− Strong suspicion of carcinogenic properties  
− Environmental pollution                                                             |
| Sanforizing            | Prevention of shrinking    | Cellulosic and man made fibres                                                    | None, as only mechanical compression is employed                                   | None                                                             |
| Sanforizing, Sanfor plus | Prevention of creasing and shrinking | − Cellulosic natural and man made fibres  
− Blends with synthetics                                                          | − Urea formaldehyde  
− Melamine formaldehyde                                                            | − Skin allergies  
− Strong suspicion of carcinogenic properties  
− Environmental pollution                                                             |
| Sanfor setting process | Prevention of creasing and shrinking | Cellulosic fibres                                                                  | − Ammonia (mechanical compression)                                                 | − Environmental pollution by ammonia vapours                                   |
| Mercerization          | Permanent lustre           | Cellulosic fibres                                                                  | − Sodium hydroxide  
− Ammonia                                                                            | None known                                                                        |
| Abrasion-resistant finish | Increased abrasion         | Cellulosic fibres                                                                  | − Silica gel  
− Plastic resins                                                                     | − Large quantities of effluent                                                   |
| Anti-felt finish       | Prevention of felting      | Wool                                                                                | − Chlorine  
− Polyamide  
− Epichlorohydrin resin                                                              | − Large quantities of effluent                                                   |
| Weighting              | Weight increase            | Silk                                                                                | − Stannic chloride  
− Sodium phosphate  
− Water glass                                                                       | − Large quantities of effluent                                                   |
| Hydrophilizing         | Faster spreading of water on the surface of fibres | Synthetic fibres                                                                  | − Polyamide  
− Polyacrylic-Silicone                                                             | − Large quantities of effluent                                                   |
| Waterproofing          | Water repellency           | All fibres                                                                         | − Paraffin  
− Aluminum salts  
− Zircon salts  
− Silicone  
− Fluorocarbon resins                                                                | − Fluorocarbon resins may cause disposal problems                                 |

*continued...*
Table 2 continued...

<table>
<thead>
<tr>
<th>Process</th>
<th>Effect/purpose Description</th>
<th>Area of application</th>
<th>Chemicals employed</th>
<th>Possible impacts on health and environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyeing</td>
<td>Prevention of high-gloss finish</td>
<td>Synthetic fibres</td>
<td>- Phenol&lt;br&gt;- Turpentine&lt;br&gt;- Pine oil&lt;br&gt;- Glauber salt&lt;br&gt;- Barium chloride&lt;br&gt;- Alkali sulphide&lt;br&gt;- Chromium salts&lt;br&gt;- Resins containing formaldehyde etc.</td>
<td>- Allergy inducing - In some cases carcinogenic substances&lt;br&gt;- Environmental pollution (heavy metals)</td>
</tr>
<tr>
<td>Moth and beetle protection</td>
<td>Indigestible fibres</td>
<td>Wool</td>
<td>- Chlorinated sulphonamide derivatives&lt;br&gt;- Biphenyl ether&lt;br&gt;- Urea derivatives&lt;br&gt;- Pyrethroids</td>
<td>- Weakly bound pyrethroids may cause neurotoxic effects</td>
</tr>
<tr>
<td>Antistatic finish</td>
<td>Prevention of electrostatic charging</td>
<td>Synthetic fibres</td>
<td>- Surface-active substances</td>
<td>- Possibly skin allergies</td>
</tr>
<tr>
<td>Antipilling finish</td>
<td>Prevention of burs, fluff</td>
<td>Synthetic fibres</td>
<td>- Acrylic polymers&lt;br&gt;- Vinyl polymers</td>
<td>- None known, when no monomers are detectable</td>
</tr>
<tr>
<td>Dirt-repellent finish</td>
<td>Prevention of soiling and/or improved dirt removal</td>
<td>Synthetic fibres</td>
<td>- Polymeric fluorocarbon resins</td>
<td>- Disposal problems</td>
</tr>
<tr>
<td>Antimicrobial finish</td>
<td>Prevention of mould, athlete's foot, bacteria, body odour</td>
<td>All fibres</td>
<td>- Quaternary ammonium&lt;br&gt;- Biophenols&lt;br&gt;- Biphenyl ethers&lt;br&gt;- Thiobiophenols&lt;br&gt;- Salicylamine derivatives&lt;br&gt;- Ethylene glycol&lt;br&gt;- Chlorometacresols etc.</td>
<td>- Possibly skin allergies&lt;br&gt;- Environmental pollution</td>
</tr>
<tr>
<td>Flame-proof finish</td>
<td>Prevention of flame formation</td>
<td>All fibres (protective clothing, floor coverings, decorative fabrics, baby wear)</td>
<td>- Halogenated hydrocarbons&lt;br&gt;- Phosphorous compounds&lt;br&gt;- Zircon and titanium complexes for wool</td>
<td>- Possibly carcinogenic&lt;br&gt;- Allergenic substances</td>
</tr>
<tr>
<td>Softening</td>
<td>Improvement of the handle</td>
<td>All fibres</td>
<td>- Quaternary ammonium&lt;br&gt;- Siloxanes&lt;br&gt;- Fatty-acid-modified melamine resins</td>
<td>- Possibly skin allergies</td>
</tr>
<tr>
<td>Deodorisation</td>
<td>Pleasant smell</td>
<td>All fibres</td>
<td>- Perfume&lt;br&gt;- Synthetic resin shrinking and creasing</td>
<td>- Possibly skin allergies</td>
</tr>
</tbody>
</table>
### Table 3 List of banned amines

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Banned Amine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4-Aminodiphenyl</td>
</tr>
<tr>
<td>2</td>
<td>Benzidine</td>
</tr>
<tr>
<td>3</td>
<td>4-Chloro-o-toluidine</td>
</tr>
<tr>
<td>4</td>
<td>2-Naphthylamine</td>
</tr>
<tr>
<td>5</td>
<td>o-Aminoazotoluidine</td>
</tr>
<tr>
<td>6</td>
<td>2-amino-4-nitrotoluene</td>
</tr>
<tr>
<td>7</td>
<td>p-Chloraniline</td>
</tr>
<tr>
<td>8</td>
<td>2,4-Diamoanisol</td>
</tr>
<tr>
<td>9</td>
<td>4,4'-Diaminodiphenylmethane</td>
</tr>
<tr>
<td>10</td>
<td>3,3': Dichlorobenzidine</td>
</tr>
<tr>
<td>11</td>
<td>3,3': Dimethoxybenzidine</td>
</tr>
<tr>
<td>12</td>
<td>3,3': Dimethylbenzidine</td>
</tr>
<tr>
<td>13</td>
<td>3,3': Dimethyl 1-4, 4' diaminodiphenylmethane</td>
</tr>
<tr>
<td>14</td>
<td>p-Kresidin</td>
</tr>
<tr>
<td>15</td>
<td>4,4' Methene-bis-(2-Chloraniline)</td>
</tr>
<tr>
<td>16</td>
<td>4,4' Oxydianiline</td>
</tr>
<tr>
<td>17</td>
<td>4,4' Thiodianiline</td>
</tr>
<tr>
<td>18</td>
<td>o-Toluidine</td>
</tr>
<tr>
<td>19</td>
<td>2,4 - Toluylen diamine</td>
</tr>
<tr>
<td>20</td>
<td>2,4,5-Trimethylenioline</td>
</tr>
</tbody>
</table>

(Source: Eco-Tex Consortium, Germany)

### Table 4 List of toxic and harmful substances used by the textile industry

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Textile process</th>
<th>Toxic substance used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cotton growing</td>
<td>Banned pesticides such as DDT, Dieldrin, Aldrin etc.</td>
</tr>
<tr>
<td>2</td>
<td>Sizing</td>
<td>Pentachlorophenol as a preservative</td>
</tr>
<tr>
<td>3</td>
<td>Scouring</td>
<td>Chlorinated products</td>
</tr>
<tr>
<td>4</td>
<td>Bleaching</td>
<td>Hypochlorite(chlorine bleaching)</td>
</tr>
<tr>
<td>5</td>
<td>Dyeing and printing</td>
<td>i Azo-dyes containing aromatic amines</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii Dyes containing traces of heavy metals such as arsenic, lead, cadmium, mercury,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nickel, copper, chromium, cobalt and zinc</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii Formaldehyde as a mordant</td>
</tr>
<tr>
<td>6</td>
<td>Finishing</td>
<td>Formaldehyde as a cross linking finish, urea formaldehyde as F.R. finish</td>
</tr>
<tr>
<td>7</td>
<td>Garment manufacture</td>
<td>Stain removers containing chlorinated products</td>
</tr>
<tr>
<td>8</td>
<td>Packaging</td>
<td>Wooden boxes treated with insecticides.</td>
</tr>
<tr>
<td>Sr. No.</td>
<td>Chemicals</td>
<td>Uses</td>
</tr>
<tr>
<td>-------</td>
<td>---------------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Benzidine</td>
<td>Dye intermediate</td>
</tr>
<tr>
<td>2</td>
<td>Bensoprine</td>
<td>Dye intermediate</td>
</tr>
<tr>
<td>3</td>
<td>Hexachloropentadiene</td>
<td>Dye intermediate</td>
</tr>
<tr>
<td>4</td>
<td>Chloro aniline</td>
<td>Dye intermediate</td>
</tr>
<tr>
<td>5</td>
<td>Dichloro aniline</td>
<td>Dye intermediate</td>
</tr>
<tr>
<td>6</td>
<td>Thiram</td>
<td>Bacteicidal/insecticide</td>
</tr>
<tr>
<td>7</td>
<td>Trichloro phenoxy acetic acid</td>
<td>Bacteicidal/insecticide</td>
</tr>
<tr>
<td>8</td>
<td>Toxaphane</td>
<td>Bacteicidal/insecticide</td>
</tr>
<tr>
<td>9</td>
<td>Dibutyl phthalate</td>
<td>Plasticiser</td>
</tr>
<tr>
<td>10</td>
<td>Tributyls phosphate</td>
<td>Plasticiser</td>
</tr>
<tr>
<td>11</td>
<td>Chlorinated paraffins</td>
<td>Plasticiser</td>
</tr>
<tr>
<td>12</td>
<td>Octachlorostyrene</td>
<td>Flame retardant</td>
</tr>
<tr>
<td>13</td>
<td>Polychlorinated terphenyls</td>
<td>Flame retardant</td>
</tr>
<tr>
<td>14</td>
<td>Tetrachloro dibenzo-p-dioxin</td>
<td>Flame retardant</td>
</tr>
<tr>
<td>15</td>
<td>Nonylphenol ethoxylates</td>
<td>Surfactant in processing</td>
</tr>
<tr>
<td>16</td>
<td>Arsenic compounds</td>
<td>Miscellaneous uses</td>
</tr>
<tr>
<td>17</td>
<td>Fluosides</td>
<td>Miscellaneous uses</td>
</tr>
<tr>
<td>18</td>
<td>Decabromo diphenyl ether</td>
<td>Flame retardant</td>
</tr>
<tr>
<td>19</td>
<td>Dichloro toluene</td>
<td>Carrier</td>
</tr>
<tr>
<td>20</td>
<td>Trichloro benzene</td>
<td>Carrier</td>
</tr>
</tbody>
</table>

Table 6 Chemicals being phased out from textile processing
Table 7 Some of the suggested alternatives in textile processing

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Chemicals used at present</th>
<th>Suggested alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chlorine bleaching</td>
<td>Peroxide bleaching</td>
</tr>
<tr>
<td>2</td>
<td>Benzidine based dyestuffs</td>
<td>Mineral / pigment dyes</td>
</tr>
<tr>
<td>3</td>
<td>Acetic acid</td>
<td>Formic acid</td>
</tr>
<tr>
<td>4</td>
<td>Starch based warp sizes</td>
<td>Synthetic ones like PVA and acrylates</td>
</tr>
<tr>
<td>5</td>
<td>Kerosene in pigment printing</td>
<td>Synthetic thickness based on poly-carboxylic acids</td>
</tr>
<tr>
<td>6</td>
<td>P/C two-stage dyeing</td>
<td>Single class dyes like indigisol, pigments</td>
</tr>
<tr>
<td>7</td>
<td>Carding oils and antistatic</td>
<td>Non-ionic emulsifiers lubricants</td>
</tr>
<tr>
<td>8</td>
<td>Formaldehyde</td>
<td>Polycarboxylic acid method</td>
</tr>
<tr>
<td>9</td>
<td>Pentachlorophenol</td>
<td>Benzothiazol</td>
</tr>
<tr>
<td>10</td>
<td>Alkylphenol ethoxylate</td>
<td>Fatty alchoholethoxylates</td>
</tr>
<tr>
<td>11</td>
<td>Sodium sulphide</td>
<td>Glucose based reducing agent</td>
</tr>
</tbody>
</table>

Table 8 Details of equipment required for the testing of eco-parameters

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Eco-parameter</th>
<th>Equipment required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dyestuffs which release aromatic amines (carcinogenic)</td>
<td>High performance liquid and thin-layer chromatography</td>
</tr>
<tr>
<td>2</td>
<td>Fastness to perspiration</td>
<td>Perspirometer</td>
</tr>
<tr>
<td>3</td>
<td>Fastness to water</td>
<td>Wash wheel machine</td>
</tr>
<tr>
<td>4</td>
<td>Presence of heavy metals</td>
<td>Atomic absorption spectrometer and accessories</td>
</tr>
<tr>
<td>5</td>
<td>Free formaldehyde content</td>
<td>UV-visual spectrometer</td>
</tr>
<tr>
<td>6</td>
<td>pH of aqueous extract</td>
<td>pH</td>
</tr>
<tr>
<td>7</td>
<td>Presence of pesticides</td>
<td>i Gas chromatography with mass spectrometer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii FTIR (Fourier transforming infra red spectrometer)</td>
</tr>
<tr>
<td>8</td>
<td>Presence of penta chloroformol</td>
<td>i Gas chromatography with mass spectrometer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii High performance liquid chromatography</td>
</tr>
<tr>
<td>9</td>
<td>Biological oxygen demand</td>
<td>BOD and COD monitors</td>
</tr>
<tr>
<td></td>
<td>Chemical oxygen demand</td>
<td></td>
</tr>
</tbody>
</table>

A Workbook for Trainers : Cleaner Production in Textile Wet Processing
Annex II

A Compilation of the Best Environmental Practices in Textile Wet Processing

The purpose of this document

Environmental considerations have undoubtedly become a significant business concern in a number of industrial sectors, and the textile industry is not an exception to this trend.

If it wants to remain competitive and survive profitably, every textile company needs to examine environmental issues and find ways to integrate them into an overall business strategy.

Environmental issues are no longer limited to the volume and concentration of pollutants in the effluents or stack emissions, or noxious odours in the workplace. Issues now include the levels of consumption of raw materials such as chemicals, water and energy, and environmental acceptance of the residual substances remaining on the product or fabric.

One way to tackle these environmental issues is to opt for cleaner technologies, implement them correctly, and use environmentally acceptable substances in the correct proportions. Textile industry representatives often face barriers when choosing cleaner technology options, as there are few (if any) appropriate compilations of the best operating practices in the textile industry. Those that have been published are difficult to obtain.

The purpose of this document is to bridge this gap and to provide a state-of-the-art (as of December 1995) compilation on best operating practices with supportive resource information and recommendations. The topics covered include useful definitions and scope (which focuses on preventive and in-plant related practices), followed by process specific recommendations (both upstream and downstream). Recommendations relating to products and emissions are also provided, supplemented by short notes on future technological trends.

While the purpose of this document is to provide information, it must be remembered that the approaches, options and technologies cited below are only recommendations, and, as such, should not be viewed as rules. However, due to stringent environmental regulations and the emerging interest in compliance to product related expectations (such as eco-labelling), these recommendations may become mandates for the textile processors of tomorrow. And tomorrow is not far away!
Definitions

**Textile** Any product derived from the manufacture of natural fibres such as wool, cotton, flax and/or the manufacture of fibres synthesized and processed from petrochemicals and modified wood pulp such as polyester, nylon, polypropylene and viscose.

These products can be yarns, fabrics or consumer products (e.g. garments, carpets, upholstery, technical textiles).

**Textile processing** The preparation of natural and man-made (semi-natural and synthetic) fibres, including both:

- the mechanical processes such as carding, spinning, weaving, knitting or tufting and
- the physico-chemical processes which mainly take place in aqueous (wet) media, such as pretreatment, colouring and finishing of the fibres, yarns and fabrics.

The upstream definition is the production of raw material from which a treatable fibre can be produced (both the growing of natural fibres and the production of (semi-) chemical fibre such as viscose); these processes were not considered in the formation of the Standard Operating Procedures (SOPs).

The downstream limits are determined by the last process which alters the intrinsic properties of yarns or fabrics, before they are merely handled or reassembled into final products such as for the garment industry.

**Unit operations** consist of:

- preparations for spinning (spin finish) and weaving (slashing)
- preparation for clothing and finishing by scouring, washing, wool carbonising, desizing, bleaching, and mercerising
- colouring by dyeing, printing, and spacing
- finishing (e.g., softening, wool fulling, carpet backing, insect resist-proofing, fire resist-proofing, shrink resist-proofing, easy care, anti-soiling, water- or oil repellency).

**Textile improvement** Includes such processes as bleaching, dyeing or printing, and (high) finishing.

(Commission) Improvement companies specialize in those physico-chemical processes.

**Non-integrated companies** Companies in which only part of the necessary textile processes take place (e.g., spinning and weaving, or dyeing and finishing).

**Integrated companies** Companies which operate all the required textile processes, both the mechanical and the physico-chemical processes.

**Hazardous substances** Substances which are toxic, persistent and liable to bioaccumulate.

**Cleaner technology** Technologies which use less resources or produce less residues or residues of less toxicity and persistence when compared with existing (or conventional) technology. Cleaner technologies are therefore expected to be more resource efficient, more environmentally friendly, and generally have higher product conversion efficiencies.

Scope

*These recommendations are relevant to the entire life cycle of the textile industry.*

Application of BAT and BEP concepts

Application of the BAT and BEP concepts lead to a Cleaner Production framework, and are presented herein in the form of prevention and in-plant measures. Details regarding treatment are currently excluded.

Cleaner Production in Textile Wet Processing: A Workbook for Trainers

Annexes
Prevention

[a] Banning the use of substitutable hazardous or dangerous substances.
[b] Selecting raw materials and chemicals by considering their utility and environmental impact (quality requirements).
[c] Limiting the use of a substance, both in a qualitative sense when there is no alternative available and in a quantitative sense (i.e. by using little as possible).

In-plant measures

[a] Limiting application of a process (depending on product quality targeted).
[b] Using production facilities suited to the product, the production environment and designed to minimize wastes (hardware requirements).
[c] Optimization of processes (e.g. by automation) to save energy, water and chemicals and limiting the amount of waste produced (e.g. products failing to meet quality standards); spill prevention.
[d] Recovering auxiliary chemicals.
[e] Reusing residues.
[f] Reusing water.

Treatment

[a] Purifying of unavoidable emissions (wastewater, but also air purification when applicable) by suitable techniques.

Information assessment, generation and dissemination concerning BEPs

The following measures are of a sectoral nature extending beyond the workflow (Best Environmental Practice).
[a] Establishment and use on a sector-wide basis of a central database with ecological information on the chemicals used in the textile industry. Some examples of such databases on a European or national level are: the ETAD-database for dyes, the CENTEXBEL Ecodatabase in Belgium, and the TNO-database, a Swedish database on chemicals in the textile industry, enabling assessments to be made using the maximum amount of information. Dissemination of up-to-date information is of prime importance in a sector in which thousands of commercial formulations are in use, with the rapid appearance of new products and disappearance of 'old-fashioned' ones.
[b] Inventories of material pathways: raw materials, end products, wastes, water, types of processes and their operation.
[d] Diffusion of information on BAT/BEP management systems.
[e] Environmental labelling of products.
[f] Active sector participation in new developments of BAT/BEP environmental protection measures, such as technological research.
Fibre production

Cultivation of fibre plants

Prevention
[a] Eliminate or minimize use of persistent pesticides, herbicides, fungicides and plant growth regulators which are known to cause adverse effects to the environment during cultivation of cotton.

Some of these specific chemicals include (as recommended in the Nordic eco-labelling schemes and by the European Union):

- 2,4,5-T Endosulfan
- 2,4-D Endrin
- Aldrin Fenvalerate
- Atrazine Fluazifop butyl
- Camphechlor Hexachlorobenzene
- Captan Methoxychlor
- Carbaryl Methyl bromide
- DDT Pentachlorophenol
- Diazinon Pirimicarb
- Dichlorvos Quintozene
- Dicofol Simazine
- Dieldrin Trifuraline

Individually, any of the above pesticides should not exceed 10 micrograms per kg of raw fibre, and the sum of the listed chemicals should not exceed 20 micrograms per kg of the raw fibre (as stipulated by the Nordic eco-labelling scheme).

Recycled cotton, wool and flax are exempt from these requirements.

[b] Do not overuse fertilizers, as this practice can increase leaching of nutrients to the environment, leading to nitrate contamination and eutrophication of receiving waters.

[c] Avoid use of persistent and toxic compounds such as Pentachlorophenol (PCP) as preservatives for transportation of cotton bales.

[d] Use hand-picking over mechanical methods wherever economically feasible. Mechanical picking requires use of defoliants or desiccants which are bioaccumulative and contain heavy metals.

Production of synthetic fibres

Prevention
[a] No use of halogenated monomers and lubricants is permitted in production (as specified in the Swedish and the Nordic eco-labelling schemes)

Production of regenerated cellulose

Prevention
[a] Chlorine bleaching is not permitted, and at least one of the two bleaching stages must be performed without chlorine (as specified in the Swedish and the Nordic eco-labelling schemes).

[b] Optimal whiteners and de-inking chemicals must be readily biodegradable (specified in the Swedish eco-labelling scheme).
Fibre conditioning in spinning and weaving

(see also desizing)

Actual spin finishes (spin finish containing spinning oil, emulsifier, antistatic agent), spooling oils and sizes applied to the surface are to be removed by water in a later production stage (pretreatment, dyeing or finishing).

Prevention

[a] Non-degradable spin finish (oils, antistatics, emulsifier) should be substituted by degradable alternatives (e.g. substitution of non-degradable mineral oils and mineral oils containing significant amounts of aromatics) by:
- degradable synthetic oils
or

• vegetable oils without hazardous preserving agents for integrated mills.
Sizes amenable for recycling should be used preferentially.

[b] Use of spin finish and sizes should be minimized and optimized, reducing the load of Total Organic Carbon (TOC) and nitrogen.

In-plant measures

[a] For integrated companies, the reuse of size residues can be considered a viable option.

[b] Acceptance by the weaving mills of (universally applicable) recovered sizes from the desizing plant should be considered.

[c] If reuse is considered impossible (also for non-integrated and commission improvement companies), preventive measures (choice of degradable substances which can be removed easily with water) are necessary.

[d] Recovery of spinning oils (efficient washing and filtration) and reuse (e.g. incineration).

Washing and scouring

Part of the pollution from the pretreatment of raw cotton and wool could be avoided by importing pre-treated fibres. However, this would generally mean transfer of the environmental problem to the fibre-exporting country without solving it, and is therefore an unsatisfactory measure.

Prevention

Surfactants

[a] Surfactants are used as wetting agents, detergents, emulsifiers or dispersants. They should have a high degree of ultimate biodegradability without producing metabolites that are toxic to aquatic species.

[b] Some of the specific recommendations of chemicals to avoid are:

• Linear alkylbenzenesulphonate (LAS) C10-13 (carbon chains with average length of less than 10)

• Nonylphenolethoxylate

• Dialkyl(dimethyl) ammonium chloride (DTDMAC)

• Distearil dimethyl ammonium chloride (DSDMAC)

• di (hardened yellow) dimethyl ammonium chloride (DHTDMAC)
• Sulphosuccinates
• Alkylphenolethoxylates (APEO)
• bis (hydrogenated tallow alkyl)
• complexing agents with poor biodegradability
  – EDTA
  – phosphonic acid
  – NTA
  – Phosphonates

Solvents
[a] Solvents should be selected by considering their utility and environmental impact. The use of solvents should be avoided when their environmental impact is considered more damaging than available alternatives.

[b] Use of halogenated solvents in open systems should cease.

[c] Halogenated solvents may only be used in small quantities for spot removal to avoid the waste of valuable produced textile. They should also only be used when their overall environmental impact is considered less damaging than other methods for grease removal.

Alkalis
[a] Salination and the need for acid consumption should be avoided by:
• minimization of alkaline treatments, such as mercerising (e.g., by application of additional mercerising)
• choice of textile materials with good dyability
• adaptation of dyeing processes or choosing dyes applicable in neutral media and low salt concentrations.

Oxygen consuming substances
Special emphasis should be placed on minimizing the use of organic substances which are not eliminated in the biological treatment plant (recalcitrant Chemical Oxygen Demand) by a suitable choice of auxiliaries using the material data sheets.

Other harmful substances
[a] Insect resistance treatment of wood and rotproofing of cellulose materials is widely used by both producing and exporting countries. Pentachlorophenol, DDT and other chemicals are used to protect fibrous material during production, storage and transport. Metals such as mercury, arsenic and copper are in use as alternative preserving agents for textiles, natural sizes, thickeners and vegetable or animal spinning oils.

[b] Member companies of the Ecological and Toxicological Association of the Dyes and Organic Pigments Manufacturers (ETAD) have set low limits for metal content in non-metallised dyes (see Appendix 2). Imported dyes from non-ETAD member companies/countries should meet the same quality standards.

[c] In the context of ecolabelling developments, buyers of raw materials and importers should stimulate quality control schemes in supplier countries through chemical analysis of potentially polluting substances.

[d] Import of raw materials (fibres, textiles, chemicals) should be investigated for their potential contribution to aquatic emissions of black-list pollutants. When assessing this issue, the following concentrations in untreated waste water from any pretreatment step can be used as an indication when preventive action may be warranted:
• DDT: 1 mg DDT/L
• pentachlorophenol (PCP): 20 mg PCP/L
• arsenic: 200 mg As/L
• lead: 50 mg Pb/L
• cadmium: 5 mg Cd/L
• mercury: 1 mg Hg/L
• zinc: 3 mg Zn/L (viscose or recuperated proteinous fibres)
• total chromium: 0.5 mg Cr/L (recuperated proteinous fibres)

When these threshold levels are exceeded, preventive or remedial measures should be considered, such as:
• substitution of the pollution carrying imported material
• installation of an adequate water treatment system which can remove these persistent compounds from the effluent.

[e] Substances that contain PCP or p-chlorophenol (a precursor of PCP) should be avoided. Chemicals containing hazardous substances should be investigated for their substitution.
In plant measures

General
[a] Efficient washing machines should be used, allowing for a high recovery rate of the size (e.g., up to 50% of the size can be recovered in the first washing stage).
[b] A minimum preparation approach should, whenever possible with regard to the final product, be chosen, instead of the classical preparation.
[c] Counter-current water flow should be used.
[d] Wool-washing stages should be kept separate to prevent dilution of pollutants and to enable separate recovery of substances.
[e] Wool-grease should be separated for valorisation (lanoline and/or energy).
[f] Pretreatment stages should be combined as much as possible to reduce consumption of water and energy (combined scouring, desizing, bleaching). Oxidative (peroxide) combined desizing gives lower pollution than three stage scouring, desizing, and bleaching.

Solvents
[a] The use of potentially ozone-depleting solvents should be in agreement with the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer.
[b] In scouring, fulling, dry-cleaning of wool etc., the use of perchloroethylene (PERC) is only justified when equipment for the complete recycling of the solvent, cleaning of the exhaust air (activated carbon adsorption) and freeing the sludge or grease from PERC to less than 0.1% is in place.

Alkalis
[a] No more than optimum amounts of alkaline recipes should be prepared; carry-over should be prevented; alkalis should be recycled and reused as much as possible; rinsing water should be reconstituted (upgraded).

Mercerising

The highest amount of NaOH used is in mercerization of cotton for lustre and better dyeability. The effluent pH from mercerizing or lyeing is nearly 14. NaOH is furthermore becoming more expensive (amongst other factors), due to the environmental measures taken in the chlor-alkali industry.

In plant measures
[a] Diluted alkali from mercerising should be reused in scouring, bleaching or dyeing operations.
[b] Alkali should be recovered and recycled or reused after regenerative treatment to remove dirt (coagulation, flotation, microfiltration, nanofiltration) and after concentration of NaOH (electrochemical membrane cell technology or distillation).
[c] Processes should be optimized so that discharges from alkaline treatment (mercerising) can be minimized.
Carbonization

Carbonization removes burrs and other vegetable matter from loose wool or woven fabric goods.

In-plant measures

[a] The preferred option is to work in a medium without chlorinated solvents.
[b] The use of PERC is allowed only when complete recycling of PERC is practised. This is made possible by treating wool with PERC followed by rinsing with sulphuric acid and recovery of PERC in a closed system.
[c] Foreign materials should be removed by mechanical means wherever possible.

Desizing

(See also Fibre Conditioning in Spinning and Weaving Mills)

Prevention

[a] Non-integrated and commission improvement companies should seek agreement on the choice of sizes used within the weaving mill(s).
[b] Degradable, recoverable, water soluble (for staple fibres), universally applicable, efficient sizes should be promoted.

In plant measures

[a] Desizing should preferably be done with water without chemical modification of the size.
[b] Efficient washing processes and equipment should be used to conserve water, energy and make recovery of the size (PAC, PVA/CMC, PES) feasible. Efficient washing processes use pre-washing with low volumes of water to obtain a concentrate which is partially recyclable in the weaving section. Sizes with a low viscosity (PVA, CMC) can be recovered to about 50% by using high pressure or vacuum technology in a pre-wash stage. It can be reused after sterilization (>80°C). Recovery of up to 90% is possible by partial recycling of the prewash and additional ultrafiltration of diluted wash water (size concentration >1%). The reuse of recovered sizes should be promoted.
[c] If recovery is not possible and degradation of the size is required, an integrated chemical pretreatment (scouring, desizing, bleaching all in one) is preferred; this will reduce the consumption of water and energy and minimize pollution.
[d] Acids should be replaced to render the vegetable or animal size water soluble (hydrolysis) by enzymatic and/or oxidative desizing which is more universally applicable: PVA, CMC, PAC, and starch from all sources can be removed.
Bleaching

Prevention

The recognition that some bleaching processes are polluting ‘beyond necessity’, combined with the subsequent acceptance by consumers of selected products having a lower standard for whiteness, would reduce the need for bleaching.

[a] Reductive sulphur-containing bleaches should be substituted by peroxide bleaches.
[b] Sodium perborate should be avoided.
[c] Bleaching, using hydrogen peroxide ($H_2O_2$), is preferred to bleaching with chlorine containing compounds. In any case, the content of hazardous organohalogen substances in the final effluent should be minimized. Hydrogen peroxide should be the bleaching agent of choice, with an emphasis placed towards high-efficiency and the use of environmentally friendly stabilizers. Chlorite may still be accepted, provided the necessary wastewater treatment is performed, in the following examples:
• for products which have to remain white
• for articles to be printed
• for fragile cottons in order not to reduce their degree of polymerization
• for some synthetics (mostly polyamides) which cannot be correctly bleached with $H_2O_2$.
[d] When no nutrient elimination stage is present in the wastewater treatment, phosphates can be substituted in many cases by non-hazardous stabilizers and pH-control systems.
[e] Wetting agents, emulsifiers, surfactants and all other organic chemicals should be readily biodegradable (OECD-test 301) without producing metabolites which are toxic to aquatic species.

In plant measures

[a] Textiles that need to be coloured in deep shades should not be bleached excessively.
[b] At least for bluish and bright white (≥ 6% on Berger-scale) fabrics, alternatives for chlorine bleach are not always available. Hazardous organohalogen substance production should be reduced or their emissions treated adequately.
[c] Precursors (proteins and pectins) should be removed in order to prevent the formation of hazardous organohalogen substances when bleaching with chlorine.

Dyeing

Prevention

[a] Dyes containing PCBs (e.g. certain sources of cupthalocyanine) should be substituted immediately.
[b] Cadmium containing pigments should not be used.
[c] Benzidine-based azo-dyes should not be used.
[d] Carriers containing chlorine (e.g. trichlorobenzene, chlorinated aromatics) should not be used.
[e] Reduction of dyes by sulphide should be avoided. Dichromate oxidation of vat dyes and sulphur dyes should be substituted by peroxide oxidation.
[f] Azo-dyes which can under reductive conditions release aromatic amines which are suspected carcinogens should not be used. In addition, dyestuffs with established carcinogenic effects as well as those with acute toxic effects (LD$_{50}$ < 200 mg/kg) should be excluded.
[g] The use of sodium hydrosulphite should be minimized and whenever used it should be stabilized so that it is environmentally safe (e.g.
mechanically or by polymers instead of aldehydes and toxic metal-containing compounds).

[H] Halogenated solvents and dispersants for dyes and chemicals should be substituted where possible by water-based systems. For polyester, bioeliminable dispersants should be used.

[I] Metal containing dyes (Cu, Cr, Ni, Co, etc.) should be substituted when the same degree of fastness can be obtained by other dyes and/or techniques.

[U] Urea should be substituted as dye-solvent as much as possible.

[H] When no nutrient elimination stage is present in the wastewater treatment, the use of N/P based pH regulators should be avoided.

[I] To reduce the need for auxiliaries (buffers, levelling agents, retarders, etc.), dyeing should be carried out as much as possible with decarbonated water controlled by temperature and pH. In any case, EDTA should be substituted by NTA.

In plant measures

[A] The use of liquid versions of dyestuffs (with minimal amounts of solvents or organic solubilizing agents) or low dusting granules suitable for automated dispensing, particularly for continuous dyeing and printing, is preferred.

[B] In order to minimize the discharges of BOD, COD, etc., as well as that of coloured substances, it may be necessary to make a general re-evaluation of all continuous and semi-continuous processes in terms of unused pad liquor, its treatment and possible recycling. The exhaust dyeing is less polluting for dyeing knitted goods. In addition, the pad-batch option is not the best option for waste minimization (all parameters) in cases where a lower fixation is achieved in the pad-batch process and where there is the need to ensure that excess pad liquor is available to avoid running out of colour during the process.

[C] The padthrough needs to have a minimal volume (minimal application techniques) and the distance from the feed tank must be very small to reduce the extra make-up of dye liquor.

[D] For batchwise dyeing of polyester or cotton, there are major benefits from moving from a two-batch process to a telescoped procedure where the cotton and polyester are dyed simultaneously. Such procedures must be right the first time to prevent the necessity for shade correction or stripping of the dye.

[E] For batch dyeing, waste minimization can be best achieved by, in order of importance:
- pad-batch dyeing
- operating at the lowest liquor ratio possible
- minimizing and ideally avoiding the need to strip and re-dye

[.J] * avoiding shading additions.

[F] Exhaustion should be controlled by pH, temperature, and time steering instead of through use of chemical egalisators and retardants.

[G] Polyester dyeing should be performed without carriers if possible. High temperature (HT) dyeing is preferred. If carriers are necessary (polyester/wool blends), non-hazardous, non-halogenated carriers must be used. Hazardous carriers include bi- or trichlorobenzene, butylibenzoate, methylcresolate, o-phenylphenol, biphenyl, biphenyloxide, benzylbenzoate and chlorinated aromatics.

[H] If possible, dyes can be recycled by the standing bath technique, going from light to darker shades.

[I] In the case of repeated dyeing, a rinsing bath should be used as the next dye bath, if the after-treatment chemicals are compatible with the dyebath chemicals.

[J] Stabilized hydro-sulphite should be used to prevent oxidative decomposition of sodium-hydro-sulphite in continuous pad-steam dyeing of cellulosic and cellulosic blend fabrics with vat dyes. In view of the environmental concern about possible harm from the use of aldehyde (formaldehyde or acetaldehyde forming sulfoxylate) stabilizers and toxic metallic salts (Ni-cyanides) or borohydrides for release of the reducing agent, such systems – if used – should be replaced by, for example, mechanical methods or high molecular weight polymeric auxiliaries.

[K] In dyeing vat and sulphur dyes, the reduced solubilized dyes are oxidized after dyeing to the insoluble state. Traditionally the oxidant is
dichromate, which is still used to a large extent. ‘Chrome’ oxidation should be replaced immediately or, if this is not possible, strictly controlled. Two alternatives for chrome replacement are alkaline and acid hydrogen peroxide. [l] With respect to heavy metals, the use of metal-complex dyes and chrome dyeing of wool poses some problems. Novel application processes such as low-chrome afterchrome dyeing methods may enable the continuation of the use of such dyeing methods.

[m] Dyes must be checked for metal content, and if possible replaced, at least when the following concentrations are exceeded in the effluent from the dyeing stage before treatment:
- chromium: 4.0 mg Cr/L and 1.0 kg Cr/day
- copper: 0.5 mg Cu/L and 0.5 kg Cu/day.

[n] Recovered dyes should be reused as much as possible.

Printing/pigmentation

Prevention

[a] The use of white spirit should be replaced by water-based systems.

[b] Biodegradable natural thickening auxiliaries or highly degradable synthetic thickeners should be chosen.

[c] The use of urea in printing with reactive dyes should be reduced by (or in combination with) other techniques (e.g. pre-wetting of fabric) on the conditions that the nitrogen emissions do not increase. The printing paste may contain not more than 30g of urea/kg of textile.

[d] The use of copper and chrome salts is not permitted and should be minimized as much as possible. In the case of pigment printing, solvent based printing pastes are not allowed.

In plant measures

[a] Where feasible, pigmentation is preferred over dyeing because this may reduce dyeing and printing operations saving energy, water and chemicals.

[b] Pastes can be recovered through optimized paste preparation and supplying systems; they should be recycled and reused.

[c] Printing techniques should be used without premixing of the chemicals to reduce waste from the kitchen and applicator(s).

[d] Printing screens should be replaced by non-contact techniques (e.g. ink-jet printing).

[e] Automation may lead to less pollution.

Finishing

The majority of treatments are applied in the liquid state. Wet finishing involves the application of a wide range of chemicals to extend the function of a textile product.
Prevention

[a] Reduce the use of formaldehyde releasing products as much as possible.
[b] The use of hazardous chemicals for the conservation of textiles should be minimized, either through substitution or through ‘tailor-made’ selective use to only those textiles which are exposed to possible environmental degradation.

[c] Limitation of the chlorination stage in wool shrinkproofing by substitution of other techniques (e.g. peroxycyanic treatment) should be considered. An exception is the continuous silver treatment of knitted wool garments and socks before piece dyeing.
[d] Polybrominated diphenylethers, biphenyls and similar compounds should be substituted.

In plant measures

[a] Whenever feasible, building finishing chemicals into the fibre during production (copolymerisation, extrusion) or during spinning is preferred over applying the finish at a later stage.
[b] Application of fireproofing chemicals on fibres or yarns can be adequate (e.g. application of Zr-containing chemicals on wool).

c] Application of fireproofing chemicals should preferably be done by techniques which consume minimal amounts of water – e.g. vacuum, back coating, foam or lead – to minimal amounts of residues, particularly, for example, foam.
[d] Finishing chemicals should be reused whenever possible.

Fibre production stage

Wool fibre

Flax separation
Oxygen consuming emissions of wastewater during flax separation must be reduced by:
• at least 75% measured by COD or TOC values (as suggested in the Nordic Eco-labelling Scheme)
• at least 85% measured by COD (as suggested in the Swedish Eco-labelling Scheme)

Washing of wool fibre
[a] COD emissions should be within 70 kg/tonne of wool produced (as suggested in the Nordic Eco-labelling Scheme).
[b] COD emissions should be within 100 kg/tonne of washed wool (as suggested in the Swedish Eco-labelling Scheme)

Synthetic fibres

Limits set to different pollutants are listed below with the source.
• Volatile Organic Compounds (VOCs) 1.2 kg/kg of polyester
  (as suggested by the European Eco-labelling Scheme)
• Antimony
  100 ppm in the fibre
  (as suggested by the European Eco-labelling Scheme)
  0.5 mg/L in effluents
  (as suggested by the European Eco-labelling Scheme)
Regenerated cellulose

- **COD** 40 kg/tonne of fibres (as suggested in the Swedish Eco-labelling Scheme)
  100 kg/tonne of fibres
  (as suggested in the Eco-labelling scheme by the European Union).
- **Sulphur** 10 kg/tonne of fibres
  (as suggested by Eco-labelling schemes of Sweden and European Union).
- **Zinc** 1 kg/tonne of fibres
  (as suggested by Eco-labelling schemes of Sweden and the Nordic Countries).

Fibre processing

Desize

Non-readily biodegradable warp adhesive should not exceed 30 g/kg of textile prior to wastewater treatment, as suggested in the Swedish Eco-labelling scheme.

Overall process emissions

- **COD** 30 kg/tonne of textile (as suggested in the Swedish Eco-labelling scheme)
  50 kg/tonne of textile (as suggested in the Nordic Eco-labelling scheme).
- **Dye** 4 g/kg of textile (as suggested in the Swedish Eco-labelling scheme).
- **Phosphorus** 5 g/kg of textile (as suggested in the Swedish Eco-labelling scheme).
- **Energy** 70 MJ/kg of textile (as suggested in the Swedish Eco-labelling scheme)
- **Water** 100 litres/kg of textile

Note:

A significant variation in water usage exists even in the same category (e.g. wool, woven fibre, knitted fibre, carpet etc.), due to the differences in the washing cycles, washing equipment and extent of water reuse employed.

Situations of extreme difference can exist, which probably reflect the instances of indiscriminate water use including bad housekeeping. In many situations today, water use less than 100 L/kg to as low as 60 L/kg is achievable for all categories and for most types of processing.

Technological progress for environmental protection

Research and development is under way or proposed for obtaining substantial pollution reduction, recycling of water and reuse of resources. Efforts are being made by a concerted ‘clean technology’ action for a quicker transfer of information on BAT. This is a very dynamic process, driven by the requirements of consumers, end users of chemicals and substrates, manufacturers of machinery, and manufacturers and distributors of chemicals and dyes. The following areas indicate new developments for the future.
**Fibre production stage**

Natural fibres are renewable resources. Substantial reduction in the use of pesticides and other harmful substances need to be stimulated. Potential options are:

- controlled and optimized treatment schemes and, even better,
- the use of natural protecting agents, enzymes, and genetic improvements.

**Fibre conditioning stages**

[a] For a drastic reduction of the pollution caused by chemicals applied to the surface of textiles (e.g. pin finish, sizes, surfactants), the following ideas should be considered:
- permanent surface conditioning (conditioning not removed during improvement operations such as pretreatment and dyeing) that does not interfere with bleaching, dyeing or high finishing
- recoverable spin finishes that can be separated by mechanical means and concentrated by filtration before recycling or reuse
- universally applicable sizes to improve the potential for recycling in non integrated weaving/improvement companies.

**Textile improvement operations**

[a] Reduction of the salt content of wastewater by application of new R & D into:
- recovery and reuse of alkali, acid, salts – in particular, sulphate and sulphuric acid from carbonizing, viscose production, and dyeing (e.g. electrodialysis)
- new dyes that exhaust with low amounts of salt and fix in the neutral pH range (e.g. reactive dyes).

[b] Advanced oxidation processes and in particular radical peroxidation are potential methods to:
- transfer refractory material in biodegradable material
- dehalogenate to eliminate hazardous organohalogen substances and prevent emissions to the air
- make fibre-substrates and dyes reactive (radical dyeing), improving the fastness through additional or stronger covalent bonding
- destroy the unfixed dye in situ, reducing colour and rinse water
- de-colour water for reuse and recycling
- replace chlorine treatment in stonewashing, bleaching of knitwear and linen, and shrink-resist proofing of wool

- in general, clean destruction of hazardous compounds by activated peroxide, generating hydroxyl radicals and providing opportunities for complete mineralisation.

[c] Efficient dyes containing chromophores with very high colour strength.

[d] Foam finishing technologies should be reconsidered where air replaces organic thickening agents responsible for high oxygen demand and nitrogen content. If this is not a viable option, methods for recycling or reuse should be developed for concentrating printing pastes.

[e] To prevent pollution from hazardous catalysts and resins and from finishes in general, new technologies of fixation and polymerization need further attention. General applicable methods for preventing the generation of surplus finishes and pastes are a clear possibility, although they may require additional investment.

[f] New back-coating techniques for carpets are needed with the aim of producing totally recyclable textiles, at least preventing the discharge of zinc and other pollutants.
General options

It is possible to extend the colour matching computer software and recipe calculation with expert-systems and predict the environmental impacts of recipes and alternatives. State-of-the-art BAT and BEP has to be selected, described and transferred to each potential user, using advanced multimedia and open communication technologies. Expert systems as a tool for Best Available Techniques in Textile Management (dissemination of up-to-date information) are already under development at CEC in the framework of the EC BRITE-EURAM II programme.

Abbreviations

List of abbreviations used

<table>
<thead>
<tr>
<th>APEO</th>
<th>Alkylphenolethoxylates</th>
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<tr>
<td>BAT</td>
<td>Best Available Techniques</td>
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<tr>
<td>BEP</td>
<td>Best Environmental Practice</td>
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<td>BOD</td>
<td>Biological Oxygen Demand</td>
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<td>CMC</td>
<td>Carboxymethylcellulose</td>
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<td>COD</td>
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<td>DIFFCHEM</td>
<td>Paris Commission Working Group on Diffuse Sources</td>
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<td>EDTA</td>
<td>Ethylenediaminetetra-acetic acid</td>
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<td>EO</td>
<td>Ethoxylates</td>
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<td>ETAD</td>
<td>Ecological and Toxicological Association of Dyes and Organic Pigments Manufacturers</td>
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<td>NTA</td>
<td>Nitrilotriacetic acid</td>
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<td>Polyacrylate</td>
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<td>Pentachlorophenol</td>
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<td>Polyvinylacetate</td>
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<td>TOC</td>
<td>Total Organic Carbon</td>
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<td>TOD</td>
<td>Total Oxygen Demand</td>
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<td>TRI</td>
<td>Trichloroethylene</td>
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</table>

A Workbook for Trainers: Cleaner Production in Textile Wet Processing
Literature references used to prepare the text

US Environmental Protection Agency
Environmental Research Information Centre
Technology Transfer [1978] Environmental Pollution Control, Textile Processing Industry.
Pollution Prevention Pays Program,
Department of Natural Resources and Community Development, Raleigh, North Carolina, USA.
Smith, B. [1988] 'A workbook for pollution prevention by source reduction'. In Textile Wet Processing. Pollution Prevention Pays Program,
Division of Environmental Management, North Carolina, USA.
United Nations Environment Programme:

United Nations Environment Programme:
Industry And Environment Office (UNEP IEO)
Criteria in Environmental Labelling: A Comparative Analysis of Environmental Criteria in Selected Eco-labelling Schemes (Draft), June 1995, Environment and Trade, UNEP.
Appendices

I Supporting Documents for this Package

II List of Training Resource Packages available from UNEP IE

III About UNEP Industry and Environment
Appendix I

Supporting Documents for this Package

During trials, the following documents were shown to be of great use in supporting the use of this package. They form an integral part of the package.

- *Energy Efficiency and Climate Change* [1991] UNEP / IPIECA.
Appendix II

List of Training Resource Packages available from UNEP IE

The following training resource packages have been developed by UNEP IE. They all use interactive training methodologies to explain the subject, and are aimed at educators who, although technically skilled, may not have specialized knowledge in this particular area. The packages are available from UNEP IE.

Some trainers' packages are still under development, and users are encouraged to assist UNEP to bring these to a final stage of publication.

Due to the cost of printing of the packages (between 100 and 400 pages), the completed documents are offered for sale to most users. However, a limited number of draft packages are free of charge to users prepared to contribute to their further development through review, field testing and adding material. Assistance with translation would also be welcome.

**Cleaner Production: a Training Resource Package** [1996] First Edition. Contains background reading, transparencies, bibliography, and work exercises. 110 pages. Price $120. This package also helps to explain the APELL programme.


<table>
<thead>
<tr>
<th>Title</th>
<th>Year</th>
<th>Price (developed countries)</th>
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</table>

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Cleaner Production in Textile Wet Processing: A Workbook for Trainers  
Appendices
**Appendix III**

About UNEP Industry and Environment

Industry and Environment was established by UNEP in 1975 to bring industry and government together to promote environmentally sound industrial development.

UNEP IE is located in Paris and its goals are to:  
1. encourage the incorporation of environmental criteria in industrial and development plans;  
2. facilitate the implementation of procedures and principles for the protection of the environment;  
3. promote the use of safe and clean technologies;  
4. stimulate the exchange of information and experience throughout the world.

UNEP IE provides access to practical information and develops co-operative on-site action and information exchange backed by regular follow-up and assessment. To promote the transfer of information and the sharing of knowledge and experience, UNEP IE has developed three complementary tools: 
- technical reviews and guidelines;  
- Industry and Environment: a quarterly review;  
- a technical query-response service.

In keeping with its emphasis on technical cooperation, UNEP IE facilitates technology transfer and the implementation of practices to safeguard the environment through promoting awareness and interaction, training and diagnostic studies.

Some relevant UNEP IE publications

Refer to Appendix II for trainers' packages. For complete list, refer to publications catalogue.

*Industry and Environment* (quarterly) deals with issues relevant to industrial development, such as auditing, waste management, industry-specific problems, and environmental news.  

A Workbook for Trainers: Cleaner Production in Textile Wet Processing


Cleaner Production in Textile Wet Processing: A Workbook for Trainers Appendices
Evaluation Form
Cleaner Production in Textile Wet Processing

As part of the continuing review of this trainers package, we would appreciate your cooperation in answering the following questions. Please return the completed evaluation form to:

UNEP IE, Tour Mirabeau, 39-43 quai André Citroën, 75739 Paris Cedex 15, France
Fax 33 (1) 44 37 14 74.

1. Do you have any suggestions for improvement of the trainers package? How could we improve its readability, contents, practical use, and so on?

2. How was the package useful in preparing your own training activity?

3. Did the background information and transparency set provide you with enough information? What was missing?

continued ...
4. What resource information was useful to you? What else should be included?

5. What are your experiences with the exercises? What worked, and what didn't?

6. Do you have training material which could be incorporated into this workbook?

7. What additional topics related to cleaner production would you want to be included in the final version of this workbook?

Thank you for taking the time to complete this evaluation form. Please return the completed form to UNEP IE, Tour Mirabeau, 39-43 quai André Citroën, 75739 Paris Cedex 15, France.