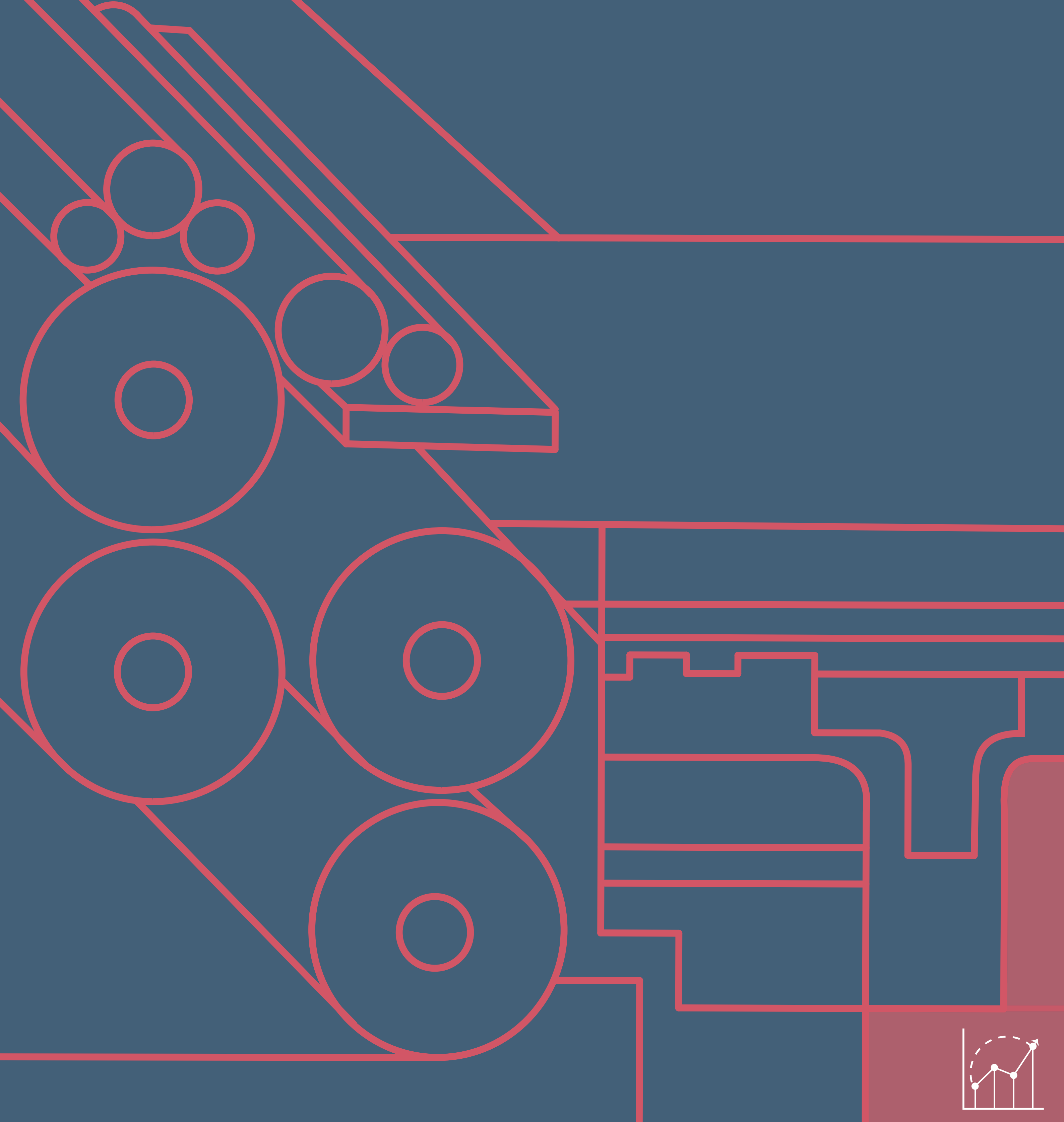
UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

BENCHMARKING REPORT

Enhancing Productivity in the Indian Paper and Pulp Sector



Designed by Athenea International/Omnilang (Mauricio Mondragon & Maria Grineva).

BENCHMARKING REPORT

Enhancing Productivity in the Indian Paper and Pulp Sector

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

2017

TABLE OF CONTENTS

LIST OF ABBREVIATIONS 6
ACKNOWLEDGEMENTS 8
EXECUTIVE SUMMARY 9
1 INTRODUCTION 13
2 OVERVIEW OF THE INDIAN PULP AND PAPER INDUSTRY 17
- 2.1. General overview 17
- 2.2. Structure of the Indian paper industry 18
- 2.3. Analysis of database of potential paper clusters/units in four regions - north, south, east and west 22

3 ASSESSMENT OF THE TECHNOLOGY STATUS 29
- 3.1. Approach 29
- 3.2. Units visited 29
- 3.3. Overall perceived technological challenges 31
- 3.4. Qualitative evaluation of the technology in the mills 34

4 BEST AVAILABLE TECHNIQUES (BAT) 39
- 4.1. Scope 39
- 4.2. General considerations 39
- 4.3. Emission levels associated with BAT 39
- 4.4. Averaging periods for emissions to water 40
- 4.5. Averaging periods for emissions to air 40
- 4.6. Definitions and acronyms 40
- 4.7. General BAT conclusions for the pulp and paper industry 42
- 4.8. BAT conclusions for Kraft and soda pulping processes 51
- 4.9. BAT conclusions for processing paper for recycling 59
- 4.10. BAT conclusions for papermaking and related processes 62

5 STATUS AND ISSUES RELATED TO BAT AND POTENTIAL FOR APPLICABILITY 67
- 5.1. Raw material handling and preparation 67
- 5.2. Pulping and chemical recovery process 70
- 5.3. Papermaking 71
- 5.4. Effluent treatment 72
- 5.5. Techniques to reduce fresh water use, waste water flow and the pollution load in waste water 73
- 5.6. Potential for applicability of identified BAT in the Indian paper industry 77
- 5.7. Summarized qualitative assessment of the technology status 89

6 INTERNATIONAL TRENDS IN THE PULP AND PAPER INDUSTRY 91
- 6.1. Global Megatrends 91
- 6.2. Trends – Newspaper and printing and writing grades 93
- 6.3. Trends – Packaging Grades 94
- 6.4. Market trends – Tissue paper and hygiene products 96
- 6.5. Market trends – biocomposites 96
- 6.6. Market trends – nanocellulose 97
- 6.7. New processes– bio-economy 97

7 ACTION PLAN BASED ON THE EVALUATION OF THE TECHNOLOGY STATUS 101
- 7.1. Background 101
- 7.2. Action plan points 101
- 7.3. Summary 109

REFERENCES 110

LIST OF FIGURES

Table 1: Structure of the Indian Paper Industry...21
Table 2: Production of Various Grades of Paper from Different Raw Materials 21
Table 3: Projected Growth of Different Varieties of Paper 23
Table 4: Paper Mills in North India (Haryana, Punjab, UP and Uttarakhand), 2015-16 25
Table 5: Paper Mills in Kashipur, Uttarakhand Cluster (North India), 2015-16............ 25
Table 6: Paper Mills in Muzaffarnagar, UP Cluster (North India), 2015-16 25
Table 7: Paper Mills in Punjab Cluster (North India), 2015-16.. 27
Table 8: Paper Mills in Western India (Gujarat), 2015-16 27
Table 9: Paper Mills in Vapi, Gujarat Cluster (Western India), 2015-16 27
Table 10: Paper Mills in South India, 2015-16.. 29
Table 11: Paper Mills in Coimbatore, Tamil Nadu Cluster (South India), 2015-16............. 29
Table 12: Paper Mills in East India (West Bengal), 2015-16... 29
Table 13: Overview of the Visited Units with Locations..31
Table 14: Overview of the Raw Materials Used for the Visited Units 32
Table 15: Overview of the Main Products and Production Capacity of the Visited Mills......... 32
Table 16: Averaging Periods - Water................ 42
Table 17: Averaging Periods - Air.................... 42
Table 18: Definitions...................................... 42
Table 19: Acronyms 43
Table 20: Principles for Minimising the Environmental Impact of Production Processes... 45
Table 21: Techniques for Reducing the Release of Not Readily Biodegradable Organic Chelating Agents 45
Table 22: Techniques for Reducing Waste Water 45
Table 23: Techniques for Reducing Fresh Water Usage and Generation of Waste Water... 46
Table 24: BAT- Associated Waste Water Flows ... 46
Table 25: Techniques for Reducing Fuel and Enegy Consumption..................................... 47
Table 26: Techniques for Preventing and Reducing the Emission of Odorous Compounds 47
Table 27: Monitoring of Key Parameters.......... 48
Table 28: Monitoring and Measurement of Emissions to Air... 48
Table 29: Monitoring and Measurement of Emissions to Water 49
Table 30: Waste Management 50
Table 31: Techniques for Reducing Emissions of Pollutants into Receiving Waters 51
Table 32: Techniques for Reducing Emissions of Pollutants into Receiving Waters 51
Table 33: Techniques for Reducing Emmissions of Noise 52
Table 34: Techniques for Preventing Pollution Risks When Decommissioning a Plant... 53
Table 35: Techniques for Reducing Emissions of Pollutants 54
Table 36: BAT-associated emission levels for the direct waste water discharge to receiving waters from a bleached Kraft pulp mill 55
Table 37: BAT-associated emission levels for the direct waste water discharge to receiving waters from an unbleached Kraft pulp mill.. 55
Table 38: Techniques for Reducing Emmissions in Strong and Weak Odorous Gases 55
Table 39: Techniques for Reducing SO_2 and TRS emissions 56
Table 40: BAT-associated emission levels for SO_2 and TRS emissions from a recovery boiler.. 56
Table 41: Techniques for Reducing NO_X emissions from a Recovery Boiler................. 56
Table 42: BAT-associated emission levels for NOX emissions from a recovery boiler 57
Table 43: BAT-associated emission levels for dust emissions from a recovery boiler..... 57
Table 44: Techniques for Reducing the Emmissions from a Lime Kiln 57
Table 45: BAT-Associated Emission Levels for SO2 and Sulphur Emissions from a Lime Kiln... 58
Table 46: Techniques for Reducing TRS Emissions from a Lime Kiln 58
Table 47: BAT-Associated Emission Levels for TRS and Sulphur Emissions from a Lime Kiln.. 58
Table 48: Techniques for Reducing NO_X Emissions from a Lime Kiln 58
Table 49: BAT-Associated Emission Levels for NO_X Emissions from a Lime Kiln 58
Table 50: BAT-Associated Emission Levels for Dust Emissions from a Lime Kiln 59
Table 51: BAT-Associated Emission Levels for SO_2 and TRS Emissions from the Incineration of Strong Gases in a Dedicated TRS Burner....... 59
Table 52: Techniques for Reducing NO_X Emissions from the Incineration of Strong Odorous Gases in a Dedicated TRS Burner ... 59
Table 53: BAT-Associated Emission Levels for NO_X Emissions from the Incineration of Strong Gases in a Dedicated TRS Burner....... 59
Table 54: Techniques for Recuding Energy Consumption and Improving Efficiency 60
Table 55: Techniques for Increasing the Efficiency of Power Generation..........................60
Table 56: Techniques for Material Management . 61
Table 57: Techniques for Reducing Fresh Water Usage, Waste Water and Emissions to Water 62
Table 58: Techniques for Mainitaining Advanced Water Circuit Closure.................... 62
Table 59: BAT-Associated Emission Levels for the Direct Waste Water Discharge to Receiving Waters from the Integrated Production of Paper and Board from Recycled Fibres Pulp, Produced Without Deinking on Site 63
Table 60: BAT-Associated Emission Levels for the Direct Waste Water Discharge to Receiving Waters from the Integrated Production of Paper and Board from Recycled Fibres Pulp, Produced With Deinking on Site 63
Table 61: Techniques for Reducing Eletrical Energy Consumption within RCF Mills........... 63
Table 62: Techniques for Reducing the Generation of Waste Water................................ 64
Table 63: Techniques for Reducing Fresh Water Use and Emissions to Water from Speciality Paper Mills 65
Table 64: Techniques for Reducing the Emission Loads of Coating Colours and Binders 65
Table 65: BAT-Associated Emission Levels for the Direct Waste Water Discharge to Receiving Waters from a Non-Integrated Paper and Board Mill (Excluding Specialty Paper)............66
Table 66: BAT-Associated Emission Levels for the Direct Waste Water Discharge to Receiving Waters from a Non-Integrated Specialty Paper Mill 66
Table 67: Techniques for minimizing the amount of solid waste 67
Table 68: Techniques for Energy Consumption and Efficiency 67
Table 69: Raw Material Handling.................... 70
Table 70: Raw Material Preparations...............71
Table 71: Pulping and Chemical Recovery Process 72
Table 72: Papermaking (1) 73
Table 73: papermaking (2)............................. 73
Table 74: Effluent Treatment 74
Table 75: Description of the Techniques for Reducing Fresh Water Use/Waste Water Flow and the Pollution Load in Waste Water... 75
Table 76: Summary of the evaluation given in Chapter 3.4... 91
Table 77: Action Plan- Raw Material Handling 104
Table 78: Action Plan- Raw Material Preparation 104
Table 79: Action Plan – Pulping and Bleaching Process......................................105
Table 80: Action Plan – Papermaking (1) 106
Table 81: Action Plan – Papermaking (2) 106
Table 82: Action Plan – Effluent Treatment 107
Table 83: Action Plan – Reduction in Fresh Water Use/Waste Water Flow and the Pollution Load in Waste Water 108
Table 84: Summarized Qualitative Assessment of the Technology Status 110
Table 85: Summary of Technological Challenges.. 111

LIST OF ABBREVIATIONS

3D	Three Dimensional
ADt	Air Dry tonnes (of pulp) expressed as 90% dryness
AMS	Automated Measuring System
AOX	Adsorbable organic halides
BAT	Best Available Techniques
BMT	Bare Minimum Technology
BOD	Biochemical oxygen demand-quantity of dissolved oxygen required by microorganisms to decompose organic matter in waste water
CETP	Common Effluent Treatment Plant
CHP	Cogeneration of Heat and Power
CMP	Chemi-mechanical pulp
CNC	Cellulose Nanocrystalline
CNCG	Concentrated Non-Condensable Odorous Gases
CNF	Cellulose Nanofibrils
CPCB	Central Pollution Control Board of India
CPPRI	Central Pulp and Paper Research Institute
CTMP	Chemi-thermomechanical pulp
COD	Chemical oxygen demand; the amount of chemically oxidisable organic matter in waste water
DAF	Dissolved Air Flotation
DIP	De-inked pulp
DIPP	Department of Industrial Policy and Promotion
DS	Dry Solids
DTPA	Diethlyenetriaminepentaacetic acid
E7-countries	Emerging countries comprising China, India, Brazil, Russia, Indonesia, Mexico and Turkey
ECF	Elemental Chlorine Free
EDTA	Ethylene diaminetetraacetic acid
ETP	Effluent Treatment Plant
EU	European Union
G7-countries	US, Japan, Germany, UK, France, Italy and Canada
GDP	Gross Domestic Product
H_2S	Hydrogen sulphide
IARPMA	Indian Agro and Recycled Paper Mills Association
IC-ISID	International Centre for Inclusive and Sustainable Industrial Development
ICRA	Investment Information and Credit Rating Agency of India
ICT	Information and Communication Technologies
INMA	Indian Newsprint Manufacturers Association
IPMA	Indian Paper Manufacturers Association
IRPMA	Indian Recycled Paper Mills Association
KPI	Key Performance Indicators
LVHC	Low Volume High Concentration Gas System
LTI	Low Temperature Incineration
LWC	Light-weight coated paper
MF	Machine Finished
MFC	Micro-Fibrillated Cellulose
MG	Machine Glazed
MTPA	Million Tonnes Per Annum
NCG	Non-Condensable Odorous Gases
NCO	Newsprint Control Order
NOX	The sum of nitrogen oxide (NO) and nitrogen dioxide (NO_2), expressed as NO_2
NSSC	Neutral Sulphite Semi Chemical
ODL	Oxygen Delignification
OECD	Organisation for Economic Co-operation and Development
RCF	Recycled fibres
RDH	Rapid Displacement Heat
SEK	Swedish Krona (currency)
SO_2	Sulphur dioxide
TCF	Totally Chlorine Free
TMP	Thermo-Mechanical Pulp
TOC	Total Organic Carbon
TRS	Total Reduced Sulphur
TSS	Total Suspended Solids
VOC	Volatile Organic Compounds
UNIDO	United Nations Industrial Development Organization
USD	United States Dollars (currency)
USA	United States of America
ZLD	Zero Liquid Discharge

ACKNOWLEDGEMENTS

The Benchmarking Report was drafted in the context of project - Development and adoption of appropriate technologies for enhancing productivity in the paper and pulp sector - funded by the Government of India, Department of Industrial Policy & Promotion (DIPP).

The report was produced by UNIDO's department of Trade, Investment and Innovation (TII), under the directorship of Dr. Bernardo Calzadilla-Sarmiento, the project being managed by Dr. Anders Isaksson.

The technical content is the work of the following UNIDO technical expert Dr. Øyvind Eriksen.

The results presented in this report, have been reviewed and edited by Dr. Ritin Koria, Mr. Vikas Kumar, Dr. Rakesh Kumar Jain and Ms. Ashima Marwaha.

Proof reading was undertaken by Ms. Lauren Cooke, and final layout and Design was undertaken by Mr. Mauricio Mondragon and Ms. Maria Grineva.

Furthermore, we would like to extend thanks to the staff of the Central Pulp & Paper Research Institute (CPPRI), Indian Paper Manufacturers Association (IPMA), Indian Newsprint Manufacturers Association (INMA), Indian Agro & Recycled Paper Mills Association (IARPMA), and Indian Recycled Paper Mills Association (IRPMA), in particular Bipin Prakash Thapliyal, Mr. Rohit Pandit, Mr. Vijay Kumar Raghotam, Mr. PGN Mukundan and Mr. RC Rastogi respectively, for availing the necessary logistical support for the hosting of technical workshops and seminars, for support in data collection and active participation in the project.

EXECUTIVE SUMMARY

The United Nations Industrial Development Organization (UNIDO) has implemented a project titled '*Development and adoption of appropriate technologies for enhancing productivity in the paper and pulp sector*', in collaboration with the Department of Industrial Policy and Promotion (DIPP), Ministry of Commerce and Industry, Government of India.

Under the aegis of the UNIDO International Centre for Inclusive and Sustainable Industrial Development (IC-ISID), New Delhi, the project aimed to support the Indian paper and pulp industry by strengthening the capacity and capability of the nodal technical institution for the sector, the Central Pulp and Paper Research Institute (CPPRI), and select industry associations to provide better management and technical support to the industry to strengthen the global competitive position of the Indian pulp and paper sector.

The identified industry associations were the Indian Paper Manufacturers Association (IPMA), Indian Agro and Recycled Paper Mills Association (IARPMA), Indian Newsprint Manufacturers Association (INMA) and Indian Recycled Paper Mills Association (IRPMA).

The project facilitated a range of technical capacity building and knowledge sharing activities including the demonstration of appropriate technologies, knowledge dissemination workshops, study tours, fellowship training programmes and twinning with international organizations.

These activities were preceded by a diagnostic component, which included an analysis of the Indian pulp and paper industry to assess the status of the technology and the potential for applicability of the globally best available techniques (BAT) in the Indian context, a diagnostic assessment of CPPRI and select associations, development of the Key Performance Indicators (KPI) for the sector and a comprehensive action plan to build the capacity and capabilities of CPPRI and selected associations and to address the technical gaps and challenges being faced by the industry.

The report, The Indian Pulp and Paper Industry – An Overview of Technology Status, provides an overview of the industry, identifies technology gaps and challenges, and assesses the potential for applicability of the best available techniques (BAT) in the Indian context. It also throws light on the international trends in the pulp and paper industry, where a decline has been observed, especially in printing paper. The report accordingly provides recommendations to prepare the industry for changes in the market by diversifying their product offerings.

The Indian paper industry contributes approximately 4.28% of the global paper production, producing over 17.28 million tonnes per annum (MTPA) of paper, paperboard and newsprint, against an operational installed capacity of around 21.39 MTPA. With an estimated turnover of approximately INR 50,000 crore (US$ 7.3 billion), the industry contributes over INR 5,500 (US$ 0.8 billion) to the national exchequer. There are around 600 operational mills producing industrial, writing and printing, and newsprint grades of paper.

Over the last decade, the Indian paper market has grown steadily at an average annual growth rate of around 7%, compared to the global growth rate of 3%. The demand for paper is expected to rise from the current 18.17 million tonnes per annum (MTPA) to more than 20 MTPA by 2020.

However, despite tremendous demand for domestic consumption, the average capacity utilization rate is around 80%. The Indian paper industry is highly fragmented, predominately consisting of small/medium scale units based on recycled paper and agro residue fibres, and few of the large mills using wood. The operational capacity of the mills varies from 10 to 1500 tonnes per day.

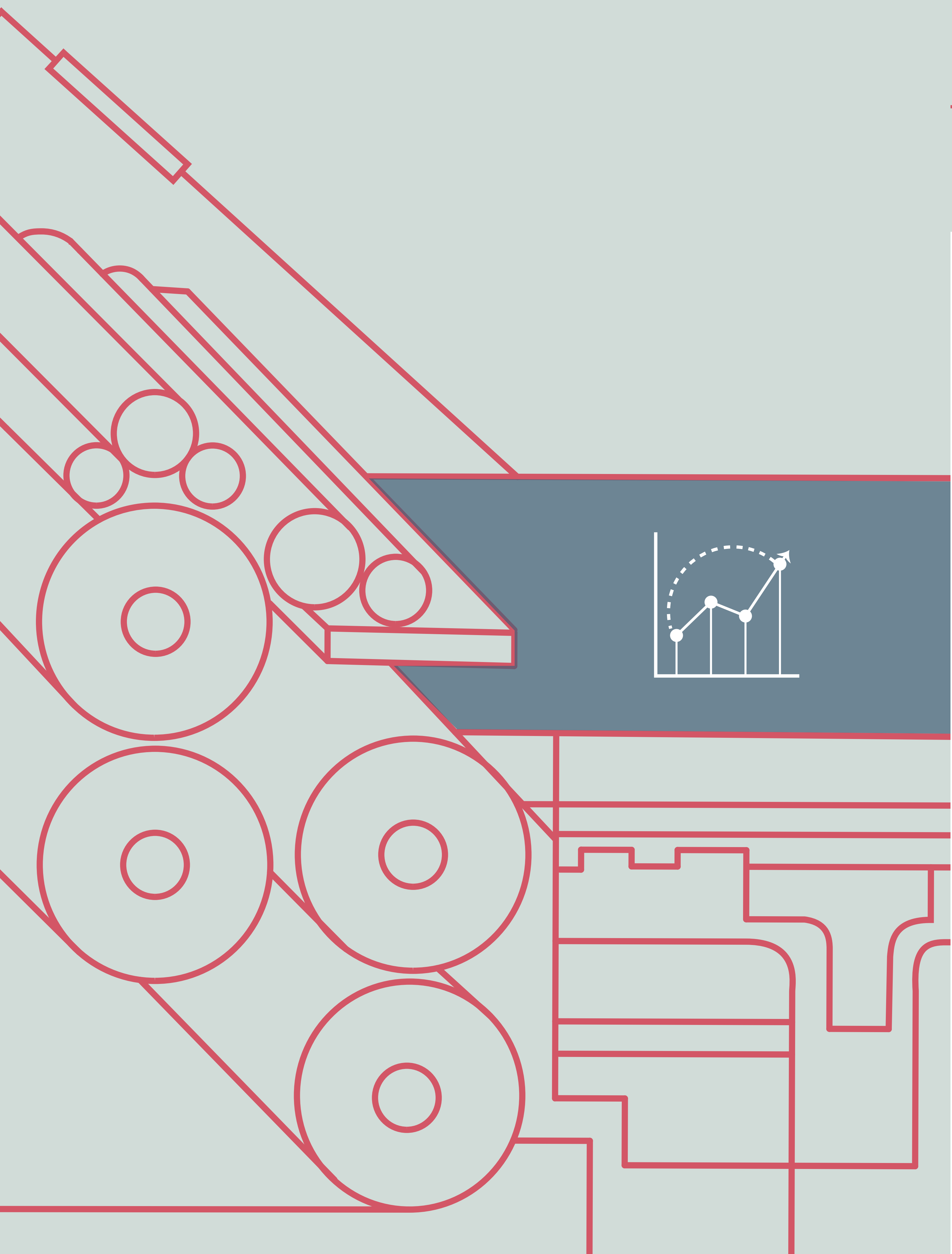
The sector is facing several challenges in areas such as scarce availability of raw materials, low economies of scale, energy efficiency, low pulp yield, inefficient internal water handling and environmental concerns regarding solid waste disposal and effluent treatment. As such, there is a growing need to modernize Indian mills, improve productivity and augment capacities.

To review the status of technology, a representative sample of mills located in different regions- having variation in size, the raw material used, the level of technology, and product basket- was selected, to have the broadest possible representative sample of raw materials, location and products. The data was gathered through interviews with technical personnel at the different units, combined with a short tour through each of the units. Various stages of manufacturing of paper, right from raw material handling, pulping process and bleaching to papermaking, finishing/packaging, effluent treatment, process control and product quality assessment, were evaluated.

Accordingly, a summary of the best available techniques (BAT) for the processes most important for the Indian pulp and paper industry and their applicability has been discussed. The report delineates the following possible solutions/actions for improvement of the product quality, production efficiency, environmental aspects and competitiveness of the Indian pulp and paper industry:

Area	Main challenges	Affects	Solution related to
Raw material handling	Storage	Product quality, environment	Investment/practice
Pulping and bleaching	Efficiency/yield	Product quality, costs, environment	Investment/process layout/ knowledge
Papermaking	General water handling	Quality, costs, environment	Investment/process layout/ knowledge
Effluent treatment	Removal of enough material	Environment, costs, quality	Investment/process layout
Health and safety			Practice

The technology being used by the industry, in general, is not the most advanced and latest. However, as the implementation of new technology will require major investments, the report recommends optimization of existing processes. This would improve cost, efficiency, environmental impact and product quality at a substantially lower cost than investing in technology that might improve a small part of their production process.



1 INTRODUCTION

UNIDO has implemented a project titled '*Development and adoption of appropriate technologies for enhancing productivity in the paper and pulp sector*', in collaboration with the Department of Industrial Policy and Promotion (DIPP), Ministry of Commerce and Industry, Government of India.

Under the aegis of the UNIDO International Centre for Inclusive and Sustainable Industrial Development (IC-ISID), New Delhi, the project aimed to support the Indian paper and pulp industry by strengthening the capacity and capability of the nodal technical institution for the sector, the Central Pulp and Paper Research Institute (CPPRI), and select industry associations to provide better management and technical support to the industry to strengthen the global competitive position of the Indian pulp and paper sector.

The identified industry associations were the Indian Paper Manufacturers Association (IPMA), Indian Agro and Recycled Paper Mills Association (IARPMA), Indian Newsprint Manufacturers Association (INMA) and Indian Recycled Paper Mills Association (IRPMA).

The project facilitated a range of technical capacity building and knowledge sharing activities including the demonstration of appropriate technologies, knowledge dissemination workshops, study tours, fellowship training programmes and twinning with international organisations. In order for any intervention to be successful, it was underpinned by a thorough diagnostic assessment.

The diagnostic assessment of the Indian pulp and paper industry thus aimed to identify the industry's technology level -thereby providing an accurate baseline scenario of the industry and identify the challenges and opportunities,- and also to assess the potential for applicability of the best available techniques (BAT) in the Indian context. Furthermore, the report throws light on the international trends in the pulp and paper industry, where a decline has been observed, especially in printing paper. The report accordingly provides recommendations to prepare the Indian industry for changes in the market by diversifying their product offerings.

The assessment was carried by a team of international experts through a structured consultative process and review of the technology being employed by a presentative sample of the Indian paper mills, combined with a comparison with the globally best available technologies. The sample of units was selected by CPPRI and UNIDO in order that a cross-section of the paper units located in different regions are well represented with variations in size, raw materials used, level of technology and product ranges.

This report is structured into seven chapters:

Chapter 1 – Introduction – This chapter gives an introduction to the report.

Chapter 2 - Overview of the Indian pulp and paper industry –This chapter gives an overview of the Indian pulp and paper industry.

Chapter 3 - Assessment of the technology status of the Indian pulp and paper industry – This chapter gives a description of the units visited during the trip to India in the period (15/3-2016 to 19/3-2016). A total of 8 units were visited. These units were selected by CPPRI and UNIDO in order to give the broadest possible selection of raw materials, locations and products.

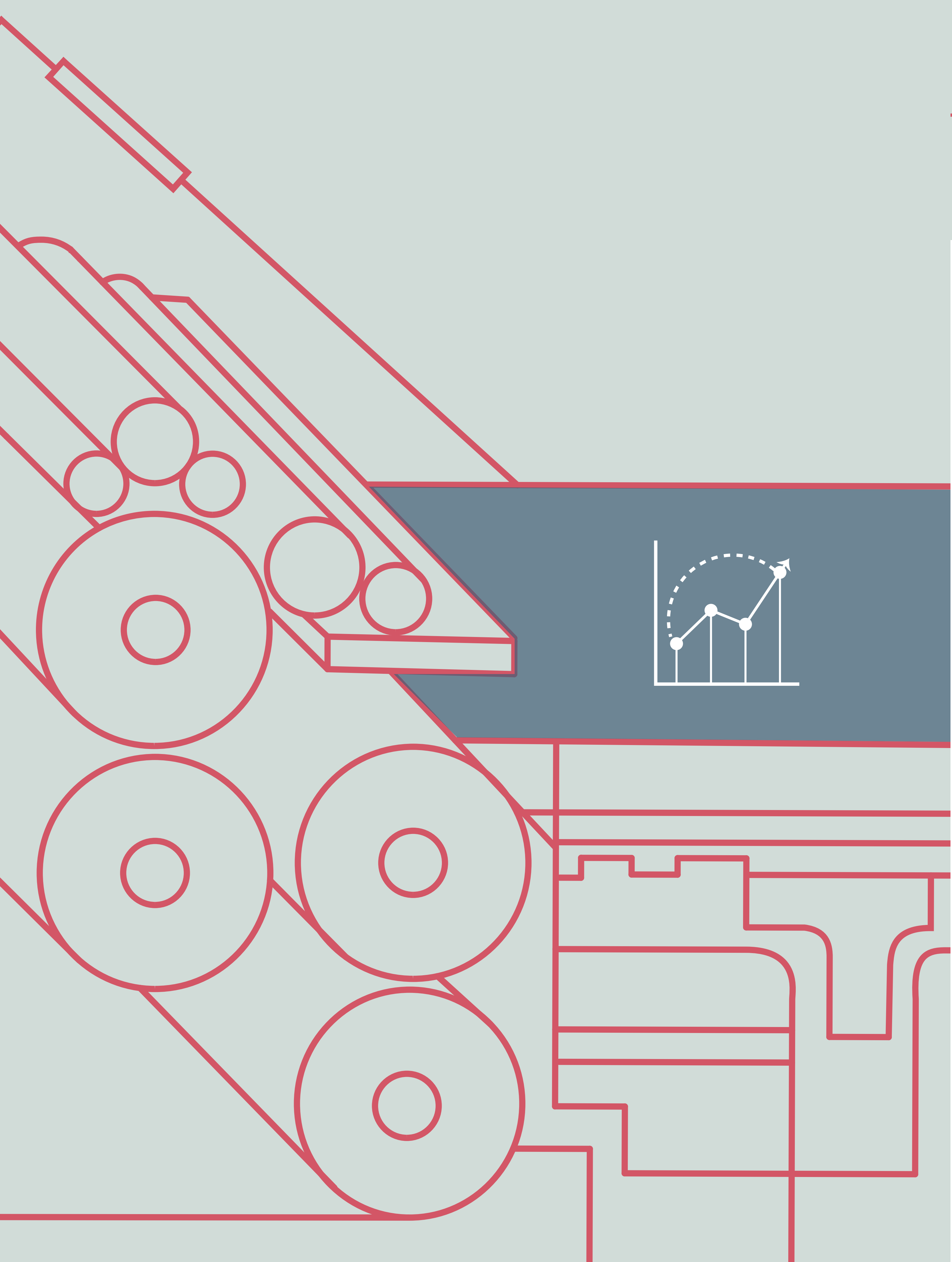
Chapter 4 - Best available techniques (BAT) – This chapter gives a summary of the best available techniques (BAT) for the processes most important for the Indian pulp and paper industry. The chapter is based on the official 2015 BAT document. The chapter may be used as an overview of the relevant conclusions given in the BAT document.

Chapter 5 - Status and issues of the Indian pulp and paper industry discussed based on best available techniques (BAT) and potential for applicability of identified BAT in the Indian context – Using the findings in Chapter 3 and Chapter 4 as a basis, an assessment of the technology status of the industry is given in this chapter. Some of the conclusions given in the BAT document are evaluated, as is the applicability of the identified BAT in the Indian context.

Chapter 6 - International trends in the pulp and paper industry – The market situation as experienced in India is somewhat different to the more mature markets in Europe where a decline has been observed, especially in printing paper. This chapter tries to describe the mechanisms of the market change in order to raise awareness of how the market can change in India, thus preparing the industry for other product segments prior to the expected changes.

Chapter 7 - Action plan based on the evaluation of technology status - This chapter provides a summary of the action points and possible solutions for improving the product quality, production efficiency, environmental aspects and competitiveness of the Indian pulp and paper industry, which may be applicable to the majority of the paper mills in India.

> “The diagnostic assessment of the Indian pulp and paper industry thus aimed to identify the industry’s technology level -thereby providing an accurate baseline scenario of the industry and identify the challenges and opportunities,- and also to assess the potential for applicability of the best available techniques (BAT) in the Indian context. Furthermore, the report throws light on the international trends in the pulp and paper industry, where a decline has been observed, especially in printing paper. The report accordingly provides recommendations to prepare the Indian industry for changes in the market by diversifying their product offerings.”



OVERVIEW OF THE INDIAN PULP AND PAPER INDUSTRY

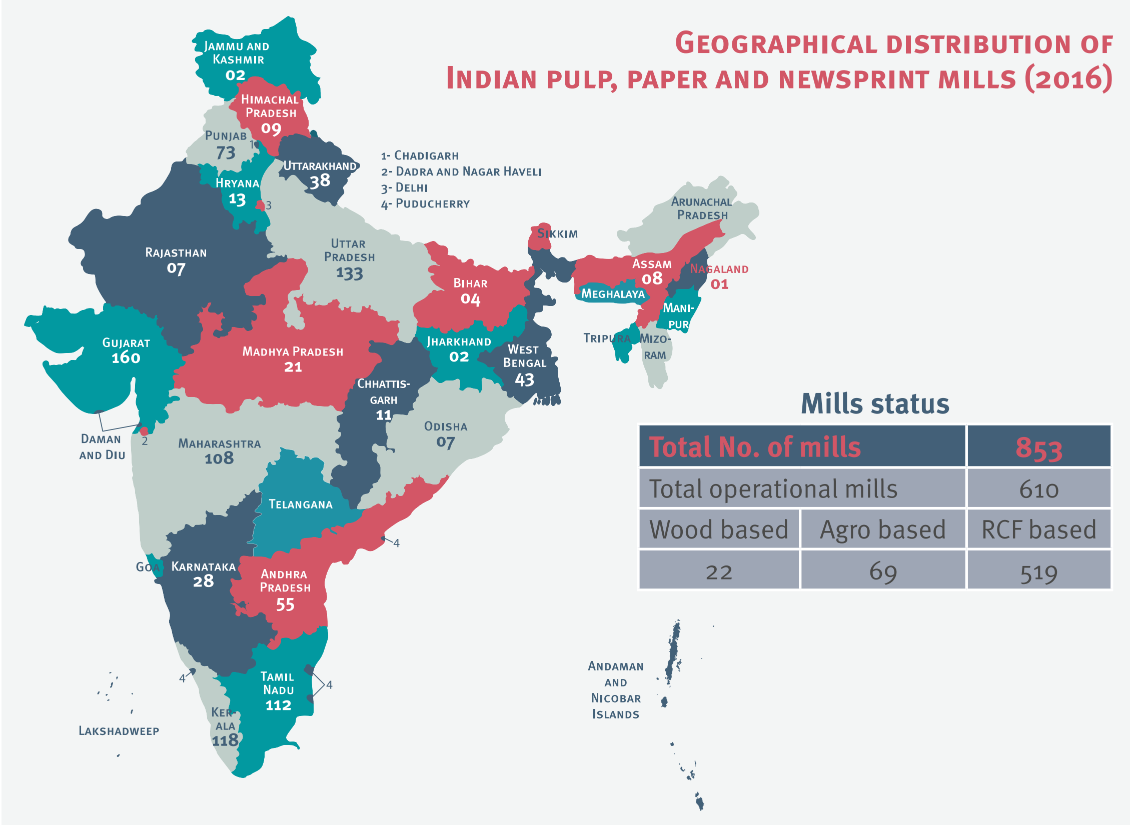
2

This chapter presents a statistical study on the productivity, raw materials used, products and location of 610 operational pulp and paper mills. The database containing the information was delivered to PFI from UNIDO.

2.1. General overview

The Indian paper industry contributes 4.28% of the global paper production, producing over 17.28 million tonnes per annum (MTPA) of paper, paperboard and newsprint, against an operational installed capacity of around 21.39 MTPA. Despite tremendous demand for domestic consumption, capacity utilization rates are only around 80%. There are around 850 pulp and paper mills in India, with a highly fragmented structure consisting of small, medium and large size paper units with capacity ranging from 10 to 1500 tonnes per day (tpd).

Figure 1: Distribution of Paper Mills in India



Total No. of mills		853
Total operational mills		610
Wood based	Agro based	RCF based
22	69	519

As per the information and data available, only 610 pulp, paper and board mills are operational. The annual turnover of the Indian paper industry is over Rs. 50,000 crore, contributing over Rs. 5,500 crore to the national exchequer. The industry employs more than 0.5 million people (directly) and over 1.5 million people (indirectly).

The paper mills are distributed throughout India, with some pulp and paper mills clusters located in the western, the northern and the southern regions. Figure 1 shows the location of the Indian pulp, paper and newsprint mills which are spread all over the country.

2.2. Structure of the Indian paper industry

2.2.1. Structure based on raw materials

The Indian paper industry uses diverse raw material like wood, agro residue and recycled waste paper with a highly fragmented structure, producing 17.28 MTPA of paper and board. As can be seen from Figures 2 and 3, 67% of the paper production is contributed by recycled waste paper-based mills (519 mills), 22% by wood-based mills (22 mills) and the remaining 11% of the production is contributed by agro-based mills (69 mills).

Table 1 presents the structure of the Indian paper industry, categorized on the basis of the size with respect to the installed capacity and production, and the raw materials used.

Out of 610 operational paper units, 519 of the units use recycled waste paper as the main raw material with an installed capacity of 14.94 MTPA and producing 11.52 MTPA of all varieties of paper. Out of 519 paper mills using recycled waste paper, 233 paper mills are below 50 tpd capacity. 131 paper mills have the capacity between 50-100 tpd, whereas the capacity of 134 paper mills varies between 100-300 tpd. Only 21 paper mills have a capacity of more than 300 tpd, out of which 9 units are of larger size with a capacity of over 500 tpd. Furthermore, it can be observed from the data that wood-based category of paper mills, which are only 22 in number, have an installed capacity of 4.21 MTPA and are producing 3.88 MTPA of high quality writing and printing paper and white coated board. The majority of these mills have a paper production capacity of more than 300 tpd.

Figure 2: Number of Firms Using Different Raw Materials

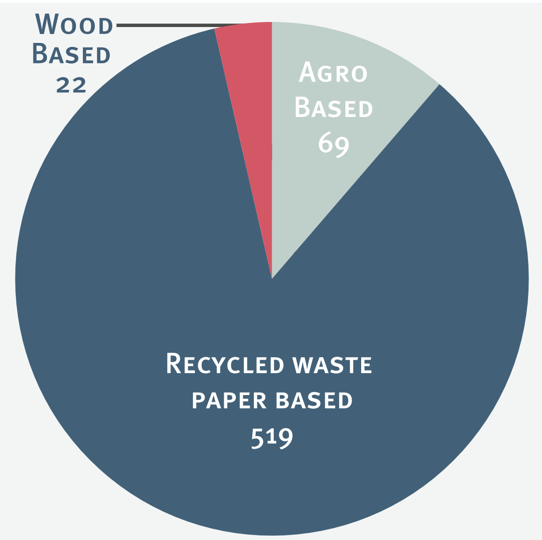
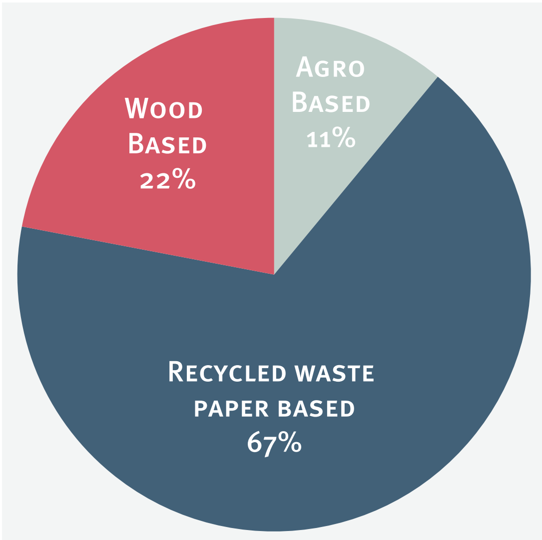


Figure 3: Production Share of Paper Mills Using Different Raw Materials



The third category of paper mills uses agro residues and is 69 in number. These mills have an installed capacity of 2.24 MTPA and contribute around 1.88 MTPA. These mills are mainly of smaller size, below 50 tpd (34 units), and/or of medium size with a capacity of 100 to 300 tpd (24 units). There are 3 paper mills with a capacity ranging between 300-500 tpd and 1 with a capacity of over 500 tonnes per day.

2.2.2. Structure based on varieties of paper

The Indian paper industry mainly produces industrial, writing and printing, and newsprint grades of paper. In terms of volume, the highest contribution to the domestic paper production comes from industrial grade paper, followed by writing and printing grade paper, and finally followed by newsprint grade paper. Out of the total production of 17.28 MTPA of paper and paperboard, writing and printing paper constitutes 35%, packaging paper 57% and newsprint around 8%. However, certain specialty papers such as security papers and cheque papers are imported into the country.

The writing and printing grade of paper comprises mainly of uncoated varieties such as cream wove, maplitho and branded copier. It is mainly produced from wood based raw materials with a little share from agro and recycled waste paper. Whereas the industrial grade paper, classified into Kraft paper, white board, machine glazed (MG) poster, duplex board and grey board, is mainly produced by the small and medium sized

recycled waste paper and agro based mills. Newsprint grade paper is produced by mills utilizing mainly recycled waste paper as a raw material. Table 2 presents the grade-wise production of paper on the basis of the raw material used.

Table 1: Structure of the Indian Paper Industry

Category Index (tpd)	Agro Based Mills			Wood Based Mills			Recycled Waste Paper Based Mills			Total Mills (units)	Total Installed Capacity (MTPA)	Production (MTPA)
	No. of Mills (units)	Installed Capacity (MTPA)	Pro-duction (MTPA)	No. of Mills (units)	Installed Capacity (MTPA)	Pro-duction (MTPA)	No. of Mills (units)	Installed Capacity (MTPA)	Pro-duction (MTPA)			
‹50	34	0.2	0.126	NIL	NIL	NIL	233	1.64	1.29	267	1.84	1.416
50-100	7	0.17	0.126	1	0.03	0.03	131	2.77	2.27	139	2.97	2.426
100-300	24	1.38	1.21	6	0.46	0.31	134	6.88	5.31	164	8.72	6.83
300-500	3	0.32	0.27	5	0.57	0.5	12	1.31	1.08	20	2.2	1.85
500‹	1	0.17	0.15	10	3.15	3.04	9	2.34	1.57	20	5.66	4.76
Total	**69**	**2.24**	**1.88**	**22**	**4.21**	**3.88**	**519**	**14.94**	**11.52**	**610**	**21.39**	**17.282**

Table 2: Production of Various Grades of Paper from Different Raw Materials

Grade of Paper	Raw Material	Production (MTPA)	Total production (MTPA)	Contribution (%)
Writing and printing grade	Wood-based	3.12	6.04	35*
	Agro-based	0.63		
	Recycled waste paper-based	2.29		
Packaging grade	Wood-based	1.03	9.84	57*
	Agro-based	1.30		
	Recycled waste paper based	7.50		
Newsprint grade	Wood-based	0.08	1.40	8*
	Agro-based	0.00		
	Recycled waste paper-based	1.32		
Total Production			17.28	100

From the above table it can be inferred that nearly 52% of the writing and printing grade paper comes from the wood-based mills, followed by 38% from the recycled waste paper-based mills and only 10% comes from the agro-based mills.

In the industrial grade of paper, more than 76% of the packaging grade of paper is contributed by the recycled waste paper-based mills, whereas the remaining 24% is contributed almost equally by the agro-based and the wood-based mills. In the case of newsprint grade of paper, almost 98% of the newsprint grade is manufactured from the recycled waste paper-based mills.

2.2.3. Demand and supply scenario[1]

Riding the crest of economic boom, India's paper industry has been growing at a robust pace. The growth of the Indian paper industry has been largely driven by the growth in domestic paper demand. As per the industry estimates, the demand of paper is set to rise from the current 18.17 MTPA to more than 20 MTPA by 2020. Several factors have contributed to the rising demand of paper, the most significant being:

- growth in the education sector through government initiatives like Sarva Shiksha Abhiyan and Operation Black Board;
- increased corporate activity and lifestyle change;
- growth in press publications;
- increase in demand for packaging; and
- growing affluence of the population.

In the last decade of the twentieth century, the growth in the per capita consumption of paper has mirrored the growth of the country's Gross Domestic Product (GDP). In the years to come, as per the Industry estimates, the growth of paper consumption will be in multiples of GDP. It is expected that an increase in consumption of paper by one kg per capita per annum would lead to an increase in demand of 1.25 MTPA. With the demand of paper hovering around 8% for some time, India is considered one of the fastest growing paper markets in the world.

To harness the potential of the growing market, in the last five years, the Indian paper industry has made investments worth Rs. 20,000 crore for capacity expansion and technology up-gradation. The growth and growth potential of the Indian market has also generated a lot of interest from the global paper manufacturers. Global giants have extended their geographic footprint in India through acquisitions. For instance, International Paper bought a 53% stake in a large Indian paper mill in 2011.

The per capita consumption of paper in India has increased steadily over the past several years, indicating steady growth in the demand of paper in the country. However, despite the rising trend, India's per capita paper consumption at 13.8 kg continues to be far below the world average of 57 kg. The low consumption figure can be attributed to the low share of the manufacturing sector in the Indian economy. The low per capita consumption is however indicative of an enormous potential for growth in paper demand in the medium to long term in India.

Growth in demand is likely to continue in the future as the main drivers of demand, like growth in literacy and print media, and government initiatives in the education sector etc., will continue to expand in the medium to long term. As per the Investment Information and Credit Rating Agency of India Limited (ICRA), assuming a conservative demand growth of 6% per annum, about 0.7 MTPA of additional demand will be generated each year[2].

[1] Central Pulp and Paper Research Institute (CPPRI), 2015. *Compendium of Census Survey of Indian Paper Industry*. CPPRI, Saharanpur, India.

[2] Ministry of Commerce and Industry, Government of India, Department of Industrial Policy and Promotion, 2011. *Working Group Report on Pulp and Paper for the Twelfth Five Year Plan* [Online]. New Delhi, India. Available at: http://planningcommission.gov.in/aboutus/committee/wrkgrp12/wg_paper.pdf [Accessed: 2 November 2016].

2.2.4. Export and import scenario

India imports only certain specialty papers and paperboard, mainly the coated varieties and art paper. The volume of the imported paper and paperboard was around 1.34 MTPA in 2007-08, which increased to around 1.48 MTPA in 2015-16, contributing around 8.55% of the total consumption of paper and paperboard. India exports around 0.64 MTPA of paper and paperboard. Paper exports account for a meagre 3.70% of the total pulp and paperboard production in the country.

The newsprint sector in the country is governed by the Newsprint Control Order (NCO), 2004. The mills listed under the Schedule of this Order are exempt from excise duty, subject to actual user condition. At present, there are 124 mills registered under the Schedule to the NCO. With an installed capacity of 2.2 MTPA, only 40 mills are producing newsprint, which makes the operating installed capacity only 1.2 MTPA. 84 mills have closed operations or discontinued the production of newsprint. The domestic production of newsprint fell from 1.2 MTPA in 2014-15 to 0.9 MTPA in 2015-16. Nearly half of the newsprint demand in the country is met by imports. 1.5 MTPA of newsprint was imported in 2015-16, which is higher than the previous year's imports of 1.3 MTPA. The export of newsprint from the country is negligible[3].

2.2.5. Growth and future projections

Driven by the need to meet the rising demand of paper in the country, the paper industry in India witnessed a more than two-fold increase in the paper and paperboard manufacturing capacity in the past ten years. Installed capacity increased from 7.32 MTPA in 2005-06 to 21.39 MTPA in 2015-16 with significant capacity expansions occurring during 2009-2010 and incremental capacity additions in the subsequent years. The main driver in the growth of paper industry has been the positive growth in domestic paper demand. As per the data available, the Indian paper industry has indicated a steady growth with an average rate of around 6 - 7%, which has been indicated by the growth in the capacity, which has increased from 12.7 MTPA (2010-11) to 21.39 MTPA (2015-16).

Based on the average growth rate of around 7.8% and the average consumption growth of around 7.4% in the last decade, the projected production of paper in India in 2025 is expected to be 25 million tonnes and consumption around 27 million tonnes (approximately).

The projected per capita per annum consumption in India will be around 18 kg by the year 2025.

Looking at the demand scenario of paper, it is estimated that the production of paper will be 25 million tonnes in 2025 against the present production of 17.28 million tonnes. Therefore, industry requires the addition of 7.7 million tonnes production capacity over a period of 10 years, i.e. an addition of about 0.77 MTPA. The expected growth rate of various paper products is summarised in Table 3.

Table 3: Projected Growth of Different Varieties of Paper

Paper Grade	% Growth Rate
Writing and Printing Paper	
Coated paper	10
High end Maplitho	8
Copier paper	15
Cream wove	5
Industrial Paper and Board	
Container and Corrugated Board	10
Carton Board	8
Newsprint	**6**
Specialty Paper	**5**

[3] Indian Newsprint Manufacturers Association (INMA) and Central Pulp and Paper Research Institute (CPPRI) estimates.

2.3. Analysis of database of potential paper clusters/ units in four regions - north, south, east and west

While analysing the distribution of paper mills across the country, it has been observed that the majority of the paper mills are small in size. The most preferred raw material used is recycled waste paper, followed by wood and the least used raw material category is agro-based. The majority of these paper mills exist in clusters located in different regions of the country.

2.3.1. Paper mill clusters in northern region of India (Haryana, Punjab, Uttar Pradesh and Uttarakhand)

As can be seen from the data shown in Table 4 and Figure 4, the north region, covering mainly Punjab, Haryana, Uttarakhand and Uttar Pradesh (U.P.), consists of 186 paper mills. The region produces around 5.68 MTPA of paper and paperboard.

In the northern region, the majority of the mills exist in three clusters located in the state of Punjab (48 paper mills), the state of U.P. (Muzaffarnagar cluster, 30 paper mills) and the state of Uttarakhand (Kashipur cluster, 34 paper mills).

Out of the 186 paper mills in north India, 137 paper mills are based on recycled waste paper producing around 3.87 MTPA of mainly the unbleached variety of packaging grade paper and paperboard. 46 paper mills produce around 1.37 MTPA, consisting mainly of the bleached variety of writing and printing grade paper with a small amount of the unbleached variety of packaging paper using agro-based raw materials. Only 3 large paper mills use wood and produce around 0.45 MTPA of only the bleached variety of writing and printing grade paper.

2.3.1.1. Kashipur paper mill cluster (north India)

In the Kashipur paper cluster there are 34 units of paper mills using various raw materials, such as: recycled waste paper, agro-based and wood-based. 26 paper mills use recycled waste paper as the major raw material and produce mainly the unbleached variety of packaging grade paper. Only 1 mill produces the bleached variety of writing and printing grade paper. 7 paper mills are agro-based and also produce mainly the unbleached variety of paper, with the exception of one paper mill based on agro raw materials, which produces high quality writing and printing grade paper.

One of the paper mills in the Kashipur cluster is a large-sized unit using mainly wood-based raw materials along with bagasse and imported white cuttings and market pulp, producing high quality writing and printing, white coated paperboard and soft tissue paper. Table 5 and Figure 5 show the data related to Kashipur paper cluster.

2.3.1.2. Muzaffarnagar paper mill cluster (north India)

In the Muzaffarnagar paper cluster around 0.82 MTPA of paper and paperboard is produced, mainly from recycled waste paper and agro-based raw materials. The cluster mainly produces around 0.75 MTPA of the unbleached variety of packaging grade paper and paperboard from both recycled waste paper (70%) and agro-based raw materials (30%). Only 1 paper mill produced the bleached variety of writing and printing grade paper (around 0.07 MTPA), using agro-based raw materials. None of the mills used wood-based raw materials. The data is shown in Table 6 and Figure 6.

Table 4: Paper Mills in North India (Haryana, Punjab, UP and Uttarakhand), 2015-16

Raw Material	No. of Mills	Installed Capacity	Production
Agro-Based	46	1625838	1367512
Wood-Based	03	593810	447478
Recycled Waste Paper-Based	137	4583780	3866151
Total	186	6803428	5681141

(Installed Capacity and Production in Tonnes)

Figure 4: Paper Mills in North India (Haryana, Punjab, UP and Uttarakhand), 2015-16

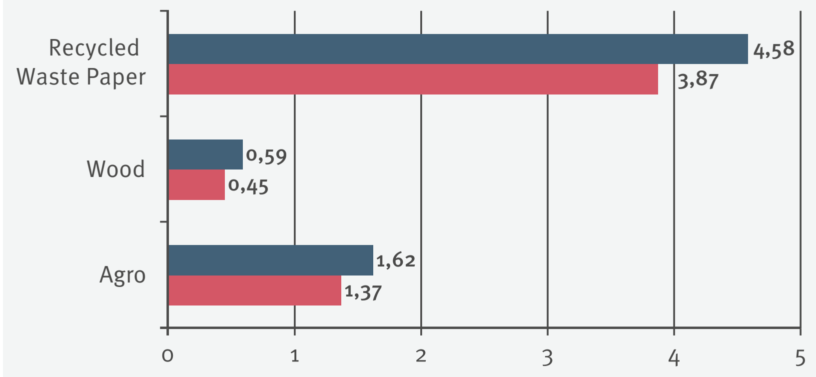


Table 5: Paper Mills in Kashipur, Uttarakhand Cluster (North India), 2015-16

Raw Material	No. of Mills	Installed Capacity	Production
Agro-Based	07	359700	343135
Wood-Based	01	413810	305788
Recycled Waste Paper-Based	26	888300	712050
Total	34	1661810	1360973

(Installed Capacity and Production in Tonnes)

Figure 5: Paper Mills in Kashipur, Uttarakhand Cluster (North India), 2015-16

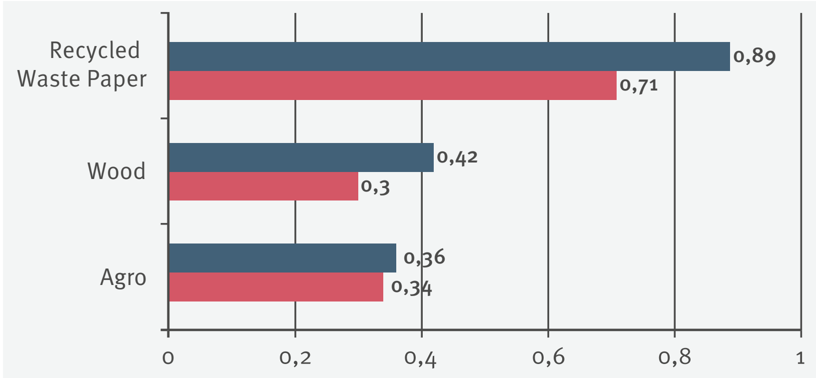
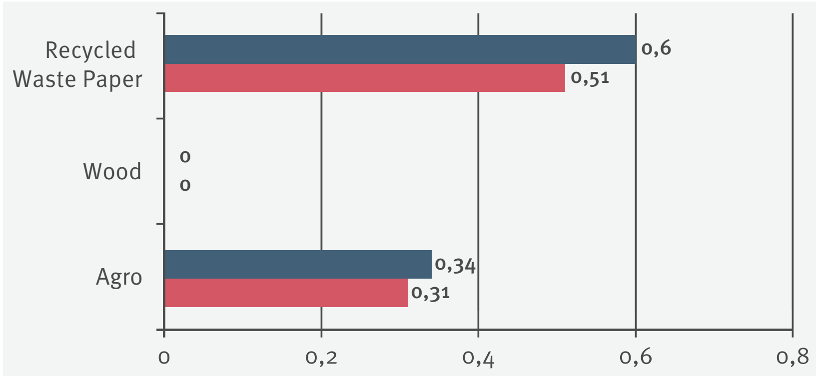


Table 6: Paper Mills in Muzaffarnagar, UP Cluster (North India), 2015-16

Raw Material	Installed Capacity	Production
Agro-Based	345000	308433
Wood-Based	NIL	NIL
Recycled Waste Paper-Based	602200	513656
Total	947200	822089

(Installed Capacity and Production in Tonnes)

Figure 6: Paper Mills in Muzaffarnagar, UP Cluster (North India), 2015-16



Installed Capacity (MTPA) Production (MTPA)

2.3.1.3. Punjab paper mill cluster (north India)

As can be seen from Table 7 and Figure 7, the Punjab paper mill cluster consists of 48 paper mills using mainly agro-based and recycled waste paper-based raw materials. Out of these mills, 32 paper mills use recycled waste paper, 16 paper mills use agro-based, while none use wood-based raw materials.

The Punjab cluster is known to produce good quality writing and printing grade paper from agro-based raw materials using advanced technologies for the processing of the agro-based fibers. These mills are medium-sized with an installed capacity varying between 200 - 500 tpd.

Of the total production of 1.32 MTPA, one-third (0.43 MTPA) is contributed by mills using agro-based raw materials, which produce mainly high quality writing and printing grade paper along with a small quantity of packaging grade paper by smaller mills. Whereas, two-thirds (0.89 MTPA) of production comes from recycled fibre-based mills, which produce mainly the unbleached variety of paper; except for one of the large paper mills which produces high quality writing and printing grade paper, employing state of the art technologies for recycled fibre processing.

2.3.2. Paper mill cluster in western region of India (Gujarat)

The western region has 102 paper mills and produces around 3.23 MTPA of paper. Both the unbleached variety of packaging grade and the bleached variety of writing and printing grade paper are produced using mainly recycled waste paper. Only one mill uses wood-based raw materials and produces high quality writing and printing grade paper along with coated white board.

In this region, the majority of the paper mills exist in clusters located in Vapi (35 paper mills), Ahmadabad (33 paper mills) and Morbi (32 paper mills). Paper mills located in the Vapi paper cluster produce around 1.05 MTPA, consisting mainly of the unbleached variety of packaging grade paper, except for a few mills which produce high quality writing and printing grade paper. Similarly, in the Morbi paper mill cluster, all 32 paper mills produce the unbleached variety of packaging grade paper. The Ahmadabad paper mill cluster has a few paper mills that are larger in size. They produce high quality writing and printing grade paper and the remaining paper mills produce the unbleached variety of packaging grade paper. Tables 8 and 9 and Figures 8 and 9 show the status of paper mills in the western region and in the Vapi paper mill cluster.

2.3.3. Paper mill clusters in southern region of India (Tamil Nadu)

There are 168 paper mills in southern India, producing 5.2 MTPA of paper. 147 paper mills are based on recycled waste paper are mainly small sized, producing around 2.8 MTPA of paper (both bleached and unbleached varieties). There are 10 wood-based large paper mills producing around 2.22 MTPA of writing and printing grade paper and white-coated board. Only 11 paper mills are based on agro raw materials. All of them are small-sized and produce only 0.18 MTPA of the unbleached variety of packaging grade paper. The status of paper mills in the southern region can be seen from the data shown in Table 10 and Figure 10.

The southern region is dominated by the Tamil Nadu paper cluster (around Coimbatore), comprised of 84 paper mills which are a mix of small, medium and large-sized paper mills using mainly recycled waste

Table 7: Paper Mills in Punjab Cluster (North India), 2015-16

Raw Material	No. of Mills	Installed Capacity	Production
Agro-Based	16	493637	434167
Recycled Waste Paper-Based	32	995210	887857
Total	186	1488847	1322024

(Installed Capacity and Production in Tonnes)

Figure 7: Paper Mills in Punjab Cluster (North India), 2015-16

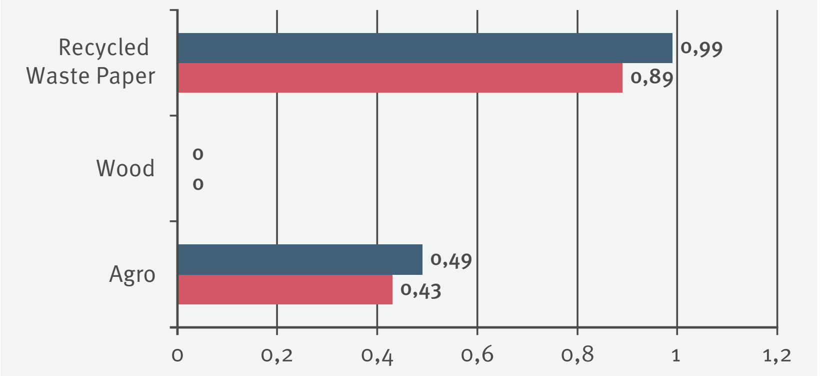


Table 8: Paper Mills in Western India (Gujarat), 2015-16

Raw Material	No. of Mills	Installed Capacity	Production
Wood-Based	01	165000	154332
Recycled Waste Paper-Based	101	3895094	3080490
Total	102	4060094	3234822

(Installed Capacity and Production in Tonnes)

Figure 8: Paper Mills in Western India Gujarat), 2015-16

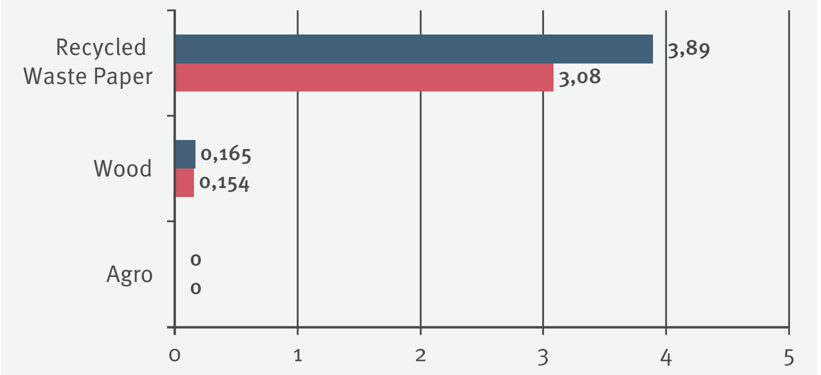
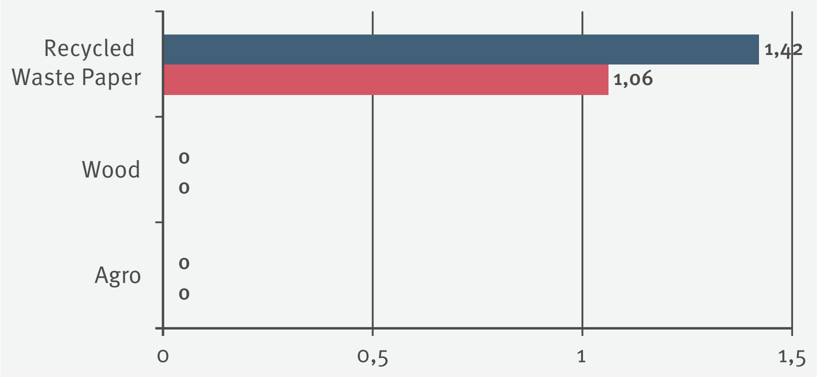


Table 9: Paper Mills in Vapi, Gujarat Cluster (Western India), 2015-16

Raw Material	No. of Mills	Installed Capacity	Production
Recycled Waste Paper-Based	35	1415294	1058490

(Installed Capacity and Production in Tonnes)

Figure 9: Paper Mills in Vapi, Gujarat Cluster (Western India), 2015-16



Installed Capacity (MTPA)   Production (MTPA)

paper, wood-based raw materials and a small quantity of agro-based raw materials. These mills (mainly the large-sized) are producing excellent quality writing, printing and coated board from wood and agro-based raw materials. Packaging grade paper is mainly produced from the recycled waste paper. Table 11 and Figure 11 indicate the data of the Tamil Nadu paper cluster.

2.3.4. Paper mill clusters in eastern region of India (West Bengal)

As can be seen from the data shown in Table 12 and Figure 12, the eastern region has 36 paper mills which mainly use recycled waste paper as the major raw material and produce around 0.7 MTPA of paper.

Out of 36 paper mills, one mill uses wood-based raw materials and produces around 0.03 MTPA of high quality specialty paper, whereas 34 paper mills produce mainly the unbleached variety of packaging grade paper from recycled waste paper and only one small mill uses agro-based raw materials and only produces 0.0016 MTPA paper annually[4].

[4] Though the eastern region (West Bengal) was not covered in the present diagnostic study of the paper mills, however, the available data of the paper mills in the region, show that paper mills in this region are similar to paper mills located in other regions in terms of size of the units, raw material usage, level of technology, production processes, products and environmental issues.

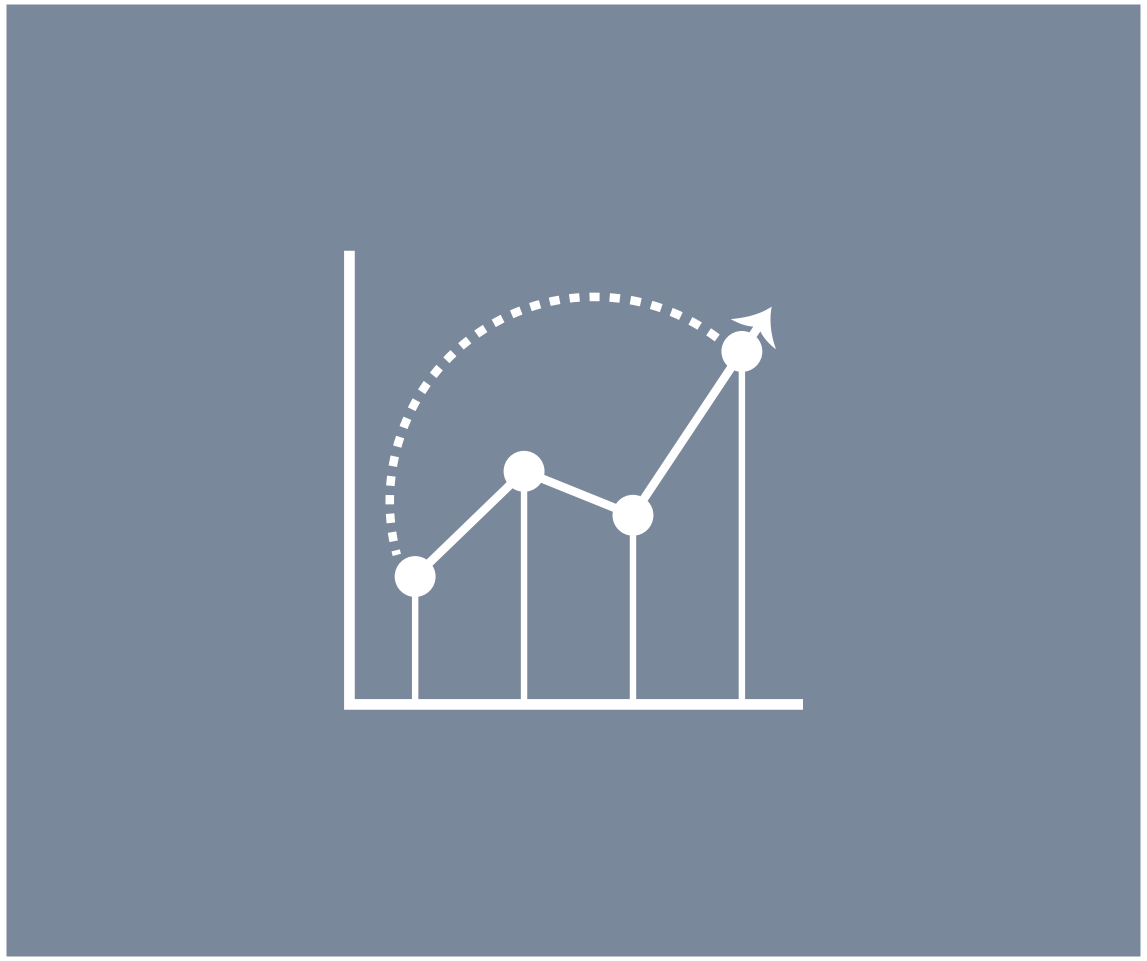


Table 10: Paper Mills in South India, 2015-16

Raw Material	No. of Mills	Installed Capacity	Production
Agro-Based	11	209950	175560
Wood-Based	10	2171043	2222171
Recycled Waste Paper-Based	147	4162970	2843050
Total	168	6543963	5240781

(Installed Capacity and Production in Tonnes)

Figure 10: Paper Mills in South India, 2015-16

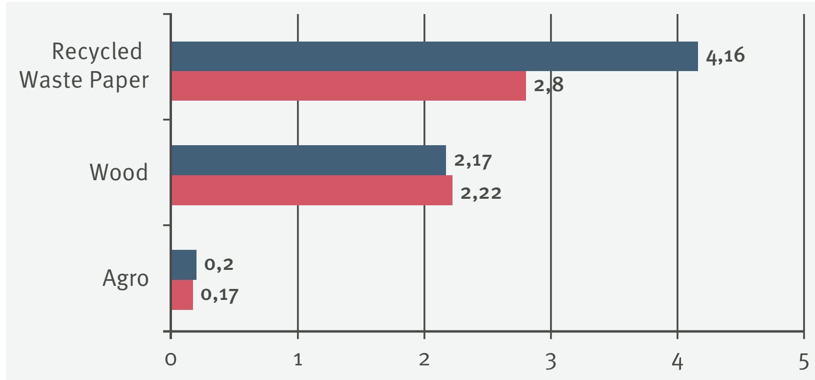


Table 11: Paper Mills in Coimbatore, Tamil Nadu Cluster (South India), 2015-16

Raw Material	No. of Mills	Installed Capacity	Production
Agro-Based	02	12300	6150
Wood-Based	02	12300	555893
Recycled Waste Paper-Based	80	2322850	1387560
Total	84	2910150	1949603

(Installed Capacity and Production in Tonnes)

Figure 11: Paper Mills in Coimbatore, Tamil Nadu Cluster (South India) 2015-16

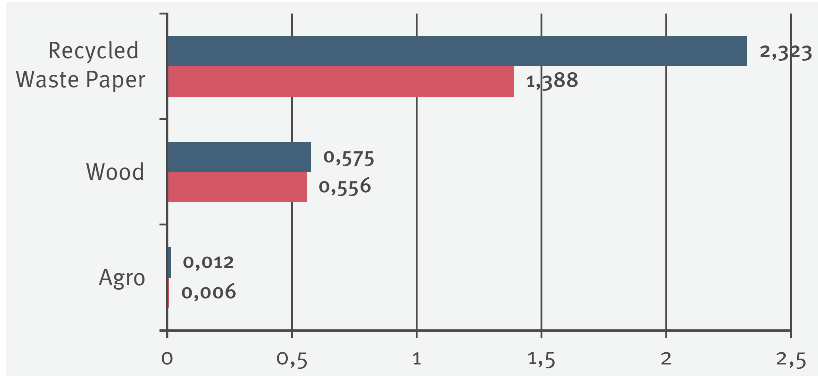
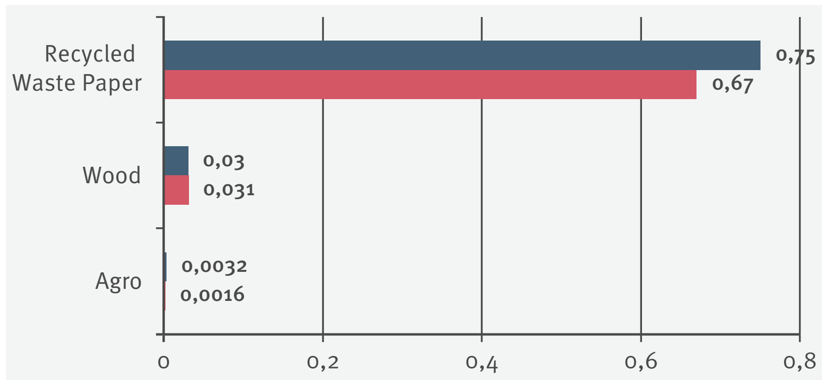


Table 12: Paper Mills in East India (West Bengal), 2015-16

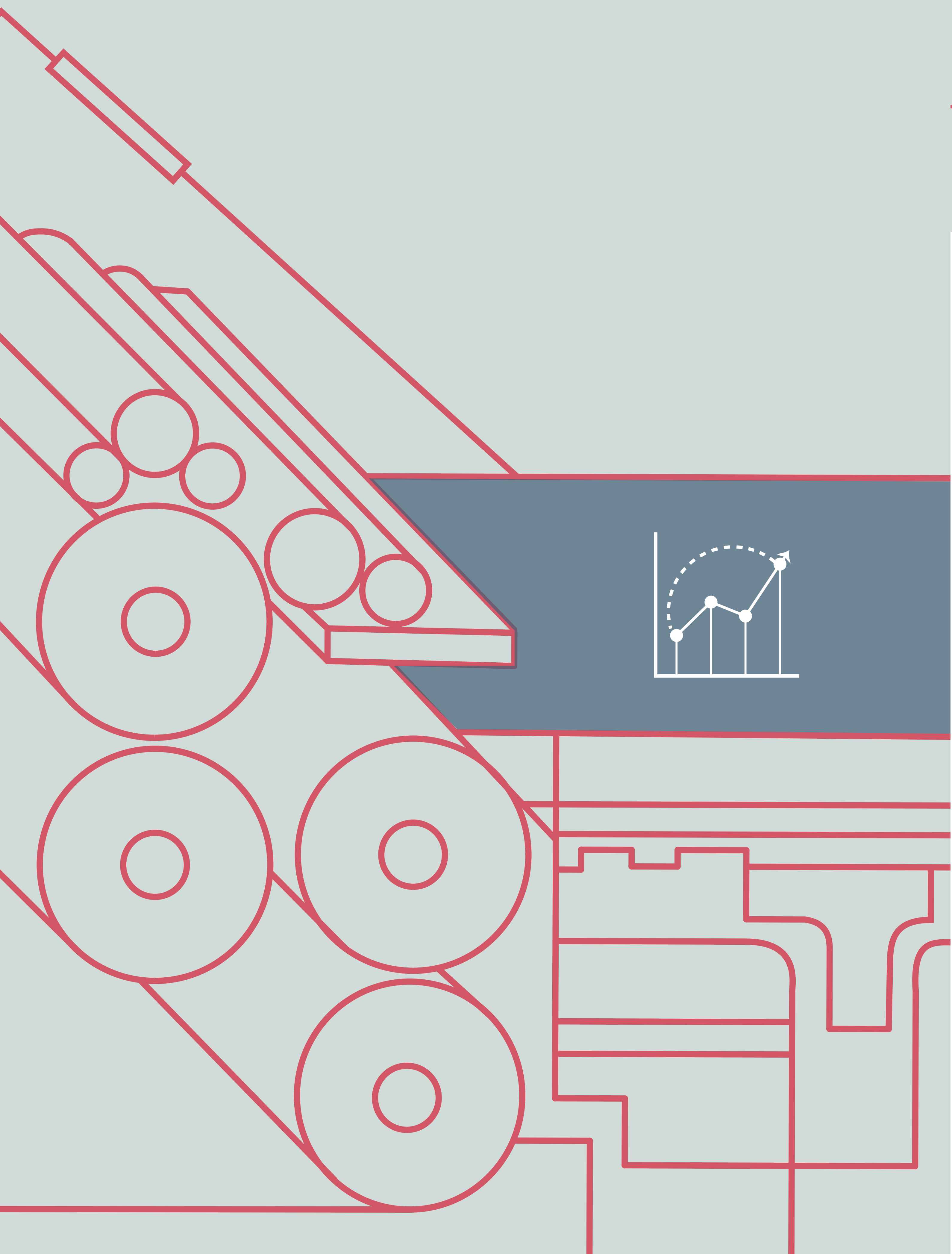
Raw Material	No. of Mills	Installed Capacity	Production
Agro-Based	1	3200	1367512
Wood-Based	1	30000	31350
Recycled Waste Paper-Based	34	751238	670622
Total	36	784438	703572

(Installed Capacity and Production in Tonnes)

Figure 12: Paper Mills in East India (West Bengal), 2015-16



Installed Capacity (MTPA)   Production (MTPA)



ASSESSMENT OF THE TECHNOLOGY STATUS

3

3.1. Approach

The information given in this chapter was gathered during a visit to India during March 15, 2016 to March 19, 2016. A total of 8 units were visited. These units were selected by CPPRI and UNIDO in order to give the broadest possible selection of raw materials, locations and products.

The data was gathered through interviews with technical personnel at the different units, combined with a tour through each of the units. All assessments are qualitative and give a snapshot of the perceived technology level.

3.2. Units visited

3.2.1. Locations, size, general

Table 3 shows an overview of the locations of the visited mills. As seen in Chapter 2 of this report, the Indian pulp and paper mills are located across the entire country, with some major clusters. The mills visited for this report were located in 4 different states in 3 regions. This was in order to make it possible to get a certain impression of any challenges related to geography (although only one unit was visited in the Southern part of India).

Table 13: Overview of the Visited Units with Locations

Mill	Location	State	Region
Mill 1	Kashipur	Uttarakhand	North India
Mill 2	Lalkua	Uttarakhand	North India
Mill 3	Kashipur	Uttarakhand	North India
Mill 4	Muzaffar-nagar	Uttar Pradesh	North India
Mill 5	Vapi	Gujarat	Western India
Mill 6	Vapi	Gujarat	Western India
Mill 7	Vapi	Gujarat	Western India
Mill 8	Coimbatore	Tamil Nadu	South India

3.2.2. Raw materials

Table shows an overview of the raw material used by the visited units. As seen in the table, most of the visited mills used recycled paper as a raw material, although units utilizing both agricultural and wood-based raw materials were visited. The recycled paper was both locally collected and imported.

As seen in Chapter 2, recycled paper is the most important raw material, followed by wood-based raw materials with the least used raw material being agro-based. Neither agricultural nor wood (eucalyptus)-based raw materials have long fibres (fibre lengths from 0.5 to 1 mm), which means that the fibres produced locally in India will not have sufficient strength for high end products. The most important source of long fibres is imports of either recycled paper containing long fibres or long fibre market pulp.

The recycled paper is a mix of imported recycled paper and locally collected paper, which means that the amount of short fibres would increase with increasing local recycling.

3.2.3. Pulping and bleaching processes

Table 15 shows an overview of the main processes in the visited mills. A majority of the visited mills had a recycling process (as recycled paper was the raw material). A few of the mills had the capacity to de-ink the recycled paper (DIP), while others had a simple process of pulping the recycled paper, without bleaching. In the case of the majority of large wood-based mills that are also using agro-residues, the pulping process adopted is 'Alkaline Kraft Pulping' followed by 'Elemental Chlorine Free Bleaching' with the DEpD bleach sequence. Whereas, in the medium sized agro-residues-based paper mills, the preferred pulping process was the 'Soda Pulping' process followed by the usage of elemental chlorine and hypochlorite as bleaching agents. However, these mills are in the process of phasing out the elemental chlorine and hypochlorite with elemental chlorine free bleaching agents.

3.2.4. Products and paper machines

Table 15 gives an overview of the products and production capacity of the visited mills. Printing/writing paper and duplex paper were the most important products for the visited mills. The selection of units ranged from small (~20 000 tonne/year) to large (~450 000 tonne/year) in Indian scale.

3.2.5. Other aspects

This section describes a few other observed points, not directly related to the technology status, but points that may have an effect on the pulp and paper industry overall.

Table 14: Overview of the Raw Materials Used for the Visited Units

Mill	Raw materials	Main processes
Mill 1	Bagasse, wheat straw	Soda pulping + Bleaching CEH
Mill 2	Wood + agricultural + RCF + imported	Kraft pulping + Bleaching DEpD
Mill 3	Recycled paper	Recycling + Bleaching (Hypo)
Mill 4	Recycled paper + agricultural	Recycling, Soda pulping
Mill 5	Recycled	Recycling
Mill 6	Recycled	Recycling, DIP, Bleach (Hypo)
Mill 7	Recycled	Recycling
Mill 8	Recycled	Recycling

Table 15: Overview of the Main Products and Production Capacity of the Visited Mills

Mill	Products	Size [tonne/year]
Mill 1	Printing/writing	54750
Mill 2	Printing/writing, board, tissue, rayon	456250
Mill 3	Printing/writing	91250
Mill 4	Duplex, kraft	91250
Mill 5	Duplex, writing/ printing	18250
Mill 6	Newsprint, writing/ printing	93075
Mill 7	Board	109500
Mill 8	Printing/writing	23725

Focus on health and safety for the workers in the mills seemed in general to be quite low, especially compared to more developed countries. Personal safety gear (e.g. helmets) was observed in only one of the units, while other gear such as safety goggles to prevent eye damage from chemical spill was non-existent. A use of helmets, safety goggles and safety shoes in the production area is normally a minimum requirement in the Nordic countries. Ensuring a safe environment for the workers is an important issue, and may become even more important if the industry in a future scenario has a larger international export demand (through customer demands).

Logistics of both raw materials and products seem to have a huge improvement potential. Considering a seemingly short effective radius of both raw materials access and sales (especially for units not located close to a coastline), this is something that may limit growth in the industry (and also potentially limit the number of larger, centralized units).

It was observed that quite a few smaller mills were located in clusters. It is evident that future consolidations are inevitable for the survival of the industry. The smaller mills will have limited investment capacity and will lack the possibility to invest in new technology. Throughout the world the economy of scale has led to fewer and larger mills. For small mills to survive the only possible strategy is to identify niche markets that are not covered by larger competitors.

3.3. Overall perceived technological challenges

This section gives an overview of the main technological challenges perceived at the visited units. It is divided into the different regions visited (although only one mill was visited in South India). The challenges listed here are those addressed by the technical staff at the different units, some are common for several units, while some are more unit specific. Some of the more common challenges may be relevant for several other units in the different regions. The challenges range from issues regarding raw materials, yield and process efficiency to quality-related issues and issues related to effluent treatment. Some of the challenges may be addressed by technology, while others cannot be solved through investments at the different mills (issues related to industrial structure, logistics, social conditions etc.).

3.3.1. North India

Four mills were visited in the northern region of India, mills that had a large variation in raw materials, processes and products.

The issues identified were as follows:

- Colour in the discharged effluent from effluent treatment plants, especially in integrated paper mills producing chemical grade bleached pulp – This issue relates to compliance with the norms for colour as specified in the Charter for Water Recycling and Pollution Prevention imposed by pollution control authorities.
- Raw material accessibility – One of the major raw materials used in the paper mills was agro-based (wheat, straw, bagasse, and sarkanda). The main challenge faced by these mills has been the high price of the agro based raw materials, particularly the wheat straw. One of the factors contributing to the higher price could be the transportation in loose form without compact bailing, which has a direct bearing on the cost of the raw material being delivered to the mills, in particular the small-sized paper mills which do not have the capacity to store beyond the season and therefore have to pay more to procure in the off-season. This price challenge is therefore more relevant to the smaller mills.

Mills with the capacity to procure and store seasonal-based raw materials will experience fewer problems with this issue. The issue of availability of these raw materials at a competitive price could be addressed through adoption of advanced technologies like compact bailing and mechanized harvesting of wheat straw which should help in facilitating a higher quantity of raw materials at a competitive cost.

- Issues related to the inferior quality of the product due to pitch and the need for better pitch control in mills producing pulp from wood – This is a worldwide issue for all mills producing pulp from certain raw materials (e.g. eucalyptus), but is also related to water system closure, water cleaning systems, white water chemistry and mill maintenance systems.
- Increased yield in the pulping process – Although this issue was mentioned by only few mills, this is something that should be relevant for all mills. Increased yield and yield optimization are issues that are important for all pulping and bleaching processes.
- Chemical optimization to reduce costs – A typical challenge for mills where a majority of the costs are related to chemical usage, but also important for mills with low chemical usage. Chemical usage optimization will also affect product quality and emissions.
- Reduction in energy consumption/energy efficiency – Reduction in electrical energy is relevant for all process industries. Reduction in thermal energy (e.g. steam) is also relevant for all consumers (despite the current low cost of coal, the major energy source for most mills).
- Reduction in effluent treatment costs – A challenge related to most mills due to the strict effluent treatment regulations. Small mills follow the same regulations as larger mills, thus costs related to effluent treatment plant investment and energy/chemicals in effluent treatment systems are considerable.
- Stickies/slime issues related to closing of the water systems – Also an issue partly related to the compliance of the effluent treatment norms for fresh water use under the Charter for Water Recycling and Pollution prevention. The reduction in the use of fresh water consumption leads to more closed water systems in the mills resulting in the build-up of slime stickies. This issue is extremely important, and will create huge quality and chemical usage issues unless the water management in the mills is handled correctly.
- Interested in higher yield (i.e. an increased production) – Issue related to all production processes (recycling, digestion, bleaching etc.). Optimization of the process conditions during pulping for efficient delignification (preferable use of continuous digesters using extended modified cooking process in agro-based mills), adoption of the oxygen delignification process before bleaching of pulp coupled with the use of an eco-friendly bleaching process (ECF/TCF) should help in improved pulp yield. In the case of recycled waste paper mills, optimization of the process conditions for pulping in Hydra-pulper and in bleaching (use of proper bleaching equipment and use of environmental friendly bleaching chemicals should help in obtaining an improved pulp quality and yield with enhanced productivity).
- Plastic in the raw material – An issue especially important for mills using recycled paper as their raw material. This issue cannot be solved in the mill alone; the collection system should apply better sorting systems to minimize the amount of plastic in the raw material delivered at each unit. Better sorting will never remove the issue completely; it will however be somewhat improved by screening technology.
- Utilization of waste (e.g. plastic) – A challenge not directly related to the scope of the current work, but something that needs to be addressed at some stage (an issue strongly connected to the above-mentioned issue).

3.3.2. Western India

The three mills visited in western India all used recycled fibres as raw materials.

- Raw material situation, better utilization of the raw material – Again an issue related to the process yield in the different process steps of the mills.
- Lesser quantity of long fibres – A quality-related issue that is difficult to solve directly. This is due to the fibre properties of the raw materials available in India. The issue, however, is partly possible to address through proper fibre processing to enhance fibre bondability.
- Stickes/deposit challenges – This is related to the closing of the water systems (see the comments regarding this for northern India).
- Usage of sludge - DIP-sludge is today considered hazardous waste and therefore cannot be burned according to political restrictions. This issue can be solved through a combination of technology and policies, the technology to treat air emissions exists and there are no issues regarding the burning of sludge as long as the emissions are treated correctly (on a side note: this sludge is burned in Norway. Burning combined with smoke gas cleaning and ash deposit is a viable solution).
- Production of competitive high quality paper – Paper quality is an issue. Optimization of paper quality to ensure competitiveness is an ongoing activity in all paper mills.
- Sorting of raw material (recycled paper) is not optimal – This is an issue especially relevant for this particular region as recycled paper is the major raw material. As commented above, this issue cannot be solved at the individual units alone. A huge benefit would be sorting systems to both remove waste components such as plastic and to improve the sorting of paper into different product categories (tailored for the product; the right fibre to the right product).
- Plastic waste in the raw material and cost-effective methods of transferring plastic waste to something valuable (cement industry is today one of the users) – An issue already mentioned, and once more it should not be the paper manufacturer alone who solves this issue.
- Issues regarding the Indian raw material (for this mill issues regarding low bulk) – Also related to the fibre issue.

3.3.3. South India

The one mill in south India had two specific challenges:

- Issues regarding low brightness – Partly related to the low water consumption, but also related to optimization of the chemicals.
- Better efficiency in the pulp line, better bleaching efficiency – Yield related issue, i.e. better yield in the different process units would benefit the entire Indian pulp and paper industry.

3.3.4. Overall perceived challenges

Based on the identified challenges at the different units, the following issues in particular are interesting topics that can benefit the Indian industry.

- Issues related to low water consumption and closing of the water systems in the mills (i.e. issues connected to internal water handling). Resulting in challenges related to both quality and production efficiency.
- Issues related to treatment of the effluent (e.g. colour, COD).
- Paper quality issues connected to fibre quality (e.g. strength, bulk, optical properties). Using the right fibre for the right purpose; increased fibre bondability.
- Plastic waste from recycled paper. Regarding both production related issues and the handling of waste for the different mills.

3.4. Qualitative evaluation of the technology in the mills

This section gives a qualitative evaluation of the technology status of the visited mills. The observations are structured according to a normal process flow in most pulp and paper mills. The section describing the relevant best available techniques (BAT) will form the basis for a more specific comparison and any recommendations.

3.4.1. Raw material handling

This section describes the observations made regarding storage and handling of the raw material (e.g. agricultural waste, recycled paper) at the visited units.

The different units had different practices when it came to storage of the raw materials. Some stored the raw materials indoors/ under a roof, while others stored the raw materials outdoors. Depending on climate, the storage will affect the quality of the raw material. When it comes to lignin containing recycled paper storage, for example, direct sunlight will promote yellowing of the paper (with a subsequent potential increased consumption of bleaching chemicals). Also, storage under wet conditions will increase fungal/microbial growth, thus darkening and degrading the fibre material. Thus, depending on the size of the raw materials storage and the average time for storage, this can have a large effect on the quality of the fibres and have a detrimental effect on the final paper quality.

The flooring where the raw materials were stored also varied from mill to mill. Some stored the raw materials on gravel, while other mills stored the raw materials on concrete flooring. Storage on gravel may give rise to impurities in the material before pulping, thus introducing unwanted components (such as inorganics) into the process and causing the wear of the process equipment. This is especially the case in the mills where the raw materials are transferred from storage to the pulping process by mechanical means (e.g. by tractors).

Manual labour seemed to be widely used for the raw materials handling in most of the mills visited. The manual labour was an important step in the removal of e.g. plastic from the recycled paper, but also when it came to sorting the right fibres for the right product. Ideally the recycled paper should be sorted before it enters the raw materials storage (both regarding plastic waste and paper quality), thus making manual labour less important and also improving the overall efficiency of the raw materials handling.

Overall, good practice when it comes to storage and handling the raw materials is the first important step in order to ensure good product quality and less process variations.

3.4.2. Pulping process

Both continuous and batch digesters were seen in the mills producing their own pulp. The mills had a variety of cooking liquor compositions and also had different strategies regarding the amount of delignification done in the digestion. One mill had a fairly low degree of digestion and had more focus on lignin removal in the subsequent bleaching stage. The impression was that the efficiency of the digesters was low, newer technology to more efficiently remove lignin exists. Removal of dissolved substances after cooking with belt presses, screw presses etc. is important to improve the efficiency of the bleaching.

A range of pulpers (ranging from low consistency to high consistency) was seen for the mills using recycled fibres as raw material. The dimensions of the pulpers seemed to be in accordance with the size of the paper machines. Evaluation of the efficiency of the different pulpers regarding energy consumption and how well the pulp was disintegrated requires more thorough studies of both pulp and energy consumption.

3.4.3. Bleaching

A wide range of both bleaching chemicals and layouts of the bleaching stages were observed. Some had a defined bleaching stage with designated bleaching towers, while others seemed to add the bleaching chemicals at a suitable place in the process. For instance, one of the mills used two different bleaching chemicals; the first chemical was added directly to the pulper, while the second was added right before a screw press later in the process.

The smell of bleaching chemicals was quite strong in many of the mills. This raises the question of whether the pulp washing was optimal after the bleaching step. A common practice of measuring residual chemicals after bleaching did not seem to exist. Mills visited also used chlorine and hypochlorite in the bleaching process. From an environmental perspective, the mills should aim for bleaching sequences without elemental chlorine (TCF, ECF).

Optimization of the bleaching process could benefit the mills with regards to both the usage of chemicals and environmental aspects. Generally good mixing, correct temperature and residence time before washing are required for an optimum bleaching efficiency combined with minimum costs for bleaching chemicals.

3.4.4. Papermaking

A wide range of different paper machine layouts was observed in the mills visited (in principle the layout was different in each mill). Both standard Fourdrinier machines and one machine with newer duo formers were observed. Both active dewatering elements such as suction boxes and passive dewatering elements were seen. An evaluation of efficiency of the forming sections of the paper machines is not possible to perform without measurements of formation (quality) and dry content through measurements. The retention of the machines was not assessed (although the impression from the discussions implies that this could be improved).

Different layouts of the press sections of the paper machines were also seen, but a standard 3 nip press section seemed to be the most common. Again, efficiency of the press sections were not assessed as this requires measurements compared to nip loads and energy usage.

The layout of the drying sections also varied between the mills (variation from Yankee cylinders to a more normal slalom layout). Few of the observed paper machines had a drying hood installed above the drying sections. A drying hood will reduce the energy consumption during drying and thus improve the drying efficiency but also improve the work conditions in the mill. The paper quality is also generally improved by using a drying hood combined with a proper hood ventilation system as the drying conditions of the paper across the width of the machine can be controlled and kept equal.

One aspect to note is the internal water handling inside the mills. An evaluation of this would require extensive mapping of the water systems in each mill, something which is out of the scope of the current report. The impression is that the awareness of water handling in general was low and that the mills could improve the way they are managing their paper quality by following best practices of internal water handling.

Several of the machines seemed to be old and quite a few had been built locally in India. Few machines were built by the international leading suppliers of paper machines (Voith, Valmet). An assessment of the efficiency, e.g. electrical consumption of the machines was not done, but this is something that should be done through a benchmark study.

In general, many of the mills had rather slow and small paper machines with widths of down to two metres (even in mills which began operations later than the year 2000). These machines will without doubt lose the benefit of economy of scale.

3.4.5. Finishing/packaging

Quite a few mills relied heavily upon manpower in the packaging of the finished product, and no fully automatic packaging lines for the paper were observed. This was the case for mills producing both sheets and reels.

3.4.6. Effluent treatment

In general, all visited mills seemed to have a high focus on the effluent treatment from the mill. Typical layouts with primary-, secondary- and tertiary-sedimentation combined with aeration steps were common. A few had sand filters and biogas reactors to reduce the COD even further.

There existed different strategies for water usage from the different stages of the effluent treatment. Some used the water directly in the pulper (at the start of the process) and some used the water from the effluent treatment plant as dilution at different steps in the process.

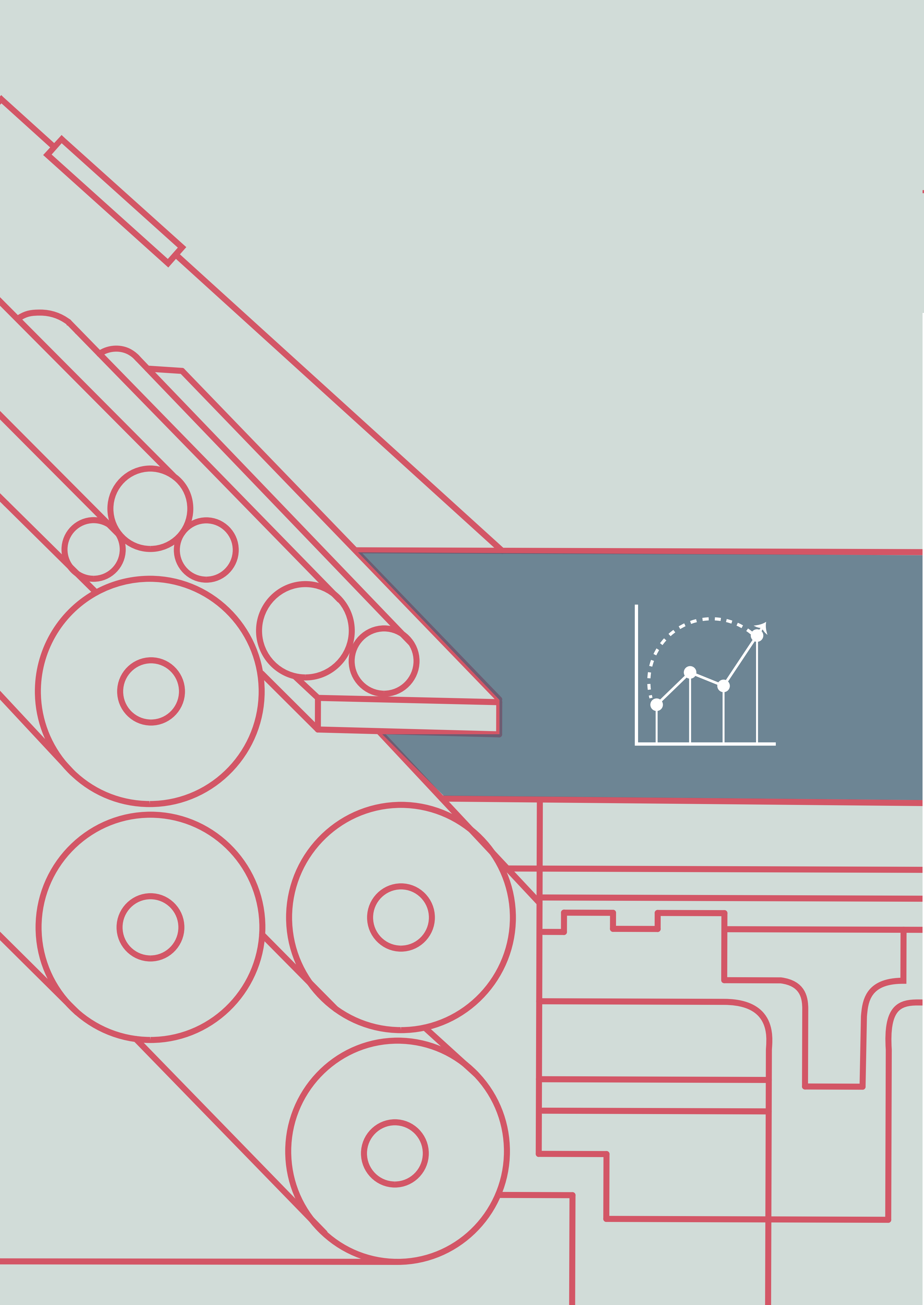
The practice of handling sludge from the effluent treatment plant was different in the mills visited; some sold the sludge to other industries (cement industry, cardboard producers).

3.4.7. Process control and product quality assessment

A few of the visited mills had centralized control rooms for the different parts of the production process. Most of the control of the machines was done via control panels located close to the process units. A few of the larger mills had newer, more advanced systems with computers for controlling the process and logging data.

Some mills had modern online measuring systems for monitoring some quality parameters (after the drying section); some had plans to install such while others had none.

The capacity of controlling the process and product quality (physical measurements of important paper quality parameters and chemical analysis of process waters/components) seemed to be low at most of the units visited.



4 BEST AVAILABLE TECHNIQUES (BAT)

This chapter is largely built on the report Best available techniques (BAT) reference document for the production of pulp, paper and board published by the European Commision[5]. In addition, some BAT advice on soda pulping is added.

4.1. Scope

These BAT conclusions concern:

1. pulp from timber or other fibrous materials
2. paper or cardboard with a production capacity exceeding 20 tonnes per day

In particular, these BAT conclusions cover the following processes and activities:

1. chemical pulping:
   a. Kraft (sulphate) and soda pulping processes
2. processing paper for recycling with and without deinking
3. papermaking and related processes
4. all recovery boilers and lime kilns operated in pulp and paper mills.

4.2. General considerations

The techniques listed and described in these BAT conclusions are neither prescriptive nor exhaustive. Other techniques may be used that ensure at least an equivalent level of environmental protection.

Unless otherwise stated, the BAT conclusions are generally applicable.

4.3. Emission levels associated with BAT

Where emission levels associated with the best available techniques (BAT-AELs) are given for the same averaging period in different units (e.g. as concentration and specific load values (that is per tonne of net production), those different ways of expressing BAT-AELs are to be seen as equivalent alternatives.

For integrated and multi-product pulp and paper mills, the BAT-AELs defined for the individual processes (pulping, papermaking) and/or products need to be combined according to a mixing rule based on their additive shares of discharge.

[5] Suhr, M., Klein, G., Kourti, I., Rodrigo Gonzalo, M., Giner Santonja, G., Roudier, S. and Delgado Sancho, L., 2015. *Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control)*. Publications Office of the European Union. [Online]. Available at: <http://publications.jrc.ec.europa.eu/repository/handle/JRC95678> [Accessed on 2 November 2016].

4.4. Averaging periods for emissions to water

Unless stated otherwise, the averaging periods associated with the BAT-AELs are as defined in Table 16.

Table 16: Averaging Periods - Water

Daily average	Average over a sampling period of 24 hours taken as a flow-proportional composite sample[i] or, provided that sufficient flow stability is demonstrated, from a time-proportional sample[i]
Yearly average	Average of all daily averages taken within a year, weighted according to the daily production, and expressed as mass of emitted substances per unit of mass of products/materials generated or processed

[i]In special cases, there may be a need to apply a different sampling procedure (e.g. grab sampling)

4.5. Averaging periods for emissions to air

Unless stated otherwise, the averaging periods associated with the BAT-AELs for emissions to air are defined as follows:

Table 17: Averaging Periods - Air

Daily average	Average over a period of 24 hours based on valid hourly averages measured by continuous measurement.
Average over the sampling period	Average value of three consecutive measurements of at least 30 minutes each.
Yearly average	In the case of continuous measurement: average of all valid hourly averages. In the case of periodic measurements: average of all 'averages over the sampling period' obtained during one year.

4.6. Definitions and acronyms

For the purpose of these BAT conclusions, the definitions given in Table 18 will apply.

Table 18: Definitions

Term used	Definition
New plant	A plant first permitted on the site of the installation following the publication of these BAT conclusions or a complete replacement of a plant on the existing foundations of the installation following the publication of these BAT conclusions.
Existing plant	A plant which is not a new plant.
Major refurbishment	A major change in design or technology of a plant/abatement system and with major adjustments or replacements of the process units and associated equipment.
New dust abatement system	A dust abatement system first operated on the site of the installation following the publication of these BAT conclusions.
Existing dust abatement system	A dust abatement system which is not a new dust abatement system.
Non-condensable odorous gases (NCG)	Non-condensable odorous gases, referring to malodorous gases of Kraft pulping.
Concentrated non-condensable odorous gases (CNCG)	Concentrated non-condensable odorous gases (or 'strong odorous gases'): TRS-containing gases from cooking, evaporation and from stripping of condensates.
Strong odorous gases	Concentrated non-condensable odorous gases (CNCG).
Weak odorous gases	Diluted non-condensable odorous gases: TRS-containing gases which are not strong odorous gases (e.g. gases coming from tanks, washing filters, chip bins, lime mud filters, drying machines).
Residual weak gases	Weak gases that are emitted in ways other than through a recovery boiler, a lime kiln or a TRS-burner.
Continuous measurement	Measurements using an automated measuring system (AMS) permanently installed on site.
Periodic measurement	Determination of a measurand (particular quantity subject to measurement) at specified time intervals using manual or automated methods.
Diffuse emissions	Emissions arising from a direct (non-channelled) contact of volatile substances or dust with the environment under normal operating conditions.
Integrated production	Both pulp and paper/board are produced at the same site. The pulp is normally not dried before paper/board manufacture.
Non-integrated production	Either (a) production of market pulp (for sale) in mills that do not operate paper machines, or (b) production of paper/board using only pulp produced in other plants (market pulp).
Net production	1. For paper mills: the unpacked, saleable production after the last slitter winder, i.e. before converting. 2. For off-line coaters: production after coating. 3. For tissue mills: saleable production after the tissue machine before any rewinding processes and excluding any core. 4. For market pulp mills: production after packing (ADt). 5. For integrated mills: Net pulp, production refers to the production after packing (ADt) plus the pulp transferred to the paper mill (pulp calculated at 90 % dryness, i.e. air dry). Net paper production: same as (i).
Speciality paper mill	A mill producing numerous paper and board grades for special purposes (industrial and/or non-industrial) that are characterised by particular properties, relatively small end use market or niche applications that are often especially designed for a particular customer or end-user group. Examples of speciality papers include cigarette papers, filter papers, metallised paper, thermal paper, self-copy paper, sticking labels, cast coated paper, as well as gypsum liners and special papers for waxing, insulating, roofing, asphalting, and other specific applications or treatments. All of these grades fall outside of the standard paper categories.
Hardwood	Group of wood species including e.g. aspen, beech, birch and eucalyptus. The term hardwood is used as opposite to softwood.
Softwood	Wood from conifers including e.g. pine and spruce. The term softwood is used as opposite to hardwood.
Causticising	Process in the lime cycle in which hydroxide (white liquor) is regenerated by the reaction: $Ca(OH)_2 + CO_3^{2-} \rightarrow CaCO_3$ (s) + 2 OH^-

Table 19: Acronyms

Term used	Definition
ADt	Air Dry tonnes (of pulp) expressed as 90% dryness.
AOX	Adsorbable organic halides measured according to the EN ISO: 9562 standard method for waste waters.
BOD	Biochemical oxygen demand. The quantity of dissolved oxygen required by microorganisms to decompose organic matter in waste water.
CMP	Chemi-mechanical pulp.
CTMP	Chemi-thermomechanical pulp.
COD	Chemical oxygen demand; the amount of chemically oxidisable organic matter in waste water (normally referring to analysis with dichromate oxidation).
DS	Dry solids, expressed as weight %.
DTPA	Diethylenetriaminepentaacetic acid (complexing/chelating agent used in peroxide bleaching).
ECF	Elemental Chlorine Free.
EDTA	Ethylene diaminetetraacetic acid (complexing/chelating agent).
H2S	Hydrogen sulphide.
LWC	Light-weight coated paper.
NOX	The sum of nitrogen oxide (NO) and nitrogen dioxide (NO2), expressed as NO2.
NSSC	Neutral sulphite semi chemical.
RCF	Recycled fibres.
SO2	Sulphur dioxide.
TCF	Totally Chlorine Free.
Total nitrogen (tot-N)	Total nitrogen (tot-N) given as N, includes organic nitrogen, free ammonia and ammonium (NH_4^+–N), nitrites (NO_2^-–N) and nitrates (NO_3^-–N).
Total phosphorus (tot-P)	Total phosphorus (tot-P) given as P, includes dissolved phosphorus plus any insoluble phosphorus carried over into the effluent in the form of precipitates or within microbes.
TMP	Thermo-mechanical pulp.
TOC	Total organic carbon.
TRS	Total reduced sulphur. The sum of the following reduced malodorous sulphur compounds generated in the pulping process: hydrogen sulphide, methyl mercaptan, dimethylsulphide and dimethyldisulphide, expressed as sulphur.
TSS	Total suspended solids (in waste water). Suspended solids consist of small fibre fragments, fillers, fines non-settled biomass (agglomeration of microorganisms) and other small particles.
VOC	Volatile organic compounds as defined in Article 3(45) of Directive 2010/75/EU.

4.7. General BAT conclusions for the pulp and paper industry

4.7.1. Environmental management system

BAT 1. In order to improve the overall environmental performance of plants for the production of pulp, paper and board, BAT is to implement and adhere to an environmental management system (EMS) that incorporates all of the following features:

1. commitment of the management, including senior management;

2. definition of an environmental policy that includes the continuous improvement of the installation by the management;

3. planning and establishing the necessary procedures, objectives and targets, in conjunction with financial planning and investment;

4. implementation of procedures paying particular attention to:
   a. structure and responsibility
   b. training, awareness and competence
   c. communication
   d. employee involvement
   e. documentation
   f. efficient process control
   g. maintenance programmes
   h. emergency preparedness and response
   i. safeguarding compliance with environmental legislation;

5. checking performance and taking corrective action, paying particular attention to:
   a. monitoring and measurement (see also the Reference Document on the General Principles of Monitoring)
   b. corrective and preventive action
   c. maintenance of records
   d. independent (where practicable) internal and external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained;

6. review of the EMS and its continuing suitability, adequacy and effectiveness by senior management;

7. following the development of cleaner technologies;

8. consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life;

9. application of sectoral benchmarking on a regular basis.

Technical considerations relevant to applicability
The scope (e.g. level of detail) and nature of the EMS (e.g. standardised or non-standardised) will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.

4.7.2. Materials management and good housekeeping

BAT 2. BAT is to apply the principles of good housekeeping for minimising the environmental impact of the production process by using a combination of the techniques given in Table 20.

BAT 3. In order to reduce the release of not readily biodegradable organic chelating agents such as EDTA or DTPA from peroxide bleaching, BAT is to use a combination of the techniques given in Table 21.

4.7.3. Water and waste water management

BAT 4. In order to reduce the generation and the pollution load of waste water from wood storage and preparation, BAT is to use a combination of the techniques given in Table 22

Table 20: Principles for Minimising the Environmental Impact of Production Processes

	Technique
a	Careful selection and control of chemicals and additives
b	Input-output analysis with a chemical inventory, including quantities and toxicological properties
c	Minimise the use of chemicals to the minimum level required by the quality specifications of the final product
d	Avoid the use of harmful substances (e.g. nonylphenolethoxylate-containing dispersion or cleaning agents or surfactants) and substitution by less harmful alternatives
e	Minimise the input of substances into the soil by leakage, aerial deposition and the inappropriate storage of raw materials, products or residues
f	Establish a spill management programme and extend the containment of relevant sources, thus preventing the contamination of soil and groundwater
g	Proper design of the piping and storage systems to keep the surfaces clean and to reduce the need for washing and cleaning

Table 21: Techniques for Reducing the Release of Not Readily Biodegradable Organic Chelating Agents

	Technique	Applicability
a	Determination of quantity of chelating agents released to the environment through periodic measurements	Not applicable for mills that do not use chelating agents
b	Process optimisation to reduce consumption and emission of not readily biodegradable chelating agents	Not applicable for plants that eliminate 70 % or more of EDTA/DTPA in their waste water treatment plant or process
c	Preferential use of biodegradable or eliminable chelating agents, gradually phasing out non- biodegradable products	Applicability depends on the availability of appropriate substitutes (biodegradable agents meeting e.g. brightness requirements of pulp)

Table 22: Techniques for Reducing Waste Water

	Technique	Applicability
a	Dry debarking (for description see Section 4.12.2)	Restricted applicability when high purity and brightness is required with TCF bleaching
b	Handling of wood logs in such a way as to avoid the contamination of bark and wood with sand and stones	Generally applicable
c	Paving of the wood yard area and particularly the surfaces used for the storage of chips	Applicability may be restricted due to the size of the wood yard and storage area
d	Controlling the flow of sprinkling water and minimising surface run-off water from the wood yard	Generally applicable
e	Collecting of contaminated run-off water from the wood yard and separating out suspended solids effluent before biological treatment	Applicability may be restricted by the degree of contamination of run-off water (low concentration) and/or the size of the waste water treatment plant (large volumes)

The BAT-associated effluent flow from dry debarking is 0.5 – 2.5 m^3/ADt.

BAT 5. In order to reduce fresh water use and generation of waste water, BAT is to close the water system to the degree technically feasible in line with the pulp and paper grade manufactured by using a combination of the techniques given in Table 23.

The BAT-associated waste water flows at the point of discharge after waste water treatment as yearly averages are given in Table 24.

4.7.4. Energy consumption and efficiency

BAT 6. In order to reduce fuel and energy consumption in pulp and paper mills, BAT is to use technique (a) and a combination of the techniques given in Table 25.

Description

Technique (c): simultaneous generation of heat energy and electrical and/or mechanical energy in a single process, referred to as a combined heat and power plant (CHP). CHP plants in the pulp and paper industry normally apply steam turbines and/or gas turbines. The economic viability (achievable savings and payback time) will depend mainly on the cost of electricity and fuels.

4.7.5. Emissions of odour

With regard to the emissions of malodorous sulphur-containing gases from Kraft and sulphite pulp mills, see the process-specific BAT given in Section 4.9.2.

BAT 7. In order to prevent and reduce the emission of odorous compounds originating from the waste water system, BAT is to use a combination of the techniques given in Table 26.

Table 23: Techniques for Reducing Fresh Water Usage and Generation of Waste Water

	Technique	Applicability
a	Monitoring and optimising water usage	Generally applicable
b	Evaluation of water recirculation options	
c	Balancing the degree of closure of water circuits and potential drawbacks; adding additional equipment if necessary	
d	Separation of less contaminated sealing water from pumps for vacuum generation and reuse	
e	Separation of clean cooling water from contaminated process water and reuse	
f	Reusing process water as a substitute for fresh water (water recirculation and closing of water loops)	» Applicable to new plants and major refurbishments. » Applicability may be limited due to water quality and/or product quality requirements or due to technical constraints (such as precipitation/incrustation in water system) or increased odour nuisance
g	In-line treatment of (parts of) process water to improve water quality to allow for recirculation or reuse	Generally applicable

Table 24: BAT- Associated Waste Water Flows

Sector	BAT-associated waste water flow
Bleached Kraft	25 – 50 m^3/ADt
Unbleached Kraft	15 – 40 m^3/ADt
RCF paper mills without deinking	1.5 – 10 m^3/t (the higher end of the range is associated with mainly folding boxboard production)
RCF paper mills with deinking	8 – 15 m^3/t
RCF-based tissue paper mills with deinking	10 – 25 m^3/t
Non-integrated paper mills	3.5 – 20 m^3/t

Table 25: Techniques for Reducing Fuel and Enegy Consumption

	Technique	Applicability
a	Use an energy management system that includes all of the following features: 1. Assessment of the mill's overall energy consumption and production 2. Locating, quantifying and optimising the potentials for energy recovery 3. Monitoring and safeguarding the optimised situation for energy consumption	Generally applicable
b	Recover energy by incinerating those wastes and residues from the production of pulp and paper that have high organic content and calorific value, taking into account BAT 12	Only applicable if the recycling or reuse of wastes and residues from the production of pulp and paper with a high organic content and high calorific value is not possible
c	Cover the steam and power demand of the production processes as far as possible by the cogeneration of heat and power (CHP)	Applicable for all new plants and for major refurbishments of the energy plant. Applicability in existing plants may be limited due to the mill layout and available space
d	Use excess heat for the drying of biomass and sludge, to heat boiler feed water and process water, to heat buildings, etc.	Applicability of this technique may be limited in cases where the heat sources and locations are far apart
f	Insulate steam and condensate pipe fittings	Applicable to both new and existing plants for all grades of paper and for coating machines, as long as medium pressure steam is available
g	Use energy efficient vacuum systems for dewatering	Generally applicable
h	Use high efficiency electrical motors, pumps and agitators	
i	Use frequency inverters for fans, compressors and pumps	
j	Match steam pressure levels with actual pressure needs	

Table 26: Techniques for Preventing and Reducing the Emission of Odorous Compounds

	Technique
	I. Applicable for odours related to water systems closure
a	Design paper mill processes, stock and water storage tanks, pipes and chests in such a way as to avoid prolonged retention times, dead zones or areas with poor mixing in water circuits and related units, in order to avoid uncontrolled deposits and the decay and decomposition of organic and biological matter
b	Use biocides, dispersants or oxidising agents (e.g. catalytic disinfection with hydrogen peroxide) to control odour and decaying bacteria growth
c	Install internal treatment processes ('kidneys') to reduce the concentrations of organic matter and consequently possible odour problems in the white water system
	II. Applicable for odours related to waste water treatment and sludge handling, in order to avoid conditions where waste water or sludge becomes anaerobic
a	Implement closed sewer systems with controlled vents, using chemicals in some cases to reduce the formation of and to oxidise hydrogen sulphide in sewer systems
b	Avoid over-aeration in equalisation basins but maintain sufficient mixing
c	Ensure sufficient aeration capacity and mixing properties in aeration tanks; revise the aeration system regularly
d	Guarantee proper operation of secondary clarifier sludge collection and return sludge pumping
e	Limit the retention time of sludge in sludge storages by sending the sludge continuously to the dewatering units
f	Avoid the storage of waste water in the spill basin longer than is necessary; keep the spill basin empty
g	If sludge dryers are used, treatment of thermal sludge dryer vent gases by scrubbing and/or bio filtration (such as compost filters)
h	Avoid air cooling towers for untreated water effluent by applying plate heat exchangers

4.7.6. Monitoring of key process parameters and of emissions to water and air

BAT 8. BAT is to monitor the key process parameters according to the Table 27.

BAT 9. BAT is to carry out the monitoring and measurement of emissions to air, as indicated in Table 28, on a regular basis with the frequency indicated and according to EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards which ensure the provision of data of an equivalent scientific quality.

BAT 10. BAT is to carry out the monitoring and measurement of emissions to water, as indicated in Table 29, with the frequency indicated and according to EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

BAT 11. BAT is to regularly monitor and assess diffuse total reduced sulphur emissions from relevant sources.

Description
The assessment of diffuse total reduced sulphur emissions can be done by periodic measurement and assessment of diffuse emissions that are emitted from different sources (e.g. the fibre line, tanks, chip bins etc.) by direct measurements.

Table 27: Monitoring of Key Parameters

I. Monitoring key process parameters relevant for emissions to air	
Parameter	**Monitoring frequency**
Pressure, temperature, oxygen, CO and water vapour content in flue-gas for combustion processes	Continuous
II. Monitoring key process parameters relevant for emissions to water	
Parameter	**Monitoring frequency**
Water flow, temperature and pH	Continuous
P and N content in biomass, sludge volume index, excess ammonia and ortho-phosphate in the effluent, and microscopy checks of the biomass	Periodic
Volume flow and CH_4 content of biogas produced in anaerobic waste water treatment	Continuous
H_2S and CO_2 contents of biogas produced in anaerobic waste water treatment	Periodic

Table 28: Monitoring and Measurement of Emissions to Air

	Parameter	Monitoring frequency	Applicability	Monitoring associated with	
a	NO_x and SO_2	Continuous	Recovery boiler	BAT 21 BAT 22	BAT 36 BAT 37
		Periodic or continuous	Lime kiln	BAT 24	BAT 26
		Periodic or continuous	Dedicated TRS burner	BAT 28	BAT 29
b	Dust	Periodic or continuous	Recovery boiler (Kraft) and lime kiln	BAT 23	BAT 27
		Periodic	Recovery boiler (sulphite)	BAT 37	
c	TRS (including H_2S)	Continuous	Recovery boiler	BAT 21	
		Periodic or continuous	Lime kiln and dedicated TRS burner	BAT 24 BAT 25	BAT 28
		Periodic	Diffuse emissions from different sources (e.g. the fibre line, tanks, chip bins, etc.) and residual weak gases	BAT 11 BAT 20	
d	NH_3	Periodic	Recovery boiler equipped with SNCR	BAT 36	

Table 29: Monitoring and Measurement of Emissions to Water

	Parameter	Monitoring frequency	Monitoring associated with
a	Chemical oxygen demand (COD) or Total organic carbon (TOC)(1)	Daily(2)(3)	BAT 19 BAT 33 BAT 40 BAT 45 BAT 50
b	BOD_5 or BOD_7	Weekly (once a week)	
c	Total suspended solids (TSS)	Daily(2)(3)	
d	Total nitrogen	Weekly (once a week)(2)	
e	Total phosphorus	Weekly (once a week)(2)	
f	EDTA, DTPA(4)	Monthly (once a month)	
g	AOX (according to EN ISO 9562:2004)(5)	Monthly (once a month)	BAT 19: bleached Kraft
		Once every two months	BAT 33: except TCF and NSSC mills BAT 40: except CTMP and CMP mills BAT 45 BAT 50
h	Relevant metals (e.g. Zn, Cu, Cd, Pb, Ni)	Once a year	

(1)There is a trend to replace COD by TOC for economic and ecological reasons. If TOC is already measured as a key process parameter, there is no need to measure COD; however, a correlation between the two parameters should be established for the specific emission source and waste water treatment step.
(2)Rapid test methods can also be used. The results of rapid tests should be checked regularly (e.g. monthly) against EN standards or, if EN standards are not available, against ISO, national or other international standards which ensure the provision of data of an equivalent scientific quality.
(3)For mills operating less than seven days a week, the monitoring frequency for COD and TSS may be reduced to cover the days the mill is in operation or to extend the sampling period to 48 or 72 hours.
(4)Applicable where EDTA or DTPA (chelating agents) are used in the process.
(5)Not applicable to plants that provide evidence that no AOX is generated or added via chemical additives and raw materials.

4.7.7. Waste management

BAT 12. In order to reduce the quantities of wastes sent for disposal, BAT is to implement a waste assessment (including waste inventories) and management system, so as to facilitate waste reuse, or failing that, waste recycling, or failing that, 'other recovery', including a combination of the techniques given in Table 30.

Table 30: Waste Management

	Technique	Description	Applicability
a	Separate collection of different waste fractions (including separation and classification of hazardous waste)	The separate collection of different waste fractions at the points of origin and, if appropriate, intermediate storage can enhance the options for reuse or recirculation. Separate collection also includes segregation and classification of hazardous waste fractions (e.g. oil and grease residues, hydraulic and transformer oils, waste batteries, scrap electrical equipment, solvents, paints, biocides or chemical residues).	Generally applicable
b	Merging of suitable fractions of residues to obtain mixtures that can be better utilised	Merging of suitable fractions of residue depending on the preferred options for reuse/recycling, further treatment and disposal.	Generally applicable
c	Pre-treatment of process residues before reuse or recycling	Pre-treatment comprises techniques such as: » dewatering e.g. of sludge, bark or rejects and in some cases drying to enhance reusability before utilisation (e.g. increase calorific value before incineration); or » dewatering to reduce weight and volume for transport. For dewatering belt presses, screw presses, decanter centrifuges or chamber filter presses are used; » crushing/shredding of rejects e.g. from RCF processes and removal of metallic parts, to enhance combustion characteristics before incineration; » biological stabilisation before dewatering, in case agricultural utilisation is foreseen.	Generally applicable
d	Material recovery and recycling of process residues on site	Processes for material recovery comprise techniques such as: » separation of fibres from water streams and recirculation into feedstock; » recovery of chemical additives, coating pigments, etc.; » recovery of cooking chemicals by means of recovery boilers, causticising, etc.	Generally applicable
e	Energy recovery on- or off-site from wastes with high organic content	Residues from debarking, chipping, screening etc. like bark, fibre sludge or other mainly organic residues are burnt due to their calorific value in incinerators or biomass power plants for energy recovery.	For off-site utilisation, the applicability depends on the availability of a third party
f	External material utilisation	Material utilisation of suitable waste from pulp and paper production can be done in other industrial sectors, e.g. by: » firing in the kilns or mixing with feedstock in cement, ceramics or bricks production (includes also energy recovery); » composting paper sludge or land spreading suitable waste fractions in agriculture; » use of inorganic waste fractions (sand, stones, grits, ashes, lime) for construction, such as paving, roads, covering layers etc. The suitability of waste fractions for off-site utilisation is determined by the composition of the waste (e.g. inorganic/mineral content) and the evidence that the foreseen recycling operation does not cause harm to the environment or health.	Depending on the availability of a third party
g	Pre-treatment of waste before disposal	Pre-treatment of waste before disposal comprises measures (dewatering, drying etc.) reducing the weight and volume for transport or disposal.	Generally applicable

4.7.8. Emissions to water

Further information on waste water treatment in pulp and paper mills and process-specific BAT-AELs are given in Sections 4.8 to 4.11 (Sections 8.2 to 8.6 of the BAT document).

BAT 13. In order to reduce nutrient (nitrogen and phosphorus) emissions into receiving waters, BAT is to substitute chemical additives with high nitrogen and phosphorus contents with additives containing low nitrogen and phosphorus contents.

Applicability
Applicable if the nitrogen in the chemical additives is not bio-available (i.e. it cannot serve as a nutrient in biological treatment) or if the nutrient balance is in surplus.

Table 31: Techniques for Reducing Emissions of Pollutants into Receiving Waters

	Technique	Description
a	Primary (physico-chemical) treatment	Physico-chemical treatment, such as equalisation, neutralisation or sedimentation. Equalisation (e.g. in equalising basins) is used to prevent large variations in flow rate, temperature and contaminant concentrations and thus to avoid overloading the waste water treatment system.
b	Secondary (biological) treatment[1]	For the treatment of waste water by means of microorganisms, the available processes are aerobic and anaerobic treatment. In a secondary clarification step, solids and biomass are separated from effluents by sedimentation, sometimes combined with flocculation

[1]Not applicable to plants where the biological load of waste water after the primary treatment is very low, e.g. some paper mills producing speciality paper.

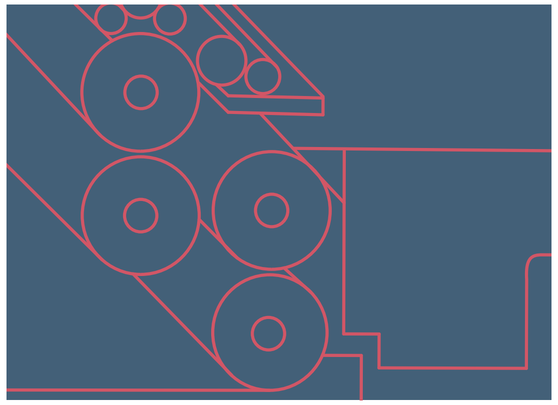
BAT 14. In order to reduce emissions of pollutants into receiving waters, BAT is to use all of the techniques given in Table 31.

BAT 15. When further removal of the organic substances nitrogen or phosphorus is needed; BAT is to use tertiary treatment. Advanced treatment comprises techniques, such as filtration for further solids removal, nitrification and denitrification for nitrogen removal or flocculation/precipitation followed by filtration for phosphorus removal. Tertiary treatment is normally used in cases where primary and biological treatment are not sufficient to achieve low levels of TSS, nitrogen or phosphorus, which may be required e.g. due to local conditions.

BAT 16. In order to reduce emissions of pollutants into receiving waters from biological waste water treatment plants, BAT is to use all of the techniques given in Table 32.

Table 32: Techniques for Reducing Emissions of Pollutants into Receiving Waters

	Technique
a	Proper design and operation of the biological treatment plant
b	Regularly controlling the active biomass
c	Adjustment of nutrition supply (nitrogen and phosphorus) to the actual need of the active biomass



4.7.9. Emissions of noise

BAT 17. In order to reduce the emissions of noise from pulp and paper manufacturing, BAT is to use a combination of the techniques given in Table 33.

Table 33: Techniques for Reducing Emmissions of Noise

	Technique	Description	Applicability
a	Noise-reduction programme	A noise-reduction programme includes identification of sources and affected areas, calculations and measurements of noise levels in order to rank sources according to noise levels, and identification of the most cost effective combination of techniques, their implementation and monitoring	Generally applicable
b	Strategic planning of the location of equipment, units and buildings	Noise levels can be reduced by increasing the distance between the emitter and the receiver and by using buildings as noise screens	Generally applicable to new plants. In the case of existing plants, the relocation of equipment and production units may be restricted by the lack of space or by excessive costs
c	Operational and management techniques in buildings containing noisy equipment	This includes: » improved inspection and maintenance of equipment to prevent failures » closing of doors and windows of covered areas » equipment operation by experienced staff » avoidance of noisy activities during night-time » provisions for noise control during maintenance activities	Generally applicable
d	Enclosing noisy equipment and units	Enclosure of noisy equipment, such as wood handling, hydraulic units, and compressors in separate structures, such as buildings or soundproofed cabinets, where internal-external lining is made of impact-absorbent material	
e	Use of low-noise equipment and noise-reducers on equipment and ducts		
f	Vibration insulation	Vibration insulation of machinery and decoupled arrangement of noise sources and potentially resonant components	
g	Soundproofing of buildings	Pre-treatment of waste before disposal comprises measures (dewatering, drying etc.) reducing the weight and volume for transport or disposal.	Generally applicable
h	Noise abatement	Noise propagation can be reduced by inserting barriers between emitters and receivers. Appropriate barriers include protection walls, embankments and buildings. Suitable noise abatement techniques include fitting silencers and attenuators to noisy equipment such as steam releases and dryer vents	Generally applicable to new plants. In the case of existing plants, the insertion of obstacles may be restricted by the lack of space
i	Use of larger wood-handling machines to reduce lifting and transport times and noise from logs falling onto log piles or the feed table		Generally applicable
j	Improved ways of working, e.g. releasing logs from a lower height onto the log piles or the feed table; immediate feedback of the level of noise for the workers		

4.7.10. Decommissioning

BAT 18. In order to prevent pollution risks when decommissioning a plant, BAT is to use the general techniques given in Table 34.

Table 34: Techniques for Preventing Pollution Risks When Decommissioning a Plant

	Technique
a	Ensure that underground tanks and piping are either avoided in the design phase or that their location is well known and documented
b	Establish instructions for emptying process equipment, vessels and piping
c	Ensure a clean closure when the facility is shut down, e.g. to clean up and rehabilitate the site. Natural soil functions should be safeguarded, if feasible
d	Use a monitoring programme, especially relative to groundwater, in order to detect possible future impacts on site or in neighbouring areas
e	Develop and maintain a site closure or cessation scheme, based on risk analysis, which includes a transparent organisation of the shutdown work, taking into account relevant local specific conditions

4.8. BAT conclusions for Kraft and soda pulping processes

For integrated Kraft pulp and paper mills, the process-specific BAT conclusions for papermaking given in Section 4.10 apply, in addition to the BAT conclusions in this section.

4.8.1. Waste water and emissions to water

BAT 19. In order to reduce emissions of pollutants into receiving waters from the whole mill, BAT is to use TCF or modern ECF bleaching, and a suitable combination of the techniques specified in BAT 13, BAT 14, BAT 15 and BAT 16 and of the techniques given in Table 35. In TCF bleaching, the use of chlorine containing bleaching chemicals is completely avoided and thus so are the emissions of organic and organochlorinated substances from bleaching. The modern ECF bleaching minimises the consumption of chlorine dioxide by using one or a combination of the following bleaching stages: oxygen, hot acid hydrolysis stage, ozone stage at medium and high consistency, stages with atmospheric hydrogen peroxide and pressurised hydrogen peroxide or the use of a hot chlorine dioxide stage.

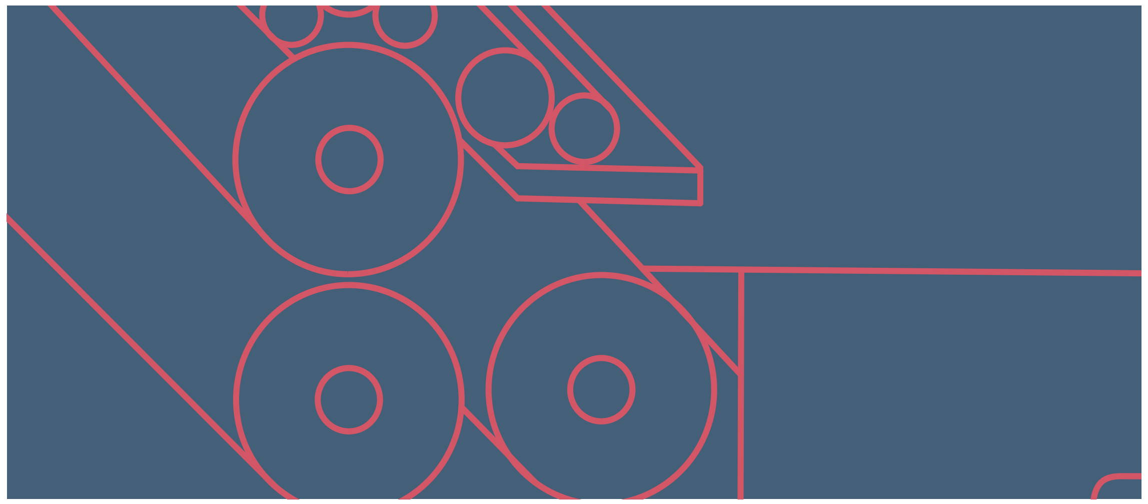


Table 35: Techniques for Reducing Emissions of Pollutants

	Technique	Description	Applicability
a	Modified cooking before bleaching	Extended cooking (batch or continuous systems) comprises longer cooking periods under optimised conditions (e.g. alkali concentration in the cooking liquor is adjusted to be lower at the beginning and higher at the end of the cooking process), to extract a maximum amount of lignin before bleaching, without undue carbohydrate degradation or excessive loss of pulp strength. Thus, the use of chemicals in the subsequent bleaching stage and the organic load of the waste water from the bleach plant can be reduced.	Generally applicable
b	Oxygen delignification before bleaching	Oxygen delignification is an option to remove a substantial fraction of the lignin remaining after cooking, in case the cooking plant has to be operated with higher kappa numbers. The pulp reacts under alkaline conditions with oxygen to remove some of the residual lignin.	Generally applicable
c	Closed brown stock screening and efficient brown stock washing	Brown stock screening is carried out with slotted pressure screens in a multistage closed cycle. Impurities and shives are thus removed at an early stage in the process. Brown stock washing separates dissolved organic and inorganic chemicals from the pulp fibres. The brown stock pulp may be washed first in the digester, then in high efficiency washers before and after oxygen delignification, i.e. before bleaching. Carry-over, chemical consumption in bleaching, and the emission load of waste water are all reduced. Additionally, it allows for recovery of the cooking chemicals from the washing water. Efficient washing is done by counter-current multistage washing, using filters and presses. The water system in the brown stock screening plant is completely closed.	Generally applicable
d	Partial process water recycling in the bleach plant	Acid and alkaline filtrates are recycled within the bleach plant counter-currently to the pulp flow. Water is purged either to the waste water treatment plant or, in a few cases, to post-oxygen washing. Efficient washers in the intermediate washing stages are a prerequisite for low emissions. A bleach plant effluent flow of 12 – 25 m^3/ADt is achieved in efficient mills (Kraft).	Water recycling may be limited due to incrustation in bleaching
e	Effective spill monitoring and containment with a suitable recovery system	An effective spill control, catchment and recovery system that prevents accidental releases of high organic and sometimes toxic loads or peak pH values (to the secondary waste water treatment plant) comprises: conductivity or pH monitoring at strategic locations to detect losses and spills; collecting diverted or spilled liquor at the highest possible liquor solids concentration; returning collected liquor and fibre to the process at appropriate locations; preventing spills of concentrated or harmful flows from critical process areas (including tall oil and turpentine) from entering the biological effluent treatment; adequately dimensioned buffer tanks for collecting and storing toxic or hot concentrated liquors.	Generally applicable
f	Maintaining sufficient black liquor evaporation and recovery boiler capacity to cope with peak loads	Sufficient capacity in the black liquor evaporation plant and in the recovery boiler ensure that additional liquor and dry solids loads due to the collection of spills or bleach plant effluents can be dealt with. This reduces losses of weak black liquor, other concentrated process effluents and potentially bleach plant filtrates. The multi-effect evaporator concentrates weak black liquor from brown stock washing and, in some cases, also bio-sludge from the effluent treatment plant and/or salt cake from the ClO2 plant. Additional evaporation capacity above normal operation gives sufficient contingency to recover spills and to treat potential bleach filtrate recycle streams.	Generally applicable
g	Stripping the contaminated (foul) condensates and reusing the condensates in the process	Stripping the contaminated (foul) condensates and reuse of condensates in the process reduces the fresh water intake of a mill and the organic load to the waste water treatment plant. In a stripping column, steam is lead counter-currently through the previously filtered process condensates that contain reduced sulphur compounds, terpenes, methanol and other organic compounds. The volatile substances of the condensate accumulate in the overhead vapour as non-condensable gases and methanol and are withdrawn from the system. The purified condensates can be reused in the process, e.g. for washing in the bleach plant, in brown stock washing, in the causticising area (mud washing and dilution, mud filter showers), as TRS scrubbing liquor for lime kilns, or as white liquor make-up water. The stripped non-condensable gases from the most concentrated condensates are fed into the collection system for strong malodorous gases and are incinerated. Stripped gases from moderately contaminated condensates are collected into the low volume high concentration gas system (LVHC) and incinerated.	Generally applicable

BAT-associated emission levels
See Table 36 and Table 37. These BAT-associated emission levels are not applicable to dissolving Kraft pulp mills.

The reference waste water flow for Kraft mills is set out in BAT 5.

The BOD concentration in the treated effluents is expected to be low (around 25 mg/l as a 24-hour composite sample).

Table 36: BAT-associated emission levels for the direct waste water discharge to receiving waters from a bleached Kraft pulp mill

Parameter	Yearly average kg/ADt[1]
Chemical oxygen demand (COD)	7 – 20
Total suspended solids (TSS)	0.3 – 1.5
Total nitrogen	0.05 – 0.25[2]
Total phosphorus	0.01 – 0.03[2] Eucalyptus: 0.02 – 0.11 kg/ADt[3]
Adsorbable organically bound halogens (AOX)[4][5]	0 – 0.2

[1]The BAT-AEL ranges refer to market pulp production and the pulp production part of integrated mills (emissions from papermaking are not included).
[2]A compact biological waste water treatment plant can result in slightly higher emission levels.
[3]The upper end of the range refers to mills using eucalyptus from regions with higher levels of phosphorus (e.g. Iberian eucalyptus).
[4]Applicable for mills using chlorine containing bleaching chemicals.
[5]For mills producing pulp with high strength, stiffness and high purity properties (e.g. for liquid packaging board and LWC), emissions level of AOX up to 0.25 kg/ADt may occur.

Table 37: BAT-associated emission levels for the direct waste water discharge to receiving waters from an unbleached Kraft pulp mill

Parameter	Yearly average kg/ADt[1]
Chemical oxygen demand (COD)	2.5 – 8
Total suspended solids (TSS)	0.3 – 1.0
Total nitrogen	0.1 – 0.2[2]
Total phosphorus	0.01 – 0.02[2]

[1]The BAT-AEL ranges refer to market pulp production and the pulp production part of integrated mills (emissions from papermaking are not included).
[2]A compact biological waste water treatment plant can result in slightly higher emission levels.

4.8.2. Emissions to air

4.8.2.1. Reduction of emissions in strong and weak odorous gases

BAT 20. In order to reduce odour emissions and total reduced sulphur (TRS) emissions due to strong and weak gases, BAT is to prevent diffuse emissions by capturing all process-based sulphur containing off-gases, including all vents with sulphur-containing emissions, by applying all of the techniques given in Table 38.

Table 38: Techniques for Reducing Emmissions in Strong and Weak Odorous Gases

	Technique	Description
a	Collection systems for strong and weak malodorous gases, comprising the following features: » covers, suction hoods, ducts, and extraction system with sufficient capacity; continuous leak detection system; safety measures and equipment	
b	Incineration of strong and weak non-condensable gases	Incineration can be carried out using: » recovery boiler » lime kiln[1] » dedicated NCG burner equipped with wet scrubbers for SOX removal; or » power boiler[2] To ensure the constant availability of incineration for odorous strong gases, back-up systems are installed. Lime kilns can serve as back-up for recovery boilers; further back-up equipment are flares and package boiler
c	Recording unavailability of the incineration system and any resulting emissions[3]	

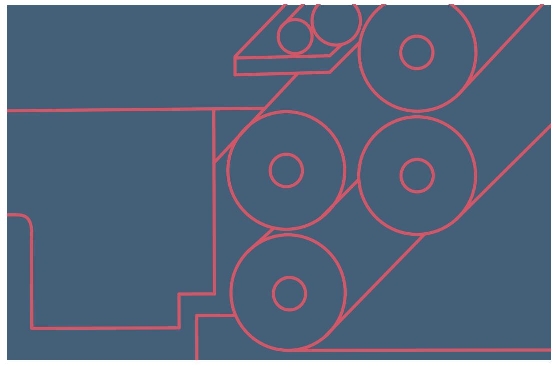
[1]The SO_x emission levels of the lime kiln increase significantly when strong non-condensable gases (NCG) are fed to the kiln and no alkaline scrubber is used.
[2]Applicable for the treatment of weak odorous gases.
[3]Applicable for the treatment of strong odorous gases.

Applicability
Generally applicable for new plants and for major refurbishments of existing plants. The installation of necessary equipment may be difficult for existing plants due to layout and space restrictions. The applicability of incineration might be limited for safety reasons, and in this case wet scrubbers could be used.

BAT-associated emission level of total reduced sulphur (TRS) in residual weak gases emitted is 0.05 – 0.2 kg S/ADt.

Table 39: Techniques for Reducing SO_2 and TRS emissions

	Technique	Description
a	Increasing the dry solids (DS) content of black liquor	The black liquor can be concentrated by an evaporation process before burning.
b	Optimised firing	Firing conditions can be improved e.g. by good mixing of air and fuel, control of furnace load etc.
c	Wet scrubber	Gaseous compounds are dissolved in a suitable liquid (water or alkaline solution). Simultaneous removal of solid and gaseous compounds may be achieved. Downstream of the wet scrubber, the flue-gases are saturated with water and a separation of the droplets is required before discharging the flue-gases. The resulting liquid has to be treated by a waste water process and the insoluble matter is collected by sedimentation or filtration.



4.8.2.2. Reduction of emissions from a recovery boiler

SO_2 and TRS emissions
BAT 21. In order to reduce SO_2 and TRS emissions from a recovery boiler, BAT is to use a combination of the techniques given in Table 39. For BAT-associated emission levels refer Table 40.

NO_x emissions
BAT 22. In order to reduce NO_x emissions from a recovery boiler, BAT is to use an optimised firing system including all of the features given in Table 41 below.

Table 40: BAT-associated emission levels for SO_2 and TRS emissions from a recovery boiler

Parameter		Daily average(1)(2) mg/Nm³ at 6% O_2	Yearly average(1) mg/Nm³ at 6% O_2	Yearly average(1) kg S/ADt
SO_2	DS <75%	10 – 70	10 – 70	–
	DS 75 – 83 %(3)	10 – 50	10 – 70	–
Total reduced sulphur (TRS)		1 – 10(4)	10 – 70	–
Gaseous S (TRSS + SO_2-S)	DS <75%	–	–	0.03 – 0.17
	DS 75 – 83%(3)			0.03 – 0.13

(1)Increasing the DS content of the black liquor results in lower SO2 emissions and higher NOX emissions. Due to this, a recovery boiler with low emission levels for SO2, may be on the higher end of the range for NOX and vice versa.
(2)BAT-AELs do not cover periods during which the recovery boiler is run on a DS content much lower than the normal DS content due to shutdown or maintenance of the black liquor concentration plant.
(3)If a recovery boiler were to burn black liquor with a DS > 83%, then SO2 and gaseous S emission levels should be reconsidered on a case-by-case basis.
(4)The range is applicable without the incineration of odorous strong gases.
DS = dry solid content of the black liquor.

Table 41: Techniques for Reducing NO_x emissions from a Recovery Boiler

	Technique
a	Computerised combustion control
b	Good mixing of fuel and air
c	Staged air feed systems, e.g. by using different air registers and air inlet ports

Applicability
Technique (c) is applicable to new recovery boilers and in the case of a major refurbishment of recovery boilers, as this technique requires considerable changes to the air feed systems and the furnace.

Dust emissions
BAT 23. In order to reduce dust emissions from a recovery boiler, BAT is to use an electrostatic precipitator (ESP) or a combination of ESP and wet scrubber.

Table 42: BAT-associated emission levels for NOX emissions from a recovery boiler

Parameter		Yearly average(1) mg/Nm³ at 6% O_2	Yearly average(1) kg NO_x/ADt
NO_x	Softwood	120 – 200(2)	DS <75%: 0.8 – 1.4 DS 75 – 83%(3): 1.0 – 1.6
	Hardwood	120 – 200(2)	DS <75%: 0.8 – 1.4 DS 75 – 83%(3): 1.0 – 1.7

(1)Increasing the DS content of the black liquor results in lower SO_2 emissions and higher NO_x emissions. Due to this, a recovery boiler with low emission levels for SO_2, may be on the higher end of the range for NO_x and vice versa.
(2)The actual NO_x emission level of an individual mill depends on the DS content and the nitrogen content of the black liquor, and the amount and combination of NCG and other nitrogen containing flows (e.g. dissolving tank vent gas, methanol separated from the condensate, bio-sludge) burnt. The higher the DS content, the nitrogen content in the black liquor, and the amount of NCG and other nitrogen containing flows burnt, the closer the emissions will be to the upper end of the BAT-AEL range.
(3)If a recovery boiler were to burn black liquor with a DS > 83%, then NO_x emission levels should be reconsidered on a case-by-case basis.
DS = dry solid content of the black liquor.

Table 43: BAT-associated emission levels for dust emissions from a recovery boiler

Parameter	Dust abatement system	Yearly average mg/Nm³ at 6% O_2	Yearly average kg Dust/ADt
Dust	New or major refurbishment	10 – 25	0.02 – 0.20
	Existing	10 – 40(1)	0.02 – 0.20(1)

(1)For an existing recovery boiler equipped with an ESP approaching the end of its operational life, emission levels may increase over time up to 50 mg/Nm³ (corresponding to 0.4 kg/ADt).

Description
ESP operates such that particles are charged and separated under the influence of an electrical field. They are capable of operating over a wide range of conditions. For web scrubber, refer Table 39.

4.8.2.3. Reduction of emissions from a lime kiln

SO_2 emissions
BAT 24. In order to reduce SO_2 emissions from a lime kiln, BAT is to apply one or a combination of the techniques given in Table 44.

Table 44: Techniques for Reducing the Emmissions from a Lime Kiln

	Technique	Description
a	Fuel selection/low-sulphur fuel	The use of low-sulphur content fuels with sulphur contents of about 0.02 – 0.05% by weight (e.g. forest biomass, bark, low-sulphur oil, gas) reduces SO_2 emissions generated by the oxidation of sulphur in the fuel during combustion
b	Limit incineration of sulphur-containing odorous strong gases in the lime kiln	Collected strong gases can be destroyed by burning them in the recovery boiler, in dedicated TRS burners, or in the lime kiln. Collected weak gases are suitable for burning in the recovery boiler, lime kiln, power boiler or in the TRS burner. Dissolving tank vent gases can be burnt in modern recovery boilers.
c	Control of Na_2S content in lime mud feed	Efficient washing and filtration of the lime mud reduces the concentration of Na_2S, thus reducing the formation of hydrogen sulphide in the kiln during the re-burning process.
d	Alkaline scrubber	Gaseous compounds are dissolved in a suitable liquid (water or alkaline solution). Simultaneous removal of solid and gaseous compounds may be achieved. Downstream of the wet scrubber, the flue-gases are saturated with water and a separation of the droplets is required before discharging the flue-gases. The resulting liquid has to be treated by a waste water process and the insoluble matter is collected by sedimentation or filtration.

Table 45: BAT-Associated Emission Levels for SO2 and Sulphur Emissions from a Lime Kiln

Parameter[1]	Yearly average mg SO_2/Nm³ at 6% O_2	Yearly average kg S/ADt
SO_2 when strong gases are not burnt in the lime kiln	5 – 70	–
SO_2 when strong gases are burnt in the lime kiln	55 – 120	–
Gaseous S (TRS-S + SO_2-S) when strong gases are not burnt in the lime kiln	–	0.005 – 0.07
Gaseous S (TRS-S + SO_2-S) when strong gases are burnt in the lime kiln	–	0.055 – 0.12

[1]'strong gases' includes methanol and turpentine

TRS emissions

BAT 25. In order to reduce TRS emissions from a lime kiln, BAT is to apply one or a combination of the techniques given in Table 46.

Table 46: Techniques for Reducing TRS Emissions from a Lime Kiln

	Technique
a	Control of the excess oxygen
b	Control of Na_2S content in lime mud feed
c	Combination of ESP and alkaline scrubber

BAT-associated emission levels

Table 47: BAT-Associated Emission Levels for TRS and Sulphur Emissions from a Lime Kiln

Parameter[1]	Yearly average mg S/Nm³ at 6% O_2
Total reduced sulphur (TRS)	<1 – 10[1]

[1]For lime kilns burning strong gases (including methanol and turpentine), the upper end of the AEL range may be up to 40 mg/Nm³.

NO_x emissions

BAT 26. In order to reduce NO_x emissions from a lime kiln, BAT is to apply a combination of the techniques given in Table 48.

Table 48: Techniques for Reducing NO_x Emissions from a Lime Kiln

	Technique	Description
a	Optimised combustion and combustion control	Based on permanent monitoring of appropriate combustion parameters (e.g. O_2, CO content, fuel/air ratio, un-burnt components), this technique uses control technology for achieving the best combustion conditions. NO_x formation and emissions can be decreased by adjusting the running parameters, the air distribution, excess oxygen, flame shaping and the temperature profile.
b	Good mixing of fuel and air	
c	Low-NO_x burner	Low-NO_x burners are based on the principles of reducing peak flame temperatures, delaying but completing the combustion and increasing the heat transfer (increased emissivity of the flame). It may be associated with a modified design of the furnace combustion chamber.
d	Fuel selection/ low-N fuel	The use of fuels with low nitrogen content is applied to reduce the amount of NO_x emissions from the oxidation of nitrogen contained in the fuel during combustion. The combustion of CNCG or biomass-based fuels increases NO_x emissions compared to oil and natural gas, as CNCG and all wood derived fuels contain more nitrogen than oil and natural gas. Due to higher combustion temperatures, gas firing leads to higher NO_x levels than oil firing.

Table 49: BAT-Associated Emission Levels for NO_x Emissions from a Lime Kiln

Parameter		Yearly average mg/Nm³ at 6% O_2	Yearly average kg NO_x/ADt
NO_x	Liquid fuels	100 – 200[1]	0.1 – 0.2[1]
	Gaseous fuels	100 – 350[2]	0.1 – 0.3[2]

[1]When using liquid fuels originating from vegetable matter (e.g. turpentine, methanol, tall-oil), including those obtained as by-products of the pulping process, emission levels up to 350 mg/Nm³ (corresponding to 0.35 kg NO_x/ADt) may occur.
[2]When using gaseous fuels originating from vegetable matter (e.g. non-condensable gases), including those obtained as by-products of the pulping process, emission levels up to 450 mg/Nm³ (corresponding to 0.45 kg NO_x/ADt) may occur.

Dust emissions

BAT 27. In order to reduce dust emissions from a lime kiln, BAT is to use an ESP or a combination of ESP and wet scrubber.

Table 50: BAT-Associated Emission Levels for Dust Emissions from a Lime Kiln

Parameter	Dust abatement system	Yearly average mg/Nm³ at 6% O_2	Yearly average kg Dust/ADt
Dust	New or major refurbishment	10 – 25	0.005 – 0.02
	Existing	10 – 30[1]	0.005 – 0.03[1]

[1]For an existing recovery boiler equipped with an ESP approaching the end of its operational life, emission levels may increase over time up to 50 mg/Nm³ (corresponding to 0.05 kg/ADt).

4.8.2.4. Reduction of emissions from a burner for strong odorous gases (dedicated TRS burner)

BAT 28. In order to reduce SO_2 emissions from the incineration of strong odorous gases in a dedicated TRS burner, BAT is to use an alkaline SO_2 scrubber.

Table 51: BAT-Associated Emission Levels for SO_2 and TRS Emissions from the Incineration of Strong Gases in a Dedicated TRS Burner

Parameter[1]	Yearly average mg/Nm³ at 9% O_2	Yearly average kg S/ADt
SO_2	20 – 120	–
TRS	1 – 5	–
Gaseous S (TRS-S + SO_2-S)	–	0.002 – 0.05[1]

[1]This BAT-AEL is based on a gas flow in the range of 100 – 200 Nm³/ADt.

BAT 29. In order to reduce NO_x emissions from the incineration of strong odorous gases in a dedicated TRS burner, BAT is to use one or a combination of the techniques given in Table 52.

Table 52: Techniques for Reducing NO_x Emissions from the Incineration of Strong Odorous Gases in a Dedicated TRS Burner

	Technique	Description	Applicability
a	Burner/ firing optimisation	Based on permanent monitoring of appropriate combustion parameters (e.g. O2, CO content, fuel/ air ratio, un-burnt components), this technique uses control technology for achieving the best combustion conditions. NO_x formation and emissions can be decreased by adjusting the running parameters, the air distribution, excess oxygen, flame shaping and the temperature profile.	Generally applicable
b	Staged incineration	Staged incineration is based on the use of two burning zones, with controlled air ratios and temperatures in a first chamber. The first burning zone operates at sub-stoichiometric conditions to convert ammonia compounds into elementary nitrogen at high temperature. In the second zone, additional air feed completes combustion at a lower temperature. After the two-stage incineration, the flue-gas flows to a second chamber to recover the heat from the gases, producing steam in the process. 1.1.1	Generally applicable for new plants and for major refurbishments. For existing mills, applicable only if space allows for the insertion of equipment

For BAT-associated emission levels, see Table 53.

Table 53: BAT-Associated Emission Levels for NO_x Emissions from the Incineration of Strong Gases in a Dedicated TRS Burner

Parameter[1]	Yearly average mg/Nm³ at 9% O_2	Yearly average kg NO_x/ADt
NO_x	50 – 400[1]	0.01 – 0.1[1]

[1]Where at existing plants a switch to staged incineration is not feasible, emissions levels of up to 1 000 mg/Nm³ (corresponding to 0.2 kg/ADt) may occur.

4.8.3. Waste generation

BAT 30. In order to prevent waste generation and minimise the amount of solid waste to be disposed of, BAT is to recycle dust from black liquor recovery boiler ESPs to the process.

Applicability
Recirculation of dust may be limited due to non-process elements in the dust.

4.8.4. Energy consumption and efficiency

BAT 31. In order to reduce thermal energy consumption (steam), maximise the benefit of energy carriers used, and to reduce the consumption of electricity, BAT is to apply a combination of the techniques given in Table 54.

Table 54: Techniques for Recuding Energy Consumption and Improving Efficiency

	Technique
a	High dry solid content of bark, by use of efficient presses or drying
b	High efficiency steam boilers, e.g. low flue-gas temperatures
c	Effective secondary heating systems
d	Closing water systems, including bleach plant
e	High pulp concentration (middle or high consistency technique)
f	High efficiency evaporation plant
g	Recovery of heat from dissolving tanks e.g. by vent scrubbers
h	Recovery and use of the low temperature streams from effluents and other waste heat sources to heat buildings, boiler feed water and process water
i	Appropriate use of secondary heat and secondary condensate
j	Monitoring and control of processes, using advanced control systems
k	Optimise integrated heat exchanger network
l	Heat recovery from the flue-gas from the recovery boiler between the ESP and the fan
m	Ensuring as high a pulp consistency as possible in screening and cleaning
n	Use of speed control of various large motors
o	Use of efficient vacuum pumps
p	Proper sizing of pipes, pumps and fans
q	Optimised tank levels

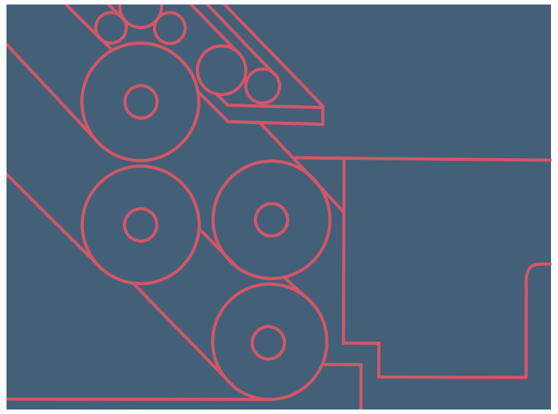
BAT 32. In order to increase the efficiency of power generation, BAT is to apply a combination of the techniques given in Table 55.

4.8.5. Soda pulping

Soda pulping as solution for silicate scaling
Many grasses, bagasse, bamboo and some tropical hardwoods contain silicates that may cause sodium aluminum silicate scales. Moderate amounts of silicates can be controlled by purging lime mud or lime kiln ash. Silicate removal from green liquor in a soda mill can be achieved by lowering the pH of the liquor

Table 55: Techniques for Increasing the Efficiency of Power Generation

	Technique
a	High black liquor dry solid content (increases boiler efficiency, steam generation and thus electricity generation)
b	High recovery boiler pressure and temperature; in new recovery boilers the pressure can be at least 100 bars and the temperature 510 °C
c	Outlet steam pressure in the back-pressure turbine as low as technically feasible
d	Condensing turbine for power production from excess steam
e	High turbine efficiency
f	Preheating feed water to a temperature close to the boiling temperature
g	Preheating the combustion air and fuel charged to the boilers



with CO_2-containing flue gases from the lime kiln or other sources. No commercial silicate removal system is available for the Kraft process, but it can handle the small amounts of silicates from northern woods.

Use of Antraquinone
Antraquinone reduces the loss of carbohydrates and increases delignification.

Use of oxygen
Oxygen is a more specific delignification method than soda pulping alone and will increase the delignification of the process. If the soda cooking gives a kappa number of some 16-18, the subsequent oxygen delignification will reduce it further to 8-10 prior to bleaching. The wash water after oxygen delignification is sent forward to wash the brown stock after cooking.

Bleaching
Most non-woods, e.g. bagasse are easily bleached. Full brightness may be achieved by the ECF sequence D-E-D. Elemental chlorine should not be used due to dioxin formation. TCF bleaching is also possible combining oxygen delignification with peroxide bleaching.

Chemical recycling and heat recovery
BAT is to increase the solids content of the black liquor by evaporation and then combust it in a soda recovery boiler, utilizing the lignin and other dissolved organic matter as an energy source and to recover the solvent (soda). The produced heat should be used for paper or pulp drying.

4.9. BAT conclusions for processing paper for recycling

The BAT conclusions in this section apply to all integrated RCF mills and to RCF pulp mills. For integrated RCF paper mills, **BAT 49, BAT 51, BAT 52c and BAT 53** also apply to papermaking in integrated RCF pulp, paper and board mills, in addition to the BAT conclusions in this section.

4.9.1. Materials management

BAT 42. In order to prevent the contamination of soil and groundwater or to reduce the risk thereof and in order to reduce wind drift of paper for recycling and diffuse dust emissions from the paper for recycling yard, BAT is to use one or a combination of the techniques given in Table 56.

Table 56: Techniques for Material Management

	Technique	Applicability
a	Hard surfacing of the storage area for paper for recycling	Generally applicable
b	Collection of contaminated run-off water from the paper for recycling storage area and treatment in a waste water treatment plant (uncontaminated rainwater e.g. from roofs can be discharged separately)	Applicability may be restricted by the degree of contamination of runoff water (low concentration) and/or the size of the waste water treatment plants (large volumes)
c	Surrounding the terrain of the paper for recycling yard with fences against wind drift	Generally applicable
d	Regularly cleaning the storage area and sweeping associated roadways and emptying gullypots to reduce diffuse dust emissions. This reduces wind-blown paper debris, fibres and the crushing of paper by on-site traffic, which can cause additional dust emission, especially in the dry season	Generally applicable
e	Storing of bales or loose paper under a roof to protect the material from weather influences (moisture, microbiological degradation processes, etc.)	Applicability may be restricted by the size of the area

4.9.2. Waste water and emissions to water

BAT 43. In order to reduce fresh water use, waste water flow, and the pollution load, BAT is to use a combination of the techniques given in Table 57.

BAT 44. In order to maintain advanced water circuit closure in mills processing paper for recycling and to avoid possible negative effects from the increased recycling of process water, BAT is to use one or a combination of the techniques given in Table 58.

Applicability
Techniques (a) – (c) are applicable to RCF paper mills with advanced water circuit closure.

BAT 45. In order to prevent and reduce the pollution load of waste water into receiving waters from the whole mill, BAT is to use a suitable combination of the techniques specified in BAT 13, BAT 14, BAT 15, BAT 16, BAT 43 and BAT 44.

For integrated RCF paper mills, the BAT-AELs include emissions from papermaking, since the white water circuits of the paper machine are closely connected with those of the stock preparation.

For BAT-associated emission levels see Table 59 and Table 60.

The BAT-associated emission levels in Table 59 also apply to RCF without deinking pulp mills, and the BAT-associated emission levels in Table 60 also apply to RCF with deinking pulp mills. The reference waste water flow for RCF mills is set out in BAT 5.

The BOD concentration in the treated effluents is expected to be low (around 25 mg/l as a 24-hour composite sample).

Table 57: Techniques for Reducing Fresh Water Usage, Waste Water and Emissions to Water

	Technique	Description
a	Separation of the water systems	Water systems of different process units (e.g. pulping unit, bleaching and paper machine) are separated by washing and dewatering the pulp (e.g. by wash presses). This separation prevents carry-over of pollutants to subsequent process steps and allows for removing disturbing substances from smaller volumes.
b	Counter-current flow of process water and water recirculation	Clarified water is recirculated as process water within a unit or in integrated mills from the paper machine to the pulp mill and from the pulping to the debarking plant. Effluent is mainly discharged from the points with the highest pollution load (e.g. clear filtrate of the disc filter in pulping, debarking).
c	Partial recycling of treated waste water after biological treatment	Many RCF paper mills recycle a partial stream of biologically treated waste water back into the water circuit, especially mills producing corrugated medium or Testliner
d	Clarification of white water	The systems for water clarification used almost exclusively in the paper industry are based on sedimentation, filtration (disc filter) and flotation. . The most used technique is dissolved air flotation. Anionic trash and fines are agglomerated into physically treatable flocs by using additives. High-molecular, water-soluble polymers or inorganic electrolytes are used as flocculants. The generated agglomerates (flocs) are then floated off in the clarification basin. In dissolved air flotation (DAF), the suspended solid material is attached to air bubbles.

Table 58: Techniques for Mainitaining Advanced Water Circuit Closure

	Technique	Description
a	Monitoring and continuous control of the process water quality	Optimisation of the entire 'fibre-water-chemical additive-energy system' is necessary for advanced closed water systems. This requires a continuous monitoring of the water quality and staff motivation, knowledge and action related to the measures needed to ensure the required water quality.
b	Prevention and elimination of biofilms by using methods that minimise emissions of biocides	A continuous input of microorganisms by water and fibres leads to a specific microbiological equilibrium in each paper plant. To prevent extensive growth of the microorganisms, deposits of agglomerated biomass or biofilms in water circuits and equipment, often bio-dispersants or biocides are used. When using catalytic disinfection with hydrogen peroxide, biofilms and free germs in process water and paper slurry are eliminated by using methods that minimise emissions of biocides.
c	Removal of calcium from process water by a controlled precipitation of calcium carbonate	Lowering the calcium concentration by controlled removal of calcium carbonate (e.g. in a dissolved air flotation cell) reduces the risk of undesired precipitation of calcium carbonate or scaling in water systems and equipment, e.g. in section rolls, wires, felts and shower nozzles, pipes or biological waste water treatment plants.

Table 59: BAT-Associated Emission Levels for the Direct Waste Water Discharge to Receiving Waters from the Integrated Production of Paper and Board from Recycled Fibres Pulp, Produced *Without* Deinking on Site

Parameter[1]	Yearly average kg/t
Chemical oxygen demand (COD)	0.4[1] – 1.4
Total suspended solids (TSS)	0.02 – 0.2[2]
Total nitrogen	0.008 - 0.09
Total phosphorus	0.001 – 0.005[3]
Adsorbable organically bound halogens (AOX)	0.05 for wet strength paper

[1] For mills with completely closed water circuits, there are no emissions of COD.
[2] For existing plants, levels up to 0.45 kg/t may occur, due to the continuous decline in the quality of paper for recycling and the difficulty of continuously upgrading the effluent plant.
[3] For mills with a waste water flow between 5 and 10 m³/t, the upper end of the range is 0.008 kg/t.

Table 60: BAT-Associated Emission Levels for the Direct Waste Water Discharge to Receiving Waters from the Integrated Production of Paper and Board from Recycled Fibres Pulp, Produced *With* Deinking on Site

Parameter[1]	Yearly average kg/t
Chemical oxygen demand (COD)	0.9 – 3.0 0.9 – 4.0 for tissue paper
Total suspended solids (TSS)	0.08 – 0.3 0.1 – 0.4 for tissue paper
Total nitrogen	0.01 – 0.1 0.01 – 0.15 for tissue paper
Total phosphorus	0.002 – 0.01 0.002 – 0.015 for tissue paper
Adsorbable organically bound halogens (AOX)	0.05 for wet strength paper

4.9.3. Energy consumption and efficiency

BAT 46. BAT is to reduce electrical energy consumption within RCF processing paper mills by using a combination of the techniques given in Table 61.

Table 61: Techniques for Reducing Eletrical Energy Consumption within RCF Mills

	Technique	Applicability
a	High consistency pulping for disintegrating paper for recycling into separated fibres	
b	Efficient coarse and fine screening by optimising rotor design, screens and screen operation, which allows the use of smaller equipment with lower specific energy consumption	Generally applicable for new plants and for existing plants in the case of a major refurbishment
c	Energy saving stock preparation concepts extracting impurities as early as possible in the re-pulping process, using fewer and optimised machine components, thus restricting the energy intensive processing of the fibres	

4.10. BAT conclusions for papermaking and related processes

The BAT conclusions in this section apply to all non-integrated paper mills and board mills and to the paper and board making part of integrated Kraft, sulphite, CTMP and CMP mills.

BAT 49, BAT 51, BAT 52c and BAT 53 apply to all integrated pulp and paper mills.

For integrated Kraft, sulphite, CTMP and CMP pulp and paper mills, the process-specific BAT for pulping also apply, in addition to the BAT conclusions in this section.

4.10.1. Waste water and emissions to water

BAT 47. In order to reduce the generation of waste water, BAT is to use a combination of the techniques given in Table 62.

Table 62: Techniques for Reducing the Generation of Waste Water

	Technique	Description	Applicability
a	Optimum design and construction of tanks and chests	Holding tanks for stock and white water storage are designed so that they can cope with process fluctuations and varying flows also during start-ups and shutdowns.	Applicable to new plants and to existing plants in the case of a major refurbishment
b	Fibre and filler recovery and treatment of white water	White water from the paper machine can be treated by the following techniques: » 'Save-all' devices (typically drum or disc filter or dissolved air flotation units etc.) that separate solids (fibres and filler) from the process water. Dissolved air flotation in white water loops transforms suspended solids, fines, small-size colloidal material and anionic substances into flocks that are then removed. The recovered fibres and fillers are recirculated to the process. Clear white water can be reused in showers with less stringent requirements for water quality. » Additional ultra-filtration of the pre-filtered white water results in super clear filtrate with a quality sufficient for use as high pressure shower water, sealing water and for the dilution of chemical additives	Generally applicable
c	Water recirculation	Clarified water is recirculated as process water within a unit or in integrated mills from the paper machine to the pulp mill and from the pulping to the debarking plant. Effluent is mainly discharged from the points with the highest pollution load (e.g. clear filtrate of the disc filter in pulping, debarking).	Generally applicable. Dissolved organic, inorganic, and colloidal materials may restrict the water reuse in the wire section
d	Optimisation of showers in the paper machine	Optimising showers involves: a) the reuse of process water (e.g. clarified white water) to reduce fresh water use, and b) the application of special design nozzles for the showers.	Generally applicable

BAT 48. In order to reduce fresh water use and emissions to water from speciality paper mills, BAT is to use a combination of the techniques given in Table 63.

BAT 49. In order to reduce emission loads of coating colours and binders which can disturb the biological waste water treatment plant, BAT is to use technique (a) given below or, in the case that this is technically not feasible, technique (b) given in Table 64.

BAT 50. In order to prevent and reduce the pollution load of waste water into receiving waters from the whole mill, BAT is to use a suitable combination of the techniques specified in BAT 13, BAT 14, BAT 15, BAT 47, BAT 48 and BAT 49.

Table 63: Techniques for Reducing Fresh Water Use and Emissions to Water from Speciality Paper Mills

	Technique	Description	Applicability
a	Improvement of paper production planning	Improved planning to optimise production batch combinations and length	Generally applicable
b	Management of water circuits to fit changes	Adjust water circuits to be able to cope with changes of paper grades, colours and chemical additives used	
c	Waste water treatment plant ready to cope with changes	Adjust waste water treatment to be able to cope with variations of flows, low concentrations and varying types and amounts of chemical additives	
d	Adjustment of the broke system and of chest capacities		
e	Minimisation of release of chemical additives (e.g. grease-/water proof agents) containing per- or polyfluorinated compounds or contributing to their formation		Applicable only for plants producing paper with grease- or water-repellent properties
f	Switch to low AOX-containing product aids (e.g. to substitute use of wet strength agents based on epichlorohydrin resins)		Applicable only for plants producing paper grades with high wet strength

Table 64: Techniques for Reducing the Emission Loads of Coating Colours and Binders

	Technique	Description	Applicability
a	Recovery of coating colours/recycling of pigments	Effluents containing coating colours are collected separately. The coating chemicals are recovered by e.g.: » ultra-filtration; » screening-flocculation dewatering process with return of the pigments to the coating process. The clarified water could be reused in the process	For ultra-filtration, the applicability may be restricted when: » effluent volumes are very small » coating effluents are generated in various areas of the mill » many changes in coating occur; or » different coating colour recipes are incompatible
b	Pre-treatment of effluents which contain coating colours	Effluents which contain coating colours are treated e.g. by flocculation to protect the subsequent biological waste water treatment	Generally applicable

For BAT-associated emission levels see Table 65 and Table 66.

The BAT-AELs in Table 65 and Table 66 also apply to the paper and board making process of integrated Kraft, sulphite, CTMP and CMP pulp and paper mills.

The reference waste water flow for non-integrated paper and board mills is set out in BAT 5.

The BOD concentration in the treated effluents is expected to be low (around 25 mg/l as a 24-hour composite sample).

4.10.2. Emissions to air

BAT 51. In order to reduce VOC emissions from off-line or on-line coaters, BAT is to choose coating colour recipes (compositions) that reduce VOC emissions.

4.10.3. Waste generation

BAT 52. In order to minimise the amount of solid waste to be disposed of, BAT is to prevent waste generation and to carry out recycling operations by the use of a combination of the techniques given in Table 67 (see general BAT 20).

4.10.4. Energy consumption and efficiency

BAT 53. In order to reduce the consumption of thermal and electrical energy, BAT is to use a combination of the techniques given in Table 68.

Table 65: BAT-Associated Emission Levels for the Direct Waste Water Discharge to Receiving Waters from a Non-Integrated Paper and Board Mill (Excluding Specialty Paper)

Parameter(1)	Yearly average kg/t
Chemical oxygen demand (COD)	0.15 – 1.5(1)
Total suspended solids (TSS)	0.02 – 0.35
Total nitrogen	0.01 – 0.1 0.01 – 0.15 for tissue paper
Total phosphorus	0.003 – 0.012
Adsorbable organically bound halogens (AOX)	0.05 for decor and wet strength paper

(1)For graphic paper mills, the upper end of the range refers to mills manufacturing paper that use starch for the coating process.

Table 66: BAT-Associated Emission Levels for the Direct Waste Water Discharge to Receiving Waters from a Non-Integrated Specialty Paper Mill

Parameter(1)	Yearly average kg/t(1)
Chemical oxygen demand (COD)	0.3 – 5(2)
Total suspended solids (TSS)	0.10 – 1
Total nitrogen	0.015 – 0.4
Total phosphorus	0.002 – 0.04
Adsorbable organically bound halogens (AOX)	0.05 for decor and wet strength paper

(1)Mills having special characteristics, such as a high number of grade changes (e.g. of ≥ 5 per day as a yearly average) or producing very light-weight speciality papers (≤ 30 g/m² as yearly average) might have higher emissions than the upper end of the range.
(2)The upper end of the BAT-AEL range refers to mills producing highly comminuted paper which requires intensive refining and to mills with frequent changes of paper grades (e.g. ≥ 1 – 2 changes/day as yearly average).

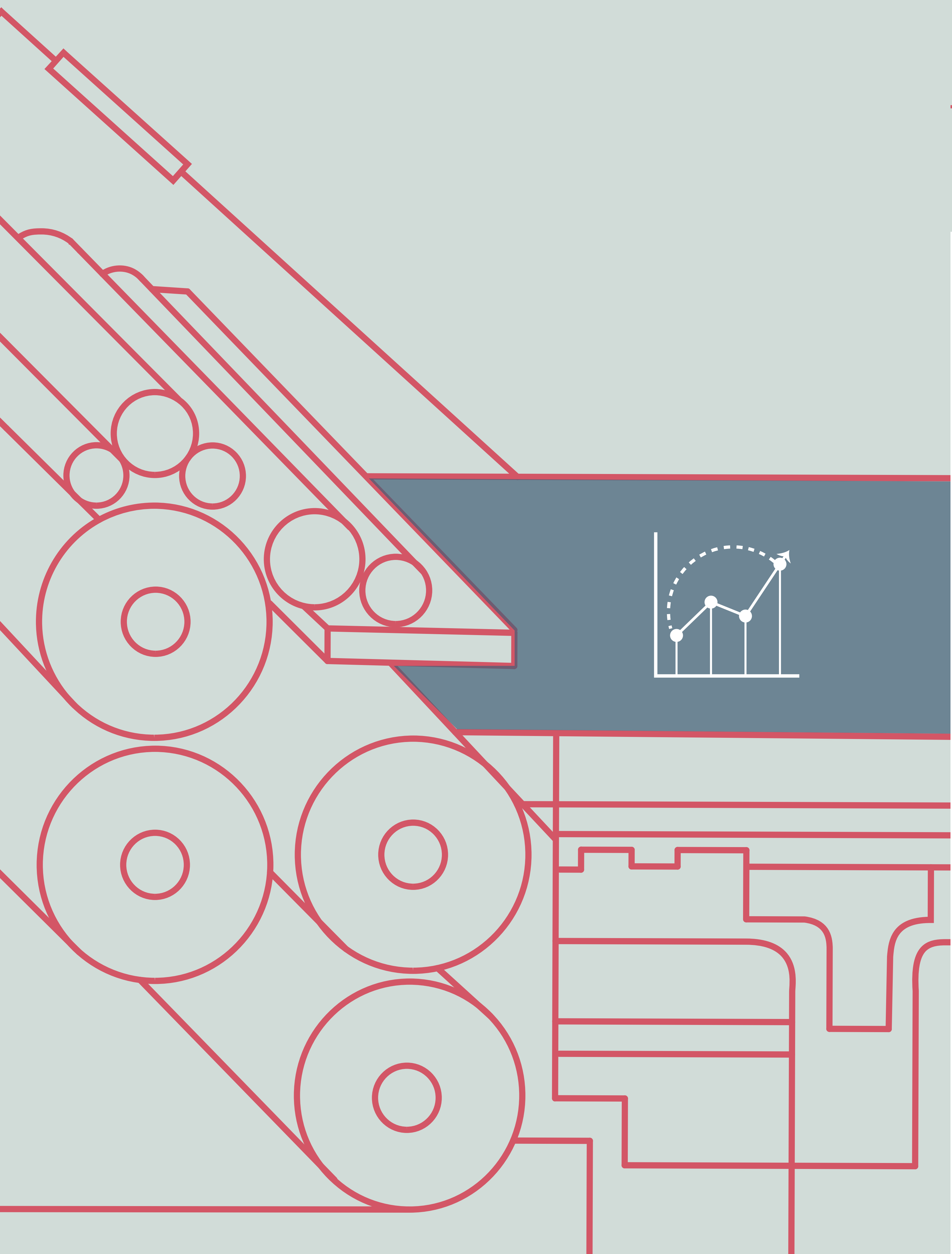
Table 67: Techniques for minimizing the amount of solid waste

	Technique	Description	Applicability
a	Fibre and filler recovery and treatment of white water	White water from the paper machine can be treated by the following techniques: » 'Save-all' devices (typically drum or disc filter or dissolved air flotation units etc.) that separate solids (fibres and filler) from the process water. Dissolved air flotation in white water loops transforms suspended solids, fines, small-size colloidal material and anionic substances into flocks that are then removed. The recovered fibres and fillers are recirculated to the process. Clear white water can be reused in showers with less stringent requirements for water quality. » Additional ultra-filtration of the pre-filtered white water results in super clear filtrate with a quality sufficient for use as high pressure shower water, sealing water and for the dilution of chemical additives	Generally applicable
b	Broke recirculation system	Broke from different locations /phases of papermaking process is collected, repulped and returned to the fibre feedstock	Generally applicable
c	Recovery of coating colours/ recycling of pigments	Effluents containing coating colours are collected separately. The coating chemicals are recovered by e.g.: » ultra-filtration; » screening-flocculation dewatering process with return of the pigments to the coating process. The clarified water could be reused in the process.	
d	Reuse of fibre sludge from primary waste water treatment	Sludge with a high fibre content from the primary treatment of waste water can be reutilised in a production process	Applicability may be limited by product quality requirements

Table 68: Techniques for Energy Consumption and Efficiency

	Technique	Applicability
a	Energy saving screening techniques (optimised rotor design, screens and screen operation)	Applicable to new mills or major refurbishments
b	Best practice refining with heat recovery from the refiners	
c	Optimised dewatering in the press section of paper machine/wide nip press	Not applicable to tissue paper and many speciality papers grades
d	Steam condensate recovery and use of efficient exhaust air heat recovery systems	Generally applicable
e	Reduction of direct use of steam by careful process integration using e.g. pinch analysis	
f	High efficient refiners	Applicable to new plants
g	Optimisation of the operating mode in existing refiners (e.g. reduction of no load power requirements)	Generally applicable
h	Optimised pumping design, variable speed drive control for pumps, gearless drives	
i	Cutting edge refining technologies	

	Technique	Applicability
j	Steam box heating of the paper web to improve the drainage properties/ dewatering capacity	Not applicable to tissue paper and many speciality papers grades
k	Optimised vacuum system (e.g. turbo fans instead of water ring pumps)	Generally applicable
l	Generation optimisation and distribution network maintenance	
m	Optimisation of heat recovery, air system, insulation	
n	Use of high efficient motors (EFF1)	
o	Preheating of shower water with a heat exchanger	
p	Use of waste heat for sludge drying or upgrading of dewatered biomass	
q	Heat recovery from axial blowers (if used) for the supply air of the drying hood	
r	Heat recovery of exhaust air from the Yankee hood with a trickling tower	
s	Heat recovery from the infrared exhaust hot air	



STATUS AND ISSUES RELATED TO BAT AND POTENTIAL FOR APPLICABILITY

5

A comparison of findings described in chapter 3 with the state–of-the-art technologies described in chapter 4. This chapter will address the challenges and how to overcome some of the experienced issues.

Sections 5.1 to 5.5 follow partly the same structure as Chapter 4.7, where observations described in Chapter 3.4 are taken into account.

Section 5.6 gives a qualitative evaluation of the status of part of the technologies seen in the visited mills. This section is merely a subjective assessment of the observations made during the rather short visit to the different units. The observations are structured according to a normal process flow in most pulp and paper mills and discussions. The chapter describes the relevant Best Available Technology (BAT) comparisons and recommendations for the potential of their application in the context of the Indian paper industry.

Section 5.7 gives a summary of the qualitative assessment of the status of parts of the technology seen in the mills and some points not discussed with basis in the BAT.

It is not considered whether the best available techniques are possible to implement for the Indian pulp and paper industry (i.e. economic considerations are not included). However, the techniques should be known for the technical staff at the different mills and is definitely something to strive for.

Also note that the evaluation given in this chapter is based on a small selection of units, a more thorough assessment of the actual performance of the mills (including efficiency of different process steps) would require a more thorough benchmarking.

5.1. Raw material handling and preparation

As described in BAT 42:

5.1.1. Raw material handling

As described in BAT 42, the techniques and their applicability with respect to raw material handling in the Indian context are discussed in Table 69.

Table 69: Raw Material Handling

Technique	Applicability	Evaluation
Hard surfacing of the storage area for paper recycling	Generally applicable	» Varied for the visited units. Did not seem to be the general practice.
Collection of contaminated run-off water from the paper for recycling storage area and treatment in a waste water treatment plant (uncontaminated rainwater e.g. from roofs can be discharged separately)	Applicability may be restricted by the degree of contamination of runoff water (low concentration) and/or the size of the waste water treatment plants (large volumes)	» This was not observed in any of the mills visited.
Surrounding the terrain of the paper for recycling yard with fences against wind drift	Generally applicable	» Was partly practiced as many of the mills were surrounded by fences.
Regularly cleaning the storage area and sweeping associated roadways and emptying gully pots to reduce diffuse dust emissions. This reduces wind-blown paper debris, fibres and the crushing of paper by on-site traffic, which can cause additional dust emission, especially in the dry season	Generally applicable	» The degree of cleaning of the sites varied. » Quite a few of the mills had waste lying around in the mill area (also partly inside the mills/around the papermachines). » Practice may in general be improved.
Storing of bales or loose paper under a roof to protect the material from weather influences (moisture, microbiological degradation processes, etc.)	Applicability may be restricted by the size of the area	» Some of the mills visited had the bales stored under roof, while others stored the bales in open air.

5.1.2. Raw material preparations

Table 70: Raw Material Preparations

Technique	Description	Applicability	Evaluation
Wood-Based Mills » Dry debarking of wood logs	Dry tumbling drums (water being used in washing of logs, and then recycled with only a minimum purge to the waste water treatment plant)	Generally applicable	» Did not seem to be the general practice. Only a few of the mills received the wood debarked at source including the mill visited. Whereas some mills use wood without debarking.
Bagasse-Based Mills » Depithing Process for efficient removal of pith from bagasse	Two stage depithing process involving moist depithing followed by wet cleaning is adopted for efficient removal of pith from bagasse before pulping.	Generally applicable, however, single stage moist depithing process also in practice.	» Few of the large bagasse-based paper mills, including the mills visited, used two stage depithing process, whereas the other mills generally had the single stage moist depithing process.
Wheat Straw-Based mills » Wet cleaning of Wheat Straw	Wet cleaning of wheat straw for removal of adhered inorganic material like silica and non-process aliments.	Generally applicable	» Was practiced in a majority of the mills visited.
Recycled Waste Paper-Based Mills » Storage and Handling	Need to segregate and sort out the foreign material both to remove waste components such as plastic and also to improve sorting of the paper into different product category (tailor for the product; the right fibre for the right product). From the paper makers point of view the bales should contain minimum impurities (plastics), economic action may be taken by the paper makers as leverage towards the supplier to improve the quality. This would force the supplier to improve their internal sorting system, thus reducing impurity related issues in the paper mills to a minimum.	No application in Indian mills, however, generally applicable in European mills	» None of the mills visited received the sorted raw material. Thereby facing the issue of plastic waste generated in ample quantity in these mills.

5.2. Pulping and chemical recovery process

As described in BAT 19 (for the Kraft process, but also relevant for the soda process), the techniques for pulping and chemical recovery process, and their applicability in the Indian context are discussed in Table 71.

Table 71: Pulping and Chemical Recovery Process

Technique	Description	Applicability	Evaluation
Modified cooking before bleaching	More details in section 5.5.	Generally applicable	» Both batch and continuous digesters were observed in the mills visited. » The efficiency (energy) of the digesters is questionable. » One of the mills cooked the pulp to a fairly high kappa number (giving a high load to the effluent treatment plant from the bleaching).
Oxygen delignification before bleaching		Generally applicable	» This did not seem to be common practice. » Improved delignification would reduce bleaching chemical consumption and effluent load.
Closed brown stock screening and efficient brown stock washing		Generally applicable	» Advanced systems like wire belt washers were not observed. » A screw press to remove dissolved substances before the bleaching is generally seen as beneficial both for bleaching chemical consumption and effluent load.
Partial process water recycling in the bleach plant		Water recycling may be limited due to incrustation in bleaching	» The details regarding the water streams were not observed. However, a general impression is that the water systems in the mills have room for improvement.
Effective spill monitoring and containment with a suitable recovery system		Generally applicable	» No automatic systems were observed.
Maintaining sufficient black liquor evaporation and recovery boiler capacity to cope with peak loads		Generally applicable	» No issues regarding the capacity were identified. » The technology used in the recovery boilers was not assessed.
Firing of high black liquor solids in chemical recovery boilers through Liquid Heat Treatment (LHT) process		Generally applicable	» The LHT process was generally not adopted. » However, the medium-sized agro-based paper mills using conventional chemical recovery has great potential to adopt the process which should enable these mills to improve efficiency of energy consumption and chemical recovery besides the advantage of reduced emissions.

5.3. Papermaking

As described for BAT 47, the techniques and their applicability with respect to papermaking in the Indian context are discussed in Table 72.

As described in BAT48, the techniques and their applicability with respect to papermaking in the Indian context are discussed in Table 73.

Table 72: Papermaking (1)

Technique	Description	Applicability	Evaluation
Optimum design and construction of tanks and chests	More details in section 5.5.	Applicable to new plants and to existing plants in the case of a major refurbishment	» This was not considered to be problematic. However, this is something to be aware of when increasing production.
Fibre and filler recovery and treatment of white water		Generally applicable	» In general there seemed to be a lack of kidneys (internal cleaning) in the white water systems which is again, an issue related to water handling.
Water recirculation		Generally applicable. Dissolved organic, inorganic, and colloidal materials may restrict the water reuse in the wire section	» In general, cleaning systems for the water in the mills seemed to be poor. » Several issues experienced related to poor water quality.
Optimisation of showers in the paper machine		Generally applicable	» Once again an issue related to water handling – use of right water at the right place.

Table 73: papermaking (2)

Technique	Description	Applicability	Evaluation
Improvement of paper production planning	Improved planning to optimise production batch combinations and length.	Generally applicable	» An issue not covered during the visits, but something to be aware of in mills alternating between several products.
Management of water circuits to fit changes	Adjust water circuits to be able to cope with changes of paper grades, colours and chemical additives used.		» Same as above, but as mentioned earlier the water systems in general were not optimal.
Waste water treatment plant ready to cope with changes	Adjust waste water treatment to be able to cope with variations of flows, low concentrations and varying types and amounts of chemical additives.		» This did not seem to be a common practice in the Indian mills.
Adjustment of the broke system and of chest capacities			» Broke was typically sent back to pulper. A separate system for handling broke did not seem to be common.
Minimisation of release of chemical additives (e.g. grease-/water proof agents) containing per- or polyfluorinated compounds or contributing to their formation		Applicable only for plants producing paper with grease- or water-repellent properties	
Switch to low AOX-containing product aids (e.g. to substitute use of wet strength agents based on epichlorohydrin resins)		Applicable only for plants producing paper grades with high wet strength	» Chemical agents used at the different units were not assessed. However, optimization of the chemicals used should be done.

5.4. Effluent treatment

Table 74 gives the techniques to reduced fresh water consumption/pollution load in fresh water as described in BAT.

Table 74: Effluent Treatment

Technique	Description	Evaluation
Primary treatment	» Physico-chemical treatment, such as equalisation, neutralisation or sedimentation. Equalisation (e.g. in equalising basins) is used to prevent large variations in flow rate, temperature and contaminant concentrations and thus to avoid overloading the waste water treatment system.	» Most of the mills visited had a combination of primary, secondary (both aerobic and anaerobic) and tertiary treatment. Several of the mills had issues related to reaching their pollution limits, something that indicates that the effluent treatment plants are not fully optimized. » Optimal water management in the mills to reduce load to the effluent should be focused (from digesting, bleaching, internal water cleaning etc.). » The potential to improve the efficiency of the effluent treatment plants exists. » The mills seemed to have no to little control of the water streams sent to the effluent treatment plant, but more control of the water quality of the treated effluent. Control of internal water streams, their composition and variation would be beneficial.
Secondary (biological) treatment	» For the treatment of waste water, by means of microorganisms, the available processes are aerobic and anaerobic treatment. In a secondary clarification step, solids and biomass are separated from effluents by sedimentation, sometimes combined with flocculation.	
a) Aerobic treatment	» In aerobic biological waste water treatment, biodegradable dissolved and colloidal material in the water is transformed in the presence of air by microorganisms partly into a solid cell substance (biomass) and partly into carbon dioxide and water. » Processes used are: • one- or two-stage activated sludge; • biofilm reactor processes; • biofilm/activated sludge (compact biological treatment plant). This technique consists of combining moving bed carriers with activated sludge (BAS). » The generated biomass (excess sludge) is separated from the effluent before the water is discharged.	
b) Combined anaerobic-aerobic treatment	» Anaerobic waste water treatment converts the organic content of waste water by means of microorganisms in the absence of air, into methane, carbon dioxide, sulphide, etc. The process is carried out in an airtight tank reactor. The microorganisms are retained in the tank as biomass (sludge). The biogas formed by this biological process consists of methane, carbon dioxide and other gases such as hydrogen and hydrogen sulphide and is suitable for energy generation. » Anaerobic treatment is to be seen as pre-treatment before aerobic treatment, due to the remaining COD loads. Anaerobic pre-treatment reduces the amount of sludge generated from biological treatment.	
Tertiary treatment	» Advanced treatment comprises techniques, such as filtration for further solids removal, nitrification and denitrification for nitrogen removal or flocculation/precipitation followed by filtration for phosphorus removal. » Tertiary treatment is normally used in cases where primary and secondary biological treatment are not sufficient to achieve low levels of TSS, nitrogen or phosphorus and/or colour, which may be required e.g. due to local conditions.	
Properly designed and operated biological treatment plant	» A properly designed and operated biological treatment plant includes the appropriate design and dimensioning of treatment tanks/basins (e.g. sedimentation tanks) according to hydraulic and contaminant loads. » Low TSS emissions are achieved by ensuring the good settling of the active biomass. » Periodical revisions of the design, dimensioning and operation of the waste water treatment plant facilitate achieving these objectives.	

5.5. Techniques to reduce fresh water use, waste water flow and the pollution load in waste water

As described in Chapter 8.7.2 in BAT, Table 75 gives the description of techniques to reduce fresh water use/waste water flow and the pollution load in waste water.

Table 75: Description of the Techniques for Reducing Fresh Water Use/Waste Water Flow and the Pollution Load in Waste Water

Technique	Description	Evaluation
Dry debarking of wood logs	» Dry debarking of wood logs in dry tumbling drums (water being used only in washing of the logs, and then recycled with only a minimum purge to the waste water treatment plant).	» Debarking was not observed.
Totally chlorine free bleaching (TCF)	» In TCF bleaching, the use of chlorine containing bleaching chemicals is completely avoided and thus so are the emissions of organic and organochlorinated substances from bleaching.	» Both hypochlorite and chlorine bleaching was observed. The mills should aim for other bleaching sequences to reduce use of chlorine based bleaching chemicals (TCF or ECF).
Modern elemental chlorine free (ECF) bleaching	» Modern ECF bleaching minimises the consumption of chlorine dioxide by using one or a combination of the following bleaching stages: oxygen, hot acid hydrolysis stage, ozone stage at medium and high consistency, stages with atmospheric hydrogen peroxide and pressurised hydrogen peroxide or the use of a hot chlorine dioxide stage.	» Chlorine dioxide was not observed in any of the mills visited. However, mills using chlorine dioxide exist in India.
Extended delignification	» (a) modified cooking or (b) oxygen delignification enhances the degree of delignification of pulp (lowering the kappa number) before bleaching and thus reduces the use of bleaching chemicals and the COD load of waste water. » Lowering the kappa number by one unit before bleaching can reduce the COD released in the bleach plant by approximately 2 kg COD/ADt. » The lignin removed can be recovered and sent to the chemicals and energy recovery system.	» As already mentioned, there is a potential to optimize both cooking and bleaching to reduce pollution load to the effluent treatment plants.
(a) Extended modified cooking	» Extended cooking (batch or continuous systems) comprises longer cooking periods under optimised conditions (e.g. alkali concentration in the cooking liquor is adjusted to be lower at the beginning and higher at the end of the cooking process), to extract a maximum amount of lignin before bleaching, without undue carbohydrate degradation or excessive loss of pulp strength. » Thus, the use of chemicals in the subsequent bleaching stage and the organic load of the waste water from the bleach plant can be reduced.	
(b) Oxygen delignification	» Oxygen delignification is an option to remove a substantial fraction of the lignin remaining after cooking, in case the cooking plant has to be operated with higher kappa numbers. » The pulp reacts under alkaline conditions with oxygen to remove some of the residual lignin.	» This did not seem to be common practice. Improved delignification would reduce bleaching chemical consumption and effluent load.

Closed and efficient brown stock screening and washing	» Brown stock screening is carried out with slotted pressure screens in a multistage closed cycle. Impurities and shives are thus removed at an early stage in the process. » Brown stock washing separates dissolved organic and inorganic chemicals from the pulp fibres. » The brown stock pulp may be washed first in the digester, then in high efficiency washers before and after oxygen delignification, i.e. before bleaching. » Carry-over, chemical consumption in bleaching, and the emission load of waste water are all reduced. » Additionally, it allows for recovery of the cooking chemicals from the washing water. » Efficient washing is done by counter-current multistage washing, using filters and presses. » The water system in the brown stock screening plant is completely closed.	» Advanced systems like wire belt washers were not observed. High dry content both before bleaching and after bleaching (i.e. before the paper machine) will be beneficial.
Partial process water recycling in the bleach plant	» Acid and alkaline filtrates are recycled within the bleach plant counter-currently to the pulp flow. Water is purged either to the waste water treatment plant or, in a few cases, to post-oxygen washing. » Efficient washers in the intermediate washing stages are a prerequisite for low emissions. A bleach plant effluent flow of 12 – 25 m^3/ADt is achieved in efficient mills (kraft).	» Based on the observations there seems to be no good practice for this (based on how the bleaching chemicals were dosed in some of the mills visited).
Effective spill monitoring and containment, also with chemical and energy recovery	» An effective spill control, catchment and recovery system that prevents accidental releases of high organic and sometimes toxic loads or peak pH values (to the secondary waste water treatment plant) comprises: • conductivity or pH monitoring at strategic locations to detect losses and spills; • collecting diverted or spilled liquor at the highest possible liquor solids concentration; • returning collected liquor and fibre to the process at appropriate locations; • preventing spills of concentrated or harmful flows from critical process areas (including tall oil and turpentine) from entering the biological effluent treatment; • adequately dimensioned buffer tanks for collecting and storing toxic or hot concentrated liquors.	» Process monitoring systems seemed to be rare or non-existent. This includes both automatic systems and manual measurements. » Not only control of the internal water loops, but also control of the chemical properties of the water would benefit the mills.
Maintaining sufficient black liquor evaporation and recovery boiler capacity to cope with peak loads	» Sufficient capacity in the black liquor evaporation plant and in the recovery boiler ensure that additional liquor and dry solids loads due to the collection of spills or bleach plant effluents can be dealt with. » This reduces losses of weak black liquor, other concentrated process effluents and potentially bleach plant filtrates. » The multi-effect evaporator concentrates weak black liquor from brown stock washing and, in some cases, also bio-sludge from the effluent treatment plant and/or salt cake from the ClO_2 plant. » Additional evaporation capacity above normal operation gives sufficient contingency to recover spills and to treat potential bleach filtrate recycle streams.	» No issues regarding the capacity were identified. The technology used in the recovery boilers was not assessed. » The capacity of the recovery systems might be too small if the stream of dissolved organic material was increased (related to increased delignification to decrease load on effluent treatment plant).
Stripping the contaminated (foul) condensates and reusing the condensates in the process	» Stripping the contaminated (foul) condensates and reuse of condensates in the process reduces the fresh water intake of a mill and the organic load to the waste water treatment plant. » In a stripping column, steam is lead counter-currently through the previously filtered process condensates that contain reduced sulphur compounds, terpenes, methanol and other organic compounds. » The volatile substances of the condensate accumulate in the overhead vapour as non-condensable gases and methanol and are withdrawn from the system. » The purified condensates can be reused in the process, e.g. for washing in the bleach plant, in brown stock washing, in the causticising area (mud washing and dilution, mud filter showers), as TRS scrubbing liquor for lime kilns, or as white liquor make-up water. » The stripped non-condensable gases from the most concentrated condensates are fed into the collection system for strong malodorous gases and are incinerated. Stripped gases from moderately contaminated condensates are collected into the low volume high concentration gas system (LVHC) and incinerated	
Evaporating and incinerating effluents from the hot alkaline extraction stage	» The effluents are first concentrated by evaporation and then combusted as bio-fuel in a recovery boiler. Sodium carbonate containing dust and smelt from the furnace bottom are dissolved to recover soda solution.	
Recirculation of washing liquids from pre-bleaching to brown stock washing and evaporation to reduce emissions from MgO-based pre-bleaching	» Prerequisites for the use of this technique are a relatively low kappa number after cooking (e.g. 14 – 16), sufficient capacity of tanks, evaporators and recovery boiler to cope with additional flows, the possibility to clean the washing equipment from deposits, and a moderate brightness level of the pulp (≤ 87 % ISO) as this technique may lead to a slight loss of brightness in some cases. » For market paper pulp producers or others that have to reach very high brightness levels (> 87 % ISO), it may be difficult to apply MgO pre-bleaching.	
Counter-current flow of process water	» In integrated mills, fresh water is introduced mainly through the paper machine showers from which it is fed upstream towards the pulping department.	» This was not the common practice.
Separation of water systems	» Water systems of different process units (e.g. pulping unit, bleaching and paper machine) are separated by washing and dewatering the pulp (e.g. by wash presses). » This separation prevents carry-over of pollutants to subsequent process steps and allows for removing disturbing substances from smaller volumes.	» No good practice and seemingly low control of the water systems in the mill.
High consistency (peroxide) bleaching	» For high consistency bleaching, the pulp is dewatered e.g. by a twin wire or other press before bleaching chemicals are added. » This allows for more efficient use of bleaching chemicals and results in a cleaner pulp, less carry-over of detrimental substances to the paper machine and generates less COD. » Residual peroxide may be re-circulated and reused.	» High consistency bleaching did not generally seem to be done in practice.

Fibre and filler recovery and treatment of white water	» White water from the paper machine can be treated by the following techniques: » 'Save-all' devices (typically drum or disc filter or dissolved air flotation units etc.) that separate solids (fibres and filler) from the process water. Dissolved air flotation in white water loops transforms suspended solids, fines, small-size colloidal material and anionic substances into flocks that are then removed. The recovered fibres and fillers are re-circulated to the process. Clear white water can be reused in showers with less stringent requirements for water quality. » Additional ultra-filtration of the pre-filtered white water results in super clear filtrate with a quality sufficient for use as high pressure shower water, sealing water and for the dilution of chemical additives.	» In general there seemed to be a lack of kidneys (internal cleaning) in the white water systems.
Clarification of white water	» The systems for water clarification used almost exclusively in the paper industry are based on sedimentation, filtration (disc filter) and flotation. » The most commonly used technique is dissolved air flotation. Anionic trash and fines are agglomerated into physically treatable flocs by using additives. » High-molecular, water-soluble polymers or inorganic electrolytes are used as flocculants. » The generated agglomerates (flocs) are then floated off in the clarification basin. In dissolved air flotation (DAF), the suspended solid material is attached to air bubbles.	
Water recirculation	» Clarified water is re-circulated as process water within a unit or in integrated mills from the paper machine to the pulp mill and from the pulping to the debarking plant. » Effluent is mainly discharged from the points with the highest pollution load (e.g. clear filtrate of the disc filter in pulping, debarking).	
Optimum design and construction of tanks and chests (papermaking)	» Holding tanks for stock and white water storage are designed so that they can cope with process fluctuations and varying flows also during start-ups and shutdowns.	» This was not considered to be problematic. However, this is something to be aware of when increasing production.
Substitution of NaOH by $Ca(OH)_2$ or $Mg(OH)_2$ as alkali in peroxide bleaching	» The use of Ca(OH)2 as alkali results in approximately 30% lower COD emission loads; while keeping brightness levels high. » Also Mg(OH)2 is used to replace NaOH.	» This is something that has been done in several mills in Europe. NaOH seems to still be most common in India.

5.6. Potential for applicability of identified BAT in the Indian paper industry

Most of the paper mills visited used recycled waste paper-based and agro-based raw materials to produce packaging grade paper/duplex board, whereas one of the mills, equipped with advance de-inking process, used RCF to produce a bleached variety of paper. The large wood-based paper mill visited also used bagasse and purchased pulp to produce superior quality paper and board, like writing printing/white board and tissue paper etc. Furthermore, a medium-sized agro-based paper mill visited used wheat straw/bagasse as major raw material, and produced a bleached variety of writing and printing grade paper.

However, it was observed that recycled waste paper was one of the most abundantly used raw materials, followed by wood and the least used raw material was agro-based (wheat straw/ bagasse/ lake reeds, etc.). A small quantity of imported market pulp with longer fibre had also been blended to produce a high-end product as per the need. The recycled paper used in the Indian paper industry was a mix of both local and imported paper grades.

5.6.1. Raw material preparation and handling

The units visited had different practices of handling and processing the different kinds of raw materials, depending on the mill size, type of raw material and variety of paper being produced.

5.6.1.1. Large wood-based paper mill

In this mill, Eucalyptus was used as a major raw material for manufacturing high quality bleached writing/printing grade paper. The wood (Eucalyptus) received at the mill was debarked at source. However, some of the wood-based mills in India also use the wood without debarking it (mills not visited during this particular visit). For these mills it is advisable to debark the wood by adopting dry debarking of the wood logs in dry tumbling drums (water being used only when washing logs and then recycled to minimize the effluent treatment plant (ETP) load.

Some of these large integrated paper mills (including the mills visited) also use bagasse as the another major raw material for paper manufacturing in its furnish. These mills use the advanced depithing process involving a two stage depithing operation-consisting of moist depithing followed by wet cleaning for efficient removal of pith and adhered sugars. The wet bagasse is stored using the advanced technique of storage i.e. wet bulk storage, considered to be a global best practice. In this mill, the recycled waste paper and imported pulp was stored properly under the shed to avoid deterioration of the quality of the paper and pulp, which is one of the globally best available practices.

5.6.1.2. Medium size agro-based paper mill producing bleached variety of writing and printing grade paper

Other medium size paper mills visited used bagasse and wheat straw as a major raw material for producing a bleached variety of white writing and printing grade paper. The raw material handling and preparation was among the globally best techniques which involved the wet washing and cleaning of the wheat straw and moist depithing technique for depithing of bagasse.

5.6.1.3. Recycled waste paper-based mills producing unbleached variety of paper and paperboard

The different units had different practices when it came to storage of raw materials. Some of the paper mills stored the raw materials indoors/under a roof, while others stored the raw materials outdoors. Depending on climate, the storage will have an adverse effect on the quality of the raw material. Especially when it comes to lignin containing recycled waste paper, storage in direct sun light will promote yellowing of the paper (with a subsequent potential increased consumption of bleaching chemicals). Also, storage under wet conditions will increase fungal/microbial growth which may result in darkening and degradation of fibrous material. Thus, depending on the size of the raw material storage and the average time for storage, this can have a large effect on the quality of the fibres and have a detrimental effect on the final paper quality.

The flooring where the raw materials were stored also varied from mill to mill. Some stored the raw materials on gravel, while other mills stored the raw material on concrete flooring. Storage on gravel may give rise to impurities in the material before pulping, thus introducing unwanted components (such as inorganics) into the process and cause wear of the process equipment. This is especially the case in the mills where the raw material is transferred from storage to the pulping process by mechanical means (e.g. by tractors).

Manual labour seemed to be widely used for the raw material handling in most of the mills visited. The manual labour may be an important step in the removal of e.g. plastic from the recycled paper, but also when it came to sorting the right fibres for the right product. Ideally the recycled paper should be sorted before it enters the raw material storage (both regarding plastic waste and paper quality), thus making manual labour less important and also improving the overall efficiency of the raw material handling.

Overall, good practice when it comes to storage and handling the raw material is the first important step in order to ensure good product quality and less process variations.

With regards to addressing the issue of sorting of the recycled waste paper, there are standard guidelines published by CEPI "Guidelines – paper for recycling quality control"[6] which describe the standard way of doing this in Europe, defining the relationship between supplier and buyer of recycled waste paper. From the papermaker's point of view the bales should contain minimal impurities (e.g. plastics) thus avoiding any impurity related issues. Economic actions may be taken by the papermaker as leverage towards the supplier to improve the quality (the market situation may restrict this unless united actions are undertaken by several buyers/papermakers). This would force the suppliers to improve their internal sorting systems thus reducing impurity related issues in the paper mills to a minimum (another benefit of this would be a more "concentrated" collection of plastic material in general, thus making subsequent processing of plastics easier). A sorting system even closer to the consumer (e.g. by local sorting stations) would make this easier for the recycled paper supplier as well. One challenge is that there are few incentives that can force the consumer to sort plastic and a solution to this would require a change in attitude and habits.

5.6.2. Pulping processes

Indian paper mills used a wide range of pulping practices depending on the type of raw material used.

In most of the large wood-based paper mills, pulping of wood-based raw material

[6] Confederation of European Paper Industries (CEPI), 2016. *Paper for Recycling Quality Control-Guidelines. Revised Edition, April, 2016.* [Online] Available at: ‹http://www.cepi.org/system/files/public/documents/publications/recycling/2016/PaperforRecyclingQuality%20Control%20Guidelines.pdf› [Accessed on November 2, 2016].

was carried out in continuous (stationary) digesters, using Rapid Displacement Heat (RDH) pulping process followed by the oxygen delignification (ODL) process to reduce the kappa number of the pulp which is considered to be the global best practice. In medium/large agro-based mills producing a bleached variety of writing and printing grade paper and paperboard, the most common practice of pulping is the use of continuous Pandia digesters with or without using an ODL step. The aim is to produce pulp with low kappa number before bleaching, to reduce the chemical requirement during bleaching and reduce the ETP load. However, adoption of extended modified cooking process, identified as one of the global BAT may further help these mills to facilitate efficient delignification with the added advantage of prevention of loss of carbohydrates and less pollution.

In another category of agro-based paper mills producing unbleached varieties of paper, most of the mills used stationary batch digesters using comparatively less cooking chemical charge, which is considered to be less efficient compared to continuous Pandia digesters in respect of consumption of steam and electrical energy. With regards to pulping of recycled waste-based paper, various types of pulpers (ranging from low consistency to high consistency) were used including efficient drum pulpers (only in few mills). The efficiency of these pulpers varies due to variation in pulp consistencies and retention time, which ultimately may have a reflection on the quality of pulp and energy consumption. However, efficiency was not assessed during the visit, but the available information suggested that there is room for optimization and/or modification of the process to make it more efficient and eco-friendly.

5.6.3. Screening and washing of brown stock

Brown stock screening is carried out with slotted pressure screens in a multistage closed cycles. Impurities and shives are removed at an early stage in the pressure screen.

Advanced systems of brown stock washing were not observed. Achieving higher pulp consistency of washed pulp before bleaching would be beneficial in respect to less soda/COD carryover, thereby requiring less bleach chemical demand and producing less pollution loads.

A majority of the medium and small agro-based mills use an conventional washing system, comprising of three stages counter current vacuum drum washers with incorporated screw presses before the drum washers (in the case of few of the mills). However, in large sized wood/ agro-based paper mills, few of these have adopted more advanced technologies such as twin roll presses before the bleaching stage to reduce the soda/tds carryover to the bleach plant. This helps to reduce bleaching chemical demand and pollution loads. Additionally, it allows for recovery of cooking chemicals from the washing liquor.

Possibilities of adoption of advanced washing systems viz. horizontal belt washers, chemiwashers, and/or twin roll presses may be explored depending on the size of the mills and end products.[7,8,9]

[7] Voith, 2016. ValmetTwinRoll Evolution - Refining a Unique Tradition. [Online] Available at: ‹www.voith.com/paper›.
[8] Voith, 2016. Voith_Thune_Screw_Press - The New Generation of Dewatering from Voith. [Online] Available at: ‹www.voith.com/Paper›.
[9] Witthuhn, V., 2015. *Biosolids Dewatering Equipment Comparisons.* In: WWOA Annual Operators' Meeting, October 5, 2015. Strand Associates, Inc. Available at: ‹https://www.wwoa.org/files/publishedpapers/2015/Annual%20Conference%202015/VCW%20WWOA%20Annual%20Meeting%20-%20Dewatering%20Evaluations-%20October%202015.pdf› [Accessed on 2 November 2016].

5.6.4. Bleaching

The smell of bleaching chemicals was quite strong in many of the mills. This raises the question whether the pulp washing was optimal after the bleaching step. A common practice of measuring residual chlorine after bleaching did not seem to exist. The mills visited also used chlorine and hypochlorite in the bleaching process. From an environmental perspective, the mills should aim for bleaching sequences without elemental chlorine (TCF, ECF).

A wide range of bleaching chemicals and layouts were observed in the paper mills depeding upon raw materials and the size of the mills. A majority of the medium-sized agro-based paper mills (visited mill also) had bleaching sequences with elemental chlorine stages. However, the majority of large-sized wood/agro-based paper mills used elemental chlorine free (ECF) bleaching sequences comprising chlorine dioxide along with hydrogen peroxide during extraction stage. In the case of recycled waste paper-based mills producing bleached varieties of paper, bleaching technology was old and obsolete and environmentally unfriendly. These used calcium hypochlorite as the bleach chemical added directly to the hydra pulper and/or in the chest before the decker washer.

Optimization of the bleaching process could benefit the mills with regards to both usages of bleaching chemicals and from the viewpoint of environmental aspects. Generally good mixing, correct temperature and residence time, before washing are required for an optimum bleaching efficiency combined and also minimum costs for bleaching chemicals.

5.6.4.1. Layout of bleaching in RCF based mills

The recommended layout of bleaching in RCF based mills is to have a thickening step in the process to separate the water loops. This step is normally a disc filter or a screw press. Even the simplest process layout with no bleaching should include a thickening step to separate the individual water loops and maintain the counter-current principle. The thickening stages combined with water loop separation are essential to reduce the amount of contaminants in the process water. A variety of equipment may be used for dewatering/thickening; disc filters, wire presses and screw presses. The aim is to achieve high pulp consistency and to keep the water loops separated. A techno-economic assessment should determine the layout for case to case[10,11].

The bleaching is not done according to the recommended layout everywhere. The best practice would include for each bleaching stage: mixing-bleaching reactor-washing. Inclusion of these steps is essential to reduce the amount of released material that causes disturbances later in the process and is also important for a best possible bleaching efficiency.

With regards to bleaching of RCF it is important to consider the type of fibres in the pulp (as the RCF may contain a mix of different fibres). As RCF often contains impurities, effective washing and cleaning is important (also often combined with the use of chelating agents). If the RCF contains chemical fibres a combination of oxidative (e.g. oxygen, peroxide and ozone) and a reductive (dithionite, FAS) bleaching may be used. In areas where the RCF may contain mechanical fibres e.g. peroxide, ozone and hydrosulphite may be used.

[10] Gillette, R., Swanback, S. and Overacre, R., 2009. *Improving Efficiency of Dewatering Alternatives to Conventional Dewatering Technologies*. PNCWA Webinar Recent Developments In Biosolids Management Processes. Available at: ‹http://www.pncwa.org/assets/documents/Alternative%20Dewatering%20Technologies%20Gillette%20200908%20pncwa.pdf› [Accessed on 2 November, 2016].

[11] Moss, L., 2012. Trends in Dewatering. Webinar, December 18, 2012. Available at: ‹http://www.weat.org/events/2012MossWEATDewateringTrends.pdf› [Accessed on 2 November 2016].

5.6.4.2. Recommended layout of bleaching of virgin wood/non-wood-based pulp:

The use of an efficient pulping process combined with an efficient oxygen delignification will not only reduce the bleaching chemicals needed but should also help in reducing the pollution loads in the effluents besides improving the quality of the product.

There are a huge variety of bleaching processes (as most process layouts) depending on both raw material and product. The chosen layout will have an impact on cost, quality and energy consumption, and must be chosen based on the aimed product performance. The choice between ECF and TCF for bleaching of virgin pulp is also partly dependant on the market situation as well as any local environmental restrictions.

Typical ECF bleaching sequences for a pulp subjected to an oxygen delignification could be; D-EOP-D, D-E-D-E-D-E, Z-E/O-D-P/O, D-E-D-D etc. All ECF sequences uses chlorine dioxide.

TCF (although considered more costly, and at least one mill has changed from TCF to ECF) it is still possible through sequences such as; Q-Z-P-E-P, Q-OP-Q-PO, Q-OP-Q/Paa-PO. Further, it is possible to fully bleach kraft bagasse pulp using EOPQP sequence.

Ozone is an extremely powerful oxidation agent that can be used for mostly any type of pulp. Optimization, however, is very important as the selectivity is rather low and an excessive dosage affects pulp strength negatively (far less selective than chlorine dioxide)[12, 13, 14]. Other benefits with ozone are the relative high reactivity and reaction rate. Compared to peroxide, where the reaction rate is slow, the demands for bleaching towers with large retention time is lower, thus implementation costs could potentially be lower. For the new implementations in any unit, efficient dewatering of pulp needs attention using dewatering equipment; techno-economic viability must be evaluated from case to case. The laboratory/pilot scale equipment for demonstration of the process could be acquired from CRS reactors[15] or any other international company having expertise in the relevant area to study the techno-economic feasibility in an Indian context.

5.6.5. Chemical recovery operations

A majority of the large wood-based and/or medium-size agro-based paper mills (including the mills visited) were equipped with a conventional chemical recovery system with incorporated advanced evaporation techniques viz. multistage falling film evaporators, recovery boilers, causticizing section and lime kilns.

As per recent charter for environmental compliance[16], all the paper mills producing bleached pulp for paper manufacturing should be equipped with conventional chemical recovery system for efficient management of black liquor. Furthermore, even the smaller paper mills (around 100 tpd capacity) using agro-based raw materials, where the conventional chemical recovery system was not techno-economically feasible, had to install a non-conventional chemical recovery system based on Low Temperature Incineration (LTI Technology), a Bare Minimum Technology (BMT), as per the charter notified for compliance of environmental

[12] Toven, K., 2000. *Ozone Based ECF Bleaching of Softwood Kraft Pulp*. Norwegian University of Science and Technology, Department of Chemical Engineering, PhD Thesis, October, 2000.

[13] Metsä Fibre, 2008.*Rauma Pulp Mill* [Online]. Available at: ‹http://www.metsafibre.com/en/about-us/Pages/Rauma-mill.aspx› [Accessed: 2 November 2016].

[14] Hassan, B., 2003. *Oxygen-Peroxide (Eop) Delignification And Peroxide (P) Bleaching Of Bagasse Kraft Pulp*. Journal of Scientific and Industrial research (J SCI IND RES INDIA) [Online]. Vol. 62, July 2003, pp. 699-706. Available at: ‹https://www.researchgate.net/publication/264782426_Oxygen-peroxide_Eop_delignification_and_peroxide_P_bleaching_of_bagasse_kraft_pulp› [Accessed on 2 November 2016].

[15] ‹www.crs-reactor.com›

[16] Central Pollution Control Board, 2015. *Charter for Water Recycling and Pollution Prevention in Pulp & Paper Industries.* [Online] Available at: ‹http://www.inpaper.com/Annexure-II.pdf› [Accessed on 2 November 2016].

norms. In these mills the chemicals are recovered in the form of sodium carbonate instead of caustic soda, as in case of the medium-sized agro and/ or wood-based mills having conventional chemical recovery systems. The recovered sodium carbonate is normally sold for its utilization in glass and/ or detergent industries.

With regards to the conventional chemical recovery system in the large or/and medium-sized wood/agro-based pulp and paper mills, the weak black liquor is concentrated by evaporation using multiple effect evaporators (falling film). The concentrated black liquor at solid concentration level of 65% -70% (60%-63% in case of agro-based mill) is fired in a chemical recovery furnace followed by causticization. The caustic soda thus recovered (95% recovery efficiency in case of wood-based and around 90% -92% in case of agro-based paper mills) is utilized back in the pulping operation.

5.6.5.1. Firing of black liquor at higher dry solids concentration using Liquor Heating Technology (LHT) in agro-based mills.

In the medium and/or large-sized bagasse/ wheat straw-based paper mills there is a great potential to adopt LHT technology. This is identified as BAT and would help in achieving improved chemical and energy recovery efficiency by firing the black liquor at comparatively higher dry black liquor solids. This would result in extra steam with an added advantage of lower emissions.

The potential of adopting the LHT process in medium and large-sized agro-based mills equipped with a conventional chemical recovery processes needs to be clarified through a techno-economic feasibility study.

In the LHT process, the semi - concentrated black liquor (30% - 35% w/w), is thermally treated in a reactor at a temperature of 180 - 185°C in presence of alkali for a certain time period which results in a drastic reduction in the viscosity of black liquor, making it possible to achieve and fire the black liquor at comparatively higher black liquor solids. Thus, firing of the black liquor at higher dry solids results in extra steam generation with improved chemical recovery efficiency and less SO_x/NO_x emissions. There is a need to demonstrate the LHT process on demonstration pilot/commercial scale and also to develop/design and fabricate the required equipment indigenously with the technical support of international experts/companies.

5.6.5.2. Effective spill monitoring and containment with chemical recovery and energy recovery

Spill monitoring and containment system (including both automatic and manual) seemed to be non-existing or rare. An effective spill control, catchment and recovery system by way of installing conductivity or pH monitoring at strategic locations to direct losses or spills may help in:

- » collecting diverted or spilled liquor at the highest possible liquor solid concentration,
- » returning collected liquor and fibres to the process at appropriate locations, and
- » preventing spills of concentrated and harmful flows from critical process areas from entering the effluent treatment plants.

5.6.5.3. Stripping the contaminated foul condensate and reusing the same in the process

None of the mills visited had a system for stripping the contaminated (foul) condensate and re-using it in the process. This is an important step as it helps to reduce the requirement of fresh water and at the same time reduction in pollution in ETPs. However, as per the information provided very few large wood-based paper mills have adopted the process of stripping of non-condensable gases (NCGs) and incinerating these in the boilers.

5.6.6. Paper making

A wide range of different paper machine layouts were observed in the mills visited (in principle the layout was different in each mill). Both standard Fourdrinier machines and one machine with newer duo formers were observed. Both active dewatering elements such as suction boxes and passive dewatering elements were seen. Several of the machines seemed to be old and quite a few had been built locally in India. Few machines were built by the international leading suppliers of paper machines (Voith, Valmet). An assessment of the efficiency, e.g. electrical consumption of the machines was not done, but this is something that should be done through a benchmark study.

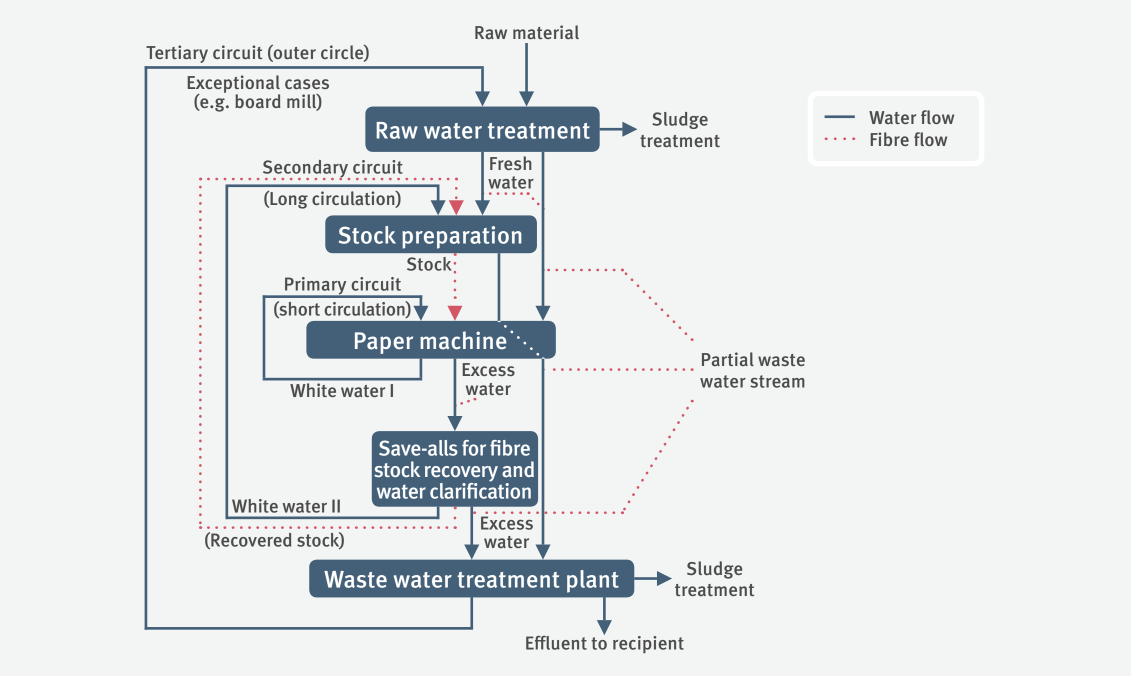
In general many of the mills had rather slow and small paper machines with widths down to 2 metres (even in mills set up after2000). These machines will without doubt lose the benefit of economy of scale.

The retention of the machines was not assessed. However, the impression from the discussions imply that this could be improved.

Different layouts of the press sections of the paper machines were also seen, but a standard 3 nip press section seemed to be the most common. Again, efficiency of the press sections were not assessed as this require measurements compared to nip loads and energy usage.

The layout of the drying sections also varied between the mills (varying from Yankee cylinders to a more normal slalom layout). Few of the observed paper machines had a drying hood installed above the drying sections. A drying hood will reduce the energy consumption during drying and thus improve the drying efficiency, besides improving the work conditions in the mill. The paper quality is also generally improved by using a drying hood combined with a proper hood ventilation system as the drying conditions of the paper across the width of the machine can be controlled and kept equal.

Figure 13: Layout for More Efficient Internal Water Handling



One aspect to note is the internal water handling inside the mills. An evaluation of this would require extensive mapping of the water systems in each mill. The impression is that the awareness of water handling in general was low and that the mills have something to gain when it comes to run-ability and paper quality by following best practices for internal water handling. For a better control of internal water handling, the layout as shown in Figure 13 may provide a better understanding of the different waste water streams/water circuits which should help in reduction of consumption of fresh water and pollution loads in discharged effluents with added advantage of fibre recovery,

The water system of a paper mill may consist of three water loops: the primary circuit, the secondary circuit and, in some cases (e.g. RCF packaging paper mills), the tertiary circuit.

In the primary circuit (short circulation), the fibre-, fines- and filler-rich water obtained in the sheet-forming zone of the wire section (white water I) is recycled for stock dilution in the stock approach flow system. The primary circuit is kept as closed as possible.

Excess water from the sheet-forming section, suction and press water, as well as cleaning water, is called white water II and is circulated in the secondary circuit (long circulation). The white water draining from the wire is typically treated through a 'save-all', which may be a sedimentation plant, flotation plant or a filtration unit (a drum or disc filter). This water is called clarified water.

A disc filter pre-coated/conditioned with raw pulp produces stocks with the highest consistency (10 - 30%) and is designed to produce a three-way (or four-way) separation of the white water into fibre and clarified water. The first draw is cloudy water and the subsequent draws are clear and super clear filtrate. The cloudy filtrate is usually recycled back to the filter as dilution water, but can also replace fresh water in the process or be used for the dilution of the stock. A higher recycling rate of cloudy filtrate back to the disc filter results in a cleaner filtrate. The concentration of suspended solids in the clear filtrate (fines and fillers) is usually about 10 - 150 mg/l for virgin pulp or 100 - 400 mg/l for recycled pulp.

Flotation systems are also used as save-alls. Under operational conditions, the efficiency of flotation for solids removal is up to 90%, resulting in a concentration of suspended solids of 10 –- 50 mg/l (for virgin pulp). The consistency of the floated sludge is between 3% and 10%. Flotation plants consist of a clarifying basin with sludge removal, aeration equipment for a partial stream of clarified water, and a dosing plant for the flotation chemicals. The advantage of flotation is that small-sized colloidal material can also be removed. This is a great advantage in paper recycling plants (with deinking, where a large part of the solid material in the process water is colloidal; in a deinking plant, the floated sludge is pumped to sludge dewatering instead of being recycled to the process).

Sedimentation installations are suitable for the clarification of filler-loaded process water but necessitate large volumes and therefore a large space requirement.

The fibre stream that is recovered in save-alls is returned to the stock chest and the different quality waters are returned to different uses relevant to their quality where replace fresh water.

The tertiary circuit contains excess water from the secondary circuit and, in addition, all other process water which is not directly, reusable because of its degree of contamination. It is treated in chemi-mechanical and/or biological waste water treatment plants. The reuse of treated waste water is not applicable for all paper grades but mainly to some RCF packaging paper mills and in rare cases, to RCF newsprint mills (only one example mill). In those cases, purified water is partially returned to the process (5 - 30 %). Closed water circuits are only realized in a few paper mills producing corrugated medium-based on processing paper for recycling or board.

This description shows that a very large quantity of water is involved at the wet end of a paper machine and there is usually a high degree of water re circulation in different water loops. About 1 - 2 m^3 of process water per tonne of paper is usually evaporated in the dryer section of a machine and is lost from the process. 'Dry' paper in equilibrium with the normal atmosphere is around 6 - 10% water.

Resource management in terms of efficient fibre recovery is standard practice in paper mills. In virgin fibre processing, typically over 98% of the pulp fed through the paper or board machine stock preparation is acceptable for the end product. Paper and board mills achieve minimized losses of fibres and fillers by optimization of the processes given below:

- Screening in stock preparation.
- Wet-end save-alls, the most common being disc filters or flotation cells. Also micro filters with low energy consumption are used. Depending on the application (treatment of the filtrate from screw presses, of vacuum sealing water, of white water for fibre and water recovery, for polishing the water from existing save-alls to a super clear filtrate quality), the filter medium of the micro filter can vary from a very fine 6 µm for special polishing applications up to a coarser quality of 1 000 µm used, for example, for thickening applications.
- Wet- and dry-end broke handling.

In integrated mills, rejects from the screening in stock preparation are normally returned to the pulping department where they are reprocessed. The good stock is sent back to the paper machine.

When the pulp is discharged from the paper machine head box to the wire and starts forming the paper web, a fair amount of fibres and fillers are not retained the first time but are discharged to collection pits under the machine. During the short circuit, the drained water is recycled untreated. The rest of this water is passed through a save-all unit, typically a drum or disc filter or a dissolved air flotation unit, to separate solids from the water stream. These solids are then collected into a chest and are recycled back to the paper machine feed. The clarified water, called white water, is typically collected as clean and cloudy filtrates and is recycled to the appropriate uses in the paper machine: for pulp dilution in the machine stock preparation, for broke dilution or for paper machine showers. In integrated mills, the excess white water is best used in the pulping process or in the paper or board machines. In non-integrated paper mills, the excess white water forms the waste water.

For paper machine fibre and filler recovery with a save-all unit, the disc filter is for most cases an efficient solution to attain high recovery. A pre-coat-type unit in particular, which utilizes a small amount of paper machine pulp feed on the filter surface to improve filtering efficiency and solids recovery, is often used at modern mills. The filter works in batch mode, but the removal of solids and the regeneration by applying the pre-coat take only a short period of time. Other systems for the recovery of fibre and fillers are flotation cells, disc thickeners or membrane filters.

The disc filter allows efficient fractionation of white water to clear and cloudy filtrates and in many cases also produces a super-clean filtrate that can be reused in low-pressure showers. The super clear filtrate from a disc filter could have 10 – 20 mg/l suspended solids and clear filtrate with 20 – 50 mg/l suspended solids (up to 100 mg/l in some cases). Clear filtrate can be used in low-pressure shower water at the paper machine and reduces fresh water usage. The cloudy filtrate and the rest of clear filtrate can be used for pulp dilution preceding the paper machine in the short circuit, for machine broke dilution and in integrated mills in the pulping process.

Other measures to reduce fibre and filler losses are given below:

» Tuning of the pulp refining and screening just ahead of the feed to the paper machine to maintain a proper balance of different types of fibres in pulp. Heavy refining increases the amount of short fibres that in turn may be removed as rejects in screening. In integrated mills, a certain fraction of rejects from the screening may be recycled to the pulping department.

» Efficient control of the paper machine head box to produce an even paper web across the machine width.

» Efficient use of chemical additives together with a modern control system to reach improved fibre retention on the wire and good paper web formation.

» The broke and white water storage capacity also has an effect on solids management and water conservation. The chest sizes should allow at least two- to three-hour machine flow to be stored in broke chests to recover these fractions that are high in fibre content. This reduces the frequency and length of sudden peak fibre or hydraulic discharges to the mill sewer.

» In paper machines producing coated grades, the broke collected after the coater can be mixed with fresh pulp and wet-end broke.

Further polishing of the white water could be possible with the use of micro filtration and/or ultra-filtration process which have been proved to be the effective techniques making the white water free of suspended solids and colloidal substances, microbes, latex and other micro stickiest including the anionic trash (up to 50%) making it possible to use maximum back water for recycling[17]. This may be step towards achieving of Zero Liquid Discharge or Zero Effluent System. However, the process needs to be demonstrated on laboratory/pilot scale to prove the techno-economic feasibility in Indian context.

5.6.6.1. Issue related to stickies/ slime build-up

The best ways to deal with stickies include avoiding them (by selecting the kind of pulp source), removing them during deinking of the wastepaper (easier said than done), or adding enough talc to the system to overcome their tackiness. It is sometimes difficult to remove stickies by screening due to their ability to deform and become extruded through very small holes. Also, high levels of shearing action during processing of wastepaper can result in micro-stickies that are not easily retained[18].

Stickies may be removed by flotation, be reduced to micro stickies by dispersion and (optionally) subsequently removed by ultra-filtration.

Particular care should be exercised in the case of chemicals which are designed to have a biological effect such as biocides, disinfectants and slimicides. Build-up of slime in mill systems should be prevented in the first place by proper design and operation of the systems to avoid having equipment, pipes and tanks where pulp suspensions can be left standing for prolonged periods of time and by choosing operating temperatures at or above about 40°C. These measures may not be sufficient at all times to entirely manage slime growth but will lead to the use of chemical additives only occasionally and/or in low quantities. Practical experience says that recycled mills for printing papers

[17] Shammas, N, Wang, L., and Selke, W., 2010. *Completely Closed Water Systems In Paper Mills.* In *Flotation Technology.* Humana Press, pp. 401-427.

[18] Stickies. [Online] Available at: ‹http://www4.ncsu.edu/~hubbe/TShoot/G_Sticki.htm›

and tissue commonly operate the systems at about 45 °C and for packing material up to 50°C to avoid the formation of slime. A large RCF mill, for example, manufacturing packaging paper successfully applies dispersing agents and enzymatic treatment when the bacteria of the process water systems are forming slime, thus completely substituting the use of biocides[19]. Moreover, hydrogen peroxide is also a good environmentally friendly water cleansing substance, as it doesn't introduce toxic compounds. After decomposing, it forms oxygen radicals that react with microbes and organic matter within the water system. It is recommended that the dosage and addition points need to be discussed and identified which may differ from mill to mill[20]. A combination of biocides and bio-dispersants help to reduce the amount of biocides used[21].

5.6.7. Environmental Management

5.6.7.1. Effluent treatment plants

In general, all mills visited had a large focus on effluent treatment plants. All the mills had a typical layout consisting of a primary clarifier, aeration tank, secondary clarifier, and few of the advanced large wood/agro-based mills had a bio-methanation as well as tertiary treatment system to further improve the treatment efficiency of effluents with respect to colour, COD and BOD etc. As per the mandatory requirement, the ETPs were equipped with online monitoring systems connected to the Central Pollution Control Board (CPCB)'s monitor. Any deviation noticed by the authorities leads to the issuance of show cause notice of non-compliance to the mill.

However, the wood and agro-based mills are looking for improvement in the tertiary treatment technology/system for further reduction/removal of colour and TDS aimed towards a reduction in water usage and more opportunities for water recycling which has emerged as one of the challenges before the Indian paper industry.

5.6.7.2. Effluent treatment cost

A possible solution to address the issue of the high cost of treatment of effluents in small-size paper mills located in clusters may be to have a common effluent treatment plant (CETP). The treatment of the combined effluents from the paper mills or any other industry having similar affluent characteristics located in a cluster may be carried out using CETP facility consisting of a combination of a bio-methanation process along with a conventional activated sludge treatment process for recovery of bio-gas to use as a source of energy and would also reduce the COD level of the effluent.

This should also provide advantage for recovery of bio-gas (to be utilised as a source of energy) and improved pollution reduction efficiency with respect to COD and BOD in the final discharged effluents[22], there is a need to set up a demonstration plant that has CETP facilities in any one of the identified paper mill clusters to reveal the potential and establish eco-feasibility of the proposed project.

5.6.7.3. Safe disposal of plastic waste

Reducing the amount of plastic to a minimum in the mills should be the ultimate goal. The small amounts of plastic that would be generated in the mills could be burned in centralized units for energy purposes. The best approach would be to recycle as much of the plastic as possible (also as close as possible to the consumers). Collected plastics could be sent to centralized facilities where

[19] Schrijver, J et. al., 2008. *Biocides for deposit control in the production of corrugated base paper.* In: Zellcheming TC ed., *Chemical Additives for the Production of Pulp & Paper,* pp. 319-339.

[20] ‹www.biocide in paper_industry_chemical.html›

[21] Kolari, M. *New research gives breakthrough in cutting slime and corrosion risk on PM.* World Pulp & Paper. Available at: ‹http://www.kemira.com/Materials/new-research-gives-breakthrough-in-cutting-slime-and-corrosion-risk-on-pm-article-kemira.pdf› [Accessed on 2 November 2016], pp.51-54.

[22] Energos, 2016. ‹http://www.energ-group.com/energy-from-waste›.

sorting/production of new raw material (e.g. granules) were done. This would require effective sorting systems and effective logistic solutions (e.g. most of the sorted and collected plastic in Norway is sent to facilities in Germany for sorting and further processing).

5.6.7.4. Usage of DIP sludge

DIP sludge is today considered hazardous waste and therefore cannot be burned according to political restrictions. This issue can be solved through a combination of technology and policies. The technology to treat emissions to air exists and there are no issues regarding burning of sludge as long as the emissions are treated correctly (furthermore, this sludge is burned in Norway deink sludge utility[23] burning combined with smoke gas cleaning and ash deposit is a viable solution). However, a variety of usages of DIP sludge has also been reported; the only need is to investigate the possibilities of exploring these options, keeping the logistics and geography near the deinking facility in mind.

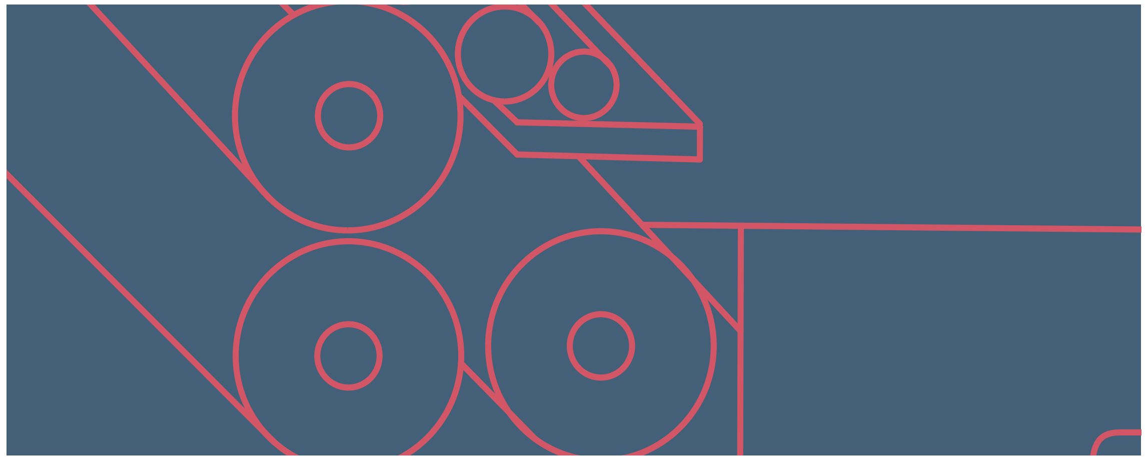
[23] Deviatkin, I., Kujala A. and Horttanainen M, 2015. *Deinking Sludge Utilization Possibilities: Technical, Economic, and Environmental Assessments- Report on responsibilities of LUT Energy in EMIR project, 2012 - 2014*. Lappeenranta, Finland: LUT Scientific and Expertise Publications, pp.12-15.

5.6.8. Process control and product quality assessment

A few of the mills visited had centralized control rooms for the different parts of the production process. Most of the control of the machines was done at control panels located close to the process units. It is unclear how and whether process data is logged at these mills. A few of the larger mills had newer, more advanced systems with computers for controlling the process and logging data.

Some mills had modern online measuring systems for monitoring some quality parameters (after the drying section); some had plans to install such systems, while others had none.

The capacity of controlling the process and product quality (physical measurements of important paper quality parameters and chemical analysis of process waters/components) seemed to be low at most of the units visited.

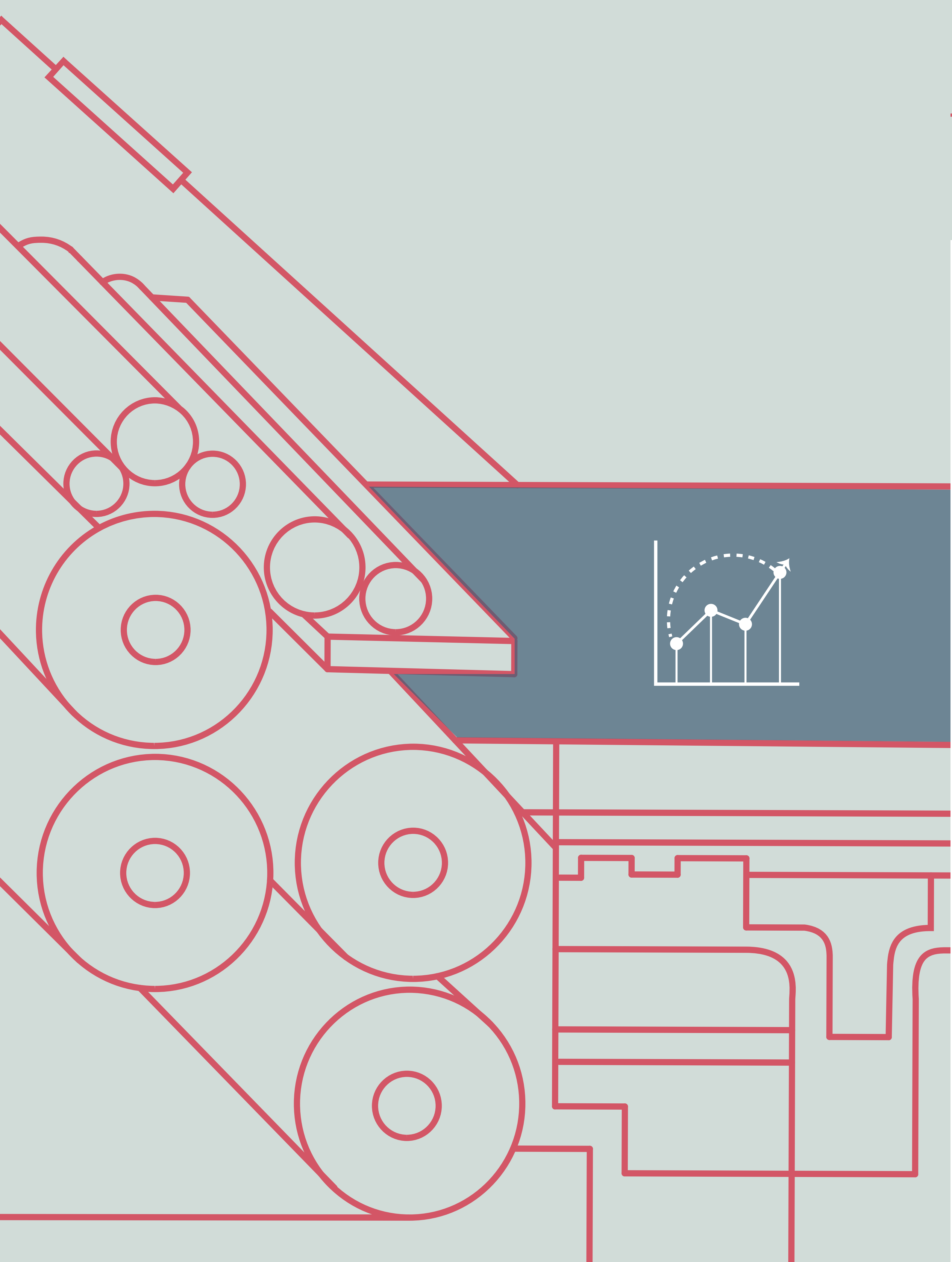


5.7. Summarized qualitative assessment of the technology status

Table below gives a bullet point summary of the assessment of technology given in Chapter 3.4.

Table 76: Summary of the evaluation given in Chapter 3.4

Area	Assessment
Raw material handling and preparation	» Varying practice regarding storage of raw material – In general not done optimally to preserve fibre quality and excessive waste in the mill area. » Manual labor widely used (ranging from sorting to feeding conveyer belts to pulper). » Quite a few impurities in the incoming raw material (especially plastic for the mills using recycled paper).
Pulping process	» Efficiency of digesters questionable. Pulping process varied from batch to continuous digestion, however scope for improvement and possibility for adoption modified extended delignification. » Room for improvement regarding removal of dissolved substances after cooking. » Control of pulp and cooking liquid after cooking seemed limited.
Bleaching	» Lack of designated bleaching steps/bleaching towers (bleaching in the pulper is not an optimal solution). » Washing and dewatering after bleaching questionable. » Still use of chlorine and bleaching chemicals containing chlorine. » Strong smell of bleaching chemicals in parts of the mills. » Seemingly room for optimization of the bleaching processes.
Papermaking	» Many mills had standard Fourdrinier machines. Retention and formation questionable. » Dewatering efficiency will require measurements (including forming and press sections). » Lack of hoods over the drying sections. » Not optimal internal water handling (internal water loops questionable). Internal cleaning of white water seemed to be rare. » Generally slow machines with old design, efficiency questionable.
Finishing/packaging	» Heavily depending on manpower in packaging. No full automatic packaging line for the paper was observed.
Effluent treatment	» High focus on the effluent treatment from the mill. » Different layouts including/combinations of primary-, secondary- and tertiary-sedimentation combined with aeration steps were common. » A few had sand filters and biogas reactors to reduce the COD. » Different strategies for water usage from the different stages of the effluent treatment. Questionable whether the water was used in an optimal manner. » The practice of handling sludge from the effluent plant was different in the mills visited; some sold the sludge to other industry (cement industry, cardboard producers). » The pollution load to the effluent treatment plant may be reduced by better internal control and cleaning of process water.
Process control and product quality assessment	» Few control rooms and logging of process specific data. » In general little control of the constituents in the different process streams in the mills (charge properties, pH, etc.) » Few online measuring systems for monitoring paper quality and product quality analysis was partly missing.



6 INTERNATIONAL TRENDS IN THE PULP AND PAPER INDUSTRY

The market situation as experienced in India is somewhat different to the more mature markets in Europe, where a decline in especially printing paper consumption has been observed. The reduction in printing paper consumption came quite fast and a reduction in overall production capacity was needed (resulting in the closing of several mills). It is important to know the mechanisms for this decline and also be aware of how the market can change in India, thus preparing the industry for other product segments prior to the expected changes.

6.1. Global Megatrends

Market developments, process developments and product developments are all governed by the major development trends in the world – often referred to as global megatrends. Below, five important global megatrends are described, all likely to have a large impact on both society as well as the forest- and paper industries.

6.1.1. Demographic changes and urbanization

The world population is expected to increase from 7.1 billion inhabitants in 2014 to 9.3 billion inhabitants in 2050[24]. The Indian population is expected to be among the fastest growing populations, with an expected increase from 1.2 billion inhabitants in 2010 to 1.6 billion inhabitants in 2050[25] .

The world population is ageing. The fraction of the world population above 60 years is expected to increase from 10% in year 2000 to 21% in 2050[26].

People will continue to move to urban areas, and the world urban population is expected to increase with 72% from 2011 to 2050[27].

Some implications of these demographic changes are:

- The increasing world population will generally increase the global consumption.
- The ageing population will tend to increase focus on products designed to meet the needs of the elderly. Examples include easier-to-use packaging solutions and hygiene products such as incontinence products.

[24] United Nations, Department of Economic and Social Affairs, Population Division, 2015. Population Statistics.

[25] World Bank Group, 2016. *Population Estimates and Projections*. [Online] Available at: ‹http://data.worldbank.org/data-catalog/population-projection-tables›.

[26] United Nations, Department of Economic and Social Affairs, Population Division, 2015. *World Population Ageing 2015* (ST/ESA/SER.A/390) [Online]. New York, USA. Available at: ‹http://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2015_Report.pdf› [Accessed on 2 November 2016].

[27] United Nations, Department of Economic and Social Affairs, Population Division, 2012. *World Urbanization Prospects: The 2011 Revision (ST/ESA/SER.A/322)*[Online]. New York, USA. Available at: ‹http://www.un.org/en/development/desa/population/publications/pdf/urbanization/WUP2011_Report.pdf› [Accessed on 2 November 2016].

6.1.2. Lack of resources and climate change

The growing world population means increased need for resources. Compared to today's level, it is expected that in 2030 the world will need 50% more energy, 40% more water and 35% more food[28].

Anthropogenic emissions of greenhouse gases to the atmosphere have led to global warming and climate changes[29]. There is a strong focus on taking steps to mitigate climate changes, both on an international and national level, by the authorities as well as by the consumers.

These trends will give implications such as:

- » Demands for reduced CO_2-emissions
- » Demands for reduced energy consumption and renewable energy sources
- » Demands for renewable raw materials that can substitute fossil-based raw materials
- » Demands for use of sustainable raw materials not competing with food production
- » In many regions there will be demands for reduced water consumption

6.1.3. Globalisation and change in economic power

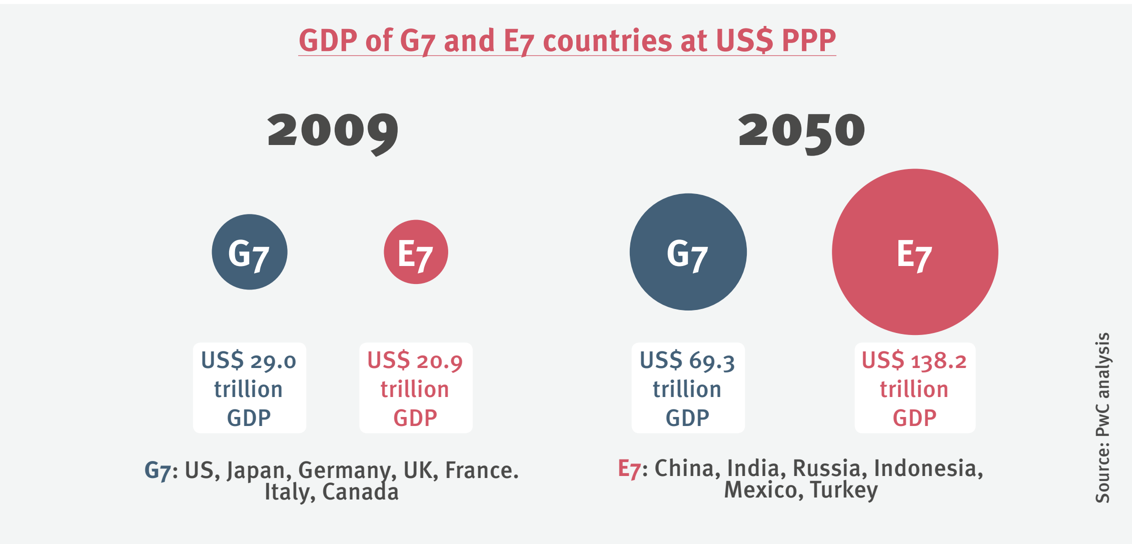
In the period towards 2050, the economic growth is expected to be highest in new emerging regions. In 2009, the total GDP of the G7-countries (US, Japan, Germany, UK, France, Italy and Canada) were at the same level as the E7-countries (China, India, Brazil, Russia, Indonesia, Mexico and Turkey). However, in 2050, the total GDP of the E7-countries is expected to be twice the total GDP of the G7-countries[30].

[28] National Intelligence Council, 2012. *Global Trends 2030: Alternative Worlds [Online]*. Washington, DC, USA. Available at: ‹https://globaltrends2030.files.wordpress.com/2012/11/global-trends-2030-november2012.pdf› [Accessed on 2 November 2016].

[29] Intergovernmental Panel on Climate Change, 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. In T. Stocker, D. Qin, G. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. Midgley eds. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

[30] Yang, Silas, 2014. Global Annual Review 2014: Shift in Global Economic Power [Online]. PwC. Available at: ‹www.pwc.com/gx/en/annual-review/megatrends/shift-in-global-economic-power-silas-yang.jhtml› [Accessed on May, 2016].

Figure 14: GDP of G7 and E7 countries in 2009 and 2050 (prognose)



A new global middle class is emerging. According to an OECD-study, Asia Pacific countries accounted for less than 30% of the total middle class in 2009, with an expected rise to 54% of the total middle class in 2020 and 66% in 2030[31]. This development will mean that the increase in global consumption primarily will take place in the emerging regions, and that the growth opportunities will shift towards these regions. Another effect of this shift is that the consumer pattern may change. In a survey done by Innventia AB, 18% of Swedish respondents had recurring worries over whether food might have been thawed prior to being placed in the freezer. The corresponding share among Indian respondents was 77%[32]. The Innventia survey also indicated that it is three times as common to avoid retailer own brands in India as in USA (51 percent vs. 17 percent). Hence, food safety (and safety of packaging) is a topic of increasing importance.

As there is a shift in demographics, different household structures might be an equally important issue. According to the Innventia survey, mentioned above, 30% of the Indian respondents reported to have more than three generations represented in their household, compared to only 6% among the American respondents. Consequently, child-proof packaging might turn out to be a far more important issue in the emerging markets than in the West.

6.1.4. Technological breakthroughs

Technological breakthroughs are changing the world. One example is the comprehensive developments within ICT. The introduction and evolution of the World Wide Web and electronic media has led to a dramatic reduction in demand for newspaper and traditional printing and writing grades. Due to ICT-innovations, developments in society are now taking place at a much faster pace than before. Industry companies are forced to change their innovation speed to keep up the pace with their competitors. ICT-innovations also give many new opportunities, including product traceability, new intelligent functionality and the "internet of things".

Nanotechnology is another example, opening for novel, strong and light materials, as well as materials and products with new functionality. A third example is the development of 3D-printer technology. 3D-printing opens up local manufacturing, based on designs that can be made anywhere. This technology also opens up production of specialized products in small volumes. New structures may also be 3D-printed, that hitherto have been difficult or impossible to manufacture. Many different raw materials can be foreseen, including bio-based raw materials such as cellulose.

[31] Kharas, H., 2010. *The emerging middle class in developing countries*. Working Paper No.: 285. Paris, France: OECD Development Centre. Available at: ‹http://www.oecd.org/dev/44457738.pdf› [Accessed on 2 November 2016].

[32] Innventia, 2013. *Innventia Global Outlook: Packaging 2020*. Report No. 387. Stockholm, Sweden: Innventia AB.

6.2. Trends – Newspaper and printing and writing grades

In the past decade there has been a dramatic reduction in demand for Newspaper and traditional printing and writing grades. The most important reason for this development is the strong competition from electronic media. In 2007, the global demand for printing and writing grades peaked at 105 MTPA. Since then, the global demand has on average decreased at an annual rate of 2.3%, to a level of 91.2 MTPA in 2013[33].

The demand for wood-containing printing paper has had a negative growth during the last few years (see Fig. 15), and a continued reduction in demand is expected in the years to come. However, it is uncertain how fast

[33] Skog22, 2014. *Working Group Report Fibres and Biorefining*.

this trend will be. Also, the trend is different for different regions and for different product segments. While the demand for several qualities has been increasing in several Asian and Eastern-European countries, the demand has been falling in North America and Western Europe (see Fig. 16).

The demand for wood-containing printing paper has decreased more than the demand for wood-free printing paper grades.

6.3. Trends – Packaging Grades

6.3.1. Product segments

Fiber-based packaging comprises the main grades of cardboard, containerboard, kraft paper and specialty board grades. Within carton board, the most important qualities are folding boxboard, bleached and unbleached solid board and liquid board with the following sub-categories:

- Kraft liner (based on unbleached kraft pulp)
- Test liner (based on recycled pulp)
- White top liner (liner with top-ply from bleached chemical pulp)
- NSSC fluting
- Fluting based on recycled fibres

Kraft paper comprises sack paper, MG paper (Machine Glazed) and MF paper (Machine Finished). Specialty board grades comprise core board, wallpaper board, plaster board and saturated base paper (laminate paper).

Figure 15: Global demand for wood-containing printing paper 2000 – 2013

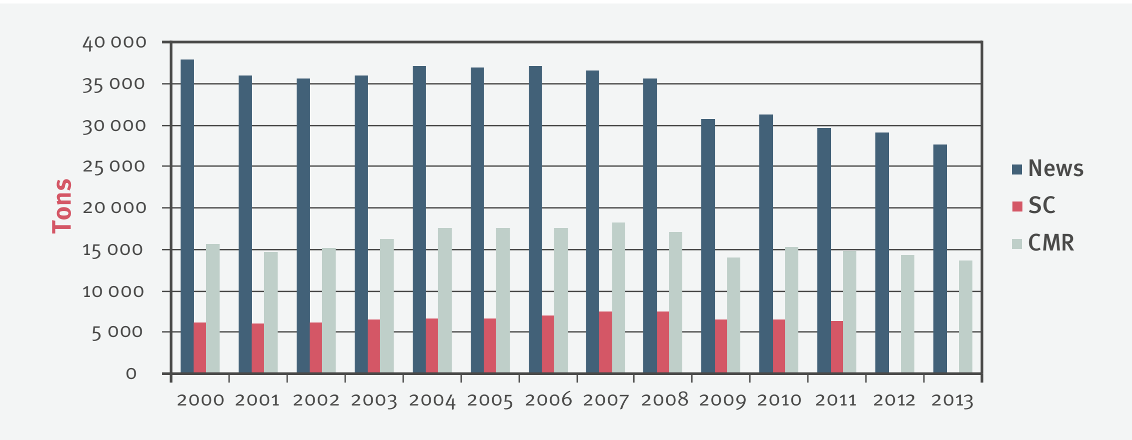
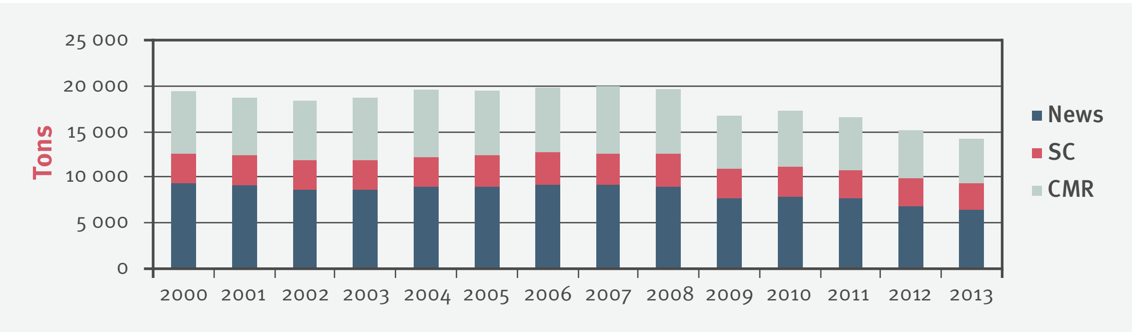


Figure 16: Demand for wood-containing printing paper 2000 – 2013, Western Europe



6.3.2. Drivers and trends

The global megatrends give important drivers for the developments of the market for packaging products. The population growth in general increases the global consumption. The shift in global economic power leads to a new, large and global middle class, where the largest growth in consumption is expected in new regions. The growing middle class will increase the demand for several packaged goods, such as foods, beverages and hygiene products. Both due to local regulatives, but also for logistic reasons, the production of packaging material (at least the converting process) will often take place locally. Lack of wood and recycled fibres will in some regions imply considerable import from Western regions.

The ageing population and increased urbanization, with new family structures and life styles, will increase the demand for certain types of packaging products (e.g. single portion packages, easy-to-open packages, packages for ready-made food and packages for the fast food sector). The increasing lack of resources and climate changes will be a strong driver for substitution of fossil-based packaging products with bio-based packaging products. In addition, there are demands for increased shelf lives and recyclability.

Web-based marketing and sales will give increased needs for secondary packaging for transport of products. The secondary packaging is meant to protect, but design will also be of importance[34]. The consumption of industry packaging will tend to be geographically linked to industry production. An example is the geographical shift of electronics production from Ireland/Scotland to Hungary /Czech Republic, which was followed by a transfer of the production of container board.

[34] Innventia, 2013. *Innventia Global Outlook: Packaging 2020*. Report No. 387. Stockholm, Sweden: Innventia AB.

A new trend is the focus on lighter and stronger packaging qualities. This trend can lead to less costly, weaker and heavier recycled-based packing grades to lose ground to stronger, lighter, virgin fibre-based packaging grades. Use of micro-fibrillated cellulose as a strength enhancer in packaging products is an example of product development in this direction.

6.3.3. The packaging market

The global packaging market was 799 billion USD in 2012, with an expected growth of 3% in 2013[35]. The expected future annual market growth for packaging products is expected to be in the range of 3%[36]. The largest growth is expected in emerging regions, such as China, India, South-East Asia and Latin America. However, steady market growth is expected also in Europe and North-America. Consumer related packaging comprise the majority of the growth.

Fibre-based packaging comprised 36% of the total packaging market in 2011[37], and had an annual growth of 4.2% in the period 2003-2009[38]. In the period 2015-2020, the demand for fibre-based packaging grades is expected to grow at an annual rate of 3.5%[39]. Container board is the largest product segment within fibre-based packaging products (almost 40% of the total packaging market). For this segment, the global market growth

[35] SmithersPira, 2013. *The Future of Global Packaging to 2018*. Ohio, US.

[36] Juntti, O., 2015. *What is the role of fibre based packaging...? ... in the global packaging markets.* Paper Industry World (Market&Trends), [Online] Available at: ‹http://www.paperindustryworld.com/what-is-the-role-of-fibre-based-packaging/› [Accessed on 2 November 2016].

[37] SmithersPira, 2011. [Online] Available at ‹http://www.smitherspira.com/›.

[38] SmithersPira. [Online] Available at ‹http://www.smitherspira.com/›.

[39] MarketsandMarkets, 2015. *Paper & Paperboard Packaging Market by Grade (SBS, CUK, FBB, WLC, Glassine & Greaseproof, Label Paper), Application (Food, Beverage, Healthcare, Personal & Home Care), & by Type (Corrugated Box, Boxboard, Flexible Paper) - Trends & Forecast to 2020*. ‹marketsandmarkets.com›.

is expected to be 4% (6% in Asia, 1.3% in Western Europe) [40,41]. Other important packaging grades are folding boxboard and liquid board. The global market for liquid board is expected to grow at an annual rate of 4% in the period of 2016 – 2020[42].

6.4. Market trends – Tissue paper and hygiene products

Tissue paper comprises products such as toilet paper, household paper and paper napkins. Hygiene products comprise products such as diapers, sanitary towels and incontinence products. The most important driving forces for growth in these markets are population growth and improved standard of living, combined with relatively few substitutes for tissue paper (apart from increased use of air dryers).

The consumption of tissue paper products varies considerably among different regions. The largest market growth is expected in emerging regions, such as India, where the consumption per capita so far has been low, but where the trend is a rapid improvement in living standard and hygiene standard. Due to the high bulk, tissue paper is favourably produced locally.

The global market for tissue paper in 2012 was 32 MTPA[43]. The largest markets are North America (28.5 %), Western Europe (20.3 %), China (18.8%) and Latin-America (11.2 %)[44].

The global market for hygiene products in 2012 was 330 billion SEK, with an expected annual growth of 5% [21]. The product group with the highest growth is incontinence products, due to the ageing population.

The global market for tissue paper products was 410 billion SEK in 2012, with an estimated annual growth of 4% in the period of 2013 – 2021[45]. The market growth is highest in emerging regions, with China in the lead.

The production capacity for tissue paper products is rapidly increasing, particularly in China, Latin-America and North America. Due to high competition, it is expected strong competition in the coming years. The production of tissue paper is very fragmented, with some large and many small producers.

6.5. Market trends – biocomposites

Biocomposites is a new product segment with a large expected market growth. Biocomposites are defined here as a material combination of a plastic matrix reinforced with bio-based fibres, either plant fibres or wood fibres. Biocomposites may also be filled with wood flour, having low reinforcement effect, but adding stiffness to the material. In the EU, the biocomposite market is expected to grow from 910,000 tonnes per year in 2012 to between 392,000 tonnes per year and 1.6 million tonnes per year in 2020[46]. Examples of areas of use include car parts and construction materials. There are several driving forces promoting the demand for biocomposites and the use of wood fibres and natural fibres as reinforcement in plastic products. The climate changes increase the demand for more environmentally friendly products. Substitution of parts of the fossil-based plastic with wood fibres or natural fibres will contribute to more sustainable products. The composite materials may also be made completely bio-based by applying bio-plastics instead of fossil-based plastic. Reinforcement with wood fibres or natural fibres can give improved mechanical properties compared to pure plastic materials. Substitution of plastic with wood fibres may also give reduced material costs. As an example, the Finnish company UPM has established production of two wood fibre composite materials, marketed under the trademarks UPM PROFI and UPM FORMI. PROFI is based on recycled fibres and surplus plastic from own label production, and are extruded products for the construction market (decking material, flooring, fences and facade material). PROFI comprises granulates of cellulose and polypropylene for injection molding of a range of different products. Hence, plastic industry will then be able to replace conventional plastic pellets with composite granules in their own production lines. As another example, Swedish Södra Cell has established production of the material "DuraPulp", which is a shapeable composite material based on cellulose fibres and PLA.

6.6. Market trends – nanocellulose

Nanocellulose is a new product group, with intensive research over the last 10-15 years. This product group is now being commercialized, and the first products have already been introduced to the market. Nanocellulose is small fibres in nano- or micro-scale, produced by decomposing cellulose fibres into smaller units. Depending upon the particle size and length-width ratio, the product may be termed as micro-fibrillated cellulose (MFC), cellulose nanofibrils (CNF) and nanocrystalline cellulose (CNC).

Nanocellulose can be used in a range of different applications, e.g. as reinforcement in paper products or composites, for rheology adjustment, for stabilization of emulsions, in biomedical applications, in filter applications, for applications in the oil industry, in packaging applications, in film production or as a food ingredient. Some companies have already started pre-commercial production of micro-fibrillated cellulose. Examples include Borregaard (Norway), UPM (Finland), Stora Enso (Finland), Daicel (Japan) and Nippon Paper (Japan). A full scale plant is under construction at Borregaard in Norway. In Canada, Domtar Corp. and FP Innovation have established commercial production of cellulose nanocrystals.

Since nanocellulose on a commercial basis should be considered as a new product group, today's sales of nanocellulose products are still limited. It has been estimated that the global production of nanocellulose will increase to between 2,800 tons/year (conservative estimate) and 24,000 tons/year (high estimate) in 2025[47].Even if the production volumes of nanocellulose may be moderate, the value-adding can be large. FP Innovations have estimated the North-American market for nanocellulose to be worth 250 million USD in 2020[48].

6.7. New processes– bio-economy

Globally innovative concepts such as bio-economy and bio-refinery which are devoted to low carbon energy efficiency based on use of natural resources and recyclable material, are continuously being brought forward. Developments are taking place with an aim to promote inclusive

[40] SmithersPira, 2014. [Online] Available at ‹http://www.smitherspira.com/›.

[41] The Freedonia Group, 2016. Ohio, USA. [Online] Available at: ‹ http://www.freedoniagroup.com/›.

[42] Technavio, 2015. *Global Liquid Packaging Board Market 2015*.

[43] Bright Market Insight, 2013. *Index & Report For The Global Pulp & Biorefinery Industry.* Issue No. 2, Summer 2013. [Online] Available at: ‹http://calejo.se/wp-content/uploads/2013/08/BMI2_show.pdf› [Accessed on 2 November 2016].

[44] SCA, 2013. *SCA Annual Report 2013*. [Online] Available at: ‹http://www.sca.com/Documents/en/Annual_Reports/SCA-Annual-Report-2013.pdf?epslanguage=en› [Accessed on 2 November 2016].

[45] Ibid., 43, 44

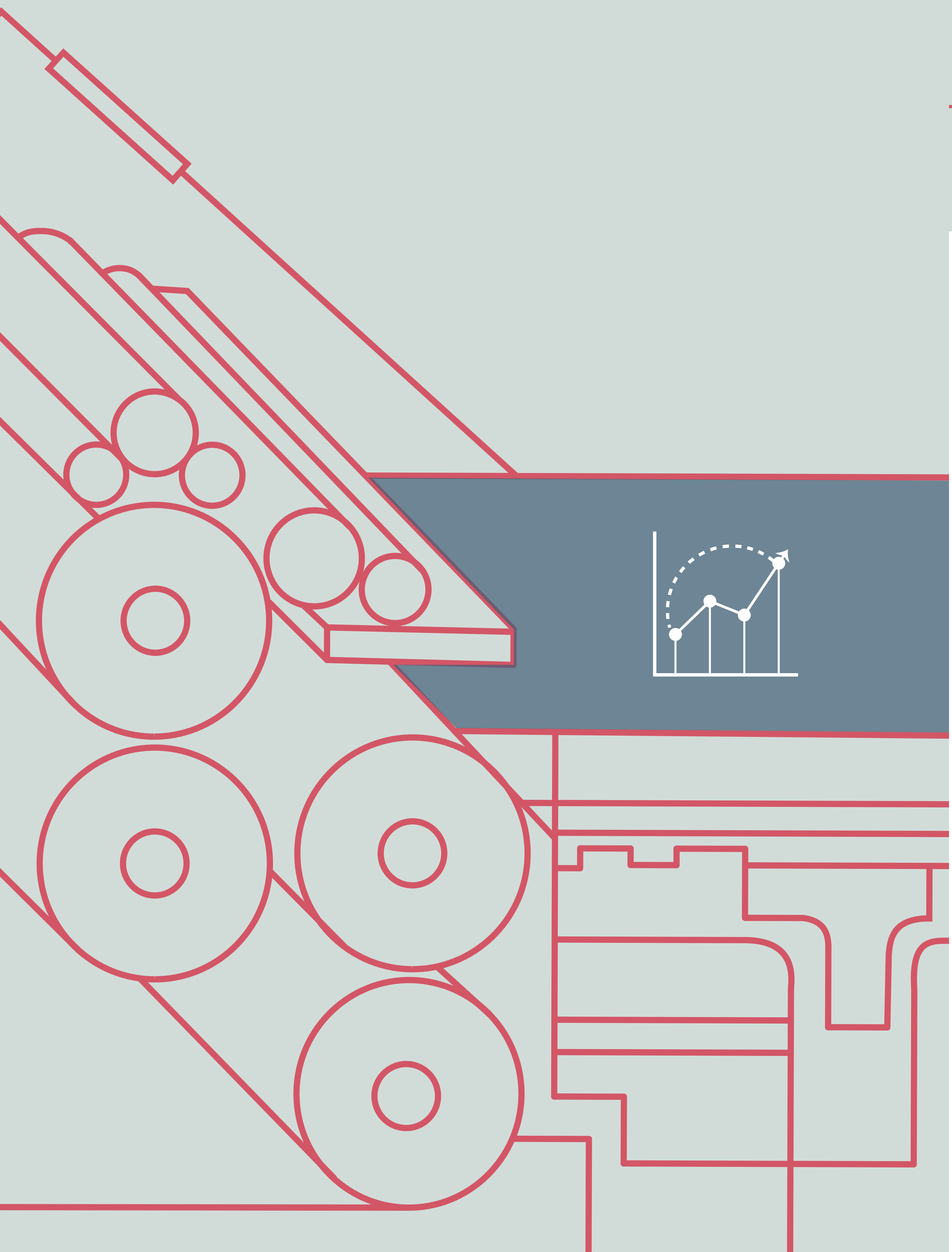
[46] Nova Institute, 2011. ‹www.nova-institute.eu›.

[47] Future Markets Inc., 2015. *The Global Market for Nanocellulose*. Edinburgh, UK.

[48] Future Markets Inc., 2012. *The Global Market for Nanocellulose*. Edinburgh, UK.

and sustainable development of the paper and pulp industry. A pulp mill in Finland is considered as a by-product mill keeping in view the national bio-economy strategy. This by-product mill concept may diversify the structure of the forest based economy and expand the products on offer, such as, lignin and hemicellulose products, bio-electricity / bio-fuels & bio-composits.

This innovative concept will be beneficial in the Indian context even for the existing paper mills to expand their existing portfolios from the current bleached pulp by producing hemicelluloses and lignin /lignin based products. This would enable these mills to create an additional revenue stream, thus improving their competitiveness.



7 ACTION PLAN BASED ON THE EVALUATION OF THE TECHNOLOGY STATUS

7.1. Background

The purpose of the current chapter is to provide a summary of the report covering possible solutions/actions to improve the product quality, production efficiency, environmental aspects and competitiveness of the Indian pulp and paper industry. It is important to note that the proposed actions described herein are general suggestions for improvement that might be relevant for a majority of the paper mills in India. The chapter, thus, covers action plan proposed for the Indian paper industry considering the potential for applicability of the Best Available Techniques (BAT) and the time period required for its implementation.

7.2. Action plan points

The tables presented in this section are modified versions of the tables given in Chapter 4 and Chapter 5 of this report which have been substantiated with suggested action points relevant to major unit operations. These suggestions may be applicable to a majority of the paper mills in India.

The comments given to the qualitative assessment in section 7.2.7 merely point at the areas (education, investment, logistics, etc.) that require attention in order to change/improve some of the observations. This is a highly qualitative assessment and is not something that can be solved by the mills alone.

Time scales used in the action plan are as follows:

Short – 1-2 years,

Medium – 3-5 years and

Long – 5-10 years.

7.2.1. Raw material handling

As described in BAT 42, Table 77 presents the proposed action plan to improve raw material handling.

Table 77: Action Plan- Raw Material Handling

Technique	Applicability	Comment	Time frame
Hard surfacing of the storage area for paper recycling	Generally applicable	» May improve the raw material quality entering the processing line.	Short / Medium • Investment
Collection of contaminated run-off water from the paper for recycling	Applicability may be restricted by the degree of contamination of runoff water (low concentration) and/or the size of the waste water treatment plants (large volumes)	» May be positive for the environment around the mill sites, from the view point of management of environmental pollution and water usage	Short / Medium • Investment
Surrounding the terrain of the paper for recycling yard with fences against wind drift	Generally applicable	» May be positive for both the environment around the mill sites and the raw material handling/quality.	Medium • Investment
Regularly cleaning the storage area and sweeping associated roadways and emptying gully pots to reduce diffuse dust emissions.	Generally applicable	» May improve both the environment around the mill sites and avoid contamination of the raw material, thereby improving its quality.	Short / Medium • Investment • Practice
Storing of bales or loose paper under a roof to protect the material from weather influences (moisture, microbiological degradation processes, etc.)	Applicability may be restricted by the size of the area	» May be positive for quality of the final product/paper properties	Medium • Investment

7.2.2. Raw Material Preparation

Table 78: Action Plan- Raw Material Preparation

Technique	Applicability	Comment	Time frame
Wood-based mills - dry debarking of wood logs in dry tumbling drum	Generally applicable	» There is a need to use debarked wood using dry-debarking process either at source or in the mills using dry debarking process.	Short • Investment
Baggase-based mills – two stage depithing process	Generally applicable, however, single stage moist depithing process also in practice.	» There is a need to adopt the good practices of using two stage depithing process consisting of moist depithing followed by wet cleaning.	Medium • Investment
Wheat straw-based mills- wet cleaning of wheat straw.	Generally applicable	» Practiced in most of the Indian paper mills	Medium • Investment
Recycled waste paper-based mills– collection and sorting	Generally applicable	» The collection system should address better sorting system adopting the guidelines published by CEPPI which should help in minimizing the impurities received in the raw material delivered to these mills. » However, better sorting will never remove the issue completely but in can somewhat be improved by the screening technology.	Medium • Investment • knowledge • policy intervention

7.2.3. Pulping and bleaching process

As described in BAT 19 (for the Kraft process, but also relevant for the soda process), Table 79 presents the proposed action plan for improving pulping and bleaching processes.

Table 79: Action Plan – Pulping and Bleaching Process

Technique	Applicability	Comment	Time frame
Modified cooking before bleaching	Generally applicable	» Better control of the efficiency of the digesters, i.e. gathering of benchmarking data to reveal the potential of each mill. » Need to implement the modified cooking to facilitate efficient delignification for producing chemical grade pulp from wood / agro-based raw materials.	Medium • Investment • Knowledge
Oxygen delignification before bleaching	Generally applicable	» Mill specific. » This process will improve the pulp quality by producing low kappa number pulp, thus helping to reduce bleach chemical demand during bleaching and pollution loads in the effluents.	Medium • Investment • Knowledge
Closed brown stock screening and efficient brown stock washing	Generally applicable	» Mill specific. » Better washing of the pulpusing advanced equipments, like belt washers, chemiwashers andtwin roll/ screwpresses, etc.,will reduce soda/ COD carryover and thus improve the efficiency of the bleaching.	Medium • Investment • Process layout • Knowledge
Use of additives in the cooking liquor formulation for soda pulping	Generally applicable	» An additive such as antraquinone will reduce the loss of carbohydrates and improve delignification. » Can be implemnted (where not already used) in existing systems.	Short / Medium • Investment • Knowledge
Partial process water recycling in the bleach plant	Water recycling may be limited due to incrustation in bleaching	» Mill specific. » Mapping of- and better understanding of how the water systems are in each mill will benefit both production and efficiency. » This will provide increased possibility of process water recycling, thereby reducing fresh water requirement. » Might also require some training of the mill personnel. » Note that this will be quite an extensive work for each unit.	Medium • Investment • Process layout • Knowledge
Effective spill monitoring and containment with a suitable recovery system	Generally applicable	» Implementation of measuring/control systems for better control of existing process, should help in improved chemical and energy recovery, besides pollution reduction loads to ETPs	Medium / Long • Investment • Process layout
Maintaining sufficient black liquor evaporation and recovery boiler capacity to cope with peak loads	Generally applicable	» If major changes are made in the cooking and bleaching processes, the capacity of the recovery boilers needs reassessment.	Medium • Investment • Process layout

7.2.4. Papermaking

Table 80 and Table 81 presents the proposed action plan for papermaking as described in BAT47 and BAT 48 respectively.

Table 80: Action Plan – Papermaking (1)

Technique	Applicability	Comment	Time frame
Optimum design and construction of tanks and chests	Applicable to new plants and to existing plants in the case of a major refurbishment	» Mill specific, but require relevant knowledge related to mapping and understanding of the water systems.	Long • Process layout
Fibre and filler recovery and treatment of white water	Generally applicable	» This will improve machine runability and product quality.	Medium • Investment • Process layout
Water recirculation	Generally applicable. Dissolved organic, inorganic, and colloidal materials may restrict the water reuse in the wire section	» Better understanding of process water systems required (including their contents and how to measure this).Details about understanding the internal water handling already covered in the section 5.6 of this report.	Short / Medium • Investment • Process layout • Knowledge
Optimisation of showers in the paper machine	Generally applicable	» See the two previous points.	–

Table 81: Action Plan – Papermaking (2)

Technique	Applicability	Comment	Time frame
Improvement of paper production planning	Generally applicable	» Mill and product specific, but something that is important is to have proper process knowledge.	Medium
Management of water circuits to fit changes	Generally applicable	» Mill and product specific, but something that is important is to have proper process knowledge.	Medium
Waste water treatment plant ready to cope with changes	Generally applicable	» It will not be possible to design an effluent treatment plant capable of handling all sorts of variation. » However,continued assessment and monitoring may help to cope with the changes.	Medium • Investment • Process layout • Knowledge
Adjustment of the broke system and of chest capacities	Generally applicable	» A separate system for handling broke may be beneficial.	Short / Medium • Investment • Process layout
Switch to low AOX-containing product aids (e.g. to substitute use of wet strength agents based on epichlorohydrin resins)	Applicable only for plants producing paper grades with high wet strength	» Optimization of strength additives is important for a short fibre raw material with inherent low strength.	Short • Investment

7.2.5. Effluent treatment

Table 82 presents the proposed action plan for more effective and better effluent treatment.

Table 82: Action Plan – Effluent Treatment

Technique	Applicability	Comment	Time frame
Primary treatment	Generally applicable	» There might be a potential of improved efficiency in the effluent treatment plants by improving the water handling prior to discharge to the effluent treatment.	Medium • Investment • Process layout • Knowledge
Secondary (biological) treatment	Generally applicable	» This again will be highly process/mill specific. » This might work as an optimal solution for all parts of the industry.	Short • Process layout • Knowledge
a) Aerobic treatment process	Generally applicable	» Mapping of the aeration tank combined with systems to control at source reduction of pollutants through processes optimization will be beneficial in order to achieve desired treatment efficiency.	Medium • Investment • Process layout • Knowledge
b) Combined anaerobic-aerobic treatment process	Generally applicable	» Highly useful and great potential exists in agro and recycled waste paper based mills to adopt the combined process. » However, prior assessment will be required in respect of the quality / quantity of effluent vis-a vis biogas production potential to assess the viability of the process.	
Tertiary treatment	Generally applicable	» Useful to address the issues related to colour/ build up of TDS due to closing up of paper machin's back water loop. » There is a need to demonstrate the techno-economic feasibility of micro /ultra-filtration process on laboratory / bench scale, to facilitate water, colour and TDS reduction possibilities required to comply with the charter norms for water reduction and prevention of pollution.	Medium • Investment • Process layout • Knowledge
Properly designed and operated biological treatment plant	Generally applicable	» Periodic assessment of the biological treatment plant should be carried out for proper design and operation of the biological treatment plant.	Short • Investment • Process layout • Knowledge

7.2.6. Fresh water use/waste water flow and the pollution load in waste water

As described in Chapter 8.7.2 in BAT, Table 83 provides the action plan for reducing the fresh water use/waste water flow and the pollution load in waste water.

Table 83: Action Plan – Reduction in Fresh Water Use/Waste Water Flow and the Pollution Load in Waste Water

Technique	Applicability	Comment	Time frame
Extended modified cooking (delignification)	Generally applicable	» Mill specific, but will improve the process for producing chemical grade pulp with lower kappa number, thereby reducing bleach chemical demand and less pollution.	Medium • Investment • Process layout
Oxygen delignification (ODL)	Generally applicable	» Mill specific, but will improve the overall efficiency of the paper mill in respect of energy and chemical recovery, quality of pulp, reduction in the demand of bleach chemicals and reduction in pollution loads.	Medium • Investment • Process layout
Closed and efficient brown stock screening and washing	Generally applicable	» Better washing of the pulp will help in reducing soda/ COD carryover to the bleach plant thereby helping to increase the efficiency of the bleaching.	Medium • Investment • Process layout
Totally chlorine free bleaching (TCF)	Generally applicable	» TCF bleach sequence is useful from an environmental perspective. » Will require both investments and partly changed production processes.	Medium • Investment • Process layout
Modern elemental chlorine free (ECF) bleaching	Generally applicable	» Avoiding or minimizing usage of chlorine dioxide will also be a major step towards a more environmentally friendly process. » Requires both investments and partly changed production processes.	Medium / Long • Investment • Process layout
Partial process water recycling in the bleach plant	Generally applicable	» Relates to bleaching/water optimization	Medium • Investment • Process layout
Effective spill monitoring and containment for improved chemical and energy recovery	Generally applicable	» Implementation of measuring/control systems for better control of existing process, should help in improved efficiency of chemical and energy recovery, besides pollution reduction loads to ETPs » Increased knowledge about the importance of this will require training.	Medium / Long • Investment • Process layout
Maintaining sufficient black liquor evaporation and recovery boiler capacity to cope with peak loads	Generally applicable	» If major changes are made in the cooking and bleaching processes, the capacity of the recovery boilers needs reassessment.	Medium • Investment • Process layout
High solids firing in chemical recovery furnace (LHT) process	Generally applicable	» Agro-based paper mills may have great potential to adopt the LHT process, helping to improve the energy and chemical recovery efficiency	Medium • Investment • Process layout • Knowledge
Counter-current flow of process water	Generally applicable	» Also relates to the already mentioned water handling.	Medium • Investment • Process layout
Segregation of waste water streams and its optimal recycling and reuse	Generally applicable	» Better knowledge and mapping of internal water systems should help in optimal recycling, thereby creating possibilities of water and pollution reduction.	Short / Medium • Investment • Process layout
High consistency (peroxide) bleaching	Generally applicable	» Optimization of the bleaching process.	Medium • Investment • Process layout
Fibre and filler recovery and treatment of white water	Generally applicable	» Mill specific, but will improve machine runability and quality. » Will be important for better internal water handling,by implementing appropriate techniques like micro-/ultra-filtration. » However, this may require demonstration (on the laboratory/ benchscale) to establish techno economic feasibility in the Indian context.	Medium • Investment • Process layout
Clarification of white water	Generally applicable	» Will be important for better internal water handling.	Medium • Investment • Process layout • Knowledge
Water recirculation	Generally applicable	» See above. Will be important for better internal water handling.	Medium • Investment • Process layout • Knowledge
Optimum design and construction of tanks and chests (papermaking)	Generally applicable	» Mill specific, but required relevant knowledge related to mapping and understanding of the water systems.	Long • Process layout
Substitution of NaOH by $Ca(OH)_2$ or $Mg(OH)_2$ as alkali in peroxide bleaching	Generally applicable	» Mill and process specific. » Something to be aware of as a possible improvement of the effluent treatment efficiency for which training/knowledge may be required by the mills	Medium • Investment • Process layout • Knowledge

7.2.7. Summarized qualitative assessment of the technology status

Table 84: Summarized Qualitative Assessment of the Technology Status

Process Details	Comment	Time frame
Raw material handling		
Varying practice regarding storage of raw material – In general not done optimally to preserve fibre quality and to handle excessive waste in the mill area.	• Education • Investment	Short / Medium / Long
Manual labour widely used (ranging from sorting to feeding conveyer belts, to pulper).	• Investment	Long
Quite a few impurities in the incoming raw material (especially plastic for the mills using recycled paper).	• Investment • Politica/ social • Logistics	Long
Pulping process		
Efficiency of digesters questionable.	• Education • Investment	Short / Medium
Room for improvement regarding removal of dissolved substances after cooking.	• Education • Investment	Medium
Control of pulp and cooking liquid after cooking seemed limited.	• Education • Investment	Medium
Bleaching		
Lack of designated bleaching steps/bleaching towers (bleaching in the pulper is not an optimal solution).	• Education • Investment	Medium
Washing and dewatering after bleaching questionable.	• Education • Investment	Medium
Still use of chlorine and bleaching chemicals containing elemental chlorine.	• Education • Investment • Politica	Medium / Long
Strong smell of bleaching chemicals in parts of the mills.	• Education • Investment	Short / Medium
Seemingly room for optimization of the bleaching processes.	• Education • Investment	Medium
Papermaking		
Many mills had standard Fourdrinier machines. Retention and formation questionable.	• Investment	Long
Dewatering efficiency will require measurements (including forming and press sections).	• Investment	Medium
Lack of hoods over the drying sections.	• Investment	Medium
Not optimal internal water handling (internal water loops questionable). Internal cleaning of white water seemed to be rare.	• Education • Investment	Medium
Generally slow machines with old design, efficiency questionable.	• Investment	Long
Finishing/packaging		
Heavily depending on manpower in packaging. No full automatic packaging lines for the paper were observed.	• Investment • Politica/ social	Medium / Long
Effluent treatment		
High focus on the effluent treatment from the mill.	• Education • Investment	–
Different layouts including/ combinations of primary, secondary- and tertiary-sedimentation combined with aeration steps were common.	• Education • Investment	–
A few had sand filters and biogas reactors to reduce the COD.	• Education • Investment	Medium / Long
Different strategies for water usage from the different stages of the effluent treatment. Questionable whether the water was used in an optimal manner.	• Education • Investment	Medium
The practice of handling sludge from the effluent plant was different in the mills visited; some sold the sludge to other industry (cement industry, cardboard producers).	• Education • Logistics	Medium
The pollution load to the effluent treatment plant may be reduced by better internal control and cleaning of process water.	• Education • Investment	Medium
Process control and product quality assessment		
Few control rooms and logging of process specific data.	• Investment	Medium / Long
In general, little control of the constituents in the different process streams in the mills (charge properties, pH, etc.)	• Education • Investment	Medium
Few online measuring systems for monitoring paper quality and product quality analysis was partly missing.	• Investment	Medium

7.3. Summary

The purpose of the current chapter is to identify possible solutions/actions for improvement of the product quality, production efficiency, environmental aspects and competitiveness of the Indian pulp and paper industry. It is important to note that the proposed actions described in this chapter are general suggestions for improvement that might be relevant for a majority of the paper mills in India.

The Table 85 gives a short summary of the main technological challenges identified for the different areas of the production process.

Newer technology and solutions exist than those currently used in the Indian pulp and paper industry. However, implementation of new technology will require major investments for the mills. Based on the observations, the mills will gain more from optimizing the existing processes instead of implementing new technologies. This might improve cost, efficiency, environmental impact and product quality at a substantially lower cost than investing in technology that might improve a small part of their production process. Focused optimization at the individual mills is needed to address many of the challenges observed (must be addressed at the mills as the process layouts are highly mill specific).

Table 85: Summary of Technological Challenges

Area	Main challenges	Affects	Solution related to
Raw material handling	Storage	Product quality, environment	Investment / practice
Pulping and bleaching	Efficiency / yield	Product quality, costs, environment	Investment / process layout / knowledge
Papermaking	General water handling	Quality, costs, environment	Investment / process layout / knowledge
Effluent treatment	Removal of enough material	Environment, costs, quality	Investment / process layout
Health and safety			Practice

REFERENCES

Bright Market Insight, 2013. *Index & Report For The Global Pulp & Biorefinery Industry*. Issue No. 2, Summer 2013. [Online] Available at: ‹http://calejo.se/wp-content/uploads/2013/08/BMI2_show.pdf› [Accessed on 2 November 2016].

Central Pulp and Paper Research Institute (CPPRI), 2015. *Compendium of Census Survey of Indian Paper Industry*. CPPRI, Saharanpur, India.

Central Pollution Control Board, 2015. *Charter for Water Recycling and Pollution Prevention in Pulp & Paper Industries*. [Online] Available at: ‹http://www.inpaper.com/Annexure-II.pdf› [Accessed on 2 November 2016].

Confederation of European Paper Industries (CEPI), 2016. *Paper for Recycling Quality Control-Guidelines. Revised Edition, April, 2016*. [Online] Available at: ‹http://www.cepi.org/system/files/public/documents/publications/recycling/2016/PaperforRecyclingQuality%20Control%20Guidelines.pdf› [Accessed on November 2, 2016].

Deviatkin, I., Kujala A. and Horttanainen M, 2015. *Deinking Sludge Utilization Possibilities: Technical, Economic, and Environmental Assessments- Report on responsibilities of LUT Energy in EMIR project, 2012 - 2014*. Lappeenranta, Finland: LUT Scientific and Expertise Publications, pp.12-15.

Energos, 2016. ‹http://www.energ-group.com/energy-from-waste›.

Future Markets Inc., 2012. *The Global Market for Nanocellulose*. Edinburg, UK.

Future Markets Inc., 2015. *The Global Market for Nanocellulose*. Edinburg, UK.

Gillette, R., Swanback, S. and Overacre, R., 2009. *Improving Efficiency of Dewatering Alternatives to Conventional Dewatering Technologies*. PNCWA Webinar Recent Developments In Biosolids Management Processes. Available at: ‹http://www.pncwa.org/assets/documents/Alternative%20Dewatering%20Technologies%20Gillette%20200908%20pncwa.pdf› [Accessed on 2 November, 2016].

Hassan, B., 2003. *Oxygen-Peroxide (Eop) Delignification And Peroxide (P) Bleaching Of Bagasse Kraft Pulp*. Journal of Scientific and Industrial research (J SCI IND RES INDIA) [Online]. Vol. 62, July 2003, pp. 699-706. Available at: ‹https://www.researchgate.net/publication/264782426_Oxygen-peroxide_Eop_delignification_and_peroxide_P_bleaching_of_bagasse_kraft_pulp› [Accessed on 2 November 2016].

Indian Newsprint Manufacturers Association.

Innventia, 2013. *Innventia Global Outlook: Packaging 2020*. Report No. 387. Stockholm, Sweden: Innventia AB.

Intergovernmental Panel on Climate Change, 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. In T. Stocker, D. Qin, G. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. Midgley eds. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Juntti, O., 2015. *What is the role of fibre based packaging...? ... in the global packaging markets*. Paper Industry World (Market&Trends), [Online] Available at: ‹http://www.paperindustryworld.com/what-is-the-role-of-fibre-based-packaging/› [Accessed on 2 November 2016].

Kharas, H., 2010. *The emerging middle class in developing countries*. Working Paper No.: 285. Paris, France: OECD Development Centre. Available at: ‹http://www.oecd.org/dev/44457738.pdf› [Accessed on 2 November 2016].

Kolari, M. *New research gives breakthrough in cutting slime and corrosion risk on PM*. World Pulp & Paper. Available at: ‹http://www.kemira.com/Materials/new-research-gives-breakthrough-in-cutting-slime-and-corrosion-risk-on-pm-article-kemira.pdf› [Accessed on 2 November 2016], pp.51-54.

MarketsandMarkets, 2015. *Paper & Paperboard Packaging Market by Grade (SBS, CUK, FBB, WLC, Glassine & Greaseproof, Label Paper), Application (Food, Beverage, Healthcare, Personal & Home Care), & by Type (Corrugated Box, Boxboard, Flexible Paper) - Trends & Forecast to 2020*. marketsandmarkets.com.

Metsä Fibre, 2008.*Rauma Pulp Mill* [Online]. Available at: ‹http://www.metsafibre.com/en/about-us/Pages/Rauma-mill.aspx› [Accessed: 2 November 2016].

Ministry of Commerce and Industry, Government of India, Department of Industrial Policy and Promotion, 2011. *Working Group Report on Pulp and Paper for the Twelfth Five Year Plan* [Online]. New Delhi, India. Available at: ‹http://planningcommission.gov.in/aboutus/committee/wrkgrp12/wg_paper.pdf› [Accessed: 2 November 2016].

Moss, L., 2012. *Trends in Dewatering*. Webinar, December 18, 2012. Available at: ‹http://www.weat.org/events/2012MossWEATDewateringTrends.pdf› [Accessed on 2 November 2016].

National Intelligence Council, 2012. *Global Trends 2030: Alternative Worlds [Online]*. Washington, DC, USA. Available at: ‹https://globaltrends2030.files.wordpress.com/2012/11/global-trends-2030-november2012.pdf› [Accessed on 2 November 2016].

Nova Institute, 2011. ‹www.nova-institute.eu›.

SCA, 2013. *SCA Annual Report 2013*. [Online] Available at: ‹http://www.sca.com/Documents/en/Annual_Reports/SCA-Annual-Report-2013.pdf?epslanguage=en› [Accessed on 2 November 2016].

Schrijver, J et. al., 2008. *Biocides for deposit control in the production of corrugated base paper.* In: Zellcheming TC ed., *Chemical Additives for the Production of Pulp & Paper,* pp. 319-339.

Skog22, 2014. *Working Group Report Fibres and Biorefining*.

Shammas, N, Wang, L., and Selke, W., 2010. *Completely Closed Water Systems In Paper Mills.* In *Flotation Technology.* Humana Press, pp. 401-427.

SmithersPira, 2013. *The Future of Global Packaging to 2018*. Ohio, US.

SmithersPira, 2016. [Online] Available at ‹http://www.smitherspira.com/›.

Stickies. [Online] Available at: ‹http://www4.ncsu.edu/~hubbe/TShoot/G_Sticki.htm›

Suhr, M., Klein, G., Kourti, I., Rodrigo Gonzalo, M., Giner Santonja, G., Roudier, S. and Delgado Sancho, L., 2015. *Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control)*. Publications Office of the European Union. [Online]. Available at: ‹http://publications.jrc.ec.europa.eu/repository/handle/JRC95678› [Accessed on 2 November 2016].

Technavio, 2015. *Global Liquid Packaging Board Market 2015*.

The Freedonia Group, 2016. Ohio, USA. [Online] Available at: ‹http://www.freedoniagroup.com/›.

Toven, K., 2000. *Ozone Based ECF Bleaching of Softwood Kraft Pulp*. Norwegian University of Science and Technology, Department of Chemical Engineering, PhD Thesis, October, 2000.

United Nations, Department of Economic and Social Affairs, Population Division, 2012. *World Urbanization Prospects: The 2011 Revision (ST/ESA/SER.A/322)*[Online]. New York, USA. Available at: ‹http://www.un.org/en/development/desa/population/publications/pdf/urbanization/WUP2011_Report.pdf› [Accessed on 2 November 2016].

United Nations, Department of Economic and Social Affairs, Population Division, 2015. *World Population Ageing 2015* (ST/ESA/SER.A/390) [Online].New York, USA. Available at: ‹http://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2015_Report.pdf› [Accessed on 2 November 2016].

United Nations, Department of Economic and Social Affairs, Population Division, 2015. Population Statistics.

Voith, 2016. *Thune Screw Press (Fibre) SP - An Excellent Choice for Pulp Dewatering*. [Online] Available at: ‹http://voith.com/en/1140_en_03_P06_Thune_Screw_Press.pdf› [Accessed on 2 November 2016].

Voith, 2016. *Valmet TwinRoll Evolution - Refining a Unique Tradition*. [Online] Available at: ‹www.voith.com/paper›.

Voith, 2016. *Voith Thune Screw Press - The New Generation of Dewatering from Voith*. [Online] Available at: ‹www.voith.com/Paper›.

World Bank Group, 2016. *Population Estimates and Projections.* [Online] Available at: ‹http://data.worldbank.org/data-catalog/population-projection-tables›.

Witthuhn, V., 2015. *Biosolids Dewatering Equipment Comparisons.* In*:* WWOA Annual Operators’ Meeting, October 5, 2015. Strand Associates, Inc. Available at: ‹https://www.wwoa.org/files/publishedpapers/2015/Annual%20Conference%202015/VCW%20WWOA%20Annual%20Meeting%20-%20Dewatering%20Evaluations-%20October%202015.pdf› [Accessed on 2 November 2016].

‹www.crs-reactor.com›

Yang, Silas, 2014. *Global Annual Review 2014: Shift in Global Economic Power*. PwC. [Online] Available at: ‹www.pwc.com/gx/en/annual-review/megatrends/shift-in-global-economic-power-silas-yang.jhtml› [Accessed on May, 2016].

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION