A REPORT

ON

OPPORTUNITIES FOR GREEN CHEMISTRY INITIATIVES:
PULP AND PAPER INDUSTRY

OFFICE OF THE PRINCIPAL SCIENTIFIC ADVISER TO THE GOI
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PREFACE

Green chemistry is becoming an important tool to modify an existing process or to develop new processes with a sustainability approach. It basically enunciates the ideal principles of sustainable chemistry with basic trait to minimise the environmental impact of a given process.

Pulp and paper (P&P) industry is one of the most polluting industries, as identified and categorised by Central Pollution control Board (CPCB). It consumes a significant quantity of water and chemicals and produces large volumes of effluent. Accordingly MoEF launched the Charter "Corporate Responsibility for Environment Protection (CREP)" in 2003. This is a voluntary charter formulated by mutual consent between MoEF and the industrial sector. Pulp and paper sector took a few initiatives for pollution control. Still it generally lags behind the global scene, particularly the small medium industries. This is because of the diversity of the Indian pulp and paper industry with a range of production capacities and raw materials.

The Office of Principal Scientific Adviser (PSA) to the Government of India has been focusing on green chemistry for sustainable chemical industry in India. Pulp and Paper industry is one of the five industrialsectors identified for developing a strategy and roadmap for R&D interventions. During the interaction with pulp and paper industry, many critical issues emerged to be addressed under the green chemistry initiative. Office of PSA constituted anExpert sub-Group to further assess these critical issues and identify the R&D avenues.

The sub-Group visited seven representative paper mills, both old and modern mills, spread over the country, in Uttar Pradesh, Kerala, Andhra Pradesh, Uttarakhand and Tamil Nadu, covering large, medium and small and using a range of raw materials and producing a range of paper products. The visits were extremely useful in understanding the problems and some of the solutions to address the problems.

The sub-Group also collected all the relevant literature and reports along with national statistics to arrive at a meaningful. Based on the data collected the sub-Group was able to put together a section on the current status of Indian P&P mills and bring out the major issues with respect to the various emissions (air, water, solid) and energy efficiency and how these have been addressed by these industries at different levels. Finally the sub-Group has come out with a set of recommendations and potential R&D interventions as well as partners for the industry to collaborate.

As a Chairman of the Sub-Group, I very much hope that this report will pave the way for collaborations between industry and R&D institutions, IITs and Universities to take the P&P industry into the sustainable path.

I would like to thank the Office of PSA for entrusting this responsibility on me and the members of Green Chemistry Core Group for their valuable input. I would like thank all the members of the sub-Group for P&P, who had put in considerable efforts for industrial visits and drafting the report. Special thanks are due to Office of PSA and Central Pulp and Paper Research Institute for their contributions.

SukumarDevotta

Former Director,
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1.0 INTRODUCTION

Pulp and paper industry is one of the most energy intensive and polluting sectors. The sector largely employs conventional technologies. These are highly intensive in terms of consumption of raw material, chemicals, energy and water thereby generating higher levels of effluents. Incidentally, it is one among the 17 industries identified by Central Pollution Control Board (CPCB) as highly polluting and compliance to environmental norms is inadequate.

There have been concerted efforts by industry, CPCB and Ministry of Environment and Forests (MoEF) towards addressing the problems of high levels of environmentally undesirable components in effluents. Industry voluntarily evolved norms for water usage, quality of effluents discharged and energy usage under the Corporate Responsibility for Environmental Protection (CREP). To achieve the set norms, the industry deployed new technologies and improved existing technologies. There has been a renewed effort from CPCB for more stringent norms for water usage per tonne of paper, quality of treated wastewater discharged and consumption of energy. Implementation of such stricter norms would be a challenge and calls for infusion of new technologies including cleaner and greener technologies, as well as research efforts to develop cost effective solutions that could readily be adopted even by smaller units for sustainability of this sector.

Globally, the sector is perceived to have a low rate of innovation, with a few recent developments being the improvement in bleaching technology and increased usage of recycled paper. Indeed the innovations in the industry are also largely driven by environmental considerations. Wide variety of raw material usage and varied operational technologies, particularly in Indian context, impose limits in standardization of improvements in operation. Increase in productivity through the adoption of more efficient and cleaner/green technologies in the manufacturing will boost the economic, environmental, and social development objectives in the pulp and paper sector.

1.1 Green Chemistry

The effect of industrial pollution on the environment has led the industry and research communities to focus on green chemistry that is concerned with developing processes and products to reduce or eliminate hazardous substances or conditions. Green chemistry, also called sustainable chemistry, is a philosophy of chemical research and engineering that encourages the design of products and processes with minimum use and generation of hazardous pollutants.

One of the primary goals of green chemistry is to prevent pollution at its source, as opposed to dealing with pollution, after it has occurred. Accordingly, utilization of nontoxic chemicals, environmentally benign solvents and renewable materials are some of the key factors in green chemistry strategy.

The key elements of green chemistry are:

- design of processes to maximize the amount of raw material that ends up in the product;
- use of safe, environment-benign substances, including solvents, whenever possible;
- design of energy efficient processes;
- design of the chemical products in such a way that at the end of their function they do not persist in the environment and break down into innocuous degradation products;
- development of analytical methodologies to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances;
- use the ideal waste disposal strategy i.e. not to generate waste in the first place.

Green chemistry is increasingly seen as a powerful tool that researchers must use to evaluate the environmental impact of the processes being developed. Now a days, attempts are being made not only to quantify the greenness of the chemical process but also to factor in other variables, such as, chemical yield, cost of reaction components, safety in handling chemicals, hardware demands, energy profile and ease of product workup and purification. Green chemistry thus combines important elements of environmental improvement, economic performance, and social responsibility to address environmental problems as well as industry competitiveness. Green chemistry developments are likely to have an impact on the global trade of chemical industry in future.

1.2 Initiative of Office of PSA to GoI

In view of its likely impact on chemical industry, the Office of Principal Scientific Adviser (PSA) to the Government of India has chosen green chemistry as one of the areas of focus for sustained R&D interventions in the chemical industry. Accordingly, the Office of PSA to GoI constituted an Expert Committee to address specific issues of Chemical Industry. The composition of the committee is as follows:

- Prof. G.D. Yadav, Vice Chancellor, ICT, Mumbai — Co-Chairman
- Dr. J.S. Yadav, Former Director , IICT , Hyderabad — Co-Chairman

- Prof. DevangKhakhar, Director, IIT-Bombay, Mumbai — Member
- Dr. P.K. Ghosh, Former Director, CSMCRI, Bhavnagar — Member
- Chairman, CPCB, Delhi — Member
- Sh. Samir S. Somaiya, CMD, Godavari Bio-Refineries Ltd., Mumbai — Member
- Dr. D. YogeswaraRao, Adviser, O/o PSA to GoI, New Delhi — Member - Secretary

The committee, as a first measure identified five sectors of Indian Chemical Industry for developing a strategy and roadmap for R&D interventions. These are: (i) Pulp and Paper (ii) Distillery, (iii) Dyes and Dye intermediates, (iv) Drugs and Pharmaceuticals and (v) Bulk Inorganic Chemicals. It was further decided to follow a four pronged approach, viz., (i) sectoral approach projects (ii) industry specific projects (iii) generic knowledge projects and (iv) new knowledge generation suited for these sectors.

Detailed discussions were held with specific industrial sectors to arrive at a common and collective strategy. During the interaction with pulp and paper industry, the important issues emerged are: (i) Conventional technologies used in manufacturing are highly intensive in consumptions of raw material, chemicals, energy and water, thereby, generating higher effluent loads, (ii) Uneconomic scale of operation, (iii) Average capacity of mills being small, their ability to introduce new technologies and automation, to improve the product quality and reduce the effluents, gets limited, (iv) High water consumption per tonne of product, (v) Colour and relatively high Chemical Oxygen Demand (COD) of the effluent, (vi) High energy input per tonne of product, (vii) Odour reduction on the premises, (viii) Solid waste management, and (ix) Absorbable Organic Halide (AOX) management. In order to understand these issues in detail, vis-à-vis the practices across the industry, as well as to identify the R&D opportunities, it was decided to undertake a scoping study of the sector.

1.3 Constitution of the Expert Sub-group

In line with the decision, a small group of experts was constituted to carry out a scoping study with the following composition:

i)	Dr.SukumarDevotta, formerly Director, NEERI	Chairman
ii)	Dr. R.M. Mathur, Director, CPPRI, Saharanpur	Member
iii)	Dr.VivekRanade, Deputy Director, NCL Pune	Member
iv)	Prof. V.V. Mahajani(formerly ICT, Mumbai)	Member

v)	Dr.TapasNandy, Chief Scientist, NEERI	Member
vi)	Representative, CPCB	Member
vii)	Dr.Manju Gerard, Scientist, Office of PSA to GoI	Member Secretary
viii)	Dr. R.K. Jain, Scientist F, CPPRI, Saharanpur	Special Invitee
ix)	Dr. D. Yogeswara Rao, Adviser, O/o PSA to GoI	Special Invitee

The terms of reference (ToR) for the Sub-group are:

- To undertake a scoping study for pulp and paper industry sector covering all the existing environmental concerns;
- To prioritize the concerns in order of preference
- To suggest possible R&D interventions to address concerns
- To identify the researchers from various institutes and industry who can take up R&D interventions;

1.4 Visit of the sub-group to the paper mills and Observations

The Expert group visited seven representative paper mills covering large, medium and small across the country to understand the existing environmental problems in consonance with the identified issues during the interaction with the industry. These visits were during April to November 2013, in the various states, such as, Uttar Pradesh, Kerala, Andhra Pradesh, Uttarakhand and Tamil Nadu. The committee visited mills with production capacities ranging from 33,000 tpa to 4,70,000 tpa and using hard wood, agro residues, bagasse and recycled waste paper as raw materials. The visits covered small old mills as well as modern plants that are adopting some of the integrated technologies of international standards. These mills produce printing, writing, newsprint and specialty paper.

2.0 INDIAN PAPER INDUSTRY

2.1 Status

Globally paper Industry is one of the high priority industries having a bearing on the socio-economic development. In India too this industry plays a vital role in the overall industrial growth. Indian paper industry is one of the world's fastest growing industries. It grew at a compounded annual growth rate of 6.7% over FY 06-11.Among the top producers of paper, India ranks at 20thposition with an estimated production of 10.9 Mtpa. The Indian sector accounts for about 2.6% of the global production, estimated at 390 Mtpa. In 2012, India recorded paper consumption of 9.3 kg/capita vis-à-vis global average of 58 kg/capita.

The consumption in USA is the highest at 320 kg/capita. The domestic demand for paper consumption is on the rise due to increasing population, literacy rate, and growth in GDP leading to generally improving living standards of the individuals.

The paper industry grew rather slowly in the first three decades after independence. The paper "famine" of 1970 changed the working environment of the paper sector, and a number of licenses were given to smaller units for manufacture of paper. These units used agricultural residues and waste paper as the raw material base, and eased the paper scarcity in the country. However, this also created a fractured structure in the industry, where small, medium as well as large mills came in to co-existence. After the economic reform in 1991, the paper industry was de-licensed. This acted as a booster dose for further growth of the industry.

Currently there are 759 pulp and paper mills with an installed capacity of 12.7 Mtpa, producing around 10.90 Mtpa paper, paper board and newsprint. The production is anticipated to grow up to 14.0 Mtpa by the year 2016.

The average annual turnover of the industry is approximately Rs. 30,000 crores, which accounts for approximately 0.37% of the national GDP. It contributes Rs. 3000 crores to exchequer and provides direct employment opportunities to about 3.7 lakh people and indirect employment of over 12 lakh people. The industry employs wood, agro residues and recycled/waste paper as the major raw material for manufacture. Indian paper industry ranks sixth among the energy intensive industries with an energy requirement of about 10 Mtpa of coal and 10.6 GWh of electricity. On an average, one tonne of virgin paper requires 2-3 tonnes of coal. Table 2.1 shows the current status of Indian paper Industry.

Table 2.1: Status of the Indian Paper Industry

Number of mills	759
Installed capacity, Mt	12.7
Capacity utilization, %	~ 90
Production of Paper, Paperboard and Newsprint, Mtpa	10.9
Per capita Consumption (kg)	9.3
Annual Turnover, Rs. Crores	30,000
Contribution to Exchequer, Rs. Crores	3000
Employment Direct, million people	0.37
Indirect Employment, million people	1.2
Indian Share in World's Production, %	2.6

Source: Working Group report of 12th FYP

The installed capacities in wood based large integrated paper mills range from 250 - 1150 tpd, with a production share of around 31%. The medium sized agro based paper mills have the capacity from 30-350 tpd with a production share of 22% whereas the small waste paper based paper mills operate in the range10-500 tpd contributing to 47% of total country's production.

2.2 Structure of Indian Paper Industry

The Indian paper Industry has highly fragmented structure consisting of small, medium and large sized paper mills having capacities ranging from 10 to 1150 tpd employing wood, agro residues and recycled waste paper as major raw materials.

The distribution of Indian paper industry based on the type of raw material used for making paper viz. wood, agro residues and recycled/waste paper is given Table 2.2.

Table 2.2 : Structure of Indian Paper Industry

	No. of Mills	**Production, Mtpa**	**Production Share (%)**
Wood based (Large Integrated)	30	3.40	31
Agro based (Medium Scale)	150	2.42	22
Recycle Fibre based (Medium and Small Scale)	579	5.10	47
Total	**759**	**10.92**	**100**

Source: Working Group report of 12th FYP

The Indian paper Industry mainly produces writing printing grade and newsprint grade as well as industrial grade paper. The writing and printing grade of paper comprised mainly of uncoated varieties viz. cream wove, maplitho; branded copier is mainly produced from wood based raw materials with a little share from agro and recycled waste paper, whereas the industrial paper, classified into kraft paper, white board, Machine glazed (MG) poster, duplex board andgrey board, is mainly produced by the small and medium sized recycled waste paper based mills. Newsprint grade paper is produced by mills utilizing mainly recycled waste paper as well as agro residues as major raw material. Table 2.3presents the category-wise production of paper from different raw materials in Indian paper Industry.

Table 2.3: Indian Production from Different Raw Materials

Variety	Raw Material	Production (Mtpa)	Total production (Mtpa)	% contribution
Writing Printing grade	Wood based	2.53	4.18	38
	Agro based	0.78		
	Recycled fibre based	0.87		
Packaging grade	Wood based	0.84	5.90	54
	Agro based	1.64		
	Recycled fibre based	3.43		
Newsprint grade	Wood based	0.03	0.84	8
	Agro based	Nil		
	Recycled fibre based	0.81		
Total Production			**10.92**	**100**

Source: Working Group report of 12th FYP

The yearly production and consumption in Indian paper industry arepresented in Table 2.4.

Table 2.4: Yearly Production and Consumption in Indian Paper Industry

Year	Capacity, Mt	Production, Mt	Export, Mt	Import, Mt
2005-06	7.32	6.80	0.312	0.981
2006-07	7.99	7.16	0.343	1.138
2007-08	8.32	7.33	0.329	1.341
2008-09	8.83	7.64	0.340	1.407
2009-10	9.34	8.02	0.382	1.464
2010-11	12.7	10.1	0.527	1.582
2011-12	13.55	10.9	0.545	2.336

Source: Working Group report of 12th FYP

2.3 Major raw materials used in Indian Paper Industry

- **Hard Wood & Bamboo:** The present consumption of wood as raw material for papermaking is 9 Mtpa. About 75% of the wood demand is being met through farm/social forestry sources. An additional 12 Mtpa of wood will be required to meet the projected production targets by the year 2025.

- Wood consists of approximately 50-55% cellulose, 25-30% ligninand 20-25% hemi-cellulose. In India, eucalyptus, casurina, subabul, poplar and bamboo are used for pulp production.

- **Agro Residues**: Use of non-wood agro based material is widespread in developing countries due to lack of forest resources and advanced processing technologies. Largest non-wood based fibre producer is China followed by India and Thailand. Agro based fibres is well suited for small scale industry, because of its low capital investment. Usually, three categories of non-wood fibres are used viz. crops such as (hemp, kenaf, flax, jute), agricultural residues (wheat, corn or rice straw, bagasse, sisal) and wild plants (grasses, bamboo and seaweed). Bagasse and wheat straw are the two major agro based raw materials used by the paper industry in India. Both these raw materials, though available in plenty, are not available to the paper industry due to diversion for other end-uses. The agro residues contain lower lignin content, higher silica and ash. Fibre from bagasse and straw generally results in low-grade pulp, whereas hemp, kenaf, cotton and flax are often used in higher quality and specialty papers such as banknote and cigarette papers. By 2025, the capacity of the agro residue based units is expected to be doubled from its present capacity of 2.1 Mt.

- **Recycled Fibre (RCF) /Waste Paper**: The recycled waste comprises both pre-consumer and post-consumer. The pre-consumer wastes are the shavings and trimmings from paper machine such as printers, rejects etc. The post-consumer waste is usually old wastepaper collected from consumers. The requirements of raw material are sourced both indigenously as well as through imports. These wastes are best suited for end products, such as newsprint, duplex board, Kraft paper etc. Table 2.5 presents the availability and share of RCF/waste paper.

Table 2.5: Availability of RCF/waste paper

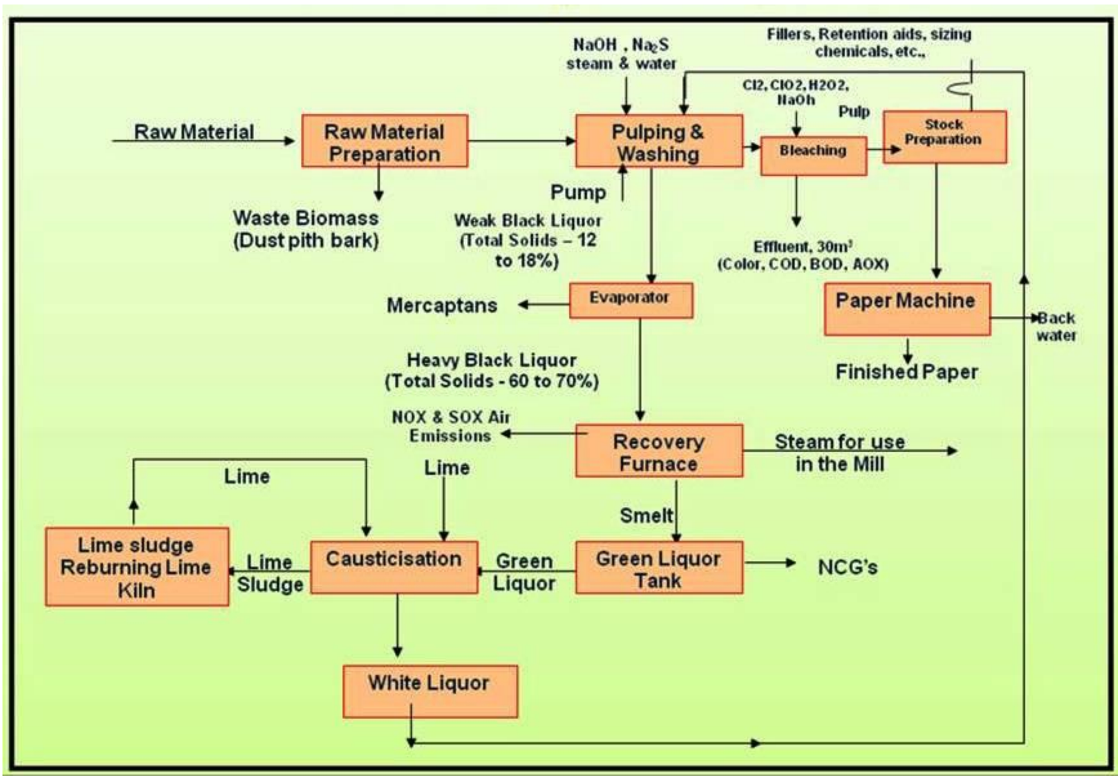
		Mt	**% Share**
1	Indigenously recovered waste paper	3.0	43
2	Waste paper import	4.0	57
	TOTAL	**7.0**	

Source: Working Group report of 12th FYP

2.4 Manufacturing Process

The manufacturing process of paper industry can broadly be divided into three sections viz. pulping, bleaching and papermaking. The process block diagram, with major unit operations in the paper industry employing wood and/or agro residues as raw material, is shown in Figure 1.0.

Figure 1.0 Diagram of a Process Block Pulp and Paper Mill



2.4.1 Pulping Process: Pulping is the major source of effluents in the manufacturing process. This process enables separation of cellulose fibres and removal of impurities. As mentioned earlier, the pulping process employs three types of raw materials viz. i) Hard wood, ii) Agro residues and iii) Recycled fibre/ waste paper. Quality of paper largely depends on the cellulose content in pulp and the fibre length. The raw materials are briefly discussed below.

Hardwoods contain higher proportion of cellulose but shorter fibre length than softwoods, which are more resinous. The removal of lignin by treating the wood chips improves the fibre quality. Generally two approaches are employed for pulping in Indian context, viz. chemical pulping and chemi-mechanical pulping. Approximately 3 Mt and 0.05 Mt pulp are made respectively.

- **Chemical Pulping - Kraft Sulphate process:** Kraft/sulphate process is the most versatile method of pulp production. It results in strong and long fibre as well as low lignin content pulp. In this process the wood chips are cooked at temperature of 165-170°C with sodium hydroxide (caustic soda) and sodium sulphide to separate lignin and wood resins from the pulp. The pulp is then washed and bleached, if necessary. About 92-95 % of the chemicals (sodium hydroxide, sodium sulphide and lime) are recovered and reused by operating in a closed loop system.
- **Chemical Pulping – Soda process:** The Soda pulping process is employed for pulping of agro residues like wheat and rice straw and bagasse. In this process these raw materials are cooked with caustic soda at a temperature of 150-160oC to separate lignin from the raw material. The pulp is then washed and bleached, if necessary, to make a bleached pulp.
- **Chemi-mechanical pulping (CMP):** In the chemi-mechanical process the wood chips are first impregnated with mild caustic soda based chemicals to extract resin and lignin from the fibre prior to mechanical refining.
- **De-inking of RCF:** For recycled fibre, dispersion or floatation pulping process is used for de-inking. The re-pulped fibre is washed and sorted to remove solid impurities. For de-inking, chemicals such as detergents, dispersants and foaming agents are added and ink is separated from the pulp with foam by aeration and concentrated into sludge for disposal. The fibre yield in this process depends upon the filler content and quality of the input fibre.

2.4.2 Bleaching Process: Bleaching process is carried out to improve the brightness of the pulp. The type of pulp involved and the destined end use are important factors in the actual process. Some of the bleaching agents used are chlorine (Cl2), chlorine dioxide (ClO2), hydrogen peroxide (H2O2), caustic, oxygen, ozone, hypochlorite, sodium bi-sulphite.

- **Chlorine Bleaching:** The process is used to remove the residual lignin in the range 5-10%. This process is followed by several stages of treatment with chlorine dioxide or hypochlorite to whiten the pulp.

- **Elemental Chlorine Free (ECF) Bleaching:** ECF bleaching technology is being practiced in many large mills where it uses oxygen delignification (ODL), followed by ClO2 and other chemical agents to achieve brightness. A typical sequence would include chlorine dioxide, caustic soda, oxygen and hydrogen peroxide.

- **Total Chlorine Free (TCF) Bleaching:** Combination of ODL with ozone / peroxide brightening leads to TCF bleaching. The bleaching process can be enhanced by the use of enzymes and a 'chelating' agent (ethylene diamine tetra acetic acid, EDTA) is added to bind the metal ions contained in the pulp and prevent them from decomposing the hydrogen peroxide. The paper whiteness of ISO 70-85% is achieved by this method and can be improved to ISO 85-90% by using ozone bleaching.
- **Hydrogen Peroxide Brightening:** Hydrogen peroxide is used for bleaching the pulp with high lignin content. Hydrogen peroxide alters the chemical structure of lignin by oxidizing and remains with the pulp. Though hydrogen peroxide is environmentally benign, it is expensive.

3.0 POLLUTANTS GENERATED FROM PULP AND PAPER INDUSTRIES

Use of significant amount of chemicals, such as sodium hydroxide, sodium carbonates, sodium sulfide, bi-sulfites, elemental chlorine or chlorine dioxide, calcium oxide, hydrochloric acid, etc. in manufacturing of paper results in generation of larger quantities of effluents containing organic and inorganic salts and toxic pollutants, which are let out. These pollutants are briefly discussed below.

- Organic Pollutants and Suspended Solids: Fugitive fibres, starch, hemi-cellulose and organic acids are the main cause for organic pollution in effluents. This results in a COD discharge in the range 25-125 kg/t of pulp. High BOD/COD concentration results in depletion of oxygen available to fauna and flora in the downstream of effluent discharge. Many toxins such as resin and fatty acids and heavy metals present in the mill effluents are absorbed by the organic solids. This can have long-term effects over a wide area as a result of bioaccumulation and transportation through the food chain.
- Organochlorine Compounds: During paper production, a large number of organochlorine compounds, such as, chlorinated derivatives of phenols, acids, dibenzo-p-dioxins/furans and other neutral compounds are generated, which is a cause for environmental concern. Bleaching process effluents may contain chloroform and carbon tetrachloride, which are classified as carcinogens. The hypochlorite stage is the major producer of chloroform. The various micro pollutants like chlorinated benzenes, phenols, epoxy stearic acid and dichloromethane present in the effluents are also classified as suspected carcinogens.

- Chemicals, such as, chloroform, chloro-acetones, aldehydes and acetic acid are formed during bleaching process, but in lower concentrations than chloro-phenolics. Generally these compounds are non-persistent and non-bioaccumulative, but some of these are moderately toxic, mutagenic and suspected carcinogens.

- Chlorophenolics: The chlorophenolics are toxic, persistent and bioaccumulative, and can transform into other compounds such as trichlorophenol and pentachlorophenol. Use of elemental chlorine in bleaching process significantly increases chlorophenol production.

- Dioxins (Polychlorinated dibenzo-dioxins) and Furans (Polychlorinated dibenzo-furans): Dioxins are extremely toxic, persistent and carcinogenic. Furans are chemically similar but of less magnitude. Dioxins and furans are found in wastewater treatment sludge, which is a cause for great concern.

4.0 NATIONAL ENVIRONMENTAL POLICY AND POLLUTION CONTROL NORMS FOR PULP and PAPER INDUSTRIES

4.1 Environmental Standards and Discharge Norms for Indian Paper Industry

TheCentral Pollution Control Board has taken several initiatives for reducing the pollution in bodies by 2020. Accordingly, CPCB brought out a charter for water recycling and pollution pulp and paper industry. Notable among these are not to allow discharge of any untreated industrial effluent in the riverwith a view to reduce the impact of effluent discharge into water prevention in pulp and paper industries located in river basin.The present environmental standards and discharge norms for Indian paper industry are given in Table 4.1 and 4.2.

Table 4.1 Wastewater Discharge Norms for Indian Paper Industry

Parameter	Discharge Standards		
	General Standards	CPCB – Pulp and Paper Mills	
		Small Scale	Large Scale
Volume, m^3/t	-	Agro based :200(150)* Waste Paper: 75 (50)*	Writing and Printing: 200 (100)* Rayon grade/ News print: 150
pH	5.5-9.0	5.5 –9.0	7.0 - 8.5
BOD_5 at 20^0C mg/l	30 (Inland surface water) 350 (Public Sewer on land discharge) 100 (Land for irrigation) 100 (Marine / Coastal areas)	30 (inland discharge) 100 (on land discharge)	30
COD, mg/l	250 (inland surface water) - (Public Sewer on landdischarge) - (Land for irrigation) 250 (Marine / Coastal areas)	Not specified	250
SS, mg/l	100 (inland surface water) 600 (Public Sewer on land discharge) 200 (Land for irrigation)	100	50
Total Organic Chloride (TOCl), kg/t_{paper}	-	Not specified	2.0
Absorbable Organic Halides (AOX), kg/t_{paper}	-	2.0	1.0
Sodium Absorption Ration (SAR)	-	26	-
Color, PCU	being implemented	500	500

Source: CPCB

Table 4.2 Air Emission Norms for Indian Paper Industry

Boiler Capacity	Control equipment	Existing Norms
>15tph	ESP	SPM ,mg/Nm^3 : 150 H_2S , mg/Nm^3: 10 SO_x , mg/Nm^3 : Not Defined NOx , mg / Nm^3 : Not Defined
<15 tph	Multi Cyclone	SPM , mg/Nm^3 : 600 (10-15tph) SPM , mg/Nm^3 : 800 (<10 tph) H_2S , mg/Nm^3: Not Defined

Source: CPCB

4.2 Charter for Corporate Responsibility for Environmental Protection (CREP)

Further, the Ministry of Environment and Forest (MoEF) had launched a Charter on "Corporate Responsibility for Environmental Protection (CREP)" in March 2003 with a view to go beyond the compliance of regulatory norms for prevention and control of pollution through various measures including waste minimization, in-plant process control and adoption of clean technologies. The Charter had set targets concerning conservation of water, energy, recovery of chemicals, reduction in pollution, elimination of toxic pollutants, process and management of residues that are required to be disposed of in an environmentally sound manner. The CREP norms are presented in Table 4.3.

Table 4.3 CREP Norms for Indian Pulp and Paper Industry

Environmental Issues	Implementation Schedule
Discharge of AOX, kg/tpaper	AOX 1.5 kg/tpaper within 2 years AOX 1.0 kg/tpaper in 5 years
Installation of lime kiln	Within 4 years
Waste water discharge m3/tpaper	< 140 m3/tpaper within 2 years < 120 m3/tpaper within 4 years for units installed before 1992 < 100 m3/tpaper for units installed after 1992
Odour Control by burning the reduced sulphur emissions in the boiler/lime kiln	Installation of odour control system within 4 years
Upgrade of ETP	One year

Utilisation of treated effluent for irrigation	Wherever possible
Compliance of standard of BOD , COD, and AOX	Either achieve the discharge standards of BOD,COD and AOX by installation of chemical recovery system or utilization of black liquor with no discharge form pulp mill within 3 years or shift to waste paper
Up-gradation of ETPs so as to meet discharge standards	Upgrade the ETP within one year so as to achieve the discharge standards
Waste water discharge	< 150m^3/tpaper within 3 years
Utilisation of treated effluent for irrigation	Wherever possible

Source: CPCB

5.0 OBSERVATIONS OF THE COMMITTEE DURING THE VISITS TO VARIOUS PAPER MILLS

The sub-committee visited various mills representing the cross-section of the industry viz. large, medium and small covering wood based, agro based and recycled waste paper.Generally, it was observed that due to the divergent raw materials, variation in capacities, quality of various end products and with the availability of finance, the larger mills were able to integrate technologies such as super batch digesters, bio-methanation plant, lime sludge reburning kiln and precipitated Calcium carbonate plant etc., well into the manufacturing process. This helped the mills to operate in a closed loop and bring down the water consumption and effluent pollution load significantly. However, smaller mills, due to financial constraints, were not able to adopt the available modern technologies and still rely on Cl_2 bleaching. This has resulted in increased pollution load of AOX and other pollutants in the effluents. In fact a large integrated mill in a specific case use oxygen delignification and ozone for bleaching and thus achieved Elemental Chlorine free bleaching. This has resulted in significant reduction of pollutants and reduced water consumption.The section wise observations of the committee are summarized below:

5.1 General

- The majority of the paper units in Indian paper industry have not kept pace with the technological development except a few of the large wood-based and agro-based mills; the implications of technology obsolescence in paper industry is thus evident in the form of high cost of production, environmental problems, inferior quality of product and lower economies of scale.

The level of technology in most of the agro and recycled fibre based mills is obsolete and majority of the small units and some of the medium sized agro based mills have not attempted to improve/ upgrade the technology. However, the wood-based large mills have upgraded the technology from time to time for improvement in the quality of product and reduction in the pollution load. Lack of technological upgrade has impacted the environmental issues in a major way.

- Raw material preparation, pulping and bleaching and chemical recovery are the major sources of environmental pollution. These operations require major technological interventions and upgrade.

5.2 Raw Material Processing

The heartwood and sapwood are useful for making pulp. Most pulping processes require that the wood be chipped and screened to provide uniform sized chips. It was observed that whilst the major raw material eucalyptus is debarked during cutting in the farms, the other raw materials such as poplar, casuarinas are chipped and digested with bark, resulting in higher consumption of chemicals and lower strength of pulps. This results in difficulties during recovery of spent pulping chemicals due to the presence of undesirable Non-Process Elements (NPEs), like calcium, silica, potassium, as well as resinous materials in the spent liquors. This leads to uneconomical chemical recovery operations. Bark contains relatively few useful fibres and can be used as fuel to provide steam in the mill.

5.3 Pulping

Chemical pulping (Kraft/Soda) process is usedin the mills producing writing and printing grade papers. Broadly in this process two types of digesters are used in cooking: (i) Batch digesters and (ii) Continuousdigesters.The former consumes larger quantities of chemicals.The chemi-mechanical pulping (CMP) process is used in the mills producing newsprint grade paper, which is a continuous process. Modified cooking systems like super batch process, rapid heat displacement pulping etc. are employed in large mills to obtain pulp with better strength properties using lower steam and chemical consumptions.

Continuous horizontal digesters are used to process the agro residues in efficient manner.Agro based mills are gradually switching over from batch digesters to continuous horizontal digesters with screw mechanism for movement of raw materials. Chemical and steam are charged at different points and cooking cycle is completed within 45-60 minutes.

5.4 Brown Stock Washing

This operation is used to separate pulp fibres from the black liquor containing spent cooking chemicals and dissolved raw materials.It was observed that only few of the large wood and agro-based mills have upgraded their washing system with installation of efficient washing systemmainly employing vacuum drum washers or belt washers or twin roll presseswith minimum dilution factor,chemical losses and maximum washing efficiency.

5.5 Extended Delignification through Oxygen Delignification (ODL)

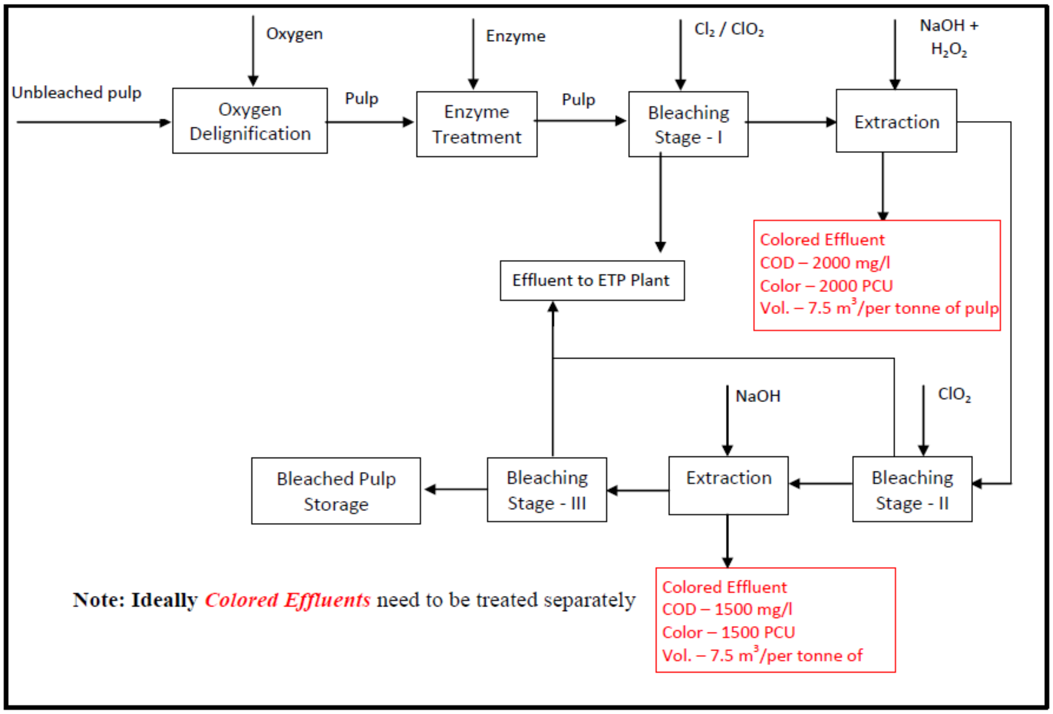
Fewof the large wood based/agro based mills have upgraded their technology with introduction of ODL process, which involves the use of oxygen and alkali to remove a substantial fraction of the lignin remaining after pulping. This results inlower Kappa pulp with higher fibre strength and brightness. The process helps to reduce the requirement of bleaching chemicals and facilitate recycling of bleach plant washwater. This significantly reduces the pollution load in the effluent.

5.6 Bleaching of Pulp

Bleaching process employed in most of medium and small Indian mills are based on elemental chlorine. However, few of the large sized wood based/ agro based mills have gone for technological up gradation with the introduction of the ECF bleaching process making use of chlorine dioxide. In one of the mills visited by the Committee, ECF in combination with ozone is being practiced with significant reduction of the pollution load.In some of the mills the effluent after thealkali extraction stage is highly coloured where ODL and ClO_2 bleaching are not employed.

The entire outline of the bleach plant process is shown in Figure 2.

Figure 2. Process Flow Diagram of Bleach Plant Operations



5.7 Chemical Recovery Operations

The process isaimed at recovery of chemicals from the spent cooking liquor, recovery of energy from incineration of dissolved lignin and other organics in the black liquor and minimization of air and water pollution. Basic steps involved in chemical recovery system consist of the following:

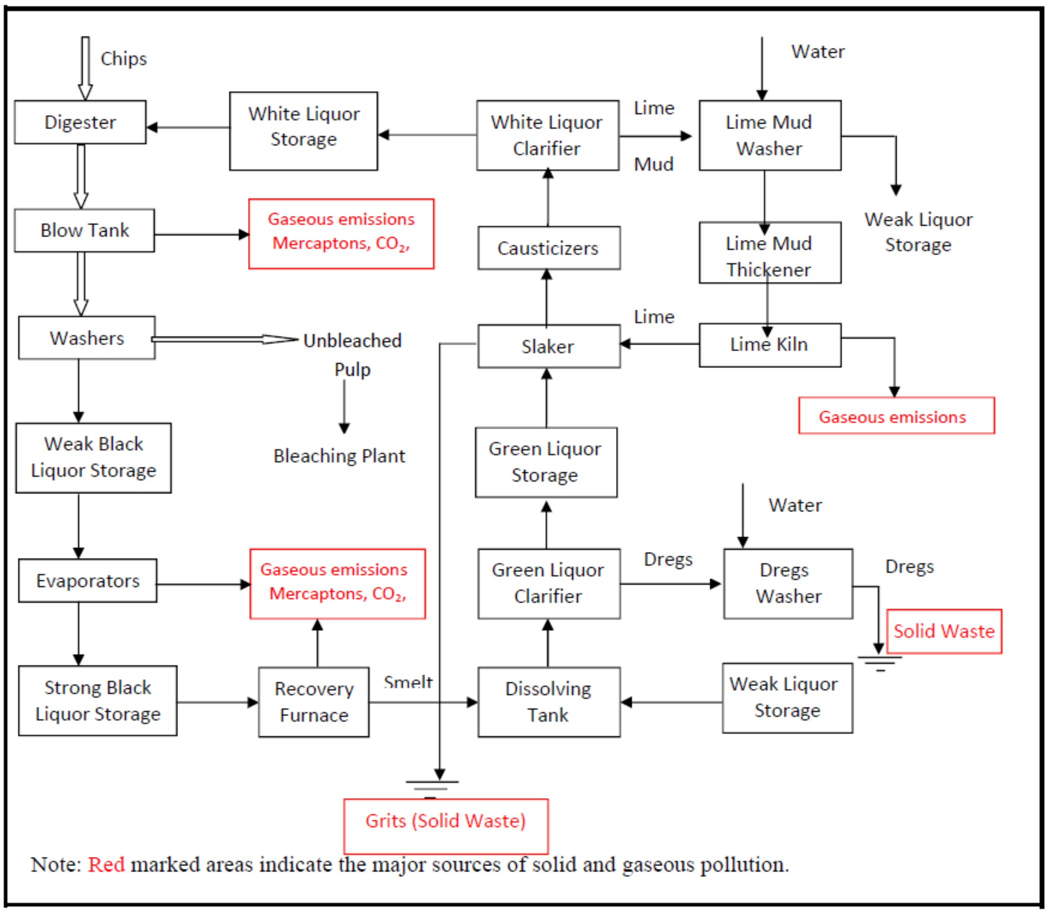
- Concentration of liquor in multiple effect evaporators to form concentrated black liquor (50% solids)
- Further concentration of liquor to get “heavy black liquor” (65% solids)
- Addition of sodium sulfate to make-up for the loss of soda
- Incineration of black liquor in recovery furnace
- Dissolution of smelt from the recovery furnace to get green liquor
- Reaction of the green liquor with slaked lime, called causticising, to get white liquor to produce “lime mud”, as a by-product.
- Burning of lime mud to recover lime for reuse in the causticising process.

It was observed that majority of the mills use 5-effect long tube vertical evaporators followed by falling film evaporators as the finisher. Generally, Indian paper mills suffer from low steam recovery from black liquor combustion, failing of evaporators due to silica and fumes, high energy consumption, high supporting steam requirement due to scaling on heat exchangers etc.

However, majority of the paper mills in developed countries use 7 effects of falling film evaporators along with thermal treatment process to facilitateconcentration of high solids from black liquor.Modern chemical recovery boilers involve the use of single drum, high pressure, high solids, and high capacity recovery boilers with advanced control systems.

The process flow diagram of entire pulping and chemical recovery is shown in Figure 3.

Figure 3. Process Flow Diagram of Pulping and Chemical Recovery Operations



5.8 Water Consumption

Pulp and paper industry consumes large quantities of fresh water. It is the third largest consumer of fresh water with consumption in the range80-150 m^3/t of paper depending on the type of raw material being used. Generally agro based mills consume much more water tha RCF based mills. Disposal of wastewater, containing various chemicals (thiols, sulphur dioxide, sulphite and sulphides, fibres and resins), bleaching agents(hydrogen peroxide, chlorine dioxide, and caustic soda) and whitening agents (kaolin, calcium carbonate, talc, and titanium dioxide), is the greatest environmental concern.

It was observed that in majority of the paper mills, all raw effluents from various unit operations are mixed together and treated using conventional activated sludge process consisting of primary and secondary treatment. It is further treated in aerated lagoons prior to discharging into receiving water bodies. Few of the large paper mills have upgraded their Effluent Treatment Plant (ETP) with installation of tertiary treatment system for better effluent quality, particularly colour and suspended solids.

Few of the medium sized agro-based paper mills have installed the non-conventional chemical recovery system, to incinerate the black liquor, which is one of the major causes of pollution, coupled with a system for tertiary treatment, involving the use of tube settler/ tertiary clarifier and pressure sand filter, to achieve better effluent quality.

The data collected during the visits and comparison with the best practices in developed countries is presented in Annexure I.

6.0 Recommendations

The Indian pulp and paper industries, especially the medium and small scale ones, require process optimization and modifications, energy efficiency systems, technology up-gradation and modernization in different unit operations for attaining enhanced quality and healthier status of environment. Towards this, the sub-Group makes following recommendations:

6.1 Raw MaterialProcessing

(i) Wood based mills: The bark of hardwood does not contribute to the fibre, but have adverse effect on the processes. Therefore, it is desirable to debark the hardwood raw material utilising efficient debarkers and chip screens, before using them for preparation of pulp in the wood-based mills. However, there is a need to demonstrate

debarking of small diameter logs from Subabul/ Casuarina / Poplar etc. Accordingly a pilot level demonstration unit in association with an industrial partner may be set up in one of the plants to evaluate its performance and usefulness in reducing the energy and chemical demand.

(ii) Bagasse based mills: In mills using bagasse, in the storage yard the raw material is constantly kept wet by water spray to avoid any untoward fire accidents. This produces foul odour due to the fermentation of compounds in wet bagasse. Such mills may monitor the air quality and identify the compound(s) responsible for the foul odour and take appropriate mitigation measures.

(iii) Bagasse based mills: Efficient raw material washing and depithing of bagasse may be useful for reducing the chemical consumption during pulping, processing of black liquor and to obtain high strength pulp. A demonstration project on the design and development of indigenous technologies and machinery for efficient depithing of bagasse needs to be encouraged.

6.2 Pulping Process

(i) Agro-based mills: Use of horizontal type continuous tubular digesters should be promoted as they help in reducing the water pollution load and the steam requirement as well as in producing better fibre quality. A demonstration project on multiple points dosing of chemicals in such digester will aid improving the quality of pulp as well as reducing the pollution load in the bleach plant and ultimately in the effluent.

(ii) Agro and hard wood based mills: Use of ODL and/or extended cooking prior to pulp bleaching of hardwood or agro fibres reduce the requirement of chemicals in the subsequent bleaching stages and thus reduces the amount of AOX generated. The process needs to be optimized to achieve the desired results, particularly for small and medium mills.

(iii) RCF mills: Use of enzymatic process for efficient deinking will help in energy efficiency and quality of pulp. Use of enzymes (Xylanases, Ligninases, Glyoxal oxidase and Mn peroxidase) prior to bleaching help to reduce the chlorine consumption. Ink removal through ink adsorption on polypropylene or similar material and use of Raschig rings/ balls are some of the recent methods. Further, membrane separation technology is a potentially attractive method for the removal of flexographic ink residues from the wash filtrate effluent of deinking mills and thereby facilitating recycle of wash filtrate. These processes may be explored.

(iv) All types of mills: Noticeable foul odour is a characteristic quality of air emission in paper mills, particularly those employing bagasse as the major raw material and Kraft pulping process, where emissions of sulphur compounds (mainly mercaptans) are high. Therefore, there is a need to undertake R & D projects for the control and masking of the foul odour.

6.3 Bleaching Process

(i) The characteristics of wastewater are highly influenced by bleaching operations as a large portion of wastewater produced at a mill originates from bleaching process. Reduction of about 90% of the total chlorinated organic material, including chloroform, dioxins and furans, can be achieved by replacing Elemental Chlorine (cause of high pollution) based bleaching operation. Use of Elemental Chlorine Free (ECF) bleaching such as ClO_2 may be encouraged to phase out the chlorine bleaching. This is particularly important for medium and small sized agro-based paper mills. A Demonstration unit for use of chlorine di-oxide in a 100-150 tpd agro-based mill shall help in the promotion of ECF paving the way for moving towards green technological solution.

(ii) Recycling and reuse of water in bleach plant is possible by characterizing and benchmarking input and output characteristics of each bleach sequence to reduce the water consumption. Reuse of secondary condensate in raw material preparation sections and brown stock washing/ bleach washing sections could also be adopted.

6.4 Chemical Recovery

(i) Bagasse and other agro residues based mills: In chemical recovery plants, high black liquor solid concentration needs to be pursued before firing into the recovery boiler to reduce air emissions and to achieve higher thermal efficiency. A pilot demonstration project on thermal treatment of black liquor, preferably with the involvement of industrial partners, should be considered.

(ii) Adoption of efficient multi-fuel high-pressure boilers, turbines and producer gas plants to utilize the biomass as a source of clean fuel, are required to reduce the carbon footprint of the mills. Use of 7 effect falling film evaporators coupled with thermal treatment to facilitate more evaporation and thermal vapour compression for higher steam economy should be promoted. Adoption of large capacity **single drum boiler** with continuous blow down should also be promoted.

(iii) Major air pollution is due to non-condensable gases (NCGs), which include odorous sulphur compounds. Therefore, the air quality around the mill should be monitored for odorous compounds and Good Housekeeping Practices (GHPs) including leakage control of gaseous emission from kiln section and liquid leakage from transfer pumps should be implemented to minimise NCG emissions. A demonstration of such a scheme may be considered.

(iv) Use of alternative sources of energy e.g. solar heating or exclusive use of waste/residue fired boilers (pith / saw dust / ETP Sludge / bark) and solar water heating system for low temperature application should be enhanced to reduce the carbon footprint of mills.

6.5 Effluent Treatment

(i) Presently the effluent water from all the operational units are mixed and collected inthe Effluent Treatment Plant for a common treatment. This mixing up all kinds of wastewater poses a problem of handling large volumes of effluents with a variety of effluent parameters. It is suggested that the coloured and non-coloured effluents may be segregated and treated separately thereby reducing the overall chemical load and possibly improving the treated wastewater quality.

(ii) Efforts must be made to initiate complete recycling of non-coloured effluent and then explore the possibility of recycling the other streams in a phased manner.

(iii) For adhering to the discharge limits for AOX, dioxins etc., advanced treatment of the effluents will be required. Many of the chemicals from paper mills are toxic and mutagenic and may have the tendency to bio accumulate on long term basis. The focus for the new technologies should be the degradation of all mutagenic compounds, resin acids, chlorinated phenols, guaiacols, catechols, and chlorinated aliphatic hydrocarbons.

(iv) Advanced modelling and water pinch technologies can be employed to reduce the water consumption. The application of this concept needs to be demonstrated. This may be taken up preferably in medium or large mills for assessing its technical feasibility.

(v) Agro based mills: The back water of the wet cleaning system can be partially recycled back to the system after clarification. Also the treated waste water from ETP can be used as make up water in wet cleaning system. These steps lead to water conservation and thus the mill will be in a position to reduce its water consumption.

(vi) In many states, the practice of unlined lagoons has been phased out. This practice still continued in some mills. Therefore, mills may initiate actions to reengineer and modernize the existing ETP to phase out unlined lagoons by providing efficient coagulation and flocculation processes and converting the existing anaerobic lagoons into a lined lagoon for active aerobic process, thereby avoiding any groundwater pollution problem, improving the quality of treated effluent as well as reducing the holding time and footprint of the upgraded ETP.

6.6 Policy measures

(i) A policy shift may be needed in setting up / operation of the units by linking it to capacity of plants. The RCF based mills are less polluting thus smaller capacity mills may be allowed. But small wood and agro based mills due to financial constraints may not be able to adopt advanced technologies leading to more pollution. Therefore, wood and agro residue based small capacity mills should not be permitted. The existing small mills in this category may be encouraged to expand capacities gradually, within a time frame, to achieve financial viability and sustainability. Further, for any green field project, the minimum capacity should not be less than 500 tpd of pulp for wood based mills and 250 tpd pulp for agro based mills.

(ii) The industry is capital intensive and requires substantialinvestments for expansion, modernization and up-gradation of technologies to attain better operating levels and competitiveness**.** The low profit margins and financial status of the industry is also making it difficult to sustain the investment requirements of the industry**.** Thus financialsupport is required to enhance production efficiency by technology up gradation, modernization and in case of small and medium mills, through capacity expansion. In view of the above, a focused Technology Modernization Scheme (TMS) aimed towards Green Technology may be considered. This would act as a catalyst for the modernization efforts within the industry. The scheme shall focus on up gradation of technology to reduce pollution and conserve resources. The scheme may also encourage the development of new technologies / demonstration projects aimed at improving the energy efficiency and quality of treated effluent.

TMS may provide funds in the form of soft loans/or interest subsidy. The industry may utilize the funds for:

- Acquisition of proven technology of foreign or indigenous origin
- Acquisition / license of patent rights
- Acquisition of capital goods for transfer of process technology

- Contractual R&D activities leading to technology up gradation of the units
- R&D and demonstration projects

6.7 Capacity Building

Educating paper mill managers and floor technical operators about the latest and emerging developments and technological advancement on sustained basis is necessary. A programme for organizing short-term courses and workshops is required for capacity building of the personnel of this sector. The expertise at IITs, CSIR Laboratories, CPPRI and Universities can support the industry through collaborative research programmes and also provide the required training to the industry personal.

7.0 CONCLUSIONS

In Indian paper industries, the raw material availability/ scale of operations, technological obsolesce and cost of implementing new technologies are some of the major issues. A few of the large wood based mills have made some progress to keep pace with the technological development adopting the State-of-the-Art green technologies. However, the medium and small agro and recycle waste paper based mills are yet to adopt some of the existing or emerging advanced technologies to achieve the desired efficiency and improved environment protection. In developed nations, they are able to reduce the environmental impact by 80-90% with improved technologies and persistent environmental and legislative norms;whereas the Indian industries are lagging behind.

The thrust areas requiring major interventions in adoption of green and clean technologies have been identified in this report. The improvements in the stock preparation, bleaching and washing, if introduced, especially in small and medium scale industries, will have a significant impact on the overall standards of Indian pulp and paper mills. Few developmental and demonstration R&D projects have been suggested to create confidence among the stakeholders, particularly technocrats and entrepreneurs for the adoption of clean and green and technologies in the Indian pulp and paper sector.

List of ABBREVIATIONS

AOX	Absorbable Organic Halides
BDMT	Bone Dry Metric Ton
BOD	Biochemical Oxygen Demand
CAGR	Computed Average Growth Rate
CMD	Chairman and Managing Director
CMIE	Centre for Monitoring of Indian Economy
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPPRI	Central Pulp and Paper Research Institute
CR	Chemical Recovery
CREP	Corporate Responsibility for Environment Protection
CSMCRI	Central Salt & Marine Chemicals Research Institute
CMP	Chemi- mechanical pulping
DCS	Direct Computer System
ECF	Elemental Chlorine Free
EOX	Extractable Organic Halides
ETP	Effluent Treatment Plant
FY	Financial Year
GDP	Gross Domestic Product
GoI	Government of India
ICT	Institute of Chemical Technology
IICT	Indian Institute of Chemical Technology
IIT	Indian Institute of Technology
ISO	International Standards Organization
MoEF	Ministry of Environment and Forests
NCL	National Chemical Laboratory

NEERI	National Environmental Engineering Research Institute
R&D	Research and Development
RDH	Rapid Displacement Heat
RSA	Principal Scientific Adviser
SAR	Sodium Absorption ratio
TCDF	Tetra ChloroDibenzo Furan
TCF	Total Chlorine Free
TOCl	Total Organic Chlorine
ToR	Terms of Reference
TPA	Tons per Annum
TPD	Ton Per Day
TPH	Ton per Hour

Annexure –I

Data Collected during the Mill Visits and Comparison with the Best Practices in Developed Countries

S. No.	Name of the Mill	Raw Material Used	Installed Capacity/ Production, tpa	Variety of Paper Produced	Energy Consumption			Con
					Steam t/tp	Electricity, kWh/tp	Specific Energy Consumption, GJ/t	
1	Paper Mill 'A'	Eucalyptus / Poplar	75000 / 63180	Writing, Printing Cards and Braille			45	90
2	Paper Mill 'B'	Eucalyptus 50%/ Poplar Bamboo 17% Agro waste 33%	85000 / 81000	Writing, Printing and Coated Paper	7.71	1150	57	
3	Paper Mill 'C'	Wheat straw Bagasse	33000 / 33000	Writing, Printing, Surface size	5.2 - 38.2	1200		
4	Paper Mill 'D'	Wood / RCF	100000 / 100000	Newsprint				
5	Paper Mill 'E'	Wood	470000 / 495000	Food grade Paper board, Writing,Printing Paper and Specialty Paper			31	
6	Paper Mill 'F'	Bagasse	400000 / 350000	Writing, Printing, Maplitho	6.2	1410	46	
7	Average Indian mills	Wood	~200000	Writing, Printing	12-13	1300-1400		U
		Agro based	50000 - 100000	Writing, Printing, Copier	12-14	1200-1400		Up
8	Paper Mills in developed countries	Wood	300000 / 1000000	Writing, Printing and Coated Paper and Specialty Paper	7-8	1000 - 1100	25-30	