MODULE III
PULP AND PAPER INDUSTRY

ReSearch for Paper
Lecture 1

Introduction to Pulp And Paper Industry, Raw Material for Paper Industry And Technological Development
The history of paper making goes back to over 2000 years while first official report on the manufacture of paper was reported in China in 105 AD. The knowledge of paper manufacturing spread westward, along with the silk and trade routes, reaching India is round 605 AD. Pulp and paper production has increased globally and will continue to increase in the near future and is one of the largest manufacturing sectors in the world. Per capita consumption of paper is sometimes yardstick for measurement of industrialization. There are about 500 kraft mills and many thousands of other types of pulp and paper mills all over the world. Pulp and paper industry is one of the oldest industries in India. With a 20 mills and installed capacity of one lakhs tonnes per annum at the time of independence the paper industry have made continuous strides and now there are about 380 mills with a production of 4.0 million tonnes.

There are about 6.5 billion people living on planet Earth. Worldwide paper consumption in this century has increased 4 times faster than population. Paper and paperboard worldwide will reach 400 million tones in 2011 and 640 million tones in 2020 with world population of 8000 million people and per capita consumption of paper and paperboard of 80 kg. There are about 500 Kraft mills and many thousands of other types of pulp and paper mills in the world.

India is fastest growing pulp and paper market in the world with growth rate of 10% over one year in per capita consumption, which is expected to grow in future. The Indian paper industry is among the top 15 global players today, with an output of more than six millions tones annually with an estimated turnover of Rs 150,000 millions. Projected demand of 13 million tones by 2020 [Sundra and Marimuthu, 2012]. The
growth rate of pulp & paper Industry is around CAGR of 7-8 percent. Total Installed
capacity of pulp and paper industry is around 9.18 million tones and is expected to
increase to 11.5 million tones by 2010-12 [Business standards, IPPTA J, Vol 22, No.3
July –Sep, 2010, p.]. Profile of Indian paper mills and world paper industry is given in
Table M-III 1.1.

Early 1970’s the share of wood, agricultural residues and wastepaper was 84%, 9% and
7% and presently it constitutes 31%, 22% and 47% in comparison to globally 57%, 39%
and 4% respectively. Out of about 11 million tonnes Paper production in 2011-12
approximately 7.5 million tonnes is produced from agro residue and wastepaper and
mainly contributed by medium and small scale paper mills. It is projected
that consumption and production of paper in next five years will be 16.5% and 14.8%
million tonnes respectively [ Nair, 2012].

Table M-III 1.1: Profile of Indian Paper Mills & Global
Competitiveness

<table>
<thead>
<tr>
<th></th>
<th>Mills (number)</th>
<th>Capacity (million Tonnes)</th>
<th>Kg/A/Capita</th>
<th>Energy consumption GJ/ t of paper</th>
<th>Water Consumption m³/tof paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>6.2 Billion</td>
<td>9000</td>
<td>370</td>
<td>55</td>
<td>32.0-40.9</td>
</tr>
<tr>
<td>India</td>
<td>1.1 Billion</td>
<td>&gt; 660</td>
<td>9.5</td>
<td>8.3</td>
<td>51.6-80.0</td>
</tr>
</tbody>
</table>


Raw material and energy sources in Indian and European countries are given in
Figure M-III 1.1. Specific energy consumption in Indian mills are higher than other
developed countries (Table M-III1.2)
Figure M-III 1.1: Raw material and Energy Sources

Sources: Mall R.C. & Narayan Moorthy R “A overview of Indian pulp and paper industry” Green Solution Week Sweden 2010,

Table M-III 1.2: Specific Consumptions: A Comparison

<table>
<thead>
<tr>
<th>Input Per Ton of Product</th>
<th>Indian Mills</th>
<th>European Mills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat, GJ/t</td>
<td>15-30</td>
<td>4-8</td>
</tr>
<tr>
<td>Electricity, Kwh/t</td>
<td>800-1500</td>
<td>400-800</td>
</tr>
<tr>
<td>(except pulp mill)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water, m3/t</td>
<td>25-150</td>
<td>5-40</td>
</tr>
<tr>
<td>Chemical Recovery, %</td>
<td>88-96</td>
<td>95-98</td>
</tr>
</tbody>
</table>

Sources: Mall and Moorthy 2010.

Technological turning point in the Indian paper industry is given below:

- Efficient management of depleting resources with sustainable forest productivity through improved resource planning, better plantation technique, good harvest management
- Conservation of natural resources
- Effective waste utilization and recycling of fibre
- Improved cleaning efficiency
• Better environmental management for reducing or eliminating toxicity
• Better fibre properties
• Improved runnability
• Improved product appeal (Higher Brightness).
• Odorless mill

PROFILE OF PAPER INDUSTRY

• Worldwide paper consumption in this century has increased 4 times faster than population.

• Paper and paperboard worldwide will reach 400 million tonnes in 2010 and 640 million tonnes in 2020 with world population of 8000 million people and per capita consumption of paper and paperboard of 80 kg.

• There are about 500 kraft mills and many thousands of other types of pulp and paper mills in the world.

• There are about 500 mills in India with 7 percent integrated (capacity more than 100 TPD), 30 percent medium (capacity between than 50 to 100 TPD), and 70 percent small paper mills with (capacity less than 50 TPD).

• The average capacity is as less as 14 tonnes per day.

Advances in Pulp and Paper Industry

• **Mechanical**: Thermo mechanical Pulping, Refiner technology
• **Biotechnology Application**: Bio-pulping, Bio--bleaching, Enzymatic Deinking, Enzymatic Refining
• **Washing And Screening**: Drum Displacer, Pressure Diffuser, Displacement Presses, Combined Deknotting and Fine Screening, High Temperature Screening Before Washing, Reverse Cleaners
• **Bleaching**: Instead Of Dioxin Free Pulp, Now, Pulp Are Classified As Chlorine Free (CGF), Chlorine Chemical Free (CCF), Molecular Chlorine Gas Free
(MCGF), Non Chlorine Compound ((NCC), Active Chlorine Free (ACF), Absolutely Chlorine Free (ACF), Almost Chlorine Free (ACF), Elemental Chlorine Free Modified (ECFM), Totally Chlorine Free (TCF).

• **Evaporation and Recovery:** Agro based paper mills require more energy to recovery of chemicals since it has high silica content. Black liquor losses from mils without recovery pose a serious environmental problem and result in energy inefficiencies.

• **Fibre Modification:** Enhancing the opacity of fibre through pigment particles, better fibre loading, pressurized sensitive adhesives (PSAS)

• **Paper Making:** High Speed Machine with Sophisticated Instrumentation and control; closed hood and insulation of dry cylinder end; installation of trinip press.

**MAJOR CHALLENGES AND SHORT COMINGS**

• Poor infrastructure
• Too many administrative hurdles, tedious bureaucratic methods
• Poor to non-existent commitment to innovation
• High cost of normal method of financing, recent setback from raising capital through equity for new companies/ developing projects
• Rising cost of inputs: fibrous raw materials, chemical, labour, energy
• Uneconomic size and obsolete technology in many mills
• High cost of production
• Poor productivity
• Poor instrumentation
• Low availability of forest raw materials and poor forest management
• Poor recycling of waste paper
• Recovery of chemicals from agro-based black liquor
• Decolourisation and detoxification
• Air pollution problem
• High energy consumption.

**Raw Material:**
Paper industry consumes a wide variety of raw materials – cellulosic derived from forest, agricultural residues and waste paper; non-cellulosic coal, chlorine, lime, sodium hydroxide, sodium sulphide, fuel oil, talcum powder etc. Major raw materials used by paper industry is bamboo, wood, bagasse, waste paper and agricultural residue like wheat straw, rice straw, jute sticks, hemp, kenaf, grasses, sea weed etc. Apart from this, paper industry consumes large amount of chemicals like caustic soda, sodium sulphide, sodium carbonate, chlorine, hypochlorite, mineral acid; coal, talcum powder etc.

India has a landmass of 3.29 million square kilometers and 0.629 million sq km of forest i.e. nearly 2.5 percent of world’s geographical area, only 1 percent of the forest area supporting 16 percent of world populations. Indian forestry is at a cross road, and actually only 12 percent land area has good forest cover against the official figure of 19 percent (Jameel, 1995). With fast depletion of forest raw material, large integrated mill which accounts for about 38 percent of the total production are facing serious challenges and hardly there is any scope for substantial capacity expansion unless and until they go for secondary fibre utilization. Small and medium mills based on agro-based accounts for nearly 31 percent of India’s production. With depleting forest raw material, agricultural residues like bagasse wheat straw, rice straw, jute, grass etc. are likely to play important role in meeting the future demand of raw material for paper industry. 

Table M-III 1.3 gives the detail of raw material use by Small and Large Integrated Pulp and Paper Mills

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Raw Materials</th>
<th>Requirement per tonne of paper</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Small Paper Mills</td>
</tr>
<tr>
<td>1</td>
<td>Cellulosic raw material, Kg (hardwood, soft wood, agricultural residues etc)</td>
<td>2500 – 3000</td>
</tr>
<tr>
<td>2</td>
<td>Cooking chemicals, Kg as Na₂O</td>
<td>70 – 90</td>
</tr>
<tr>
<td>3</td>
<td>Caustic for bleaching</td>
<td>20 – 35</td>
</tr>
<tr>
<td>4</td>
<td>Chlorine, Kg</td>
<td>100 – 160</td>
</tr>
<tr>
<td>5</td>
<td>Salt cake, Kg</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>Lime (available CaO 60%) Kg</td>
<td>70 – 100</td>
</tr>
<tr>
<td></td>
<td>for bleaching</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---------------------------------------------------</td>
<td>---</td>
</tr>
<tr>
<td>7</td>
<td>Lime (available CaO 60%) for causticising section, Kg</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Coal Tonne</td>
<td>1.0 – 1.35</td>
</tr>
<tr>
<td>9</td>
<td>Sulphuric acid, Kg</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>Alum, Kg</td>
<td>50 – 60</td>
</tr>
<tr>
<td>11</td>
<td>Rosin and Wax Emulsion, Kg</td>
<td>10 – 12</td>
</tr>
<tr>
<td>12</td>
<td>Starch, Kg</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>Hydrochloric acid, Kg</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>Furnace oil, Kg</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>Water, m³</td>
<td>150 – 300</td>
</tr>
<tr>
<td>16</td>
<td>Power, kWh</td>
<td>1200 – 1300</td>
</tr>
<tr>
<td>17</td>
<td>Steam, Tonne</td>
<td>6.0 – 7.0</td>
</tr>
<tr>
<td>18</td>
<td>Soda ash as % of Rosin</td>
<td>7 – 8</td>
</tr>
<tr>
<td>19</td>
<td>Talcum, Kg</td>
<td>120 – 150</td>
</tr>
</tbody>
</table>

**PROBLEMS IN UTILIZATION OF HARD WOOD**

- Debarking
- Chipping problem – high density chips difficult to chip
- Higher reject
- Problem in washing due to more fines and foam
- Bleaching of mixed hardwood and bamboo pulp creates problems due to varying bleach Requirement
- Shade variation, darker shade
- Problem in evaporator
- Higher percentage of hard wood affects readability of machine lower strength

**SECONDARY FIBRE IN PAPER MAKING**

Increased use of recycled fibre/paper is the current trend in the paper industry globally as it is one of survival routes for the paper industry against dwindling fibre resources and environmental related issues. Collection of domestic secondary fibre” an initiative as corporate social responsibility; shift in the raw material consumption pattern in India and Global paper recycling pattern is given in Table M-III 1.4 and Table M-III 1.5 respectively [Raghuveer, 2012]. Potential source of waste paper are domestic refuse,
industrial refuse, office refuse, trade refuse. In India around 65 percent of paper industry requirement of waste paper is met through imports which is on increase year by year [Mukundan, 2011]

Table M-III 1.4: Raw Material Consumption Pattern in India

<table>
<thead>
<tr>
<th>Year</th>
<th>Wood</th>
<th>Agro residue</th>
<th>Waste paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>8.4</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>2000</td>
<td>39</td>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td>2011</td>
<td>31</td>
<td>22</td>
<td>47</td>
</tr>
</tbody>
</table>

Table M-III 1.5: Paper Recycling in different Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>% share</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>65%</td>
</tr>
<tr>
<td>Europe</td>
<td>70%</td>
</tr>
<tr>
<td>UK</td>
<td>40%</td>
</tr>
<tr>
<td>China</td>
<td>30%</td>
</tr>
<tr>
<td>India</td>
<td>20%</td>
</tr>
</tbody>
</table>

TECHNOLOGICAL DEVELOPMENT IN PULPING & BLEACHING

Technological development in the area of pulping are- extended delignification using poly sulfide, anthraquinone, oxygen, Super batch, Rapid displacement heating, Enerbatch, Modified continuous cooking, Extended modified continuous cooking, Isothermal cooking, Black liquor impregnation isothermal cooking, organosolv pulping, steam explosion pulping, Bio-pulping, Explosion pulping etc [Pulliam, 1997]. Although anthraquinone and polysulfide pulping has been tested at laboratory as well plant level, however, because of economic reason it is not in common use in India.

MODIFIED PULPING

As the residual lignin present in the pulp before chlorination is important factor affecting toxicity of bleach plant effluent, lowering the kappa number of pulp before entering bleach plant by extended delignification is the recommended option for reducing toxicity. Reduction in lignin content of pulp potentially results in reduction of chlorinated organic matter in the effluent. Some of the options for reducing kappa number of pulp before bleaching are extended delignification using polysulphide, oxygen, anthraquinone.
Some of the options for delignification are based on either system design modification or chemical process modification. Extended delignification based on system design modification in batch digester are – Super batch, Rapid displacement heating, Enerbatch. Extended delignification in continuous digester based on system design modification are - Extended modified continuous cooking, (ITC) Isothermal cooking [Ray, 1997]. Some of the benefits to the extended delignification approach include lower bleaching chemical costs, the possibility for eliminating some elemental chlorine and an improved energy balance. Another option for extended delignification is by using chemical additives, oxygen delignification, bio-pulping, explosion pulping.

Extensive work has been done on use of anthraquinone and polysulfide pulping. The use of chemical additive anthraquinone and polysulphide has been reported as low capital investment option for decreasing the kappa number and minimizing the impact on recovery boiler with higher bleached pulp yield [Pulliam,1997]. The development of oxygen delignification or brown stock oxygen bleaching has been derived by environmental, economic and energy related considerations. Oxygen delignification offers many advantages over the conventional delignification processes and there is steady growth in worldwide production of oxygen delignified pulp. These process are now capable of producing pulp with kappa number 30-50 percent lower than conventional kraft cooking methods without significant yield or strength loss. In India some of the other mills have also switched over to oxygen delignification. Some of the advantages of oxygen delignification are – lower demand of bleaching chemicals; shorter bleaching sequences; reduction in bleach plant effluent BOD, COD, colour, toxicity and AOX; high yield; improved cleanliness of pulp by brightening shives, saving in equipment cost, reduced energy consumption, increase in efficiency of brown stock washing. Several other processes which are either in developmental or implementation stage are Alkali-sulfate-anthraquinone method (ASAM), Organo-cell-water, methanol reinforced kraft pulping, bio-pulping [Jameel, 1995]

ADVANCES IN BLEACHING

Pulp and paper market forces are driving the development of pulp bleaching technology and there have been unprecedented changes in the bleaching technology for reducing
toxicity and improving the quality of bleached pulp. Now the pulp instead of dioxin free pulp today they are classified as chlorine free (CGF), Chlorine chemical free (CCF), Molecular chlorine gas free (MCGF), Non chlorine compound (NCC), Active chlorine free (ACF), Absolutely chlorine free (ACF), Almost chlorine free (ACF), Elemental chlorine free modified (ECFM), Totally chlorine free (TCF), Totally effluent free (TEF) [Pryke,1991]

INNOVATION IN TECHNOLOGY FOR WASTE MANAGEMENT

There have been significant innovation and developments in technology in pulp and paper manufacture to improve quality, minimize the energy consumption, reduce the toxicity of bleach plant effluent, waste water generation and reduce the colour in the effluent to improve better recycle. Pulping and bleaching is one of the major areas where major technological development has taken place in the pulp and paper industry. Some of the technological development in pulping and bleaching for reducing toxicity and waste generation are:

**Process modification**

Delignification of pulp as much as possible before chlorination stage to decrease residual lignin, improved brown stock washing and screen, improvement in bleaching sequence to reduce or use of eliminate the elemental chlorine

**Control of outside Contamination**

Elimination of use of defoamer containing dioxin precursors

**External control measures**

Stabilization ponds, activated sludge, aerated lagoons, membrane process, adsorption, electrochemical process
Process Technology in the Manufacture of Pulp and Paper

- **Acquisition of Raw Material:** Hard wood, soft wood, bagasse, wheat and Rice straw, sabai grass etc.
- **Raw Material Preparation:** Debarking, Chipping, Cutting, Screening
- **Pulping**
  - **Chemical:** Sulphate (Kraft), Soda Pulping, Sulphate Pulping
  - **Semi Chemical:** NSSC
  - **Mechanical Pulping:** Stone Ground Wood (SGW)
    - Thermo Mechanical Pulp (TMP)
    - Refiner Mechanical Pulp (RMP)
    - Cold Soda Refiner Mechanical Pulp (CRMP)
  - **Sulfite:** Acid Sulfite higher % of free SO₂
    - (Ca, Mg, Na, Ammonia base)
  - **Bisulfite:** (little or no free SO₂
    - (Ca, Mg, Na, Ammonia base)
- **Washing and Screening:** 3-4 stage washing, screening and centricleaning
- **Bleaching:** CEHH, CEH, CEHD for chemical pulp
  - Hydrogen peroxide, Sodium peroxide, Hydrosulfite for mechanical
- **Stock preparation:** Beating and refining for imparting suitable properties by making paper, addition of sizing chemicals, colour and additives
- **Paper Making:** Conversion of pulp from stock preparation into a sheet of paper using Fourdrinier Machine or Mould machine
- **Chemical Recovery:** Concentration of spent liquor, burning, causticising and classification of liquors
- **Power generation**
- **Waste paper processing:** sorting, screening, hydro pulping, screening and centri-cleaning
- **Chlorine generation and Bleach liquor Preparation**
REFERENCES
4. Mall, R.C., Narayan Moorthy, R., “A overview of Indian pulp and paper Industry” Green Solution Week, Sweden 2010,
10. Ray, A. K., Proceeding of meeting on clearer production in pulp and paper mills organized by United Nations Environmental Programme (UNEP), Bangkok and Central Pollution Control Board, Delhi, India, April 25-26, 1997.