# PULPING OF DIFFERENT RAW MATERIALS (WOOD AND AGRO WASTE)

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# Brief History of Paper Making

- Papyrus in Ancient Egypt.
- True papermaking began in China (~100 AD).
- Spread to Middle East and Europe (by the 15$^{th}$ century).
- Arrival in North America (1690), near Philadelphia.
- First Indian mechanized paper mill: 1812, Serampore, West Bengal.

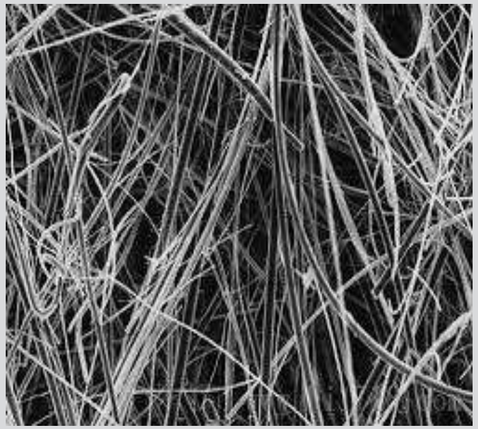
# Key Milestones in Pulping Process

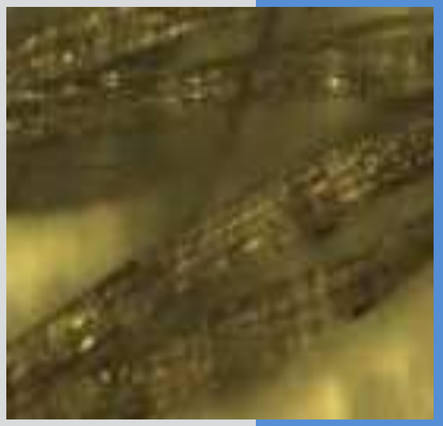
| | |
|---|---|
| **1840** | • Ground wood pulping method developed in Germany – came into commercial use in the 1860s. |
| **1854** | • First Manufacture of pulp from wood using the soda process (England). |
| **1867** | • Patent issued to Benjamin Thighman (USA) for the sulphite pulping process- first used commercially in 1874. |
| **1884** | • 1884 - Kraft pulping process invented by Carl Dahl (Germany). |

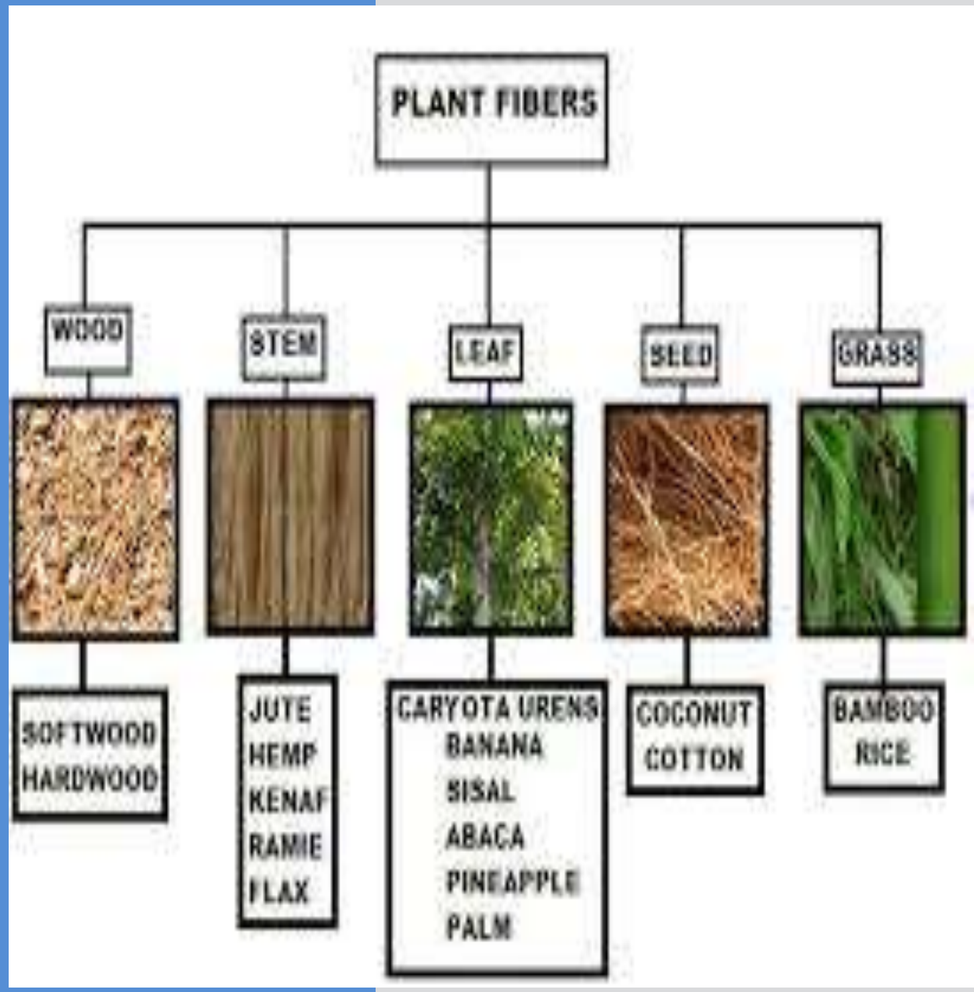
# INTRODUCTION

# FIBRE CHEMISTRY

- Plant fibres are composed mainly of cellulose, hemicelluloses, lignin and extractives.
- These components influence pulp yield, strength, brightness, and reactivity.
- Their ratios vary between woods and agro-wastes, softwoods and hardwoods.

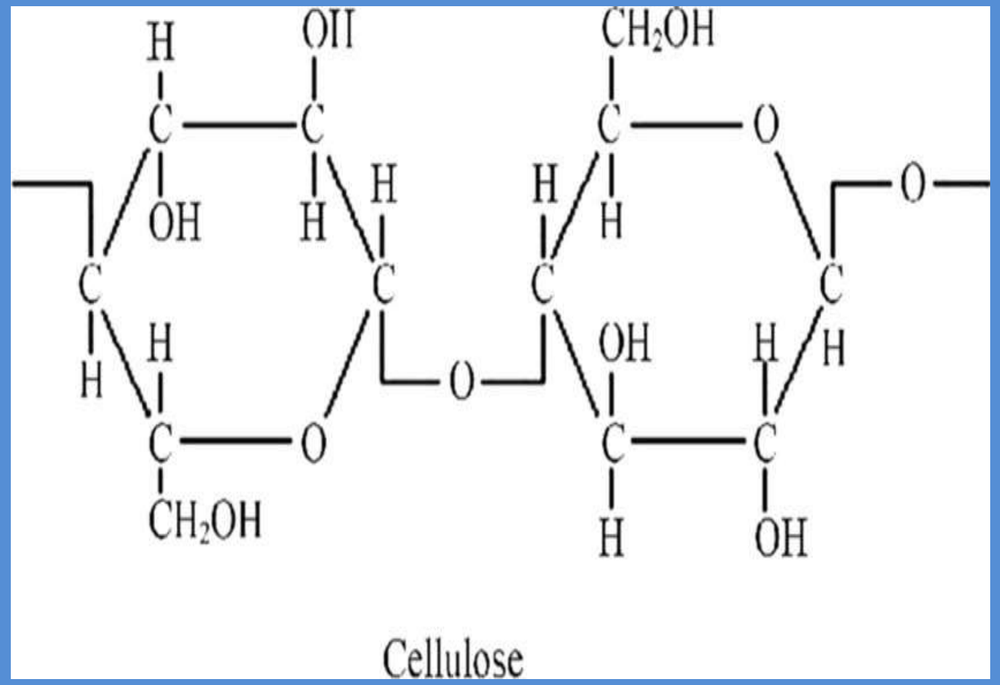






# Cellulose

- Linear homopolysaccharide of β-1,4-linked D-glucose units
- Repeating unit: Cellobiose (2 glucose molecules)
- Degree of polymerization (DP):Wood pulp: 600–1500, Cotton: up to 10,000+
- Insoluble in water and most solvents
- Forms hydrogen bonds – gives strength, flexibility
- Exists in crystalline and amorphous regions.



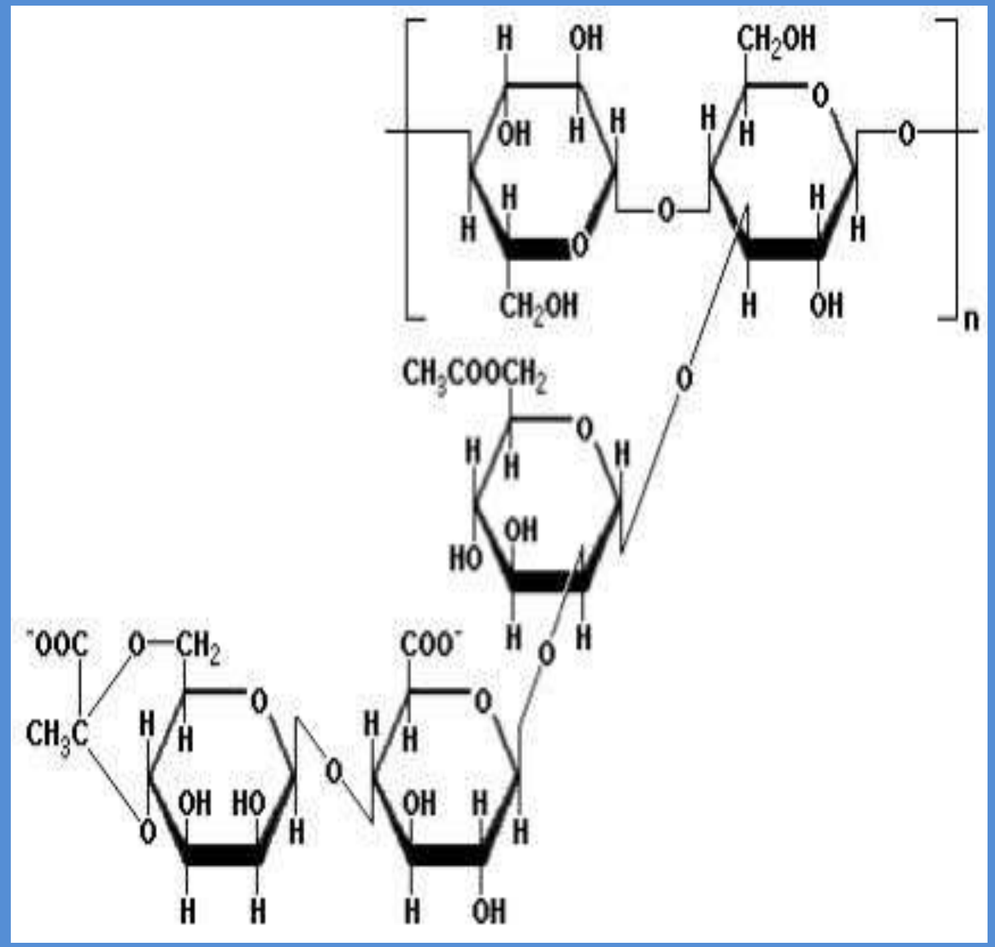
Cellulose

# Hemicellulose

- Branched heteropolysaccharide – mix of sugars: Hexoses: glucose, mannose, galactose and Pentoses: xylose, arabinose
- Less crystalline → more hydrolyzable

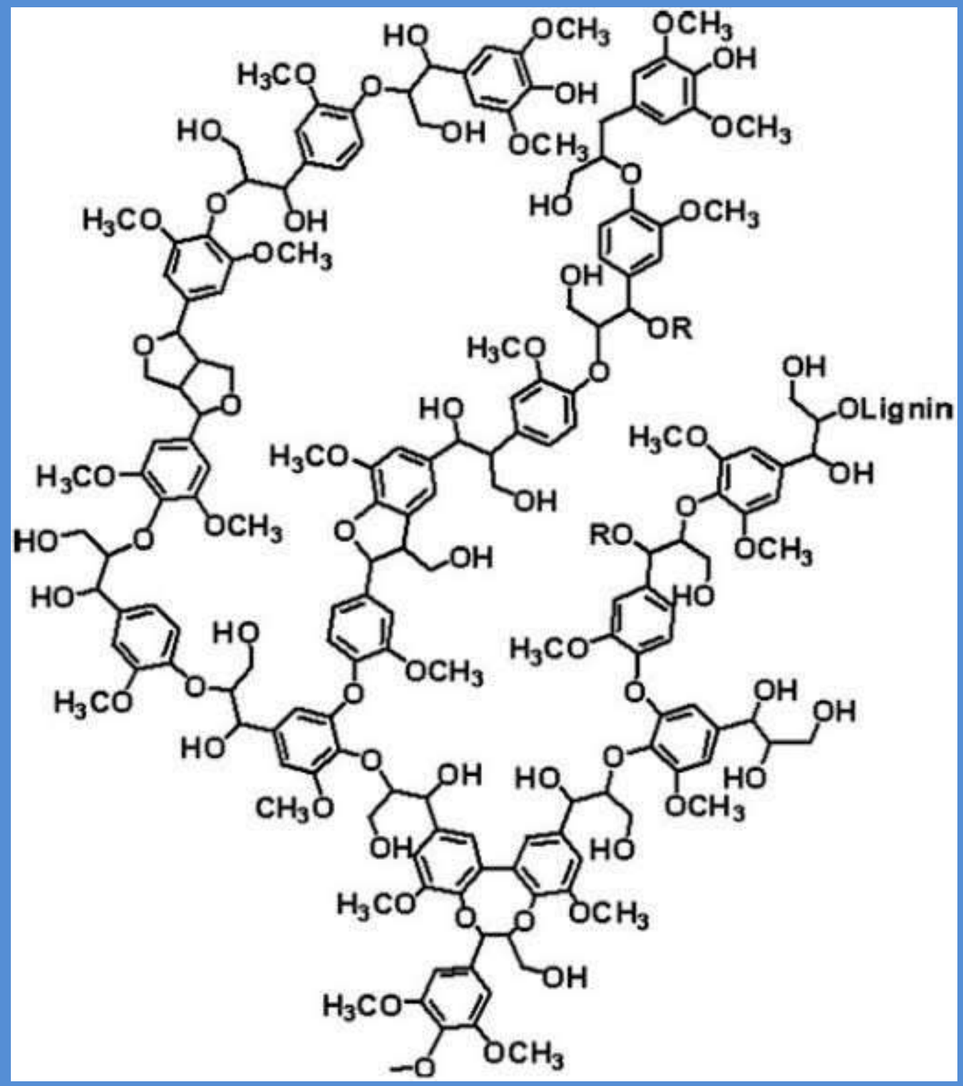
<u>Functions</u>:

- Interacts with cellulose and lignin
- Affects water retention, pulp flexibility, bonding strength
- More abundant in hardwoods (xylan) than softwoods (mannan)



# Lignin

- Complex 3D polymer of phenylpropanoid units: Syringyl (S), Guaiacyl (G), Hydroxyphenyl (H).
- Provides rigidity, water resistance.
- Cross-links with cellulose–hemicellulose matrix.
- Must be chemically removed during pulping (especially kraft/sulphite).
- Source of black liquor in kraft process.

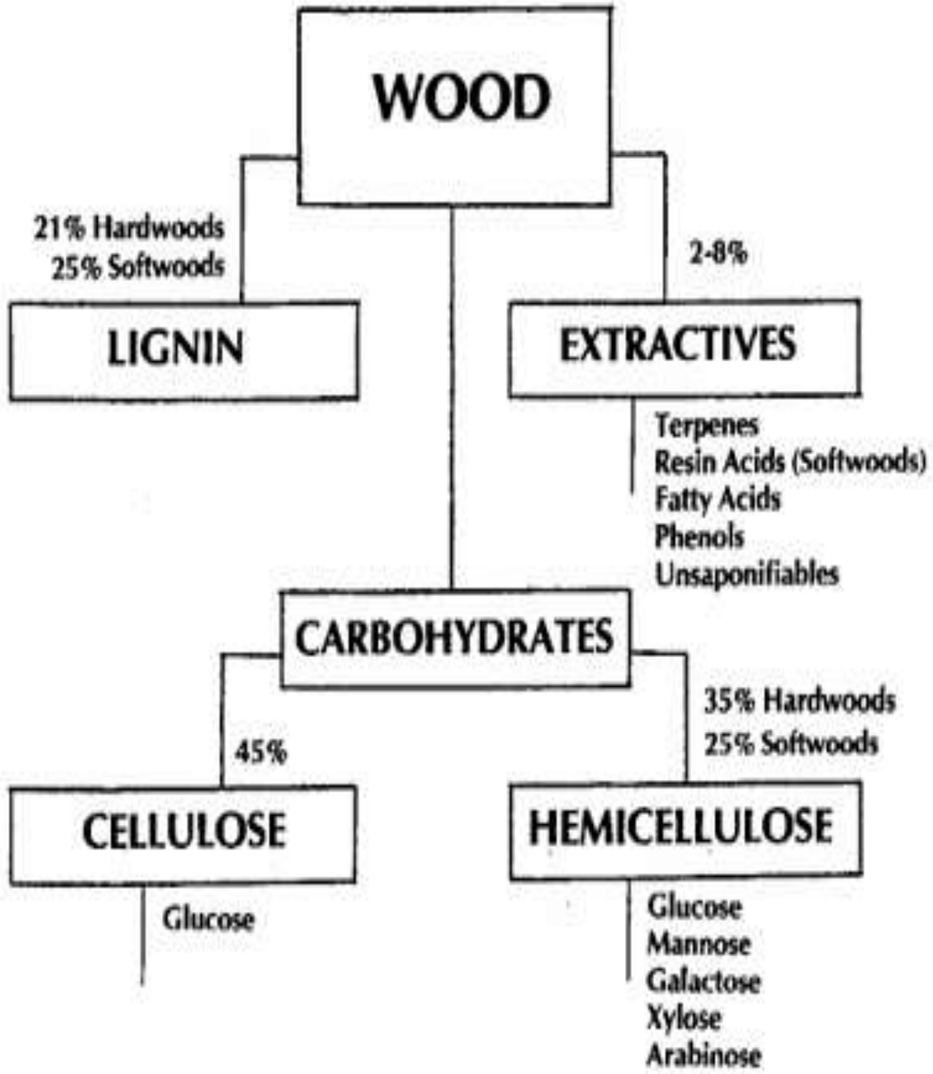


# Extractives

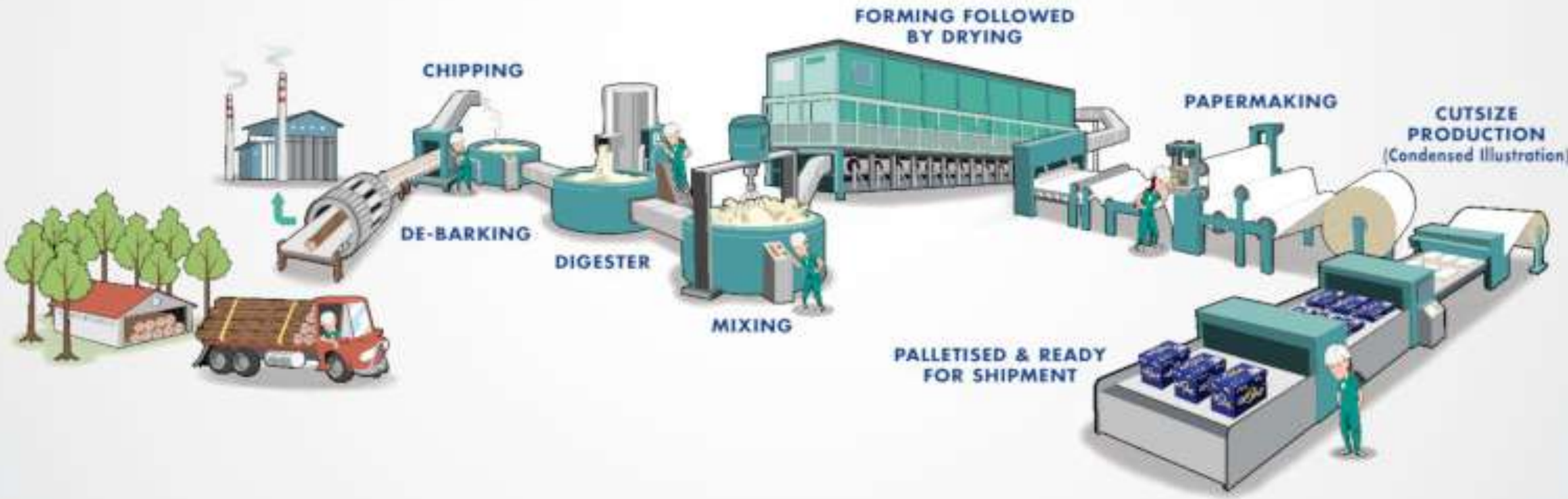
- Include resins, fats, waxes, terpenes
- Extracted using water/organic solvents

**Affect:**

- Pulp Brightness
- Chemical Consumption
- Paper Odor and Aging
- More abundant in agro-wastes and softwoods.



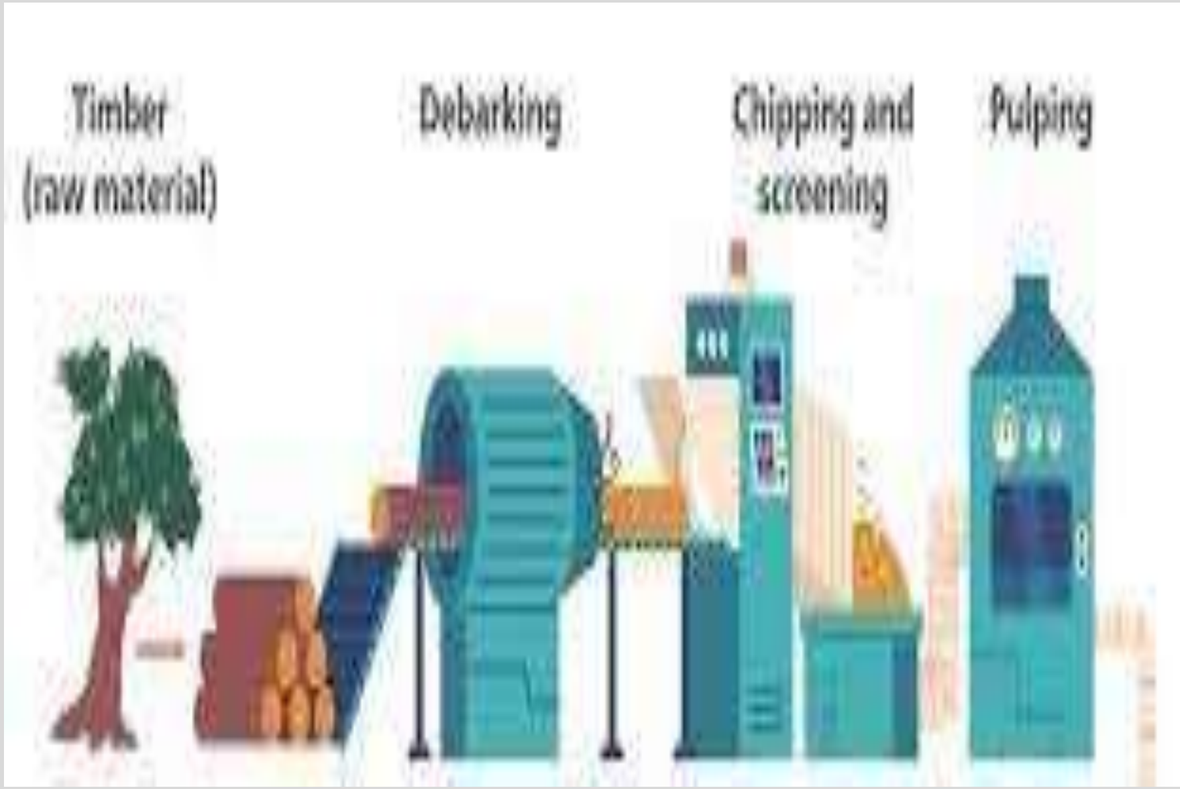
# PULP AND PAPER MANUFACTURING PROCESS



# RAW MATERIAL PREPARATION

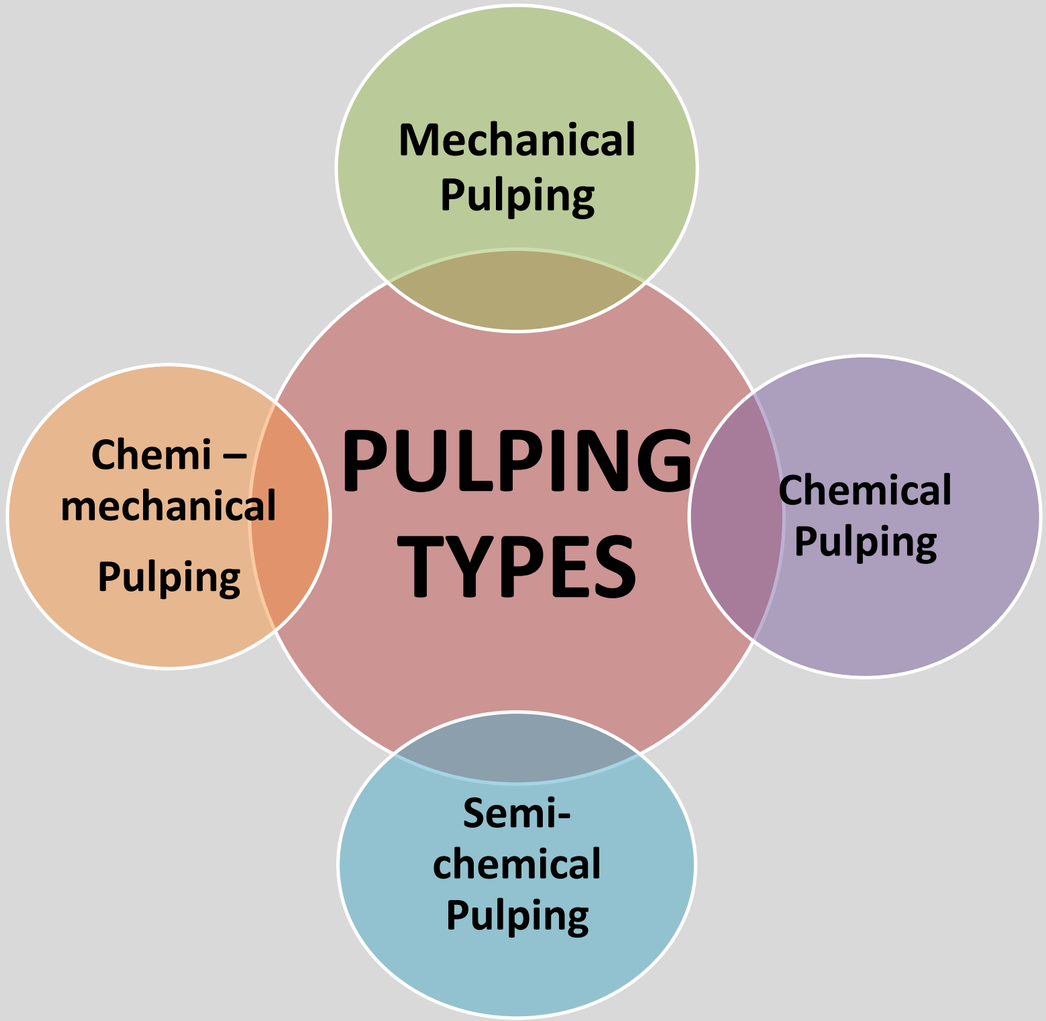
- Essential for efficient chemical penetration and uniform pulping
- Involves processing wood or agro-residues into suitable forms
- Main steps:

1. Bark removal
2. Chipping (or cutting)
3. Screening and cleaning



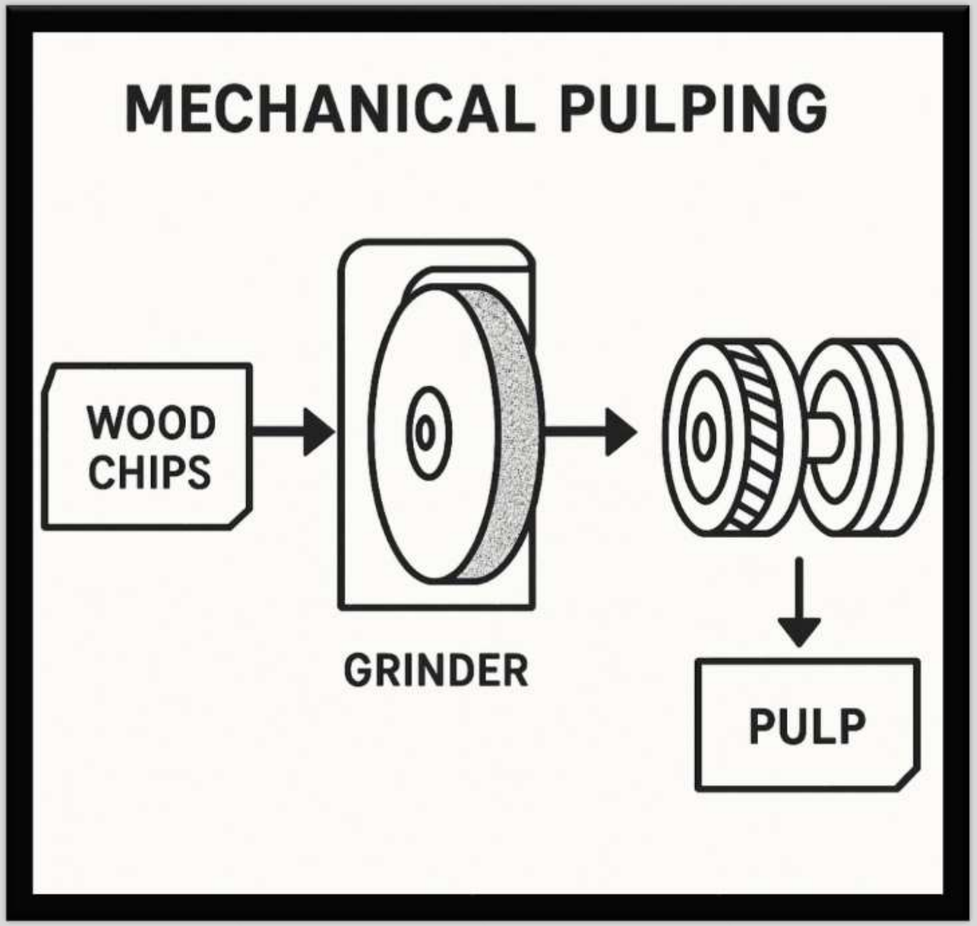
# PULPING AND ITS TYPES

- Pulping is the process of converting fibrous raw materials into a fibrous mass.
- It can be achieved through mechanical, thermal, chemical, or a combination of these methods.



# MECHANICAL PULPING

- Uses physical force to separate fibres.
- High yield, low strength.
- Suitable for newsprint, paperboard, etc.



# TYPES OF MECHANICAL PULPING

- Stone Groundwood Pulping (SGW)
- Refiner Mechanical Pulping (RMP)
- Thermo-mechanical Pulping (TMP)
- Chemi-thermo-mechanical Pulping (CTMP)

# Advantages and Disadvantages of Mechanical Pulping

## Advantages

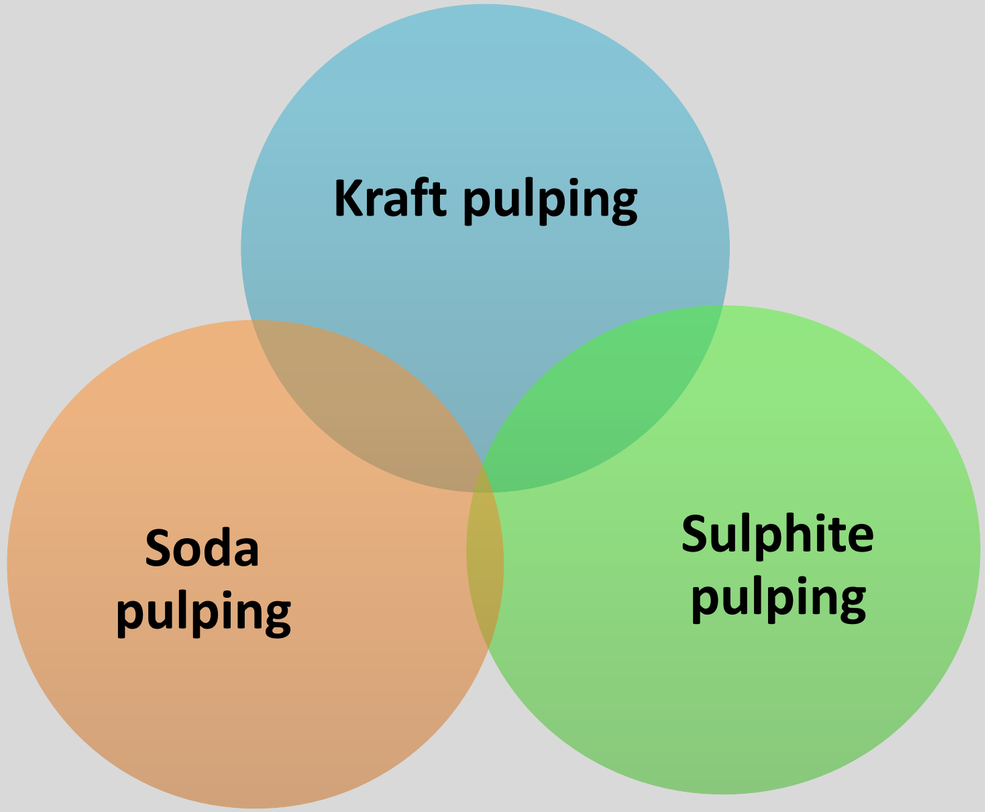
- High fibre yield (up to 95%)
- Lower raw material cost.
- Good bulk, opacity, and printability.
- Suitable for low-cost paper products.

## Disadvantages

- Weak fibres → poor paper strength.
- Paper discolours (yellows) in light.
- High energy consumption.

# CHEMICAL PULPING

- Chemicals dissolve lignin.
- Lower yield but stronger pulp.
- Ideal for writing, printing, packaging paper.




TYPES OF CHEMICAL PULPING

# SODA PULPING

- Uses only NaOH
- Ideal for agro-residues: bagasse, straws and grasses
- No sulphur emissions

Limitations:

1. Lower strength than kraft
2. No recovery cycle for agro-wastes

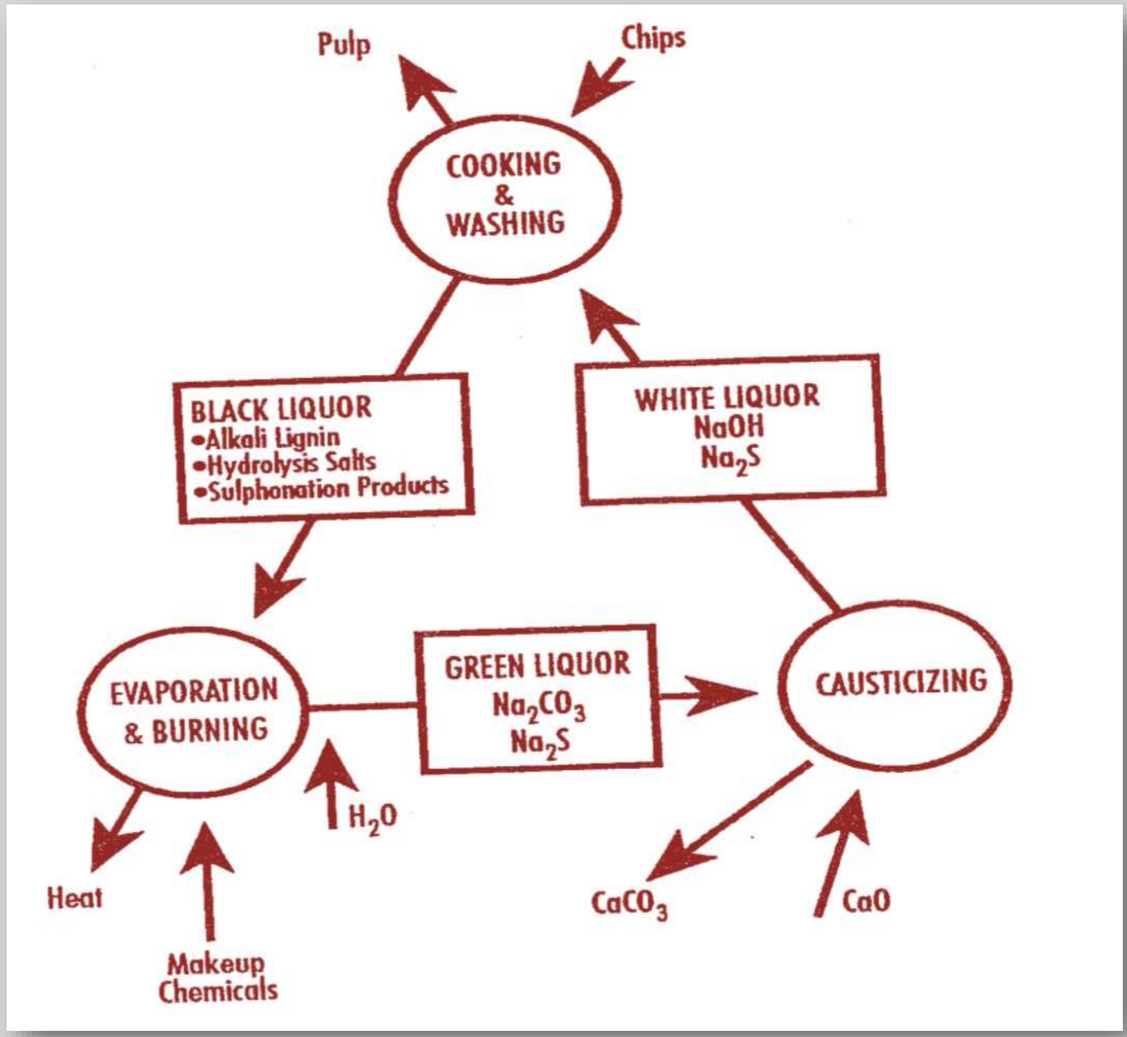
# KRAFT PULPING

- Also called Sulphate process.
- Uses NaOH + $Na_2S$ (white liquor).
- Most widely used method globally.
- Pulp: strong, brown, versatile.
- <u>Recovery system:</u>

1. Spent black liquor → recovery boiler
2. $Na_2SO_4$ → reduced to $Na_2S$

- <u>Applications</u>:

  Packaging, printing paper, tissues.



# SULPHITE PULPING

- Uses $H_2SO_3$ and bisulphite salts (Ca, Mg, Na, $NH_4$)
- Operating pH defines type:

1. Acid Sulphite (pH 1–2)
2. Bisulphite (pH 3–5)

- Produces light-coloured, easy-to-bleach pulp
- Less suitable for bark, resinous wood
- Applications: printing paper, tissue, dissolving pulp

| Advantages of Kraft Process | Advantages of sulphite process |
|---|---|
| • Produces highest strength pulp<br>• Utilizes proven technology for efficient chemical recovery<br>• Handles wide variety of wood species<br>• Tolerate bark in the pulping process | • Produces brighter unbleached pulp<br>• Pulp is easier to bleach to full brightness<br>• Produces higher yield of bleached pulp<br>• Pulp is easier to refine |

| PROCESS | CHEMICALS | WOOD TYPE | YIELD |
|---|---|---|---|
| Kraft | $NaOH + Na_2S$ | All | 40-50% |
| Sulphite | $H_2SO_3 + HSO_3^-$ | Selected species | 45-55% |
| Soda | NaOH | Agro- waste | 45-55% |

# SUMMARY OF CHEMICAL PULPING

# SEMI-CHEMICAL PULPING

- Combines chemical softening + mechanical refining
- Partial lignin removal
- Used mainly for corrugated medium (fluting)
- Key methods:

1. NSSC (Neutral Sulphite Semichemical): Hardwood, buffered $Na_2SO_3$ + $Na_2CO_3$

   Yield: 65–80%

2. High-Yield Kraft/Sulphite:

   Limited cooking, mechanical defibering

   Yield: 55–75%

# COMPARISON OF CHEMICAL & SEMI-CHEMICAL PULPING

| | Kraft | Acid Sulphite | Bisulphite | NSSC |
|---|---|---|---|---|
| Chemicals | NaOH<br>$Na_2S$ | $H_2SO_3$<br>$M(HSO_3)$<br>(M= Ca, Mg, Na, $NH_4$) | $M(HSO_3)$<br>(M=Mg, Na, $NH_4$) | $Na_2SO_3$<br>$Na_2CO_3$ |
| Cooking Time | 2-4 h | 4-7 h | 2-4 h | 1/4 – 1 h |
| Liquor pH | 13+ | 1-2 | 3-5 | 7-9 |
| Cooking Temp | 170-180 °C | 120-135 °C | 140-160 °C | 160-180 °C |

# Major Pulping Processes – Comparison

| S.No. | Classification | Process Name | Wood Used | Form of Wood | Yield(%) |
|---|---|---|---|---|---|
| 1. | Mechanical | Stone Groundwood | Softwood (mostly) | Bolts | 90–95 |
| | | RMP | Softwood (mostly) | Chips | 90–95 |
| | | TMP | Softwood | Chips | 90 |
| 2. | Chemi-mechanical | Chemigroundwood | Hardwood | Bolts | 85–90 |
| | | Cold Soda | Hardwood | Chips | 85-90 |
| 3. | Semichemical | NSSC | Hardwood | Chips | 65-80 |
| | | High Yield Sulfite | Softwood (mostly) | Chips | 55–75 |
| | | High Yield Kraft | Softwood (mostly) | Chips | 50–70 |
| 4. | Chemical | Kraft | Both | Chips | 40–50 |
| | | Sulfite | Both | Chips | 45–55 |
| | | Soda | Hardwood | Chips | 45–55 |

# DISSOLVING PULP

- High-purity chemical pulp

<u>Used for:</u>

1. Rayon
2. Cellulose acetate
3. Cellophane
4. CMC (carboxymethyl cellulose)

<u>Made from</u>:

1. Modified kraft/sulphite pulping
2. Cotton linters

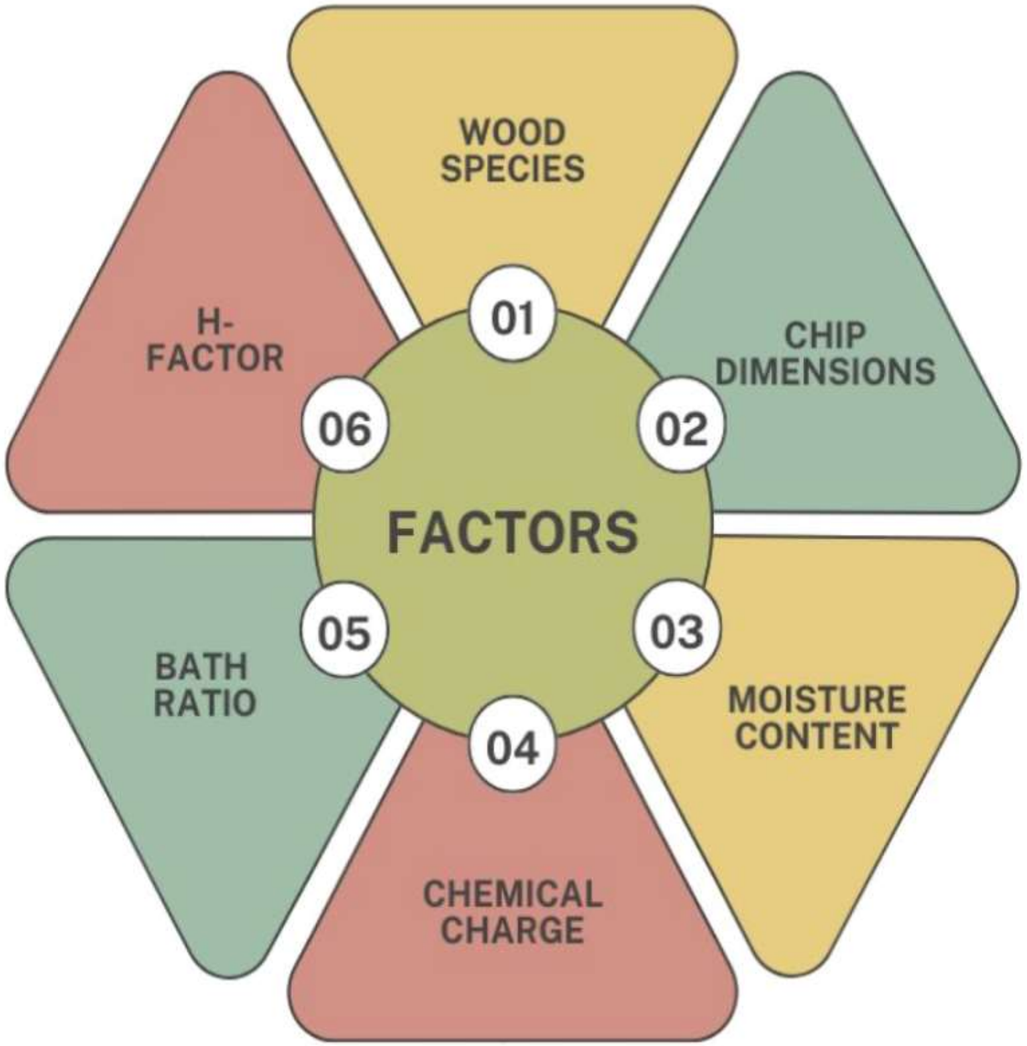
- High alpha-cellulose (>90–95%)
- Viscose process: converts pulp into fibres or films

# COMMON TERMS ASSOCIATED TO PULPING

- **DELIGNIFICATION**- It is the process of breaking down the chemical structure of lignin and rendering it soluble in a liquid.
- **KAPPA NUMBER**- It is a measure of the lignin content of the pulp.
- **PULP VISCOSITY**- It is a measure of the average chain length of cellulose.
- **FIBRE LIBERATION POINT**- It occurs when sufficient lignin has been removed during pulping that wood chips will be soft enough to break apart into fibres with little or no mechanical action.
- **FULL CHEMICAL PULP-** A pulp produced by chemical methods only.
- **DISSOLVING PULP**-It is a low yield ( 30-35%) bleached chemical pulp that has a high cellulose content.
- **LIQUOR**- Cooking or pulping liquor is an aqueous solution of chemicals used for delignification of wood for pulping.
- **H-FACTOR** – It is a pulping variable that combines cooking temperature and time into a single variable that indicates extent of delignification.

# COMMON TERMS ASSOCIATED TO PULPING

- **WHITE LIQUOR-** It is a fresh pulping liquor for the kraft process consisting of the active pulping species, NaOH and Na2S.
- **BLACK LIQUOR-** It is the waste liquor from the kraft pulping process after pulping is completed. It contains most of the original cooking inorganic elements and the degraded dissolved wood substance.
- **GREEN LIQUOR-** It is partially recovered form of kraft liquor. It is obtained after the combustion of black liquor in the recovery boiler.
- **TOTAL CHEMICAL OR TOTAL ALKALI-** It is the sum of all sodium salts in the liquor (as $Na_2O$).
- **ACTIVE ALKALI**- It includes the active ingredients in the pulping process i.e. NaOH and $Na_2S$.
- **EFFECTIVE ALKALI-** It is the ingredients that will actually produce alkali under pulping conditions.
- **SULPHIDITY**- It is the ratio of $Na_2S$ to active alkali.
- **CAUSTICITY-** It is the ratio of NaOH to active alkali expressed as %.
- **RESIDUAL ALKALI**- The EA remaining in a cook at its completion.
- **DEAD LOAD-** Inorganic materials, principally NaCl, present in kraft liquor, but cannot be regenerated in the recovery process.




# FACTORS AFFECTING YIELD DURING PULPING

# COOKING CYCLE

1. **PRESTEAMING** — It is done to remove air filled inside the pores in the chips. This eases the process of chemical penetration.

2. **IMPREGNATION** — It is the process by which cooking liquor impregnates the chips and is equally distributed within the chips.

3. **BULK PENETRATION AND DIFFUSION** — Bulk penetration is the diffusion of molecules or ions of the cooking liquor while diffusion is the movement of molecules from a higher concentration to a lower concentration and doesn't occur until the pores are filled with liquor.

4. **COOKING** — It occurs at a temperature of about 165-170˚C.

5. **BLOWING** — It refers to the release of pressure after cooking completes and the delignified pulp is taken out of the digester.

# OTHER PULPING METHODS

- Organosolv pulping
- Biological pulping
- Extended delignification
- Poly sulphide pulping

# CONCLUSION

- **Papermaking begins with the conversion of plant-based raw materials into pulp.**

- **The pulp is prepared using mechanical, chemical, or semichemical processes, depending on the desired paper quality.**

- **Key components of fibre—cellulose, hemicellulose, and lignin—influence pulp behaviour and paper properties.**

- **After pulping, the pulp is cleaned, refined, formed into sheets, pressed, and dried to make paper. The selection of raw materials and pulping method affects paper strength, brightness, durability, and cost.**

- **Sustainable practices, including use of agro-waste and chemical recovery systems, are vital for eco-friendly papermaking.**

# CONTACT US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# THANK YOU