Pulp and Paper Industry

Anders Törngren Swedish EPA
Pulp and Paper

• Production and capacity
  − Global, Europe, Sweden

• Process
  − Kraft pulp mill
  − BAT (Best available techniques)
  − Emission to air and water
  − Paper

• Energy

• Water management and Effluent treatment

• Summary
Production and Exports of Pulp 2016

Total World Production: 168 Million Tonnes (2014: 168 Million Tonnes)
Total World Exports: 51 Million Tonnes (2014: 50 Million Tonnes)

Source: RISI, CEPI
Total World Production: 411 Million Tonnes (2015: 407 Million Tonnes)
Total World Exports: 112 Million Tonnes (2015: 111 Million Tonnes)
Number of European* Pulp Mills by Volume in 2006 and 2016

Number of Pulp Mills

Size category ('000 Tonnes p.a.)

- <25
- 25 to 50
- 50 to 100
- 100 to 200
- 200 to 300
- 300+

2006
2016

10.3% 5.9%
9.4% 5.9%
17.8% 14.4%
21.1% 22.9%
16.4% 14.4%
24.9% 36.6%

1Share of Total Number of Mills
* Europe countries within Cepi

CEPI Statistics
Structure in the Swedish pulp industry 1980-2017

- **Mill #**
- **Total capacity Mton**
- **Capacity mill, 1000 ton**
Number of European* Paper & Board Mills by Volume in 2006 and 2016

Number of Paper & Board Mills

<table>
<thead>
<tr>
<th>Size category ('000 Tonnes p.a.)</th>
<th>2006</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td>22.7%</td>
<td>25.0%</td>
</tr>
<tr>
<td>10 to 25</td>
<td>14.3%</td>
<td>13.7%</td>
</tr>
<tr>
<td>25 to 50</td>
<td>14.8%</td>
<td>15.6%</td>
</tr>
<tr>
<td>50 to 100</td>
<td>14.4%</td>
<td>16.3%</td>
</tr>
<tr>
<td>100 to 200</td>
<td>12.9%</td>
<td>11.6%</td>
</tr>
<tr>
<td>200 to 300</td>
<td>6.7%</td>
<td>7.3%</td>
</tr>
<tr>
<td>300+</td>
<td>11.9%</td>
<td>12.8%</td>
</tr>
</tbody>
</table>

1 Share of Total Number of Mills
* Europe countries within Cepi

CEPI Statistics
Structure in the Swedish paper industry 1980-2017

The chart shows the number of mills and total capacity in million tons (Mton) from 1980 to 2017. The number of mills has decreased over the years, while the total capacity has increased. In 1980, there were 67 mills with a total capacity of 57 Mton. In 2017, there were 32 mills with a total capacity of 291 Mton. The capacity per mill, in thousands of tons (1000 ton), also shows an upward trend.
Share of Integrated Pulp in the Pulp and Paper Industry 2011

Total Pulp Capacity, Million Tonnes

- USA: 57
- Canada: 28
- Brazil: 15
- Sweden: 13
- Finland: 12
- Russia: 9
- Chile: 5
- Portugal: 3

Source: FAO
Market pulp production and deliveries Sweden 1980-2017

Million tonnes

Production
Exports
Domestic deliveries

Skogsindustrierna
Paper production and deliveries Sweden 1980-2017

Million tonnes

Production

Export

Domestic deliveries


Skogsindustrierna
Kraft mill process

- Debarking (water emission)
- Chipping and screening (no major environmental impact)
- Cooking (water emission, energy)
- Condensation (water emission, energy)
- Spillage (water emission)
- Washing loss (water emission)
- Bleaching (water emission)
- Recovery boiler (air emission, energy)
- Lime kiln (air emission)
- Boilers (air emission, energy)
- Paper machine (water emission, Energy)
Typical Kraft Pulp Mill
Typical Kraft Pulp Mill
## Kraft Pulp Mill- Debarking (drum debarking)

<table>
<thead>
<tr>
<th></th>
<th>Effluent volume</th>
<th>COD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m³/tonne pulp</td>
<td>kg/tonne of pulp</td>
</tr>
<tr>
<td>Wet Debarking+ bark press</td>
<td>3-10</td>
<td>20-30</td>
</tr>
<tr>
<td>Dry Debarking+ bark press</td>
<td>0,5-2,5</td>
<td>1-10</td>
</tr>
</tbody>
</table>
Kraft Pulp Mill (Cooking)

- Continuous or Batch cooking
- Residual Lignin – Kappa number
- Conventional cooking – extended cooking
- Oxygen delignification – single/double
Closure of the water streams

BAT-associated waste water flow
Bleached pulp 25-50 m³/ADt
Unbleached pulp 15-40 m³/ADt

60-100 kg COD/ADt
16-24 kg COD/ADt
### Kraft Pulp Mill (delignification)

<table>
<thead>
<tr>
<th>Process Type</th>
<th>Hardwood (Kappa)</th>
<th>Softwood (Kappa)</th>
<th>Hardwood (COD, kg/t)</th>
<th>Softwood (COD, kg/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conv. Cooking</td>
<td>14-22</td>
<td>30-35</td>
<td>28-44</td>
<td>60-70</td>
</tr>
<tr>
<td>Conv. Cooking+O₂</td>
<td>13-15</td>
<td>18-20</td>
<td>26-30</td>
<td>36-40</td>
</tr>
<tr>
<td>Extended Cooking</td>
<td>14-16</td>
<td>18-22</td>
<td>28-32</td>
<td>36-44</td>
</tr>
<tr>
<td>Extended Cooking+O₂</td>
<td>8-10</td>
<td>8-12</td>
<td>16-20</td>
<td>16-24</td>
</tr>
</tbody>
</table>
## COD before external treatment

<table>
<thead>
<tr>
<th>Process stage</th>
<th>COD kg/Adt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood handling</td>
<td>1-10</td>
</tr>
<tr>
<td>Condensates</td>
<td>2-8</td>
</tr>
<tr>
<td>Spillage</td>
<td>2-10</td>
</tr>
<tr>
<td>Washing loss</td>
<td>6-12</td>
</tr>
<tr>
<td>Bleaching</td>
<td>15-65</td>
</tr>
<tr>
<td><strong>Total from mill</strong></td>
<td><strong>31-105</strong></td>
</tr>
</tbody>
</table>

Figures are a 10 years old, today levels might be even lower.
# External Treatment - Biological Treatment

<table>
<thead>
<tr>
<th>Reduction rate</th>
<th>COD (%)</th>
<th>AOX (%)</th>
<th>P (%)</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerated lagoon</td>
<td>30-60</td>
<td>20-45</td>
<td>0-15</td>
<td>0</td>
</tr>
<tr>
<td>Activated sludge</td>
<td>50-70 (90)</td>
<td>40-65</td>
<td>40-85</td>
<td>20-50</td>
</tr>
</tbody>
</table>
Activated sludge plant

Design and technical data

- **35 000 m³** effluents
- **35 ton COD/d**
- **Aeration** 12 m water depth, 47.5 m diameter 22 000 m³
- **Secondary clarifier** 4 m water depth, 60 m diameter, 11 000 m³
- **Primary clarifier** 1.8 m water depth, 52 m diameter, 3 200 m³
- **COD-reduction** ~90%
- **Sludge production** 0.16 kg/ton COD removed (guarantee)
- **Electricity** ~1 MW
- **Chemicals** ~700 ton (mainly urea and phosphoric acid)
General BAT

- Training & motivation of staff
- Process control & optimisation
- Maintenance
- Environmental management system
Measures to reach BAT – Water- KRAFT Pulp

- Dry debarking
- Increased delignification by extended cooking and add. oxygen stages
  ECF or TCF bleaching (recycling)
  Process water recycle
- Efficient and closed brown stock washing
Measures to reach BAT – Water (cont)

• Effective spill recovery system
• In addition to process-integrated measures, primary and biological treatment of waste water
## BREF Levels Water- Kraft

*revised BREF 2014*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>BLEACHED</th>
<th>UNBL BLEACHED</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLOW</td>
<td>m³/Adt</td>
<td>30-50</td>
<td>15-25</td>
</tr>
<tr>
<td>COD</td>
<td>Kg/Adt</td>
<td>8-23 (7-20)*</td>
<td>5-10 (2,5-8)*</td>
</tr>
<tr>
<td>BOD</td>
<td>Kg/Adt</td>
<td>0,3-1,5</td>
<td>0,2-0,7</td>
</tr>
<tr>
<td>TSS</td>
<td>Kg/Adt</td>
<td>0,6-1,5 (0,3-1,5)</td>
<td>0,3-1,0 (0,3-1,0)</td>
</tr>
<tr>
<td>AOX</td>
<td>Kg/Adt</td>
<td>&lt;0,25 (0-0,2)*</td>
<td>-</td>
</tr>
<tr>
<td>Total-N</td>
<td>Kg/Adt</td>
<td>0,1-0,25 (0,05-0,25)*</td>
<td>0,1-0,25 (0,1-0,2)*</td>
</tr>
<tr>
<td>Total-P</td>
<td>Kg/adt</td>
<td>0,01-0,03 (0,01-0,03)</td>
<td>0,01-0,03 (0,01-0,02)</td>
</tr>
</tbody>
</table>
Kg COD/ton kraft pulp
Mills producing mainly bleached pulp

BAT-AEL

0 10 20 30 40 50 60 70
1998 2004 2010

Mönsterås
Skutskär
Skoghall
Iggesund
Korsnäs
Korsbäck
Östrand
Gruvön
Skärblacka
Mörrum
Mörrum
Aspa
Karlsholm
Skutskär
Gruvön
Skärblacka
Östrand
Aspa
Värö
Vallvik

0 10 20 30 40 50 60 70
1998 2004 2010

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Vallvik
Dissolved organic substances (COD) from Swedish pulp and paper mills 1978-2017

COD, mln tonnes

Pulp production

COD emissions

Pulp prod, mln tonnes


0 0,2 0,4 0,6 0,8 1 1,2 1,4 1,6

0 2 4 6 8 10 12 14 16

Skogsindustrierna
Chlorinated organic substances (AOX) from Swedish pulp and paper mills 1978-2017

1 000 tonnes AOX

AOX kg/tonne of bleached chemical pulp


1 000 tonnes AOX AOX kg/tonne of bleached chemical pulp

Skogsindustrierna
Emissions to water of Dioxins from Pulp & Paper Sector

- 1973 ~25 g/year  Maximum use of Chlorine gas, 275000 ton/year
- 1988 10 g/year  Oxygen delignification introduced, ClO₂
- 1993 4 g/year  Chlorine gas totally phased out
- 1999 1 g/year  Improve washing and WWTU
- 2006 0.1 g/year  Latest emission monitoring project
Measures to reach BAT – Air

• Collection & incineration of malodorous gases with SO$_2$ control TRS emissions mitigated (combustion control)
  Residual Weak gases: 0,05-0,2 kg S/ADt

• SO$_2$ emissions from recovery & auxiliary boilers reduced (dry black liquid)

• Use of bark or other low S fuel or scrubber
Measures to reach BAT – Air (cont)

- NOx emissions from recovery boiler reduced (controlling fire conditions, altered to proper design)
- Dust emissions from boilers reduced (electrostatic precipitators)
BREF Levels Air – Kraft- Processes
Recovery Boiler

• Dust, 0.02-0.3 kg/Adt (10-40 mg/Nm³)
• Gasous S, 0.03-0.15 kg/Adt
• NOx, 1-1.5 kg/Adt (0.8-1.6)
• TRS (as S), 0.1-0.2 kg/Adt
Sulphur Emissions 1978 - 2016
From Swedish Pulp and Paper Mills
Measures to reach BAT
Non-integrated paper mill

• Minimise water use
  − recycle process water
  − reuse clean cooling and sealing water

• Primary and secondary biological treatment of waste water (secondary could in some cases be precipitation)
Measures to reach BAT
Non-integrated paper mill (cont)

• High Energy Efficiency
• Substitution of potentially harmful substance by less harmful alternative

• Waste minimisation by waste management (separate collection and reuse)
BREF levels
Non-integrated paper mills

Water emission
- COD, 0,5-2 kg/Adt
- BOD, 0,15-0,25 kg/Adt
- TSS, 0,2-0,4 kg/Adt

Energy demand
- Process heat 5,5-8 GJ/t
- Power 0,6-1 MWh/t
Energy

Examples of energy numbers from energy efficient mills

- Kraft pulp (4 types) 10-20 GJ/t
- Mechanical pulp (4 types) 0-12 GJ/t
- Recovered paper mills (3 types) 4-12 GJ/t
- Paper mill (3 types) 5.5-8 GJ/t
Energy consumption – Integrated bleached Kraft Mill

<table>
<thead>
<tr>
<th>Process Heat, MJ/t</th>
<th>El. Power, kWh/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooking</td>
<td>2 000</td>
</tr>
<tr>
<td>O₂ Delignification</td>
<td>400</td>
</tr>
<tr>
<td>Bleaching</td>
<td>570</td>
</tr>
<tr>
<td>Evaporation</td>
<td>3 600</td>
</tr>
<tr>
<td>Recovery Boiler</td>
<td>600</td>
</tr>
<tr>
<td>Lime Kiln</td>
<td>1 300</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>1 900</td>
</tr>
<tr>
<td><strong>Total PULP</strong></td>
<td><strong>10 400</strong></td>
</tr>
</tbody>
</table>
Used electricity at Swedish Kraft Pulp Mills, kWh/t Benchmarking

- AssiDomän Frövi
- Billerud AB, Gluvno Bruk
- Billerud AB, Karlshoga Bruk
- Billerud AB, Skärblacka
- Holmen AB, Iggesunds Bruk AB
- Kappa Kraftliner AB, Korsnäsvettern
- Korsnäs AB, Korsnäsverken
- Mr real Sverige AB, Husums fabrik
- Pappelrous AB, Valviks Bruk AB
- SCA, Munk sand
- SCA, Östrands massafabrik
- Smurfit Munksjö AB, Aspa Bruk
- Smurfit Munksjö AB, Billinge fors
- Stora Enso, Nornsundetts Bruk
- Stora Enso, Sutskärs Bruk
- Södra Cell AB, Mönsterös Bruk
- Södra Cell AB, Mörrums Bruk
- Södra Cell AB, Vårbo
International Benchmarking –
Use of heat at kraft pulp mills

Use of heat, GJ/Adt

- Other
- Recovery cycle (not evaporation)
- Evaporation
- Dryer
- Pulp machine (not cooking)
- Cooking
- Wood handling
- Total

2018-06-06
Aspects regarding energy

- Phasing out fossil fuels
- Drying of bark in order to increase energy efficiency
- Increasing of internal electricity production
- Delivery of waste heat to District heating system
- Reduction of waste water will reduce energy demand
Oil consumption 1973 - 2007
Swedish pulp and paper industry

Excl. oil for back pressure power  Skogsindustrierna

2014: less than 250 000 m³
Energy System for maximizing power production

- External soot blowing steam
- Feed water preheating
- Heat Recovery from stack gases: temperature ~125 °C
- High Steam data: Example
  - 515 °C
  - 10.5 MPa
- Air preheating: Many stages
Energy Turbine and steam system example for maximizing power production

Rec.Boil ex.105 bar(e), 515 °C

Power Boil. 56 bar(e),

Soot blowing
Feed.W HeEx 3
Air and Feed.W HeEx 2
Air, Bl. Liq, Oil
Feed.W HeEx 2
Feed Watertank

ca 27 bar(e),
ca 16 bar(e),
11.5 bar(e), externt styrt
ca 7 bar(e), flytande
3.5 bar(e), externt styrt

Condensing Turbine 50-150 MW

29.10.04 Bo S.
## Energy

### Power Balance kWh/Adt

<table>
<thead>
<tr>
<th></th>
<th>Softwood</th>
<th>Hardwood</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power consumption</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood yard</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Digester</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Washing and screening</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Oxygen stage</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Bleaching</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>Final screening</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Pulp machine</td>
<td>120</td>
<td>130</td>
</tr>
<tr>
<td>Evaporation</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Causticising, lime kiln incl. fuel gasifier</td>
<td>57</td>
<td>30</td>
</tr>
<tr>
<td>Boiler house</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>Cooling tower etc</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Raw water treatment and distribution</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>Effluent treatment</td>
<td>17</td>
<td>30</td>
</tr>
<tr>
<td>Chem preparation</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Miscellaneous, losses</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>716</td>
<td>791</td>
</tr>
<tr>
<td><strong>Sold power</strong></td>
<td>579</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1 295</td>
<td>791</td>
</tr>
</tbody>
</table>

### Power production

<table>
<thead>
<tr>
<th></th>
<th>Softwood</th>
<th>Hardwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back-pressure power</td>
<td>774</td>
<td>593</td>
</tr>
<tr>
<td>Condensing power</td>
<td>521</td>
<td>0</td>
</tr>
<tr>
<td>Bought power</td>
<td>0</td>
<td>198</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>1 295</td>
<td>791</td>
</tr>
</tbody>
</table>

**Energy Balance kWh/Adt**

<table>
<thead>
<tr>
<th></th>
<th>Reference</th>
<th>Type mill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood yard</td>
<td>45</td>
<td>45</td>
</tr>
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<td>Oxygen stage</td>
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<td>Raw water treatment and distribution</td>
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<td><strong>Sum</strong></td>
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<td><strong>Sold power</strong></td>
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<td><strong>Total</strong></td>
<td>1 295</td>
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</table>
Production and use of electricity – example Värö Mill

Energy importing mills will become energy suppliers

- Production
- Consumption
Energy generation at a mill

• Heat (steam) and Electricity
• Recovery boiler
• Auxiliary boilers
Some factors for energy efficiency at the recovery boiler

- High TS in black liquor (80 %)
- High boiler pressure

<table>
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<th></th>
<th>Typical today</th>
<th>Ref. Mill</th>
<th>Max. today</th>
<th>Future</th>
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<td>110 (115)</td>
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<td>790-805</td>
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Energy efficiency
Water emissions reduction

• Reduction of volume of waste water
  – less need for energy
  – less water to heat

• Reduced volume of waste water
  – less need for energy in the waste water treatment unit

• More concentrated waste water
  – possibility to use anaerobic waste water treatment
  – production of biogas
Energy efficient mills will be energy plants

Energy efficient mills will produce more energy than is needed at the mill

One of the big Pulp and Paper companies in Sweden are making the almost the same earning from energy as from Pulp
Water management and Effluent Treatment
COD levels after technical improvements
Östränd mill

- 1980: Oxygen bleaching
- 1982: ITC, Improved washing, ITC, New oxygen bleaching
- 1994: Ozone, Closed circuit, TCF bleaching
- 2001: Multibio treatment
- 2004: Multibio treatment
AOX levels after technical improvements
Östrand Mill

kg ptp

1980
1982
1994
1996
Authority demand

Oxygen bleaching
ITC, Improved washing
MC-oxygen bleaching
ITC, MC
Ozone, Closed loop
TCF bleaching

2018-09-07
Naturvårdsverket | Swedish Environmental Protection Agency
Why biological effluent treatment in forest industry?

• Reduction of BOD/COD
• Reduction of nutrients (N and P)
• Reduction of toxic (organic) substances
• Reduction of chlorate
• Reduction of chelating agent (EDTA/(DTPA))
• Reduction of excess sludge
LAS at Mönsterås

1. Primary clarifier
2. Anoxic selector
3. Long time Activated Sludge
4. Secondary clarifier
5. Bio-pond
6. End clarifier
Combination Process

Relatively short retention time, 10 - 24 h
High reduction of BOD, 90 - 99 %
Normally low content of suspended solids in effluent, 10 - 40 mg/l
Relatively low operation cost (sludge production and energy)

Insensitive for disturbances
Södra Cell Mörrum

Activated sludge 1
Free bacteria stage
Bio-film stage
Selector
Activated sludge 2
Sludge aeration
Bio-film carrier - Natrix®

Bio film carriers
Over time focus have shifted between different environmental problems – BAT is a moving target

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</table>
Increased production and reduced emissions - European Pulp and Paper Industry

CEPI statistics 2016
Higher Production and Lower Emissions Sweden 1990-2016

Index

- Pulp Production
- Paper Production
- Electricity Consumption
- Chlorinated Organic Substances (AOX)
- Fossil Carbon Dioxide
- Sulphur
- Dissolved Organic Substances
- Nitrogen Oxides
The quality of the water in Lake Vänern is as good as in the late 19th century (TOC mg/l)