# Non-wood pulping technology Present Status and Future

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**ABSTRACT**

This paper discusses the evolution of non-wood pulping technology and key challenges for future growth. Emission of dissolved organic material including chlorinated organic compounds is the main concern. Recovery of black liquor from cooking and reduced bleach plant emissions is the way to go. Abhishek Industries Ltd. and Tamil Nadu Newsprint and Papers Ltd. have demonstrated that black liquor recovery is possible. These companies have also paved the way for future development of non-wood pulping technology by implementing achievements established in the field of wood pulping technology.

The next steps can follow along the same path. This would mean introduction of intensified oxygen delignification and ozone bleaching technologies combined with total chlorine chemical free bleaching, all of which have been tried out in full scale for production of bleached chemical kraft pulps.

## INTRODUCTION

Not considering bamboo, various species of sugar cane, straw and reed represent the bulk of non-wood raw materials for paper pulp. Production of non-wood pulp increased up till the mid 1990's and after that it has remained flat (1).

The key reason for this is related to poor environmental performance of non-wood pulp mills in combination with a growing environmental concern. There are two main areas of concern:
High amounts of organic and inorganic black liquor solids are emitted to the environment due to difficulties in recovering spent cooking liquors.

Chlorine and hypochlorite, already abandoned for bleaching of wood pulps, are still used for bleaching of non-wood pulps, forming chlorinated organic compounds discharged with bleach plant effluents.

Recent years have seen an increasing interest in implementing new and improved process technologies that abate the negative impact of emissions from non-wood pulping. This especially the case within the non-wo pulp industry of India.

In this paper we will review tl development focusing especially fiberline technology.

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**Table 1, $SiO_2$ content in raw material and black liquor (2,3)**

| Species | $SiO_2$ % of raw material | $SiO_2$ % of TS in black liquor |
|---|---|---|
| Rice Straw | 9 - 14 | 11 - 16 |
| Wheat straw | 3 - 7 | 4,5 - 8 |
| Sugar cane bagasse | 0,7 - 3 | 1,2 |
| Common reed | 2 | 2,5 - 5 |
| Bamboo | 1,5 - 3 | 2 - 2,1 |

cf. table 1, in combination with alkaline cooking liquor gives a high content of silica also in the spent cooking liquor. This well-known fact makes it difficult to evaporate and recover spent cooking

A second source of emission is discharge of bleach plant effluents. Its total content of dissolved organic material, expressed as COD, and its

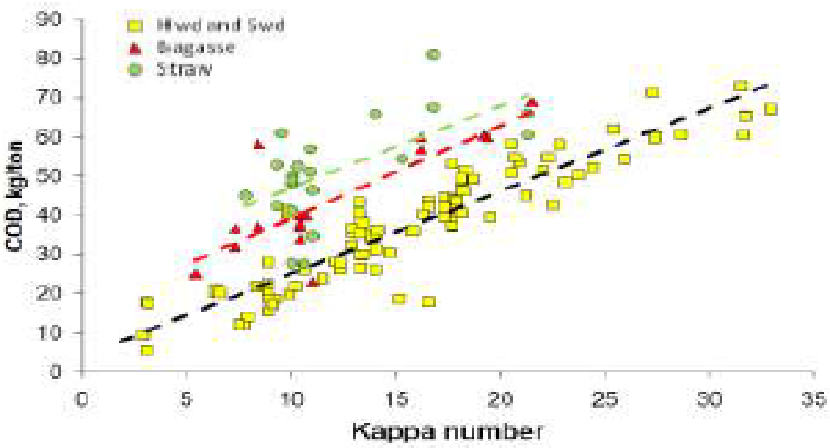



**Figure 1. COD content in spent laboratory bleaching liquors**

content of chlorinated organic material, expressed as AOX, gives an indication of the potential environmental hazards associated with bleach plant effluents.

In figure 1, COD content in spent bleaching liquor is plotted versus kappa number of unbleached pulp. In this diagram effluents from laboratory bleaching of wood, bagasse and straw pulps are compared. We have earlier shown (4) that for wood pulps the amount of dissolved organic material is proportional to the kappa number. This holds true also for bleaching of bagasse and straw pulps. However, there is one striking difference. At a given kappa number, the amount of COD has been much higher for the non-wood pulps.

In figure 2, AOX content in spent bleaching liquors has been plotted versus kappa number of unbleached pulp. The variation in AOX at any given kappa number can to a large extent be explained by the use of different chlorine containing bleaching chemicals, $Cl_2$ (C), $OCl^-$ (H), and $ClO_2$ (D). The conditions in the first bleaching stage are especially important (5). The higher the proportion of chlorine, in the first bleaching stage the higher the formation of AOX.

To decrease environmental hazards associated with bleach plant emissions, the wood-based pulp industry has:

Introduced oxygen delignification to decrease kappa number prior to bleaching.

Totally eliminated the use of chlorine and hypochlorite in favor of ECF (Elementally Chlorine Free) and gradually also TCF (Totally Chlorine chemical Free) bleaching.

*Cooking technology unique for non-woods*

In comparison with wood raw materials non-woods are easily delignified to low kappa numbers. Continuous cooking, using the tube digester and soda process, has become the technology of choice for production of non-wood pulp, exemplified in figure 3. The specific characteristics of non-wood raw materials, with exception of bamboo, in terms of material flow and permeability properties have made it impossible to use traditional vertical down-flow digesters. Cooking is performed at about 160 -170°C for 15

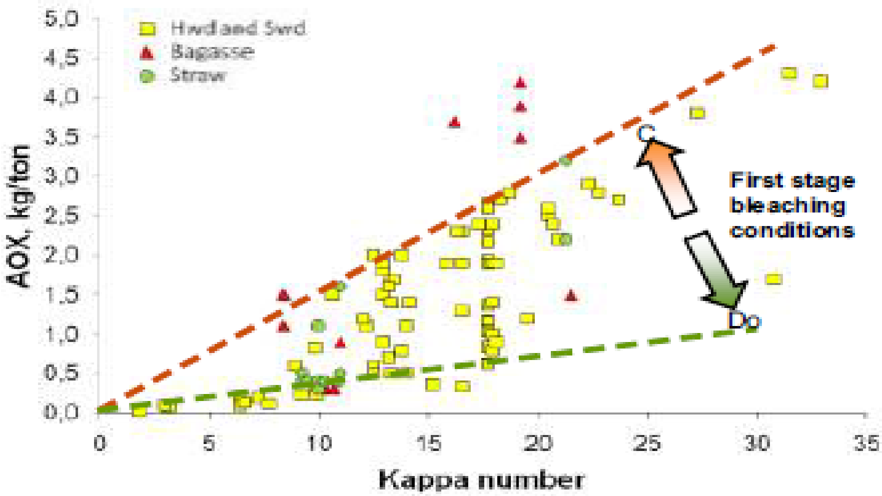



**Figure 2. AOX content in spent laboratory bleaching liquors**

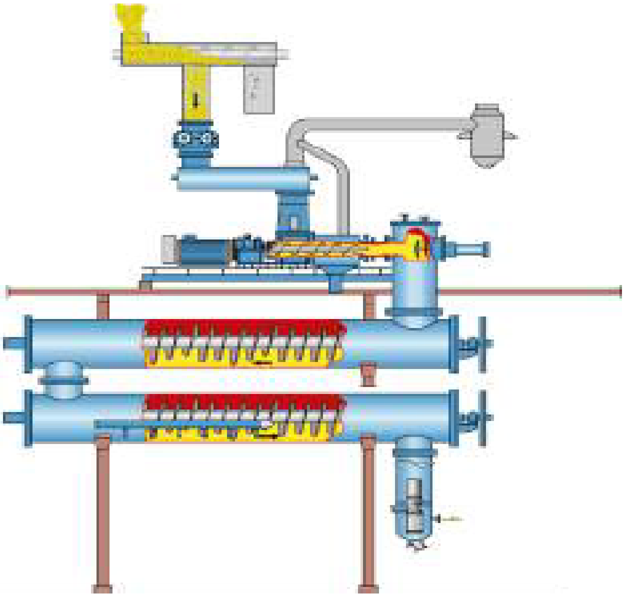


**Figure 3. Continuous cooking system for non-wood plants**

20 minutes. Depending on the specific properties of non-wood raw materials and their pretreatment, alkali charge and consumption as well as cooking yield will vary to reach a set target kappa number.

*Non-wood pulping benefits from technology achievements in the wood pulping area*

Improved screening technology, using slotted screen baskets and hydrodynamically designed screen rotors, has allowed for higher consistency feeding. At the same time sand and other debris can be taken out in the screen room. It is also possible to run screening without a cleaner plant.

In addition, improved washing technology, using TwinRoll™ presses, has been implemented in today's brown stock fiberlines for non-wood pulping.

Oxygen delignification is gradually adopted in non-wood fiberlines, allowing for a kappa number reduction after cooking in the range of 30 - 50%. This reduces bleach chemical requirement and hence the discharge of potentially harmful chlorinated organic pollutants. Since the oxygen stage is integrated with the brown stock fiberline, it also in the case that the mill recovers spent cooking liquor decreases the total emission of dissolved organic material.

Furthermore, modern ECF-bleaching

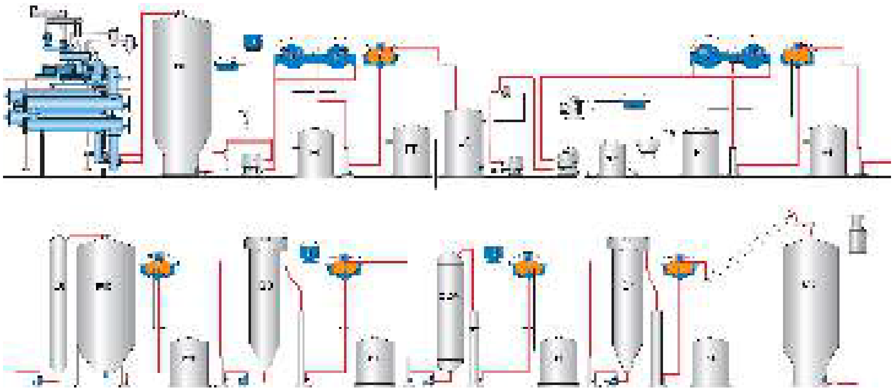


**Figure 4. A schematic flowsheet of Abhishek straw pulp fiberline started up in 2008**

technology has now also been implemented for bleaching of non-wood pulps.

The new straw pulp mill of Abhishek Industries Ltd., which was started up in 2008, is a good example of this development. A schematic flowsheet of the Abhishek straw fiberline, today the world's largest in a single line, operating at about 225 odt/d, is shown in figure 4. Cooking is performed in two parallel tube digester systems feeding a common screening and brown stock washing system. Oxygen delignification is integrated in the brown stock washing system.

Abhishek is unique in such a way that black liquor is recovered. To prevent silica from building up in the recovery cycle, a portion of the lime mud after causticizing is removed.

Tamil Nadu Newsprint and Papers Ltd., the world's largest bagasse fiberline is the next example. A schematic flowsheet of the 500 odt/d fiberline is shown in figure 5.

The ECF bleach plant is in operation since April, 2008, producing 90% ISO brightness pulp. Cooking is performed in five parallel tube digester systems. The new screening, brown stock washing and oxygen delignification systems will be commissioned in late 2009. The screen room, essentially without cleaners, is designed for improved sand removal. By thickening the accept pulp to >4% consistency it is possible to completely move away from vacuum washers, making Tamil Nadu the world's first non-wood pulp mill entirely based on TwinRoll press washing.

Black liquor is recovered together with black liquor from the mill's hardwood kraft pulp fiberline.

The introduction of press-based fiberline technology gives new opportunities to reduce liquor circulation flows in the brown stock fiberline area and to minimize fresh water usage and effluent volumes in bleaching.

The implementation of oxygen delignification and ECF bleaching technologies, replacing chlorine and hypochlorite bleaching chemicals, in both Abhishek and Tamil Nadu are also important steps for decreasing fiberline emissions of AOX and COD.

**Towards improved environmental performance the next steps**

Tamil Nadu and Abhishek have demonstrated the viability of recovering black liquor from bagasse and straw pulping. Still, however, this is an area that needs further improvement. For the future non-wood pulp mill, cost efficient black liquor recovery will be a necessity.

*Improved oxygen delignification*

## Table 2. Impact of increased oxygen pressure in oxygen delignification of bagasse pulp (laboratory trials).

| | | | |
|---|---|---|---|
| Oxygen stage | | | |
| Unbleached pulp | | | |
| Kappa number | 13,2 | | |
| Brightness, % ISO | 45,3 | | |
| Oxygen conditions | | | |
| NaOH charge, kg/odt | 20 | | |
| Temperature, °C | 105 | | |
| Time, min | 90 | | |
| Oxygen pressure, MPa | 0,5 | 0,8 | 1,0 |
| Oxygen pulp | | | |
| Kappa number | 6,7 | 6,2 | 5,9 |
| Brightness, % ISO | 57,9 | 59,6 | 60,8 |
| Viscosity, ml/g | 979 | 960 | 961 |

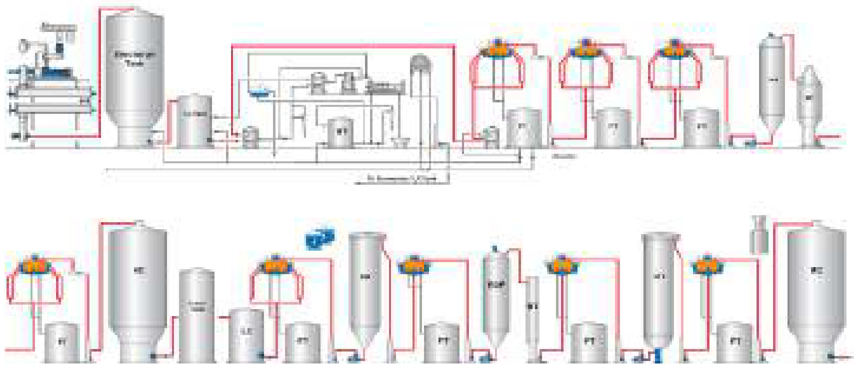


**Figure 5. Schematic flowsheet of the new Tamil Nadu bagasse pulp fiberline**

The technology for oxygen delignification of wood pulps has developed significantly in the last 10-15 years, allowing in the case of softwood pulps up to 70% degree of delignification (6). For reasons earlier explained, oxygen delignification is now also of interest for non-wood pulp mills. Current installations apply "standard" conditions in the oxygen stage, i.e. temperature in the range of 90 - 105 °C, pressure 0.3 - 0.5 MPa and retention time of about 60 minutes, yielding about 30% degree of delignification.

By analogy with wood pulps we now show that it is possible to intensify the conditions in the oxygen stage for non-wood pulps and thereby improve delignification in that stage.

In table 2 this is exemplified in laboratory trials on bagasse pulp. Retention time is extended to 90 minutes. The impact of pressure is especially emphasized. In this case 55% delignification was obtained as well as improved brightness of oxygen-delignified pulp. The importance of brightness will be demonstrated later.

An additional factor which facilitates a high degree of delignification is a low content of hexenuronic acid (HexA). HexA consumes potassium permanganate in the kappa number analysis, thus giving a misleading measure of residual lignin. One kappa number unit corresponds approximately to a HexA content of 10 mmol/kg pulp. As HexA is virtually inert in an oxygen delignification stage a high HexA content would make it more difficult to obtain a high degree of kappa number reduction in the oxygen stage. A normal level of HexA in bagasse and straw pulps is in the range of 5 - 15 mmol/kg pulp whereas in hardwood pulps the content can vary between 40 - 80 mmol/kg pulp (7).

*ECF bleaching*

By extending delignification in the oxygen stage a substantial reduction in bleach chemical consumption can be achieved in subsequent bleaching stages. In a previous paper (8) it was shown that oxygen-delignified bagasse pulp at kappa 8.4 required about 35 kg act. Cl/odt in a D(EO)D sequence to reach a final brightness of 88% ISO. In figure 6 it can be seen that the corresponding consumption for this pulp with kappa 5.4 was 22 kg act. Cl/odt in a D(EP)D sequence.

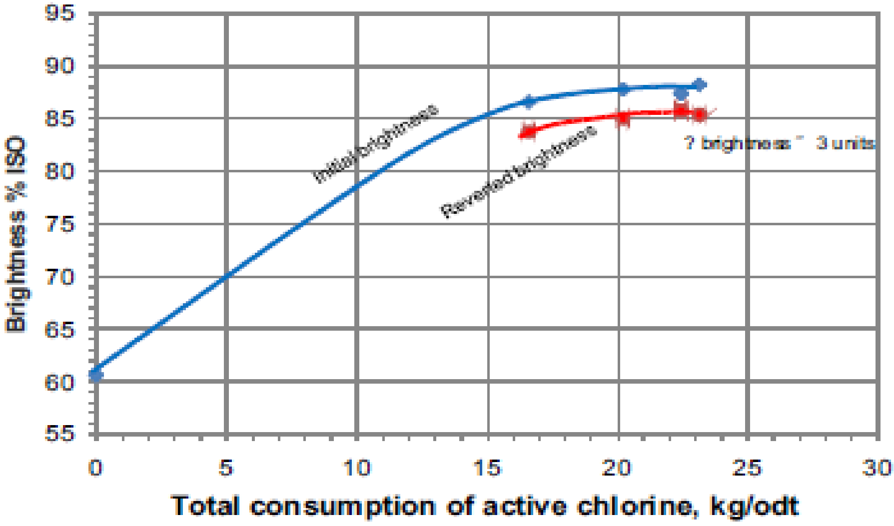



**Figure 6. Brightness and reverted brightness vs. act.Cl consumption in a D(EP)D sequence for oxygen delignified bagasse pulp, kappa 5.4 (kappa 13.5 after cooking). $PO_2$ 1.0 MPa, 90 min, 105°C, (laboratory trials).**

This pulp, when subjected to a standard test for brightness reversion (4h 105°C and dry atmosphere), showed a significant brightness reversion, about 3 brightness units. Bagasse pulp bleached in a traditional chlorine sequence, e.g. C(EP)HP, showed an even higher brightness reversion, more than 3 units, cf. table 4. To compensate for brightness reversion mills tend to increase their brightness target correspondingly higher.

*Ozone bleaching and (PO)*

Although the combination of oxygen delignification and ECF bleaching represents a huge step with regard to pollution abatement, additional steps may be taken to further decrease emissions. Implementation of ozone - ZeTrac™ - and pressurized peroxide bleaching technologies, well-established for bleaching of wood pulps, are close at hand (9,10).

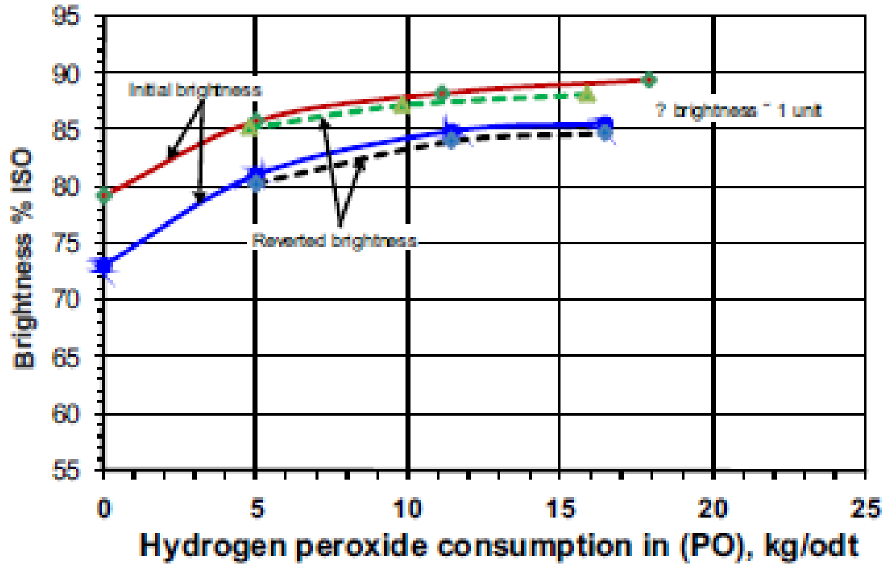



**Figure 7. Brightness and reverted brightness vs. peroxide consumption in O(Zq)(PO) applying standard and intensified conditions in the oxygen stage, cf. table 3, (laboratory trials).**

Consequences of such a strategy are indicated in figure 7 and table 3 for a O(Zq)(PO) bleaching sequence. The benefits of intensified oxygen delignification lower kappa number and higher brightness after the oxygen stage are maintained after the ozone stage.

*Pulp quality improvement and cost*
Table 4 summarizes the impact on strength and optical properties of bagasse pulps when replacing traditional C (EP)HP bleaching with oxygen delignification combined with ECF or TCF bleaching. There is a notable improvement of the tear/tensile relationship.

## Table 3. Pulp properties and chemical consumption in O(Zq)(PO) bleaching of bagasse pulp

| Oxygen stage | 1 MPa 90 min | 0.5 MPa 90 min |
|---|---|---|
| Unbleached pulp | | |
| Kappa number | 13,5 | 13,5 |
| Brightness, % ISO | 43,5 | 43,5 |
| Oxygen pulp | | |
| Kappa number | 5,4 | 7,3 |
| Brightness, % ISO | 60,6 | 54,3 |
| O(Zq)-pulp | | |
| Ozone consumption | 5,2 | 6,0 |
| Kappa number | 1,5 | 1,9 |
| Brightness, % ISO | 79,2 | 73,1 |
| O(Zq)(PO)-pulp | | |
| Brightness, % ISO | 88,0 | 85,0 |
| Reverted brightenss, % ISO | 87,2 | 84,0 |
| $H_2O_2$ consumption, kg/odt | 10,0 | 11,5 |

This is true also after the final (PO)-stage. A much more favorable brightness development was obtained for that pulp.

Thus, there is a striking improvement in brightness stability for O(Zq)(PO) pulps in comparison with OD(EP)D.

Regards brightness reversion the ECF and TCF bleaching sequences are better than C(EP)HP. As mentioned above the O(Zq)(PO) sequence gives by far the lowest brightness reversion.

Figure 8 shows a simplified flowsheet of a bagasse fiberline, incorporating intensified oxygen delignification, ozone and pressurized peroxide bleaching. By recycling (PO) filtrate to post oxygen washing, the total effluent volume from the fiberline can be decreased to about 5 $m^3$/odt.

From a plant design point of view the O(Zq)(PO) installation in comparison with OD(EP)D will require less machinery. Process conditions are less corrosive and lower cost alloys can be used in the plant. These differences will result in a lower total investment for the O(Zq)(PO) alternative.

Bleach chemical costs have been estimated at 85% ISO reverted brightness for OD(EP)D and O(Zq)(PO) sequences and at 84% ISO for the C(EP)HP sequence, cf. table 5.

A consequence of higher brightness reversion obtained with C(EP)HP is increased chemical consumption and thus a significantly higher cost compared with O(Zq)(PO) and OD(EP)D sequences.

For the ECF and TCF sequences costs were approximately the same.
It should be noted that for the O(Zq)(PO) sequence it is possible to produce pulp with even higher reverted brightness than 85% ISO. This is due to improved brightness stability and higher brightness ceiling compared with the OD(EP)D sequence.

The sequence, however, could reach significantly higher reverted brightness than the OD(EP)D sequence, cf. figures 5 and 6.

It should be noted that for the sequence the brightness ceiling had been reached, whereas for the O(Zq)(PO) even brighter pulps can be produced as a result of improved brightness stability for that pulp.

*Concluding remarks*
It has been our intent, in this paper, to demonstrate how developments in the field of wood pulping technology have been practically implemented in non-wood pulp mills. It has also been our intention to point at further improvements of non-wood pulping technology.

We conclude that this technology will follow the same development that wood pulping technology has experienced over the last 10 15 years. This will include increased closure of the brown stock fiberline and a total

**Table 4. Comparison of pulp strength and optical properties of bleached bagasse pulps.**

| Sequence | Mill pulp C(EP)HP | Laboratory bleached mill pulps | | |
|---|---|---|---|---|
| | | C(EP)HP | O(Zq)(PO) | OD(EP)D |
| Brightness, % ISO | 87,0 | 88,7 | 88,3 | 87,4 |
| Reverted brightess, % ISO | 83,6 | 82,5 | 87,5 | 85,7 |
| PFI revolutions at SR30 | 200 | 280 | 190 | 390 |
| Tensile index, Nm/g at SR30 | 57 | 59 | 56 | 63 |
| PFI revolutions at T65 | 1000 | 750 | 600 | 510 |
| Tear index, $mNm^2$/g at T65 | 3,7 | 4,2 | 4,6 | 5,0 |
| Light scattering index, $m^2$/kg at T65 | 21 | 21 | 21 | 22,5 |

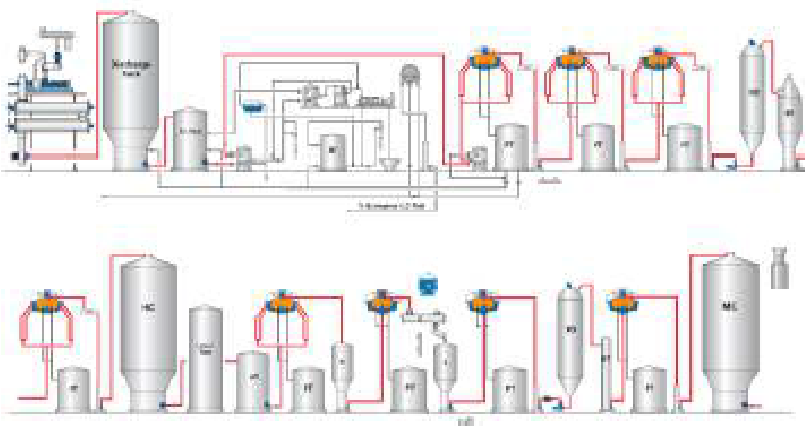
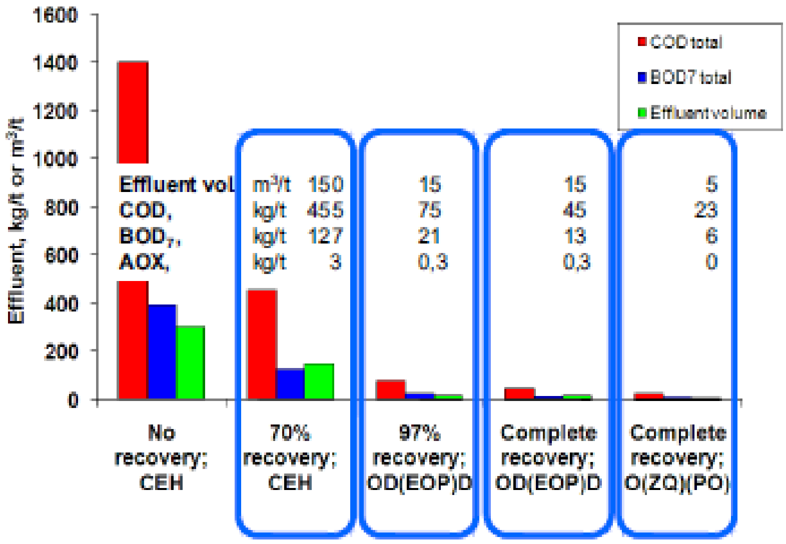


**Figure 8. Schematic flowsheet of a bagasse fiberline for TCF-bleached pulp, O(Zq)(PO).**

**Table 5. Estimate of bleach chemical costs for bagasse pulp bleached in different sequences. Impact of carry-over is considered.**

| | | C(EP)HP | | O(Zq)(PO) | | OD(EP)D | |
|---|---|---|---|---|---|---|---|
| Reverted brightness | % ISO | 84 | | 85 | | 85 | |
| Initial brightness | % ISO | 89 | | 86 | | 88 | |
| *Kappa after Cooking* | INR/kg | 13.5 | | 13.5 | | 13.5 | |
| *Oxygen stage* | | | | | | | |
| | | kg/adt | INR/adt | kg/adt | INR/adt | kg/adt | INR/adt |
| OWL (NaOH) | 4,0 | 0 | 0 | 18 | 72 | 18 | 72 |
| Oxygen | 2,0 | 0 | 0 | 16 | 32 | 16 | 32 |
| *Kappa after Oxygen* | | | | 6,5 | | 6,5 | |
| *Bleach plant* | | | | | | | |
| $Cl_2$ | 6,0 | 45 | 270 | 0 | 0 | 0 | 0 |
| NaClO, as NaClO | 13,0 | 11 | 143 | 0 | 0 | 0 | 0 |
| $ClO_2$ as ClO | 60,0 | 0 | 0 | 0 | 0 | 10 | 600 |
| NaOH | 20,0 | 33 | 660 | 14 | 280 | 10 | 200 |
| Oxygen (VSA) | 2,0 | 0 | 0 | 5 | 10 | 0 | 0 |
| $H_2O_2$ | 25,0 | 15 | 363 | 10 | 250 | 3,5 | 88 |
| $H_2SO$ | 4,0 | 0 | 0 | 14 | 56 | 5 | 20 |
| Ozone | 55,0 | 0 | | 5 | 275 | 0 | 0 |
| EDTA | 50,0 | 0 | 0 | 1 | 50 | 0 | 0 |
| **Total INR/adt** | | | 1436 | | 1025 | | 1012 |




**Figur 9. Estimate of improved recovery, ECF and TCF bleaching on fiberline effluent properties from a straw pulp mill (before external treatment)**

replacement of chlorine and hypochlorite in bleaching, eventually ending up in a totally chlorine chemical free fiberline.

This development route and its consequences regarding emission of dissolved organic material are indicated in figure 9,

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