

Section V.C.

Guidance by source category: Annex C, Part II Source Categories

Production of pulp using elemental chlorine  
or chemicals generating elemental chlorine for bleaching

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# GUIDELINES ON BAT FOR PRODUCTION OF PULP USING ELEMENTAL CHLORINE

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## References

## Draft Guidelines on BAT for production of pulp using elemental chlorine

### Summary

Annex C Part II (c) of the Convention identifies "production of pulp using elemental chlorine or chemicals generating elemental chlorine" as an industrial source category having "the potential for comparatively high formation and release of polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/PCDF), hexachlorobenzene (HCB), and polychlorinated biphenyls (PCB)."

Of these compounds HCB and PCB are not formed during pulp bleaching. Only polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/PCDF) have been identified as being unintentionally produced during the production of pulp using elemental chlorine. Of the 17 PCDD/PCDF congeners with chlorine in the 2,3,7 and 8 positions, only two congeners, namely 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2378-TCDD) and 2,3,7,8-tetrachlorodibenzofuran (2378-TCDF), have been identified being produced during chemical pulp bleaching using chlorine.

As a summary, the following measures can be made for decreasing or elimination the formation of 2378-TCDD and 2378-TCDF:

- Minimize precursors like DBD and DBF entering the bleach plant by using precursor-free additives and good washing
- Decrease the chlorine multiple
- Increase the level of chlorine dioxide substitution employed in the chlorination stage or completely replace chlorine with chlorine dioxide (Elemental Chlorine-Free bleaching)

## 1 Introduction

### 1.1 General information about pulp and paper production

Pulp and paper are manufactured from wood, recycled paper and many types of agricultural residue. Wood and the main non-wood materials used in papermaking are a complex mixture of the same substances – cellulose (40-45%), hemicelluloses (25-35%), lignin (20-30%) and extractives (2-15%). Most ligno-cellulosic and cellulosic materials of fibrous structure may be processed into various grades of papers and paperboard. Fibres from different raw materials are, however, not alike. They differ considerably in their morphological and chemical characteristics, which make them more or less suitable for papermaking.

Pulping and bleaching technology must be matched to the quality and characteristics of the pulp and paper grades to be produced. No single pulping or bleaching process can produce pulp suitable for all uses. For instance, newsprint is a high volume product of moderate strength, opacity and printability and a relatively short life. Therefore, a high yield of pulp at the expense of maximum achievable strength and brightness can be manufactured from the raw materials and there is a lower bleaching requirement due to natural brightness of the pulps. On the other hand packaging papers need strength if they are to be fit for use and here it is necessary to accept a lower yield via a different manufacturing route in order to obtain this strength but again the bleaching requirement may be low if this is a middle layer board. Further characteristics such as the brightness and its durability as required by outer packaging layers and printing and writing papers that may need to last for many years without yellowing, mean that and here the level of delignification and bleaching applied may need to be high. The amount of effort needed in bleaching can therefore vary widely.

Apart from hardwood and softwood species normally used in pulping, in some parts of the world a very high proportion of primary cellulose fibres originate from non-wood raw materials such as bagasse, cereal straw, bamboo, reeds, grasses, jute, kenaf, flax and sisal [TAPPI, 1987]. Over 10% of world pulp production is made from these non-wood fibres and in some countries it is the dominant fibre source, for instance in China and India.

Pulp and paper mills may be integrated or non-integrated. Non-integrated pulp mills (market pulp) are only manufacturing pulp that is then sold on the open market. Non-integrated paper mills use purchased pulp for their paper production. In integrated pulp and paper mills, the activities of pulp and paper making are undertaken on the same site. With recovered paper manufacturing the level of integration is high; nearly all recovered paper mills include recovered paper processing, some of them adding purchased pulp.

Compared to pulp production a relatively high number of small and medium-sized paper manufacturing facilities are in operation in many countries. A difference in relation to the scale of production is seen in different parts of the world with the capacities ranging from small mills of a few tens of tonnes per day through to major industrial complexes processing 1,000 to 1,500 tonnes per day.

## **1.2 Process Description**

### **1.2.1 Process Steps in general**

The main processes involved in making pulp, cellulose and paper products are: raw material handling and preparation, such as transport, storage, wood debarking, chipping and agricultural residue cleaning and de-noding; then pulping; pulp processing and bleaching and finally paper or paperboard making. Cellulose rich pulp products are also manufactured as raw material for other industrial processes, the manufacture of rayon, cellophane and some products in the chemical industry for example.

The industry is a divergent production process and so there is a wide range of techniques, using different pulping chemicals and process conditions as well as different bleaching sequences, that deliver the desired fibre product characteristics from a range of available raw fibre types and mixtures. The methods employed vary across the world both in relation to the characteristics of the fibre types available, the products to be made from them and the local pollution control restrictions that apply.

### 1.2.2 Pulping Methods Applied

The manufacture of pulp uses mechanical, thermomechanical, chemimechanical and chemical methods. Mechanical and thermomechanical methods are used in integrated mills to make naturally bright, high yield pulps mainly used for newsprint manufacture. Chemical pulping methods are used in integrated and non integrated pulping mills. Pulps produced in different ways have different properties that make them suited to particular products.

Pulping is the process of converting the virgin fibre into a form suitable for making paper and paperboard grades. In chemical pulping the fibres are broken down chemically: chemicals are used in a cooking process to enter the fibre lumen and dissolve lignin in the cell walls to gain access to the compound middle lamella (CML). Lignin has to be removed from the CML to free the fibres. The lignin and many other organic substances are thus put into solution. This happens in pressure vessels, called digesters, which in the case of batch processes are heated, pressurised vertical stationary vessels for wood and often spherical ones arranged to rotate to unload the contents, for non-woods, or in the case of continuous processes are vertical tower constant flow digesters.

Mechanical pulping processes use grinding for logs and disc refiners for chips. In these processes, mechanical shear forces are used to pull the fibres apart and the majority of the lignin remains with the fibres, although there is still some significant dissolution of organics. The first step is followed by secondary disc refining and direct supply to a paper machine. Mechanical pulps can often be used without bleaching, but where brightening is done it is achieved using non chlorinated compounds such as dithionite or peroxides.

The main chemical semi-chemical and chemimechanical pulping techniques are:

- **Lime, lime-soda** especially non-wood fibres;
- **Cold soda** uses sodium hydroxide pre treatment at ambient temperatures, alone or with sodium carbonate; especially hardwood and non-wood fibres; (semi chemical).
- **Soda AQ** sodium hydroxide alone or with sodium carbonate and a catalyst anthraquinone, hardwood and non-wood fibres; (chemical, similar to kraft but without sulphur), reduced odour.
- **Sulphate (kraft)** uses a mixture of sodium hydroxide and sodium sulphide under alkaline conditions to dissolve the lignin, wood and most non-wood fibres; (chemical method).

- **Sulphite - acid bisulphite, bisulphite, alkaline and neutral sulphite methods**, (Ca, Mg, NH<sub>4</sub>, Na) different bases, including anthraquinone, under a range of pH, to dissolve the lignins, most wood fibres; (chemical and semi-chemical methods).
- **Organosolv** methods, wood and non-wood applications, some proven on mill scale:
  - **Alcohol** as a solvent (not in commercial use), **organic acids** as solvent;
  - **Hybrid processes**.

### 1.2.2.1 The Kraft (Sulphate) Pulping Process

The kraft or sulphate process is an alkaline cooking liquor process and it is the dominating pulping process world wide (84 % of the world chemical pulp production and 63% of total chemical and mechanical pulp production). The kraft process uses a sodium based alkaline pulping solution consisting of sodium sulphide (Na<sub>2</sub>S) and sodium hydroxide (NaOH). Used cooking liquor (black liquor) is recovered to generate white liquor for the first pulping step. At mills with chemical recovery, most of the dissolved wood substances are combusted and the wastewater mainly contains the organics in condensates plus, at bleached mills, the substances dissolved during bleaching and the residues of the bleaching chemicals. Many small mills do not recover the liquor.

The recovery of non-wood fibre liquors is problematic due to the high silica content of fibre materials, the rapid increase of the liquor viscosity during evaporation and difficulties in achieving high solids content in the concentrated liquor fed to the recovery system. However, this area of recovery technology is currently receiving much attention with some claims for viable processes.

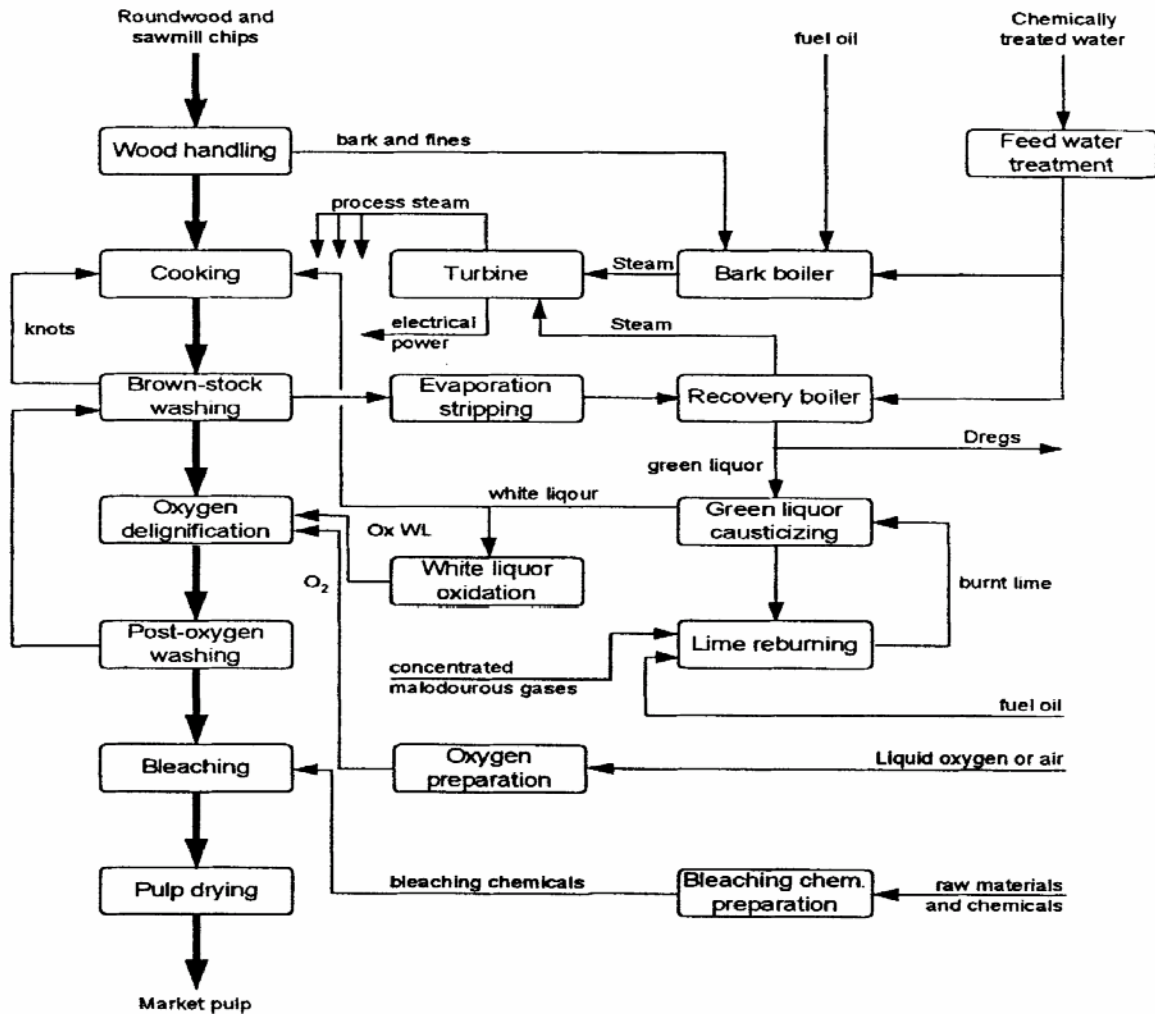


Figure 1. Pulping process flows - kraft pulping example (EIPPCB BREF, 2001)

### 1.2.2.2 Lime and Soda processes

These are processes using simple alkaline cooking liquors in a similar process to kraft pulping but without the use of sulphur compounds. At mills with no chemical recovery, all the dissolved wood substances and pulping/bleaching chemicals remain in the wastewater apart from the volatiles incidentally released to atmosphere. The de-lignification ability is inadequate for low yield, high white, wood pulping. Its application to non-wood pulps is widespread and it is also used with oxygen for straw pulping. In the soda process, the chemistry is simplified as there is no added sulphur to form undesirable by-products and the hydroxide can be recovered by lime causticization of the sodium carbonate smelt. After cooking, pulps that are not to be bleached are refined to separate the fibres.

### 1.2.2.3 Sulphite Pulping Processes

The sulphite pulping process is based on aqueous sulphur dioxide (SO<sub>2</sub>) and a base, calcium, sodium, magnesium or ammonium. This method is losing its importance and only 10% of the world pulp is produced by this method. Alkaline sulphite mills for non-wood fibres are often operated as a batch process and chemical recovery is generally not practised at such mills due to their small size and the complexity of chemical recovery from what is normally a sodium based process. Relatively bright and easily bleached pulps. Easy to bleach without chlorine chemicals.

### 1.2.3 Bleaching

The objective of bleaching is to further remove the small quantity of residual lignin left after cooking. All lignin cannot be removed selectively enough in a single bleaching stage, but pulp is usually bleached in three to five stages, using combinations of oxygen, hydrogen peroxide, ozone, peracetic acid, Caro's acid, sodium hypochlorite, chlorine dioxide, chlorine and other chemicals or treatments. The first two stages primarily release and extract lignin and the subsequent stages remove the lignin residues and finish the product. These bleaching sequences are applied to maximise the bleaching effect of each component. Water is used to perform intermediate washes to remove extracted wastes from the pulp.

Bleaching sequences where chlorine based chemicals are used are called Chlorine Chemical Bleaching (CCB). If molecular chlorine and hypochlorite are excluded, the abbreviation is Chlorine Dioxide Bleaching (CDB), or Elemental Chlorine Free (ECF). If the sequence uses only oxygen based chemicals like oxygen, alkaline or acidic peroxide the term Oxygen Chemical Bleaching (OCB), or Totally Chlorine Free (TCF) can be used.

ECF pulp bleached with chlorine dioxide accounts for the predominant share of roughly two-thirds of the bleached pulp produced worldwide. TCF pulp only accounts for about 6% and is primarily produced in mills in Northern and Central Europe. Roughly 25% of the bleached pulp produced world-wide is still bleached with some elemental chlorine.

Hardwood and straw pulps are easier to bleach by non chlorine methods due to their lower lignin content to begin with and the bleaching effort required for sulphite pulps is less due to higher pre bleach brightness.

#### 1.2.3.1 Bleaching with chlorine and hypochlorous acid

Electrophilic bleaching chemical agents such as chlorine and hypochlorous acid may be used to achieve further delignification after pulping. These electrophilic bleaching agents react with all unsaturated structures, namely lignin structures, polysaccharide degradation products such as hexenuronic acid and extractive structures that contain carbon-carbon



double bonds. These electrophilic bleaching agents are able to react with different unsubstituted aromatic carbon atoms in lignin to either:

a) chlorinate (when the carbon is not bonded with an oxygen atom), b) chlorinate and depolymerize (via displacement of an  $\alpha$ -hydroxyl group), or c) just depolymerize without chlorination (via hydroxylation) .

These chlorination or depolymerization reactions make lignin alkaline soluble and it can be removed from pulp in the alkaline bleaching stages of the bleaching sequence.

The chlorination of non-aromatic structures, such as hexenuronic acid, does not lead to the formation of polychlorinated aromatic degradation products.

Some examples of bleaching sequences when chlorine is used:

CEH (non-woods)  
CEHD  
CEHDED (higher brightness)  
CEDED  
(CD)EDED

With an oxygen de-lignification stage or reinforced extraction stage then:

OCEH (non-woods)  
(D+C)(EO)D (non-woods)

With oxygen de-lignification and reinforced extraction then:

O(D+C)(EO)D (non-woods)  
O-(CD)EDED  
O-(CD)(EO)DED

Bleaching sequence letters :

C is elemental chlorine  $\text{Cl}_2$   
E is alkaline extraction  $\text{NaOH}$   
H is hypochlorite  
D is chlorine dioxide  $\text{ClO}_2$   
(CD) is mixtures of chlorine and chlorine dioxide  
O is oxygen  
(EO) is alkaline extraction with oxygen

### 1.2.3.2 Formation of 2378-TCDD/F

Dioxins and furans (only 2378-TCDD and 2378-TCDF) may be formed in the bleaching process in which chlorine is used. Most of the formation of the 2378-TCDD and 2378-TCDF are generated in the C-stage via the reaction of chlorine with precursors of TCDD namely dibenzo-p-dioxin (DBD) and precursor of TCDF which is unchlorinated dibenzofuran (DBF). When these precursors are chlorinated, the key reaction is

electrophilic aromatic substitution. This type of reaction requires a positive-charged chlorine species and the rate of this reaction will be dependent both on the concentration of the precursor and the concentration of chlorine which is in the electrophilic form. The levels of 2378-TCDD and 2378-TCDF are not determined by the content of the lignin in the pulp /R.M.Berry, B.I.Fleming et. al/ .

The unchlorinated dioxin precursors are prevalent in certain mineral oils which are part of some defoamer formulations used in the pulp and paper industry and are the major source of precursors. Wood itself may be source of dioxin precursor. In particular compression wood contains higher concentrations of precursors than normal wood. Compression of wood also contains higher levels of coumaryl-type lignin which may be a source of DBD- and DBF-like precursors.

### **1.2.3.3 Elimination mechanisms for 2378-TCDD/F**

Preventing formation of 2378-TCDD and 2378-TCDF in the bleaching will be achieved mainly by decreasing the amount of chlorine used in the first bleaching stage. This can be done by reducing atomic chlorine multiple through use of oxygen and peroxide reinforced extraction stage and increased chlorine dioxide substitution. Figure 2. shows how formation 2378-TCDF will be reduced by increasing ClO<sub>2</sub> substitution: when ClO<sub>2</sub> substitution level is more than 85 % 2378-TCDF is not detectable in waste waters coming from the mill.

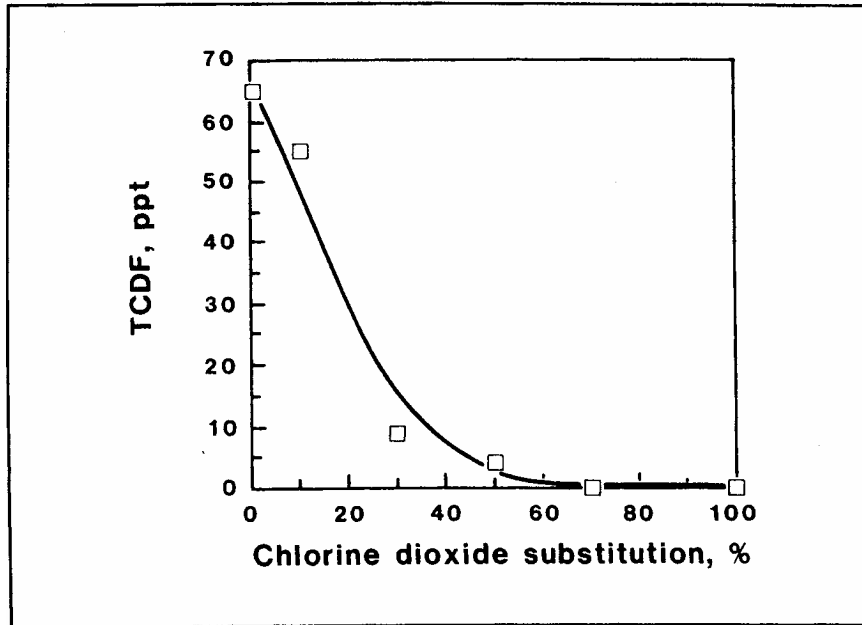


Figure 2. 2378-TCDD formation with different chlorine dioxide substitution level. 2378-TCDD formation will be reduced by increasing ClO<sub>2</sub> substitution.

The summary effect of active chlorine multiple, chlorine dioxide substitution level and precursor concentration can be seen in figure 3. Maximum level of dioxin corresponds to a high chlorine multiple and low ClO<sub>2</sub> substitution. The level of the dioxin is expected to vary depending on the DBD content of the brownstock.

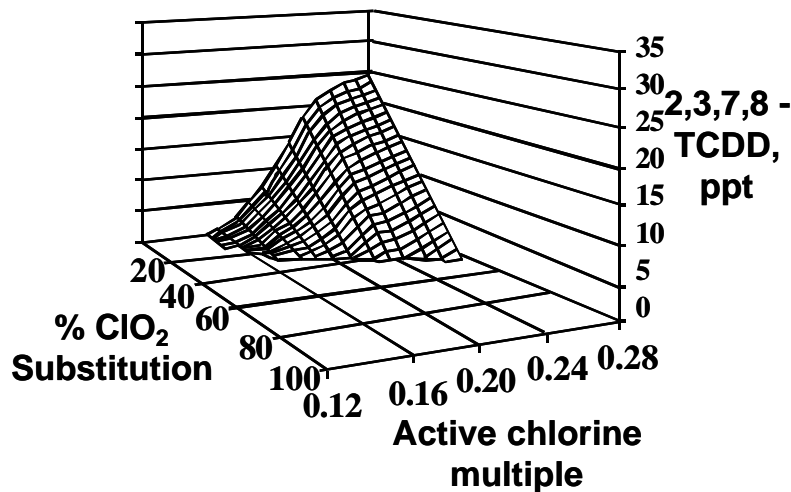


Figure 3. Effect of precursor content, active chlorine multiple and chlorine dioxide substitution level on 2378-TCDD formation.

Chlorine can be completely be replaced by chlorine dioxide (Elemental Chlorine-Free bleaching ECF). In comparison to chlorine bleaching, ECF bleaching using chlorine dioxide leads to the formation of a relatively small amount of chlorinated compounds, but even others do not lead formation of 2378-TCDD/F as the substitution is >85 %.

In most chlorine dioxide manufacturing methods, chlorine is not produced and only such chlorine by-product free generation methods should be used (Mathieson, Solvay, R8/R10 or SVP-lite to be mentioned as an examples).

As a summary, the following measures can be made for decreasing the formation of 2378-TCDD and 2378-TCDF:

- Minimize precursors like DBD and DBF entering the bleach plant by using precursor-free additives and good washing such
- Decrease the chlorine multiple and use more chemicals in the later stages
- Increase the level of chlorine dioxide substitution employed in the chlorination stage or completely replace chlorine with chlorine dioxide (Elemental Chlorine-Free bleaching)

### **1.3 Other sources of UPOS in pulp mills**

*To be taken in to consideration: should this chapter be removed or should the content of this chapter be supplemented with detailed information?*

#### **1.3.1 Releases to water from recycled fibre processing.**

The use of recycled fibre introduces contamination UPOPs contained in the fibre supply. These travel through the process are concentrated in the process sludges if de-inking is applied.

#### **1.3.2 Releases from process sludges.**

There is also the potential for UPOP releases from process sludges such as de-inking sludges and those from process water and final effluent treatment sludges, where UPOPs may be concentrated and which may be applied on land, be incinerated or landfilled.

#### **1.3.3 Releases to air from burning of organic materials in the recovery cycle to generate energy and recover inorganic process chemicals**

With any such combustion process feedstock, attention has to be paid in all cases to good combustion conditions in order to minimise the formation of UPOPs.

### **1.3.4 Releases to air from burning wood and biomass to generate energy**

Coastal pulp and paper mills using saltwater transport modes for logs can generate dioxins and furans which are created through the burning of salt contaminated hogged fuel. The material is then used as boiler fuel to produce heat and electrical energy for the pulp and paper process. Again, with any such combustion process feedstock, attention has to be paid in all cases to good combustion conditions in order to minimise the formation of UPOPs.

### **1.3.5 Releases / Transfer into products (pulp or paper)**

There is also the potential for releases from products themselves (pulp or paper). The final paper products may contain UPOPs and other chlorinated organic contaminants from elemental chlorine bleaching, chemical usage on the papermachine such as chlorinated wet end additives.

## **2 Best Available Techniques (BAT) for production of pulp using elemental chlorine**

### **2.1 Primary measurements**

The principal Best Available Techniques to minimization or elimination of formation of 2378-TCDD/F are as follows and they are independent of the raw material (wood or non-wood) used in the process:

- Utilization of DBD and DBF-free defoamers
- Effective brown stock washing
- Maximize knot removal
- Eliminate pulping of wood chips contaminated with polychlorinated phenol
- Reduce application of molecular chlorine via decreasing chlorine multiple
- Increase substitution of chlorine dioxide for molecular chlorine
- Eliminate molecular chlorine and replace with chlorine dioxide - ECF bleaching (or use totally chlorine free bleaching TCF)

### **2.2 Secondary measurements**

The following general measures are suggested:

- Substitution. The identification and substitution of potentially harmful substances with less harmful alternatives. Use of a detailed inventory of raw materials used, chemical composition, quantities, fate and environmental impact.
- Investment planning/cycles, co-ordination of process improvements to reduce technical bottleneck delays to the introduction of better techniques.
- Training, education and motivation of personnel. Training, education and motivation of staff and operators. People operate pulp and paper mills. Therefore, training of staff can be a very cost-effective way of reducing discharges of harmful substances.
- Process control monitoring and optimisation. To be able to reduce different pollutants simultaneously and to maintain low releases, improved process control is required. Raw materials specification and monitoring of raw materials for precursor materials.
- Adequate maintenance. To maintain the efficiency of the process and the associated abatement techniques at a high level, sufficient maintenance has to be ensured.
- Environmental management system. A system which clearly defines the responsibilities for environmentally relevant aspects in a mill. It raises awareness and includes goals and measures, process and job instructions, check lists and other relevant documentation. Incorporation of environmental issues in process change controls.
- Development of environmental monitoring and standard monitoring protocols.
- Release monitoring for new facilities. Demonstrate performance of combustion processes and releases to water.

### 2.2.1 Upstream and downstream aspects

*To be taken in to consideration: should this chapter be removed or should the content of this chapter be supplemented with detailed information?*

There are also other steps that can be taken both upstream and downstream of the bleaching process **particularly where chlorine bleaching is still practiced.**

Lignin removal in the cooking stage is more advantageous than bleaching both economically and environmentally. The reduction of chlorinated organic substances in the effluents of pulp mills can therefore be achieved to a large extent by in-process measures, such as increased delignification before the bleach plant; by extended or modified cooking, additional oxygen stages and efficient washing to reduce carry over to the bleach plant.

Further contributing factors that will decrease the releases of chlorinated organics other non-chlorinated toxic organic compounds into receiving waters, are the installation of end of pipe abatement measures such as effective external treatment plants of different designs.

In some parts of the world the trend within the industry is toward increased closure of the bleach plants either by using ECF (Elemental Chlorine Free) or TCF (Totally Chlorine Free) bleaching of pulps, and the increased reuse of treated process waters by implementing production-integrated advanced wastewater treatment systems.

Further steps are, therefore:

- Promote the degree of delignification in cooking processes via:
  - Use of cooking catalysts;
  - Extended (modified) cooking, Kraft;
  - Extended cooking, Sulphite;
  - Hot alkali extraction;
- Continue the delignification process using oxygen techniques;
- Use pre treatments to enhance bleaching effects, where applicable:
  - Enzyme pretreatment;
- Use chlorine dioxide generation methods with low by-product chlorine;
- Reduce use of chlorine compounds by the introduction of oxygen chemical bleaching;
- Use effective primary and biological effluent treatment;
- Control sludge disposal;
- Control combustion processes.

### 3 Performance standards

The following table summarises this information as it is applied to bleached kraft pulp mills:

New Plant	2378-TCDD / 2378-TCDF ppq To Water	2378-TCDD / 2378-TCDF ng/kg To Sludge	PCDD / PCDF ng/m <sup>3</sup> <sub>STP</sub> TEQ To Air	Defoamers DBD and DBF ppb
EU			0.1	
Canada - Federal	Non-measurable <sup>1</sup> – In treated final effluent		0.1	DBD <10 DBF <40
USA Kraft and Soda	2378-TCDD <10 2378-TCDF 31.9 - In bleach plant effluent	10 / 100		
USA Ammonium based and speciality	2378-TCDD <10 2378-TCDF <10			

sulphite				
Australia	2378-TCDD <15 2378-TCDF none – In treated final effluent			

1. Non measurable - means a concentration less than the level of quantification as defined in the Reference Method. The current level of quantification is 15 ppq.

#### 4 Performance Reporting

Performance reporting is recommended as follows:

For dioxin and furan releases to water – a monthly testing period. A mill may adopt quarterly sampling if it has had no measurable concentrations in its last three consecutive monthly samples, a mill may adopt annual sampling if it has had no measurable concentrations in its last three consecutive quarterly samples. The testing period reverts back to monthly testing if either a quarterly test or an annual test detects dioxins or furans.

Treatment sludges used for agricultural benefit may also need to be tested before use.

Where emissions testing is not possible (e.g., analytical capacity is not readily available), the use of PCDD/PCDF release factors associated with a similar mill type and operation is suggested as an interim performance reporting requirement until such time as annual emissions testing and analysis is available. Emission factors for releases of PCDD/PCDFs from mills are presented at page 184 in the UNEP Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases, May 2003 (URL:[www.pops.int](http://www.pops.int)).

The commonality of this issue across all sector guides would indicate that it needs to be covered as a separate report and draw on the information on performance levels and testing methods contained in each of the individual sector guides.



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## DEFINITIONS

ADt & ODt	Air dried tonne of paper (paper contains around 7% water under ambient conditions). ODt oven dried.
AOX	Adsorbable Organic Halogen
APP	Alkaline peroxide process
BAT	Best Available Techniques
Bleaching Sequence letters :	
C	is elemental chlorine $\text{Cl}_2$
E	is alkaline extraction NaOH
H	is hypochlorite
D	is chlorine dioxide $\text{ClO}_2$
(CD)	is mixtures of chlorine and chlorine dioxide
O	is oxygen
(EO)	is alkaline extraction with oxygen
P	is hydrogen peroxide
(EOP)	is alkaline extraction with oxygen and hydrogen peroxide
aP	is hydrogen peroxide in acidic conditions
(PO)	is peroxide pressurised with oxygen
(DN)	is chlorine dioxide with subsequent neutralisation
Z	is ozone
Paa	is peracetic acid
Ca	is Caro's acid (sulphuric acid and hydrogen peroxide)
Pxa	is mixed peracids
Q	is chelation stage
X	is enzyme treatment
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CTMP	Chemi-thermo-mechanical-pulping processes (using sulphite or APP)
DAF	Dissolved air flotation
DBD	Dibenzodioxin
DBF	Dibenzofuran
DTPA	Diethylene triamino pentaacetic acid
ECF	Elemental chlorine free (pulp bleached without elemental chlorine)
EDTA	Ethylene diamine tetra-acetic acid
EMS	Environmental Management System
Kappa No	The Kappa number is an indirect measure of the residual lignin content in a pulp measured via the consumption of an oxidant chemical (e.g. potassium permanganate). Measure used for process control.
Integrated-mill	A mill in which both pulping and papermaking take place
I-TEQ	International Toxicity Equivalents or TEQ (Toxic Equivalents)
I-TEF	International Toxicity Equivalency Factor or TEF (Toxicity Equivalence Factor)
NTA	Nitrilo triacetic acid
PAE	Polyamidoamine-epichlorhydrin resins
PAM	Polyacrylamides
PCDDs	Polychlorinated dibenzo-para-dioxins
PCDFs	Polychlorinated dibenzofurans

PCP	Pentachlorophenol
PCB	Polychlorinated biphenyls
PEI	Polyethyleneimines
RCF	Recycled fibre
TCDD	2,3,7,8 –tetrachloro-para-dibenzodioxin
TCDF	2,3,7,8 – tetrachloro dibenzofuran
TCF	Totally chlorine free (pulp bleached without any chlorine compounds)
TOC	Total Organic Carbon
Wood-free	Paper made from pulp from which the lignin has been largely dissolved by chemical mean

