

Environment Canada

**A SUMMARY REPORT ON PULP AND PAPER INDUSTRY
AIR EMISSIONS**

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A summary report on pulp and
paper industry air emissions.

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SUMMARY REPORT ON PULP AND PAPER INDUSTRY AIR EMISSIONS

1 - INTRODUCTION

Purpose

The purpose of this report is to give the reader a good understanding of the issues and control options relating to air emissions from the pulp and paper industry. The report identifies emission concerns and sources, compares emissions from the pulp and paper industry with other sources, outlines approaches to control options, presents order of magnitude costs, and describes the regulatory approach used elsewhere. Emission amounts emitted by the industry are compared both in relation those of the other sectors and national totals.

In order to describe the potential for technology to reduce emissions, the mill departments or process units responsible for these main sources are discussed in turn. The actions that are frequently taken or potentially might be considered and their effect on emissions are outlined along with mention of the barriers frequently encountered and some remarks on the permitting situations encountered in different jurisdictions.

This report draws on a study Simons undertook for Environment Canada and the British Columbia Ministry of Environment, Lands and Parks entitled "A Technical Background Information Document on Pulp and Paper Air Emissions" (October 1994). These reports are intended to support the development of any air pollution control initiative that are determined to be necessary.

The Importance of the Pulp and Paper Industry

The pulp and paper industry is very important to the economy of Canada and particularly to its exports. In 1993, the Canadian pulp and paper industry shipped a total of 26,200,000 t of all grades of pulp and paper. Of this, 21,600,000 t valued at 13.9 B\$ were sold outside the country. In terms of contribution to net exports, the pulp and paper industry provides 12.3 B\$ (as there are imports of 1.6 B\$), which compares with 10.1 B\$ from lumber and other forest products, 9.0 B\$ from energy, 7.6 B\$ from the autos, trucks and parts, and 1.6 B\$ from fisheries. Last year (1994) exports rose to 23,940,000 t and made a net contribution to the country's balance of trade of 14.2 B\$.

The number of pulp mill sites and their production in Canada by major process category and their production is:

Pulp Type	No of Locations	1994 Production (kt/a)	(%)
kraft ^a	46	12 411	44.6
Sulphite and semi-chemical ^a	21	1265	4.5
Mechanical - refiner(TMP, CTMP)	13	8281	29.7
Mechanical - stone groundwood	74	2697	9.7
Recycle ^b	61	3206	11.5
Totals	215	27 860	100

NOTES:

a - Bleached, semi-bleached and unbleached.

b - 24 of these mill locations use post consumer waste. The balance of the locations use recyclable paper purchased transferred from another plant.

The number of locations shown in the table above indicates a mill site where an intermediate or final product is manufactured, not the number of production lines or machines in that service at a particular location.

Market pulp or pulp sold to paper makers and others is dominated by bleached kraft, two thirds of which is exported, 42% to the US, 58 % to Europe, Asia and elsewhere. Sulphite and mechanical pulp exports are much less at 23% and 13% of production, with destinations of 52% and 21% to the US, and 48 % and 79% to Europe, Asia and elsewhere for each pulp respectively.

Use of recycled paper occurs within mills and between many elements of the industry and the community at large as well as imports/exports. In 1993, the last year for which statistics are available, the industry consumed 3527 kt of recyclable paper, contributing an estimated 3200 kt to the total pulp production.

The pulp not exported is made into paper and board products to meet domestic and export markets. There are paper and paperboard manufacturing facilities at 129 locations in Canada. The production by type of output is:

Paper Type	1994 Production (kt/a)	(%)
News	9312	51
Printing and Writing	4445	24
Tissue and Special	580	3.2
Containerboard, boxboard, kraft packaging	3984	21.8
Totals	18,321	100

2 - AIR EMISSIONS OF CONCERNS AND THEIR SOURCES

There are two general categories of emissions important on a national level and emitted by the pulp and paper industry in particular.

The first category are emitted at levels of thousands of tonnes per year in Canada, have health and environmental effects that are generally well understood, and for which national and provincial ambient air quality objectives have been established for most. This group of common emissions comprises CO, H₂S, NO_x, O₃, particulate, SO₂, and VOC. These happen to be the same 5 Criteria Pollutants regulated by the USEPA, one other being lead. Though emitted in much smaller quantities, Cl₂, ClO₂, are often included in this group.

The second category, which we term Trace Air Contaminants (TAC) in this report, is closely related to the group of Hazardous Air Pollutants (HAP) defined by the USEPA. TAC are emitted in much smaller quantities than the first category, are generally more localized in their impact, and for which relatively incomplete data relating to health and environmental effects is available. TAC and HAP have only recently been receiving attention as a regulatory issue.

The emissions, their source, basic concerns and requirements are presented in table 1.

Table 1 - Emission Sources and Concerns

Type	Sources	Concerns and Requirements
CO Carbon Monoxide	Combustion with poor furnace mixing and excess air control.	Loss of combustion efficiency. Ambient Air Quality objective.
Cl₂ Chlorine	Bleaching with chlorine and chlorine based bleaching chemicals.	Chlorine and resulting chlorinated organics. Provincial Labour Code workplace objectives. Listed in NPRI by Environment Canada (see TAC below). Listed as HAP by USEPA (see TAC below)
ClO₂ Chlorine Dioxide	Bleaching with chlorine based bleaching chemicals.	Chlorine dioxide and resulting chlorinated organics. Provincial Labour Code workplace objectives. Listed in NPRI by Environment Canada (see TAC below).
HAP Hazardous Air Pollutant	see TAC below.	see TAC below.

Table 1 - Emission Sources and Concerns

Type	Sources	Concerns and Requirements
NO_x Nitrogen Oxides	Combustion with significant bound nitrogen in the fuel or high flame temperatures.	Acid rain. Along with VOC, precursor of smog and low level ozone. Ambient Air Quality objective.
O₃ Ozone	Bleaching with ozone bleaching chemical. Product of atmospheric reaction between NO _x and VOC in sunlight.	Lung function impairment and vegetation damage. Ambient Air Quality (AAQ) objective. Current consideration by the USEPA to lower current AAQ objective.
PM, PM₁₀, PM_{2.5} Particulate material; smaller than 10, 2.5 microns	Combustion. Materials handling. Unpaved roads. Product of atmospheric reactions.	Respiratory health effects due to fine particulate deposition deep in the lungs. Ambient Air Quality (AAQ) objective. Current consideration by the USEPA to lower current AAQ objective.
SO_x, SO₂ Sulphur oxides (SO ₂ + SO ₃) and Sulphur Dioxide	Combustion of sulphur-containing material such as pulping liquor (kraft and sulphite), kraft pulping non-condensable gas, heavy fuel oil, and coal. Directly emitted by sulphite mills. Natural processes such as volcanoes.	Acid rain. Disagreeable odour. Ambient Air Quality (AAQ) objective. Current consideration by the USEPA to further restrict the AAQ objective to 0.6 ppm during a 5 min. period.
TRS Total Reduced Sulphur	Combustion and non-combustion processes involving kraft pulping liquor and condensates.	Highly disagreeable odour and negative public reaction to TRS which comprise H ₂ S, methyl mercaptan, and dimethyl sulphides. Ambient Air Quality H ₂ S objective.
TAC Trace Air Contaminants,	Combustion and non-combustion resulting from the reactions between the input wood, and bleaching and other chemicals. Natural processes such as forest fires, volcanoes.	Health effects of the 178 substances listed in the Canadian National Pollutant Release Inventory and the 632 chemicals in the USEPA's Hazardous Air Pollutant (HAP) list, which include heavy metals, acetone, ammonia, chlorine, chloroform, formaldehyde, hydrochloric acid, and methanol.
VOC Volatile Organic Compounds	Combustion and non-combustion processes involving kraft pulping liquor and condensates. Natural processes such as forests, marshes, natural gas wells.	Along with NO _x , precursor of smog and low level ozone.

3 - AIR EMISSION QUANTITIES

In 1990, the Canadian Council of Ministers of the Environment (CCME) developed a national management plan for NO_x and VOC, supported by an inventory of source contributions based on estimates of anthropogenic (man made) and natural sources. Subsequently, the Canadian Pulp and Paper Association funded work by Stanley to provide totals of the contribution of the various sources in the pulp and paper industry to provincial and national totals. Based on the 1985 Environment Canada national totals then available for NO_x , VOC, one conclusion was that nationally the industry contributes about 3% of the man-made sources of NO_x and VOC which, in the case of VOC, becomes 1% if natural sources are included.

More recently, The CCME has directed Environment Canada to compile emission estimates prepared by Provincial governments for CO, PM, SO_2 and TRS for the year 1990 by standard industrial code. The preliminary estimates of CO, PM, SO_2 emissions based on the first release data have been used to determine the relative importance of pulp, paper and paperboard emissions in relation to the total for all of industry and the total by province and the total for Canada. The collection of TRS data has not commenced as of the time of this writing. Because of the small number of sources in some provinces, these are grouped as a Maritime (NF, PE, NS and NB) and Prairie (MB, SK, AB) regions.

For NO_x and VOC emissions only, the Stanley estimates of pulp and paper industry emissions have been used because they have been built up from questionnaire information obtained directly from mills and are believed more accurate than the Environment Canada data which differ. The Environment Canada estimates have been used for the balance of industry and other sectors. These preliminary estimates for all emission types in 1990 are presented in Table 2.

Table 2 - Relative Importance of Pulp and Paper Emissions

	B.C.	Prairies	Ontario	Quebec	Maritimes	Canada
CO						
tonnes/a	54,151	2885	6676	13,731	6648	84,901
% of Industry ^a	9.8	2.9	1.0	4.8	6.3	4.9
% of total ^b	4.3	0.12	0.20	0.66	0.77	0.84
NO_x						
tonnes/a	15,317	4607	9642	14,565	6910	51,041
% of Industry	22.9	2.4	6.7	34.2	28.1	10.9
% of total	7.4	0.7	1.5	4.9	3.7	2.5
PM						
tonnes/a	47,550	8626	9936	21,738	9632	97,482
% of Industry	42.1	4.4	4.3	15.1	6.8	11.8
% of total	31.2	2.7	3.2	9.2	5.3	7.7

Table 2 - Relative Importance of Pulp and Paper Emissions

	B.C.	Prairies	Ontario	Quebec	Maritimes	Canada
SO₂						
tonnes/a	28,779	6823	9034	41,947	35,068	121,651
% of Industry	39.5	0.7	1.0	12.6	35.6	5.2
% of total	28.6	0.6	0.8	10.6	8.1	3.8
VOC						
tonnes/a	17,608	5470	7807	11,605	6925	49,416
% of Industry	19.0	1.1	5.3	26.2	45.7	6.3
% of total	8.5	0.6	0.9	3.0	3.9	1.9

Notes:

a - Pulp and paper emissions as a percentage of the total industry sector emissions in the Province /Canada.

b - Pulp and paper emissions as percentage of total man made Provincial/National emissions, ie: total of all industry, commercial, residential and transportation sources, but excluding natural sources.

These estimates range from lows of 0.84% for CO and 1.9% for VOC to a high of 7.7% for particulate matter, with NO_x and SO₂ in between at 2.5% and 3.8% of the national total. Thus pulp and paper contributions are relatively small and confirm the earlier work by Stanley based on the 1985 estimates. Also given that the location of most of the mills is remote from major centres of population, these emissions assume even less importance to humans, though on a local basis, poor air quality and human health effects may be of concern.

Provincially, the emissions from pulp and paper in B.C, the Maritimes and Quebec are significantly more important than Ontario and the Western provinces reflecting the structure of their industrial sectors.

Other conclusions from the Stanley report are worth mention. The CCME identified "regions of concern" in their Management Plan for NO_x and VOC as: the south atlantic region (SAR) around the bay of Fundy; the Windsor-Quebec corridor (WQC); and the Lower Fraser Valley (LFV) from the Greater Vancouver Regional District east to Chilliwack. Several of these conclusions were:

- though 52 mills or about 40% of the Canadian mills are located in the "regions of concern", their emissions, at only 11 - 12% of the industry national total, is proportionately even smaller because of the types of mills located in urban and more built up areas of the country.
- in the LFV and WQC the pulp and paper contribution is only 1% of the total regional emissions.
- in the SAR, The pulp and paper contribution is only 4 and 6% of the total regional NO_x and VOC emissions.

4 - MEASURES FOR CONTROLLING AIR EMISSIONS

Background

Advances have been made in pulp and paper production processes and equipment progressively over time. These advances eventually give rise to technological obsolescences within the stock of existing mills which may take the form of shortcomings in equipment, layout, process or design. The shortcomings may be excessive manpower requirements, small and hence uneconomic scale of operation, quality problems, uncompetitive operating cost or environmental deficiencies. These variances from new mills become more marked as the years progress.

Possible remedies may range from a relatively minor modification or addition to a situation where major groups of equipment or departments/plants require complete replacement because of a major constraint. Such major constraints may be an inherent capacity limitation of the mill, physical space restriction or mill site location.

This section describes the measures available to the principal sources of emissions in the pulp and paper industry for existing and new or planned mills assuming a major constraint is not present.

The present stock of mills in Canada consist of a variety of types of facilities of differing ages. While a few of them are of the latest design using the most advanced industrially proven emission control technology with emission levels among the lowest anywhere, the majority of the mills are at least several decades old.

(TABLE FROM G. DAS on the type and age of Canadian mills [Industry Canada ?])

In the U.S., regulators and industry are addressing the issue of hazardous air emissions under Title III of the 1990 Amendments of the Clean Air Act. The USEPA is defining the magnitude of the emissions and searching for control approaches from the pulping and bleaching areas. On December 17 1993, the EPA issued draft maximum achievable control technology (MACT) based standards for the control of the 50 or so EPA defined HAP found in pulping and bleaching operations. Promulgation requiring control of both new and existing hazardous air pollutants (HAP) from these sources is scheduled by late 1995 or 1996. At the time of writing, the American Forest and Paper Association and the USEPA are attempting to resolve differences between their estimates that indicate industry costs may be much higher than the USEPA suggest. The USEPA is planning the release of draft MACT based standards for recovery, recausticizing and kiln areas in the spring of 1995. Those for industrial boilers, paper making and paper coating operations will be released later, with emission standards due to come into effect by November 2000.

The following sections are organized sequentially by mill area from woodroom through final pulp, then chemical recovery, steam generation and effluent treatment. The most common control measures for the conventional emission parameters are mentioned first, followed by methods applicable to existing older mills, and newer control methods found in the latest designs. Finally, TAC and HAP emissions and possible control approaches are mentioned.

Add-on or in process control devices that are invariably part of the process are given mention only as there are no application opportunities. Examples are bleach plant scrubbers, or chlorine dioxide plant tail gas scrubbers for chlorine and chlorine dioxide removal.

Basis of Cost Estimates

Cost information has been prepared using information contained in the Simons report "A Technical Background Information Document on Pulp and Paper Air Emissions" of October 1994 which itself is based on literature sources and recent in-house information.

The cost estimates are presented to allow very preliminary comparison of costs of emission control options and are illustrative of the order of magnitude of total installed costs that can be expected in Canada in early 1994. In any formal screening of control alternatives, estimates based on preliminary engineering of the facility or system are required. This would comprise: preparation of technical specifications and comparisons of bid information supplied by equipment vendors; estimates of civil/structural, mechanical, electrical and process control systems and indirect costs for such as construction management, engineering, owners site costs and contractors overhead. Accordingly, there may be substantial differences between the costs presented here and the costs for a particular installation as estimated during definition engineering.

When more than one pollutant is controlled, attribution of the cost of removal must be established. In this report, the costs for control measures is attributed to the pollutant most commonly associated with the measure. In the evaluation of an actual mill NCG system, for instance, the cost for the measure to extent currently practiced for TRS control is attributed to TRS, and the costs for extension of the measure to control HAP/TAC would be attributed to HAP/TAC.

Wood Handling and Storage

Particulate emissions from this source originate from chip handling and mobile equipment movements. Besides the use of belt instead of pneumatic conveyors which diminish dust generation, and good engineering practice in design, such as enclosing conveyor galleries, no control is currently practical, given the large area involved.

VOC emission data suggest the source is significant, but emission factors have not been developed. Means for VOC capture and treatment presents practical problems and are probably not cost effective.

Chemical Pulping - Kraft

The process of cooking wood chips under pressure with white liquor in a batch or continuous digester, deknottling and washing the resulting brown stock results in the evolution of gaseous emissions containing TRS, VOC strong and weak odour. The TRS containing emissions are released from the black liquor (spent cooking liquor) consisting of solubilized lignin, hydrolysis salts, and sulphonation products, and contain primarily dimethyl sulphide and dimethyl disulphide with high odour potential. The main volatile organic compounds consist

of methanol, ethanol, and acetone.

Long established in the kraft industry is the practice of collecting the strongest TRS sources and burning them in the lime kiln or the power boiler. Today, new mill designs include collection of weaker sources as well and provide for alternative incineration disposal points.

The NCG collection and disposal methods are summarized in Table 3a.

Table 3a - Fibreline and Miscellaneous Emission Control Measures

Concentrated NCG System	Dilute NCG System
Description:	
Collection of concentrated (low vol / high conc.) non-condensable gas, white liquor scrubbing, and disposal in kiln, power boiler, or dedicated incinerator. Sources collected:	Collection of dilute (high vol./low conc.) non-condensable gas and disposal in one of the boilers. Sources collected include:
<ul style="list-style-type: none"> • digester flash and turpentine condenser • evaporator hot well • stripper overheads, from the condensate stripper^a 	<ul style="list-style-type: none"> • chip bin and feeder vent • brown stock washer hoods, filtrate tanks • tanks in the screening, brown stock and evaporator areas
Applicability and Prevalence:	
Canada: Universal in new mills, believed retrofitted to most existing mills. USA: 92% Nordic: 97%	Common in newer mills.
Benefits:	
Reduction of strongest TRS odour sources, as well as high proportion of TAC/HAP and VOC. The sulphur reduction from stripper overheads is considered under Effluent Treatment section with steam stripping technology	Further reduction of odour as well as TAC/HAP and VOC.
Potential Emission Reduction	
TRS: 0.4 - 2 kg/ADt as H ₂ S.	TRS: 0.1 - 0.2 kg/ADt as H ₂ S.
Barriers	
Operating problems on kilns. As TRS in the power boiler and kiln converted to SO ₂ , high SO ₂ may require a scrubber.	High cost of routing large diameter collection pipes in existing facilities.
Notes:	
a - The capital and operating cost of the condensate stripper and its TRS contribution affects air emissions from the effluent treatment system, and is accordingly presented in that subsection.	

The order of magnitude estimates of cost corresponding to these measures are presented in Table 3b. The cost of operating the CNCG system benefits from the fuel value of the material, particularly methanol, recovered and burned. However, since most of the methanol is obtained from the stripper, this credit is applied to the steam stripping of condensates presented under the section Effluent Treatment System.

Table 3b - Fibreline and Miscellaneous Source Emission Control Costs^a

Concentrated NCG System		Dilute NCG System	
Existing older mill	New greenfield mill	Existing older mill	New greenfield mill
Capital Costs, in M\$			
1.5 - 3	1.5 - 4	3 - 12	7 - 12
Annualized Capital Cost in k\$/a			
240 - 480	240 - 640	480 - 1900	1100 - 1900
Operating Cost in k\$/a			
60 - 140	(50) - 110	280 - 1000	660 - 1100
Annualized total cost of Control Measure in k\$/a			
260 - 620	260 - 750	760 - 3000	1700 - 3000
Annualized total cost of Control Measure, \$/ADt production			
0.90 - 3.10	0.50 - 1.80	4.40 - 11.00	3.80 - 6.20
Pollutant Removal Costs, \$ per tonne TRS as H₂S			
230 - 1600	130 - 900	22,000 - 100,000	19,000 - 60,000

Notes: a - The Order of Magnitude costs. See section Basis of Cost Estimates for details.

A white liquor scrubber included with the CNCG system removes approximately 50% of the S and returns it to the cooking liquor. This operates continuously, and significantly reduces emissions during incinerator system outage.

A standby flare is sometimes used, particularly in Europe, but is relatively ineffective in converting TRS to SO₂, so that odour reduction is diminished.

For additional sulphur removal from these sources alkaline scrubbing is sometimes added if incineration is by stand alone incinerator. The large volumes involved when scrubbing power boiler flue gas is a disincentive to burning NCG in power boilers.

In existing U.S. and Nordic mills, surveys show that most of the concentrated NCG collected is burned in the lime kiln (≈50%). In the U.S., incineration in the power boiler (≈20%) is next most common practice, then stand alone incinerator (≈9 - 12%), with disposal in the recovery boiler much less prevalent (≈4 - 6%). In the Nordic countries, the stand alone incinerator approach is much more common (≈43%), where three quarters of them have SO₂ scrubbers reflecting the importance of the acid rain issue there. A stand alone incinerator would increase capital cost by 1.8 - 4 M\$ and requires fossil fuel. The heat released is normally not recovered. Reasons for a stand alone incinerator are the lack of sufficient NCG burning capacity, unacceptable availability of boilers and kilns or the need to scrub SO₂ which is more economically achieved in stand alone incinerators.

The USEPA analysis supporting the draft MACT standards proposes control of pulping vents by collection and combustion of the HAP, VOC and TRS. Essentially, these control measures

call for extension of the NCG system to cover more sources. Data is presented of the HAP emissions and their reduction. For a representative mill, these are 0.43, 3.1 and 1.5 kg/Adt for HAP, VOC and TRS. EPA removal rates given are 98% for all three, and costs of removal for existing mills presented: 820 US\$/t for TRS (in line with those presented above for concentrated NCG control measure), 400 US\$/t for VOC and 2900 US\$/t for HAP, though these estimates are under review by the American Forest and Paper Association.

Pulping and Recovery - Sulphite

The sulphite process is older than either the kraft or the NSSC processes. Most sulphite mills were built to provide pulp for newsprint manufacturing. For this reason, most of the mills are old and small and have limited emission control equipment unless retrofitted. With one exception, the sulphite mills in Canada are part of newsprint-producing facilities and are located in eastern Canada. Of the 21 sulphite and semi-chemical mills in Canada, only four have recovery boilers, one a fluid bed furnace. Those having furnaces are located at: Port Hawkesbury, NS, (sodium base); Temiscaming, QC, and Port Alice, B.C. (ammonia base); and Edmonston, NB, (magnesium base). The sodium base process at Cabano, QC has a fluid bed (Copeland) unit.

Blowing the batch digester at the end of the cook is a major source of SO₂ emissions. The gases are scrubbed to recover SO₂. The amount of SO₂ released depends on the method of discharge used.

Other main points of SO₂ emissions in the pulping area are the SO₂ absorption tower where cooking acid is prepared and the washers. Malodorous compounds like methyl mercaptan and dimethyl sulphide are absent from the gaseous emissions because no Na₂S is present in the pulping liquor.

The liquor in sulphite mills also contain terpenes, methanol, as well as the furfural generated by a sulphite cook. These compounds would be emitted as VOC/HAP at various points in the process. Sulphite pulp mill emissions with their relatively small importance nationally and the uniqueness of each mill makes presentation of generic control strategies and costs inappropriate.

The USEPA has published HAP/VOC emission data on methanol, acetone, methyl ethyl ketone, acrolein and formaldehyde levels for sulphite and semi-chemical pulp mills along with kraft in their December 17, 1993 background information report describing MACT based standards. Control measures call for a scrubbing system to cover these sulphite sources.

Pulping - Mechanical

In the TMP and CTMP process, VOC material mainly in the form of terpenes and ethanol is carried off in the steam from the refiners. At about two thirds of these mills in Canada, which include the older ones installed in the 1970's, all the steam from the refiners is vented to atmosphere after use in chip pre-steaming, taking with it the VOC. This steam contains relatively large amounts of VOC, estimated at 1 and 1.3 kg as CH₄/ADt for hardwood and softwood respectively.

The remaining one third of the mills, including most of the newer ones have a heat recovery system which recover the heat in the steam for use in water heating or as clean steam for the paper machine. This results in the condensation of perhaps 75% of the VOC, and hence serves a secondary purpose as an air emission control measure. This reduced air emissions to the order of 0.25 - 0.35 kg as CH₄/ADt for hardwood and softwood respectively. Part of the condensate is used for chip washing, but eventually all of it ends up in the sewer system and the effluent treatment plant. With an aerated basin, a small proportion of the VOCs would be stripped by the aeration process and become an area emission source. The balance would be consumed by microbial activity in the aeration basin and be emitted as CO₂. No TRS would be expected to be emitted unless generated in anaerobic sections of the aeration basin from the small amount of sulphur in the wood and pulping chemical additions.

The VOC emissions could be addressed by steam stripping the process condensates and incinerating the overheads in the mill boiler if of adequate capacity or in a stand alone incinerator. Capital cost might be of the order of 10 M\$ for the stripper and the heat recovery reboiler. It is not believed that this measure is being undertaken anywhere at the present time.

The USEPA is planning to examine the need for HAP emission standards for mechanical pulp mills, with promulgation planned for no later than 15 Nov, 1997.

Significant gaps exist in published information on the chemical species (including sodium sulphite used in CTMP pulping), emission factors of sources in the mechanical pulping process, the effect of heat recovery and fate in the effluent treatment system.

Bleaching

The most common bleaching and brightening agents are chlorine, chlorine dioxide, hydrogen peroxide, oxygen, caustic (sodium hydroxide), sodium hypochlorite, and more recently ozone. Concern over chlorinated compounds such as dioxins, furans, and chloroform in the bleach plant effluent particularly have prompted the pulp and paper industry to shift away from the application of chlorine and hypochlorite and toward increased use of the other bleaching chemicals, in particular chlorine dioxide and ozone.

The main points of gaseous emissions from the bleaching stages are the tower vents, the washer hoods, the seal tank vents, and miscellaneous equipment such as some medium consistency pump vents. During chlorine and chlorine dioxide bleaching, recent measurements confirm that side reactions in the bleaching process produce HAPs: chloroform, phenol, methanol, chlorinated phenolics, among others. These byproduct emissions, as well as unreacted chlorine and chlorine dioxide end up in vents and bleach plant effluent.

Only stages where chlorine or chlorine dioxide is added are normally scrubbed. This practice is almost universal due to the requirements for workplace safety, and are generally subject to permitting as well. Bleach plant wastewaters go directly to effluent treatment, though the extraction stage filtrate may be used for thawing in the woodroom.

Current best source control technology from these sources is the collection and scrubbing of

the combined flow in an external scrubber. Because of the different chemical reactive properties, scrubbing may take place in several stages. A number of successful scrubber technologies are in use with a variety of scrubbing media, such as, weak wash, white liquor, chilled water, weak caustic, SO_2 and sodium hydrosulphite. In the case of chilled water, caustic or white liquor scrubbing, chemical may be recovered, otherwise spent scrubbing medium is sewerred. Removal efficiencies in excess of 95% have been shown for Cl_2 and ClO_2 . Emission rates will reflect differing scrubbing performance, bleach plant sequences, washer types (air flows are larger for vacuum washers than presses) and bleach chemical application rates.

The USEPA draft MACT control rules are aimed at reduction of chlorinated compound emissions, and provide for 99% reduction of chlorine and methanol and 70% reduction of HAPs overall. Control is proposed for the chlorination, extraction, hypochlorite, and chlorine dioxide and any ozone and peroxide stages. USEPA MACT control technology proposed is caustic scrubbing, though there are reservations on its efficacy in practice.

The pulp and paper industry research group, the National Council of Air and Stream Improvement (NCASI) for the Pulp and Paper Industry have undertaken a major emission sampling efforts to develop better technical information for use in the MACT rule making activity. The results of this sampling at 9 bleached and 4 unbleached kraft, 2 sulphite and 1 semi-chemical pulp mills have been published in a series of NCASI Bulletins. Still, some gaps exist: HAP emissions from ozone bleaching have not been measured, as there is only one full-scale ozone bleaching line operating in the United States. Neither are HAP emission data available from the Scandinavian operations. Emissions from the peroxide stage have not been measured.

Chemical Recovery - Kraft

The recovery boiler burns the black liquor washed from the brown stock after evaporation to firing concentration. Its main function is to permit the recovery of chemicals, recovery of the fuel value of the organic material in the liquor in the form of steam. It is one of the most costly pieces of equipment in a mill and is often the bottleneck to mill production capacity increases. Whether an older or newer mill, the recovery boiler stack is the major source of CO , SO_2 and sulphur and a significant source of NO_x , PM, TRS and VOC air emissions in a kraft mill.

The direct contact evaporator (DCE) chemical recovery boilers was the technology used from the 1930s when originally introduced to the 1970s. By today's standards, the units were small, had generous design capacity margins, and rudimentary combustion air systems. They were the main source of odour in kraft mills due largely to the contact between the flue gas and the black liquor in the DCE. However, the inherent staged combustion of the recovery furnace then and now resulted in low NO_x . The odour problem was by the 1980s partially abated by introduction of black liquor oxidation (BLOX), which reduced H_2S pickup in the DCE. Reductions from 50 - 80 ppm_{dv} to 12 - 25 ppm_{dv} are possible, though these are four or more times current best practice. BLOX is believed to be part of virtually all operating DCE kraft recovery systems in Canada.

In the 1970s, evaporator technology advances permitted evaporation of black liquor in concentrators to 65% which eliminated the DCE, reducing air emissions while increasing boiler efficiency. Low odour conversions have been carried out at a number of older DCE equipped recovery boilers.

In the last 15 years, maximum capacity has doubled, and emissions have decreased markedly by innovations of 3 and even 4 level combustion air introduction, automatic port rodding, improved recovery combustion and process control, and higher black liquor solids firing concentrations. More recent developments have been in the area of firing liquor of still higher solids of up to 85% and above, four levels of air for NO_x reduction and designs that are tolerant of the chemical changes resulting from increased effluent recycle.

Industrial scale research is progressing rapidly on black liquor gasification with the aim of increasing thermal efficiency, and replacing the recovery boiler entirely. Proven commercial operation, however, is still several years away.

Measures available today for most existing mill are summarized in Table 4a.

Table 4a- Recovery Boiler TRS and PM Emission Control Measures

Air System Upgrade	Low Odour Conversion and High Solids Firing	Electrostatic Precipitator Upgrade
Description:		
Installation of a three or four level air system, large ports, variable area dampers, automatic port rodding, stationary firing, bed cameras, and upgraded combustion controls.	Removal of DCE, addition of a black liquor concentrator to increase DS to 72% or more, recover more heat and upgrade the electrostatic precipitator to handle higher flow volume and meet current PM limit.	<u>Existing Mills:</u> Installation of a rigid electrode, three field, modern, two chamber. <u>New Mills:</u> Increased removal efficiency by increasing collection area.
Applicability and Prevalence:		
Kraft recovery mills built before the early 1980's. In the order of 30 - 50% kraft recovery boilers in Canada have modern air systems (new or upgrades).	Kraft recovery furnaces with DCE's where location make the odour problems a public issue. In the order of 18 - 27 kraft recovery boilers in Canada are candidates for low odour conversion.	<u>Existing Mills:</u> Kraft recovery boilers built before the mid-1980s, though many have been upgraded. <u>New Mills:</u> This expenditure would probably be made in areas where PM is of concern in Canada.
Primary Justification and Benefits:		
for better furnace mixing and concentrating the heat in the lower furnace which reduces emissions. A small capacity increase is sometimes possible.	Energy efficiency and increased net steam generation of about 10%. Major reduction of TRS.	<u>Existing Mills:</u> Reduction of PM emissions, reduced downtime and possibly maintenance. <u>New Mills:</u> Reduced PM emissions

Table 4a- Recovery Boiler TRS and PM Emission Control Measures

Air System Upgrade	Low Odour Conversion and High Solids Firing	Electrostatic Precipitator Upgrade
Potential Emission Reduction		
NO _x and VOC reduction of 0.2 kg/ADt as NO ₂ and CH ₄ respectively. CO probably reduced and possibly TRS, though the extent cannot be reliably determined.	TRS reduction from approximately 0.75 without BLOX/0.23 with BLOX to 0.05 kg as H ₂ S /ADt, ie, down to 3-6 ppm _{d,v} . VOC reduction from 0.6 - 1.00 to 0.35 - 0.41 kg/ADt, as well as reductions in CO, PM and TAC. SO ₂ will increase without firing at high solids (>70%).	No limit to reduction of PM and PM ₁₀ by adding collecting area. Existing Mills: assumes reduction from 225 to 65 mg/SDm ³ at 8% O ₂ . New Mill: assumes reduction from 120 to 65 mg/SDm ³ at 8% O ₂ .
Barriers		
Uncertain prediction of emission reduction, except for TRS.	High costs, potentially higher if space limited in older mills. Inherent capacity limitations of smaller old boilers	Existing Mills: High costs due space limitations in some cases. Mill specific studies required to reduce cost uncertainty. New Mills: Cost.

The order of magnitude estimates of cost corresponding to these measures are presented in Table 4b. The cost of removal has been attributed to the pollutant for which the technology is most commonly applied. Emission reductions have been estimated from available information in the literature, and reflect a degree of predictability.

Table 4b - Recovery Boiler Emission Control Costs

Air System Upgrade	Low Odour Conversion	Electrostatic Precipitator Upgrade	
Existing older mill	Existing older mill	Existing older mill	New Greenfield Mill
Capital Costs, in M\$			
0.5 - 1	15 - 40	1 - 13	1.5 - 3
Annualized Capital Cost in k\$/a			
80 - 160	2400 - 6400	160 - 2100	240 - 480
Operating Cost in k\$/a			
50 - 100	140 - 36,000	70 - 600	90 - 180
Annualized total cost of Control Measure in k\$/a			
130 - 260	38,00 - 10,000	230 - 2600	330 - 660
Annualized total cost of Control Measure, \$/ADt production			
0.60 - 1.00	21.00 - 43.00	1.30 - 10.00	0.80 - 1.60
Pollutant Removal Costs, \$ per tonne			
TRS as H ₂ S: 2300 - 7000	TRS as H ₂ S: 22,000 - 240,000	PM 740 - 5400	PM 470 - 700

Table 4b - Recovery Boiler Emission Control Costs

Air System Upgrade	Low Odour Conversion	Electrostatic Precipitator Upgrade
Notes: a - Order of Magnitude costs. See section Basis of Cost Estimates.		

The foregoing systems are often found to be the most operationally satisfactory and cost effective. Other control measures that are encountered and advantageous in specific mill situations include wet scrubbing (particularly when there is a need for hot water) for SO₂, particulate, and sometimes TRS reduction, dry scrubbing for SO₂ reduction, and the installation of low NO_x burners for NO_x reduction.

Designing for higher solids firing has been the trend in boiler designs of the last decade, and now 74% is commonplace for new units. Retrofitting for high solids firing from say 65% to 72% dry solids in existing boilers may be considered as a cost effective way of reducing SO₂ emissions. The difficulty is in assessing what the capital cost might be as the solutions may be relatively minor "tweaking" of an oversized evaporator plant at essentially no cost to replacement of the concentrator at 10 M\$. Accordingly, the high solids firing option is not considered a stand alone option, but is included with the low odour conversion measure already described.

Selective catalytic reduction (SCR), non-SCR and flue gas recirculation are technologies sometimes considered for still lower NO_x emissions, but rarely, if at all adopted, because of the risks of anticipated operating problems.

Smelt Dissolving Tank

The shattering and violent reaction of the quenching smelt generates large volumes of steam and air emissions comprising particulate, TRS, SO₂, VOC and other emissions in minor quantities. The sources of TRS are reduced sulphur compounds in the smelt, escape of gases from the recovery furnace, and volatilization of contaminants in the scrubber water. SO₂ emissions appear to originate from the oxidation of these gases. Trace organic compounds and VOC emissions originate from the use of contaminated condensates as makeup water in the recausticizing process.

The smelt dissolving tank is a relatively small contributor to long term mill air emissions whether considered on a controlled or uncontrolled basis. On an uncontrolled basis, that is without an NCG system, the contributions to typical total mill emissions are 1% for TRS, and 0.3% for VOC. These become 10% for TRS, and 4% for VOC for a modern mill with a dynamic scrubber, and perhaps 4% for TRS, and 2% for VOC in an older mill with sprays and mesh pad controls.

A control measure for older installations currently using mesh pads and spray is the retrofitting of a dynamic scrubber using uncontaminated weak wash as a scrubbing medium. This measure is presented in Table 5a.

If process condensates are used in the recausticizing area, these should be of sufficiently high quality to prevent contaminants being brought back by the weak wash and resulting in

excessive vent scrubber TRS and VOC emissions. If this is not possible, stripped condensates or clean water should be used on the scrubber.

The cost of upgrading to a dynamic scrubber is presented in Table 5b.

**Table 5a- Smelt Dissolving Vent
Emission Control Measures**

Scrubber Upgrade Existing older mill
Description:
Installation of a dynamic scrubber to replace mesh pads and sprays.
Applicability and Prevalence:
Kraft recovery mills built before the early 1970's. Perhaps half of the kraft recovery boilers in Canada have scrubbers.
Primary Justification and Benefits:
Reduction of TRS from the 0.04 - 0.08 kg as H ₂ S/ADt with mesh pads to the order of 0.015. PM, SO ₂ , and VOC emission reductions as well.
Potential Emission Reduction
TRS: 0.025 kg as H ₂ S/ADt assumed.
Barriers
High retrofit costs and need for detailed study on scrubbing medium.

**Table 5b - Smelt Dissolving Vent
Emission Control Costs^a**

Scrubber Upgrade Existing older mill
Capital Costs in M\$
0.3 - 0.8
Annualized Capital Cost in k\$/a
48 - 130
Operating Cost in k\$/a
60 - 110
Annualized total cost of Control Measure in k\$/a
110 - 240
Annualized total cost of Control Measure in \$/ADt production
0.50 - 1.00
Pollutant Removal Costs, \$ per tonne
TRS as H ₂ S: 12,000 - 40,000

Notes: a - Order of Magnitude costs. See section Basis of Cost Estimates for details.

The USEPA is currently working on HAP emission data gathering and reviewing MACT based standards for smelt dissolving vent emission and is expected to release a draft in the spring of 1995. Some industry emission test data for HAPs has been recently published.

Power Boilers

The steam plant with its one or more power boilers, and any recovery boilers, generate the steam to meet all the requirements of the mill. The power boiler, can be in single or multiple units of different types and capacities depending on the nature of the mill. No direct relationship directly links power boiler emissions to mill production. Even in a single product facility, the amount of steam from the power boilers per ADt of product varies according to the energy efficiency of the mill. Therefore power boiler emissions are presented per quantity of heat input (GJ), a common industrial practice.

Power boilers are fossil fuel fired only or combination fossil fuel and wood fired. Wood fuel often includes bark and wood waste commonly called hog fuel with effluent treatment sludges added.

Kraft and sulphite pulp mills will generally include one or more large wood fired field erected power boilers to burn the bark and wood waste associated with chip manufacture. Such a mill may include other gas or oil fired boilers as well. Power boilers in small paper or recycle mills will generally be of the gas fired package type. In older integrated pulp and paper mills multiple boilers may be used of all types: large wood fired units; large field erected oil, gas or coal fired boilers; and package type boilers.

The emissions from these units will reflect the age and technology of the boiler and its emission control equipment.

The emission control measures presented are for large, field erected combination wood and oil/gas fired boilers.

Emissions from these units are affected by wood/sludge fuel characteristics, boiler load, firing and combustion technique, furnace geometry, amount of refractory, overfire air design and oil or gas burners. All are important in determining the need for supplementary (support or auxiliary) fuel firing, which also affect aggregate emissions.

Several measures considered today for controlling NO_x emissions from power boilers are summarized in Table 7a for existing boilers.

Table 7a - Power Boiler Emission Control Measures

Overfire Air System Upgrade	Low NO _x Burners	Selective Non Catalytic Combustion
Description:		
Installation of large overfire air ports, dampers, & controls.	Replacement of older standard burners with newer staged combustion designs.	Injection of ammonia or urea into a high temperature section of the furnace
Applicability and Prevalence:		
Wood only and combination wood and fossil fuel water wall boilers with small ports, and poor furnace mixing, in units often built before 1980.	Combination wood and fossil fuel boilers and fossil fuel only fired boilers with older standard burners. Moderately common in new installations.	Most wood only and combination wood and fossil fuel field erected boilers. Very rare. Applied in some US locations where AAQ does not meet federal or local standards.
Primary Justification and Benefits:		
Improved furnace mixing and combustion, reduced emissions.	Lower support fuel NO _x emissions.	Reduces NO _x once formed to N ₂ .
Potential Emission Reduction:		
NO _x : 20 - 40 ng/J. Also some CO, PM, VOC (and TRS if NCG fired).	NO _x : 40 - 60 ng/J. Possibly CO and VOC reductions as well.	NO _x reduction of 50 - 80%.

Table 7a - Power Boiler Emission Control Measures

Overfire Air System Upgrade	Low NO _x Burners	Selective Non Catalytic Combustion
Barriers		
Uncertain prediction of emission reduction uncertain, unlikely suitable for very old boilers.	Reduced proportion of fossil to wood fuel usage undermines justification.	Uncertain prediction of emission reduction. If NH ₃ used: transport of a hazardous material.

Table 7b - Power Boiler NO_x Emission Control Costs^a

Air System Upgrade	Low NO _x Burners	Selective Non Catalytic Reduction with Air System Upgrade
Existing older boiler	Existing older boiler	Existing older boiler
Capital Costs, in M\$		
0.13 - 0.7	0.25 - 1.2	0.35 - 2.2
Annualized Capital Cost in k\$/a		
20 - 110	40 - 190	55 - 350
Operating Cost in k\$/a		
70 - 180	80 - 220	150 - 630
Annualized total cost of Control Measure in k\$/a		
90 - 290	120 - 410	210 - 990
Annualized total cost of Control Measure, \$/GJ heat input		
0.03 - 0.15	0.04 - 0.19	0.11 - 0.30
Pollutant Removal Costs, \$ per tonne		
NO _x as NO ₂ : 750 - 5000	NO _x as NO ₂ 600 - 3000 ^b	NO _x as NO ₂ 2000 - 10,000

Notes: a - Order of Magnitude costs. See section Basis of Cost Estimates.

b - Assuming continuous operation for 350 d/a, otherwise costs will be inversely proportional to use per year.

To give some idea of these costs of control in terms of production, consider a 500 ADt/d kraft pulp mill with a power boiler generating 70 t/h steam from wood. Such a power boiler will have a heat input of about 300 GJ/h so that the costs become : 0.50 - 1.00 \$/ADt for an overfire air system upgrade; 0.80 - 1.00 \$/ADt for low NO_x burners where burner usage is continuous; 2.00 - 2.90 \$/ADt for selective non-catalytic reduction with an overfire air system upgrade.

A number of other modifications would also be expected to improve emissions such as grate replacement, addition of furnace arches, firing wood fuel of improved quality, wood fuel drying, and reduced use of supplemental fossil fuel. The amount and direction of these changes on air emissions requires a careful analysis of the specific details of the boiler

system, and a large degree of uncertainty will typically be associated with the predictions of emission reduction.

For controlling particulate emissions, the electrostatic precipitator is currently the preferred control device in new facilities for its high availability and efficiency. A further advantage is that water is not added to the flue gas which increases plume opacity as in wet scrubbing. Bag houses have not gained wide acceptance because of concerns regarding bag life and the risks of downtime due to catastrophic bag failure. Multiple cyclones and most types of wet scrubbers generally represent older technology, though there are some promising new scrubber technologies that may be advantageous where space constraints make an electrostatic precipitator retrofit impractical.

The measures presented in Table 8a are applications for electrostatic precipitators in an existing power boiler and in a new greenfield mill.

Table 8a - Power Boiler PM Emission Control Measures

Electrostatic Precipitator Upgrade	
Existing Older Boiler	New Greenfield Boiler
Description	
Installation of a modern, rigid electrode, three field, two 50% chambers.	Increased removal efficiency by increasing collection area by 18%.
Applicability and Prevalence	
Power boilers built before the mid-1980s.	This expenditure would probably be made in areas where PM is of concern in Canada.
Primary Justification and Benefits	
Reduction of PM emissions, reduced downtime and possibly maintenance.	Reduced PM emissions.
Potential emission Reduction	
No limit to reduction of PM and PM ₁₀ by adding collecting area. This example assumes reduction from 225 to 65 mg/SDm ³ at 7% reference O ₂ .	No limit to reduction of PM and PM ₁₀ by adding collecting area. This example assumes reduction from 225 to 65 mg/SDm ³ at 7% reference O ₂ .
High costs due space limitations in many cases. Mill specific studies required to reduce cost uncertainty.	Cost.

The power boiler in the existing mill is assumed to have a multiple cyclone or scrubber providing control to 225 mg/SDm³ at 7% reference oxygen which is replaced with a precipitator to provide control to 60 mg/SDm³, the permit level of several recent mills in Canada. Given the space constraints in existing facilities, and range of power boiler sizes, the cost of control is high. As the costs for an electrostatic precipitator installation are generally greater than those for scrubbers, where space is limited and a scrubber is used, the costs presented in Table 8b will probably be found to be conservative.

For the greenfield mill, the estimates are the incremental cost for increasing the precipitator area to reduce the outlet concentration from 100 to 60 mg/SDm³ at 7% reference oxygen. This additional emission control capability built in at the time of purchase is seen to be relatively inexpensive.

Again, to give some idea of these costs of control in terms of production, consider an existing 500 ADt/d kraft pulp mill with a power boiler generating 70 t/h steam from wood. Such a power boiler will have a heat input of about 300 GJ/h. Replacement of the existing control system to an electrostatic precipitator would cost 6.50 - 12.00 \$/ADt. For a 1000 ADt/d greenfield mill with a power boiler heat input of about 540 GJ/h, upgrading a new precipitator to provide control to 60 mg/SDm³ instead of 120 mg/SDm³ would cost 0.50 - 0.80 \$/ADt.

Table 8b - Power Boiler Emission Control Costs^a

Electrostatic Precipitator Upgrade	
Existing older boiler	New Greenfield boiler
Capital Costs, in M\$	
5 - 13	0.5 - 1.5
Annualized Capital Cost in k\$/a	
800 - 2100	80 - 240
Operating Cost in k\$/a	
340 - 850	100 - 280
Annualized total cost of Control Measure in k\$/a	
1100 - 2900	180 - 440
Annualized total cost of Control Measure, \$/GJ	
0.35 - 0.80	0.04 - 0.06
Pollutant Removal Costs, \$ per tonne	
PM	PM
4600 - 10,000	1300 - 2200

Notes: a - Order of Magnitude costs. See section Basis of Cost Estimates.

Lime Kiln

The lime mud formed in the recausticizing operation is calcined in the kiln or calciner to regenerate calcium oxide for reuse. Calcination requires high temperatures, up to 1100°C to complete the reaction. The air emissions from the kiln of CO, PM, SO₂, and TRS, are all less than 10% of total mill emissions in a typical older or newer kraft pulp mill, with the exception of NO_x which can be as high as 20% of mill total. In addition, CO₂ emissions are from both combustion and the calcining reaction.

The use of low NO_x burners in lime kilns is not believed to be currently practiced because of the need for high calcining temperatures, nor is NO_x otherwise controlled in kilns.

Particulate emission control has been by wet scrubber until the 1980s, with the electrostatic precipitator being favoured since then in new mills, particularly with the

virtual elimination of the plume associated with scrubbing. Though the precipitator option creates less pressure drop and uses less power, the capital cost is higher. Group purchasing of 3 precipitators in new mills for the recovery, power and kiln create a barrier to use of the scrubber option.

In most retrofit situations, the electrostatic precipitator will be more expensive than a scrubber for the same level of control, even after including for larger lime mud washing and filtering capacity because of recycle in the case of the scrubber option. However, when two kilns are being retrofitted simultaneously, a single electrostatic precipitator serving both have been found cost effective.

Sulphur dioxide emissions are most cost effectively controlled by removing sulphur from the NCG in a white liquor scrubber, though there are examples of alkaline scrubbers operating on kilns for SO₂ removal.

TRS is controlled by combustion control and ensuring good lime mud washing with clean condensates to limit the sodium sulphide entering the cold end of the kiln.

The control measure of retrofitting of a wet scrubber to an older lime kiln to control PM, and improving lime mud washing is presented in Table 9a. The cost of these measures is presented in Table 9b.

Table 9a - Lime Kiln PM Emission Control Measure

Wet Scrubber Upgrade Existing older mill
Description: Installation of a new dynamic scrubber to replace existing scrubber and improved lime mud washing.
Applicability and Prevalence: Lime kilns built before the early 1980s.
Primary Justification and Benefits: Reduction of PM from present 460 - 230 mg/SDm ₃ range (assumed) to 85 mg/SDm ₃ at 10 % O ₂ . TRS reduction to 12 ppm _{dv} at 10 % O ₂ . VOC emission reductions as well.
Potential Emission Reduction PM: 145 - 375 mg/SDm ₃ at 10 % O ₂ assumed.
Barriers High retrofit costs for PM control

Table 9b - Lime Kiln Emission Control Costs^a

Scrubber Upgrade Existing older mill
Capital Costs in M\$ 0.8 - 1.8
Annualized Capital Cost in k\$/a 130 - 290
Operating Cost in k\$/a 150 - 260
Annualized total cost of Control Measure in k\$/a 280 - 540
Annualized total cost of Control Measure in \$/ADt production 1.00 - 2.40
Pollutant Removal Costs, \$ per tonne TRS as H ₂ S: 2500 - 15,000
Notes: a - Order of Magnitude costs. See section Basis of Cost Estimates for details.

Effluent Treatment System

Effluent contains VOCs and HAPs, and in the case of kraft mills, TRS as well. Some of the compounds are relatively volatile such as TRS and terpenes and to a lesser extent methanol and phenols. These compounds will be air stripped and released to atmosphere in effluent cooling towers and secondary treatment aeration systems. The amounts emitted will depend on the relative volatility of the compounds, the effluent temperature and the air to effluent contact ratios.

Steam stripping of the contaminated evaporator and digester condensates (blow tank, turpentine condenser) before reuse and sewerage has traditionally been undertaken to reduce biochemical oxygen demand load into the effluent treatment system caused by the presence of VOC in the effluent. An additional benefit has been the reduction of TRS emissions from the effluent treatment system and from areas of the mill where contaminated condensates are used. Steam stripping of contaminated condensates is effective for VOC and HAP control in

all pulping processes whether kraft, sulphite or mechanical pulping and the mill effluent treatment systems as well.

The steam stripper uses a distillation column to concentrate the VOCs in a small vent flow which is incinerated along with concentrated NCG in the lime kiln or power boiler. Modern designs using a steam to feed ratio of 18 - 20% remove about 94% of the TRS, 90% of the methanol, and 99% of a number of other HAPs.

Retrofitting a steam stripper in an existing kraft pulp mill for control of TRS is presented in Figure 10a.

The order of magnitude estimates of cost corresponding to these measures are presented in Table 10b. The cost of operating the CNCG system benefits from the credit from the fuel value of methanol recovered and burned. It is assumed that disposal will be in the lime kiln where it will displace fossil fuel fired there; if disposal is in a wood fired power boiler, wood fuel is displaced and a smaller credit would result.

Table 10a - Effluent Treatment TRS Emission Control Measures

Scrubber Upgrade Existing older mill
Description:
Installation of a steam stripper for evaporator and digester condensates.
Applicability and Prevalence:
Kraft recovery mills built before the early 1970's. Perhaps one third to half of the kraft mills in Canada have no steam stripper.
Primary Justification and Benefits:
Reduction of TRS, VOC and HAPs emissions as well as BOD ₅ reducing aeration horsepower.
Potential Emission Reduction
TRS: 0.6 - 1.3 kg as H ₂ S/ADt assumed.
Barriers
High retrofit and energy consumption costs.

Table 10b - Effluent Treatment TRS Emission Control Costs^a

Steam Stripping
Existing older mill
Capital Costs in M\$
3.5 - 9.0
Annualized Capital Cost in k\$/a
568 - 1430
Operating Cost in k\$/a
750 - 1600
Annualized total cost of Control Measure in k\$/a
1300 - 3100
Annualized total cost of Control Measure in \$/ADt production
7.00 - 8.90
Pollutant Removal Costs, \$ per tonne
TRS as H ₂ S:
5400 - 15,000
Notes: a - Order of Magnitude costs. See section Basis of Cost Estimates for details.

A new development in Scandinavia is the addition of a methanol rectification section in the column to produce methanol of high purity, though relatively expensive. This is a good fuel and, liquid at ambient temperatures, is as

convenient to store and fire as light oil.

Other Uncontrolled Sources

There are materials handling operations in pulp and paper manufacturing that lead to fugitive particulate emissions such activities as:

- Salt cake unloading
- Burned lime handling
- Power boiler ash and fly ash handling
- Purchased limestone and lime storage and handling
- Dried lime mud storage and handling and
- Miscellaneous bulk chemical handling and storage (titanium dioxide, dyes, clays, alum, sulphur, soda ash, talc, etc.)

The degree to which these operations actually result in fugitive emissions will be equipment specific and depend largely on operating practices. No method for predicting the aggregate magnitude of these emissions from the industry have been identified in the literature.

In addition, paved and unpaved roads are a major source of fugitive particulate emissions, due to their prevalence around many mills. Emissions from unpaved roads were estimated to account for 47% of the total particulate emissions in the US from open sources in 1976. This figure is 18 times the emissions from all anthropogenic sources. OK

Emissions from emergency vents such as overpressure relief are generally not considered in any discussions of discharges from mills. Such sources are not considered candidates for treatment, because emissions during upset conditions are often exempted in permits. A further difficulty is determining the magnitude of the emissions during such periods of abnormal operation. Being of brief duration, and limited quantity, they are accordingly not a major focus of regulatory effort.

Miscellaneous and minor process sources have often been termed fugitive when they have contributed some odour but have not had sufficient flow or concentration to justify collection in one of the NCG systems.

TRS and chemical vapour emissions will find their way into the mill ventilation system from leaks, spills, etc., whenever black liquor or certain chemicals are used. These will be exhausted to the atmosphere via the area ventilation system.

Although pulp and paper mill sludge landfills have been in widespread use for decades, there have been no indications that gas generation by microbial activity, migration and emission of methane and H₂S from these sites is a significant problem.

5 - REGULATORY EMISSION LIMITS

Industry-specific regulation often supplemented by mill operating permits are the means used by governments to ensure that air and other emissions from pulp and paper mills are controlled to levels that adequately safeguard public health and the environment.

New Mills

New mills are treated differently in regulations and permits than existing mills. New mills are invariably required to meet tighter limits than the existing stock of mills. Starting in the last decade, and particularly for the new mills completed in the early 1990s, new Canadian mill limits have reflected permit levels required in more demanding jurisdictions elsewhere, particularly the USA.

These new mill regulatory and permit levels have been reviewed in the study Simons undertook for Environment Canada and the British Columbia Ministry of Environment, Lands and Parks entitled "A Technical Background Information Document on Pulp and Paper Air Emissions". The report reviewed permitting practice in demanding jurisdictions in North America and Europe, the identification of stringent permits, and selection of 22 air emission permits from mills in the US, Canada and Europe (Sweden, Finland, France, Austria, and Germany). The mill locations comprise 17 kraft, 2 sulphite and one mechanical, and the breakdown by process and equipment is:

	Kraft Recovery	Smelt Vent	Lime Kiln	Sulphite mill	Power - Wood and Fossil	Power - Gas only
Canada	4	4	4	-	4	3
US	4	4	2	1	3	1
Sweden, Finland	11	6	9	1	7	-
France, Germany	1	-	1	1	3	-
Total	20	14	16	2	17	4

A summary of regulations and permits for the main kraft pulp mill sources is presented in Tables 11 - 14 based on this survey. These sources comprise the recovery and power boilers, kiln and smelt dissolving tank and account for virtually all the CO, NO_x, and PM, 60 - 95% of the sulphur and 40 - 70% of the VOC sources in existing and newer kraft mills. A large part of the remainder is often emitted by the effluent treatment system.

Table 11 - Regulations, Permits and Technology Representative of Best Current Practice: kraft Recovery Boilers^{a,b}

Source/ Emission	Juris- diction	Range of Regulations	Permits: ^a Range (Fraction)	Control Technology
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CO in ppm _{dv}	Canada	None	None (0/4)	Design and operation for good furnace mixing and excess air control
	USA/States	None	200 - 1000 (4/4)	
	Europe	98	None (0/12)	
NO _x in ppm _{dv}	Canada	None	125 (1/4)	Design for staged air and operate for low excess air
	USA/States	None	95 - 150 (4/4)	
	Europe	158-211	79 - 190 (3/12)	
Opacity in %	Canada	None	20 (2/4)	Design for low PM emissions
	USA/States	35/20-45	20 - 35 (4/4)	
	Europe	None	None (0/12)	
PM in mg/SDm ³	Canada/Quebec	305/102 - 203 ^c	60 - 229 (4/4)	Electrostatic precipitator
	USA/States	100/67-300	46 - 69 (4/4)	
	Europe	38-233	65 - 113 (12/12)	
SO ₂ in ppm _{dv}	Canada	None	150 - 600 (3/4)	Design, process control and operation for good furnace mixing
	USA/States	None/750 - 2000	75 - 200 (4/4)	
	Europe	91 - 531	50 - 77 (6/12), and total mill "S" limits	
TRS in ppm _{dv}	Canada/Quebec	18/20 - 5 ^c	5 - 6.5 (4/4)	Design, process control and operation for good furnace mixing
	USA/States	5/5 ^d	3 - 5 (4/4)	
	Europe	7, 11	5 - 5 (10/12)	
VOC in ppm _{dv}	Canada	None	None (0/4)	Design, process control and operation for good furnace mixing
	USA/States	None	50 - 115 (3/4)	
	Europe	None	None (0/12)	

Notes:

a. Standard(S) Conditions of 20 °C and 101.325 kPa, dry(D), NO_x as NO₂ and VOC as CH₄. Emissions at reference O₂ conditions of 8% by volume. Permit range given is for 4 lowest; fraction indicates proportion of permits specifying limits.

b. Space limitations prevent inclusion of averaging time which is critical for comparison of values for which a high degree of random variability is associated, such as CO, SO₂, TRS and to a lesser degree NO_x.

c. In Quebec, the lower limit applies to new mills operating after 22 October 1992. The higher limit applies to existing mills operating before 22 October 1992 which comes into effect on 31 December 1996.

d. The New Hampshire limit is 20 ppm_{dv}.

Source/ Emission	Juris- diction	Range of Regulations	Permits: ^a Range (Fraction)	Control Technology
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SMELT DISSOLVING TANK^{a,b}

CO in ppm _{dv}	All	None	None	Insignificant source
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Source/ Emission	Juris- diction	Range of Regulations	Permits: ^a Range (Fraction)	Control Technology
NO _x in ppm _{dv}	All	None	None	Insignificant source
Opacity in %	Canada USA/States Europe	None None/20 ^c - 40 None	None (0/4) 20 (3/4) None (0/12)	Design for low PM emissions
PM in g/tBLS	Canada/Quebec USA/States Europe	166/165-100 ^d 100/100-167 None	84 - 107 (4/4) 60 - 100 (4/4) 44, 109 (2/6)	Dynamic scrubber
SO ₂ in g/tBLS	Canada USA/States Europe	None None/1000 - 2000 None	50 (1/4) 15 - 33 (3/4) (0/6)+Millwide "S" limits	Design, process control and operation
TRS in g/tBLS	Canada/Quebec USA/States Europe	None/16 16.5/8.4-16.5 7, 11	13 - 17 (3/4) 8.4 - 16.5 (4/4) 7 (1/6)+ Millwide "S" limits	Design, process control and operation
VOC	All	None	None	

Notes:

a. Standard(S) Conditions of 20 °C and 101.325 kPa, dry (D), NO_x as NO₂ and VOC as CH₄. Emissions at actual O₂ conditions. Permit range given is for 4 lowest; fraction indicates proportion of permits specifying limits.

b. Space limitations prevent inclusion of averaging time which is critical for comparison of limits due to the often high degree of random variability associated with the emission.

c. Florida requires either an opacity of 10% or compliance with PM standard.

d. In Quebec, the lower limit applies to new mills operating after 22 October 1992. The higher limit applies to existing mills operating before 22 October 1992 which comes into effect on 31 December 1996.

Source/ Emission	Juris- diction	Range of Regulations	Permits: ^a Range (Fraction)	Control Technology
<u>LIME KILN</u> ^{a,b}				
CO in ppm _{dv}	Canada	None	None (0/4)	Design and operation for good furnace mixing and excess air control
	USA/States	None	40, 52 (2/2)	
	Europe	None	None (0/9)	
NO _x in ppm _{dv}	Canada	None	None (0/4)	Design for staged air and operate for low excess air
	USA/States	None	100 - 341 (2/2)	
	Europe	134 - 179	93 - 193 (3/9)	
Opacity in %	Canada	None	20 (1/4)	Design for low PM emissions
	USA/States	None/20 ^e -80	20 (2/2)	
	Europe	None	None (0/9)	
PM in mg/SDm ³	Canada/Quebec	465/129 - 292 ^c	59 - 180 (4/4)	Electrostatic precipitator
	USA/States	153 - 298 ^d /153 - 465	80 - 229 (2/2)	
	Europe	38-233	55 - 85 (9/9)	
SO ₂ in ppm _{dv}	Canada	None	350 (1/4)	Design, process control and operation for good furnace mixing
	USA/States	None/231 - 2000	35 - 44 (2/2)	
	Europe	91-531	43 - 110 (2/9)+ millwide "S" limit	
TRS in ppm _{dv}	Canada/Quebec	None/8.5 - 8.5	10 - 12 (3/4)	Design, process control and operation for good furnace mixing
	USA/States	8/20 - 80 ^c	8 (2/2)	
	Europe	9	8 - 24 (9/9)+ millwide "S" limit	
VOC in ppm _{dv}	Canada	None	None (0/4)	Design, process control and operation for good furnace mixing
	USA/States	None	78 - 308 (2/2)	
	Europe	None	None (0/9)	

Notes:

- a. Standard(S) Conditions of 20 °C and 101.325 kPa, dry (D), NO_x as NO₂ and VOC as CH₄. Emissions at reference O₂ conditions of 10% by volume. Permit range given is for 4 lowest; fraction indicates proportion of permits specifying limits.
- b. Space limitations prevent inclusion of averaging time which is critical for comparison of values for which a high degree of random variability is associated, such as CO, SO₂, TRS and to a lesser degree NO_x.
- c. In Quebec, the lower limit applies to new mills operating after 22 October 1992. The higher limit applies to existing mills operating before 22 October 1992 which comes into effect on 31 December 1996.
- d. Lower limit for gaseous fuel, higher for oil.
- e. Florida requires either an opacity of 10%, or compliance with PM standard.

Source/ Emission	Juris- diction	Range of Regulations	Permits: ^a Range (Fraction)	Control Technology
POWER BOILER FIRING ONLY WOOD WASTE FUEL^{a,b}				
CO in ppm _{dv}	Canada	None	None (0/4)	Design and operation for good furnace mixing and excess air control
	USA/States	None	390 - 3400 (1/3)	
	Europe	98	112 - 120 (2/10)	
NO _x in ppm _{dv}	Canada/Quebec	None None	131 - 168 (2/4)	Design for staged air and operate for low excess air
	USA/States	177 None	92 - 177 (3/3)	
	Europe	205 - 256	165 - 206 (7/10)	
Opacity in %	Canada	35	20 (4/4)	Design for low PM emissions
	USA/States	20/20 ^d -40	10 - 20 (3/3)	
	Europe	None	None (0/10)	
PM in mg/SDm ³	Canada/Quebec	340/346 - 458 ^c	45 - 102 (4/4)	Electrostatic precipitator
	USA/States	113, 113 - 388	41 - 113 (3/3)	
	Europe	38-233	39 - 53 (10/10)	
SO ₂ in ppm _{dv}	Canada	None	3.8 - 235 ((2/4)	Design, process control and operation for good furnace mixing
	USA/States	None/340 - 2000	20 - 510 (3/3)	
	Europe	91-531	49 - 68 (4/10)+ millwide "S" limits	
TRS in ppm _{dv}	Canada	None	None (0/4)	Design, process control and operation for good furnace mixing
	USA/States	None	None (0/3)	
	Europe	None	5 (1/10)	
VOC in ppm _{dv}	Canada	None	None (0/4)	Design, process control and operation for good furnace mixing
	USA/States	None	34 - 226 (3/3)	
	Europe	None	39 (1/10)	

Notes:

- Standard(S) Conditions of 20 °C and 101.325 kPa, dry (D), NO_x as NO₂ and VOC as CH₄. Emissions at reference O₂ conditions of 7% by volume. Permit range given is for 4 lowest; fraction indicates proportion of permits specifying limits.
- Space limitations prevent inclusion of averaging time which is critical for comparison of values for which a high degree of random variability is associated, such as CO, SO₂, TRS and to a lesser degree NO_x.
- Excluding salt-laden hog fuel.
- Oregon requires an opacity of 10%.
- 100 mg/Nm³(92 mg/SDm³) has been proposed by the Quebec Minister of Environment in April, 1993. Also, the lower limit given applies to new mills operating after 22 October 1992. The higher limit applies to existing mills operating before 22 October 1992 which comes into effect on 31 December 1996.

From the foregoing, it is apparent that permits are set significantly more restrictive than regulations, and that permits often limit emissions for which there are no corresponding regulations. The one exception is the CO regulation for recovery boilers though there are none in Germany.

Existing Sources

In most countries, regulations that apply to new pulp and paper facilities are also applicable to any rebuilds or replacements of equipment in an existing mill where the changes are major, while lesser modifications are exempt. Central to the practicality of this distinction is a clear definition of what constitutes a major modification.

In the US, the Major Modification rule only applies to major sources. A major source is defined in terms of its annual emissions. In regions of the US with acceptable ambient air quality, a major source is one emitting 100 tons/a of Criteria Pollutants in the case of kraft pulping and 250 tons/a in the case of sulphite or mechanical pulping. For other areas not meeting national ambient air quality standards, a major source is one emitting 100 tons/a of Criteria Pollutants from any source.

(The foregoing means that third sentence of §7.1.1.1 is wrong, as well as the first line in the HLA Table 1. Help !)

A modification is a major one if a threshold emission rate is exceeded. The threshold emission level also depends on the air quality at the site, but in addition, the emission type. In regions of the US with acceptable ambient air quality, the emission thresholds are: 100 short tons per annum (T/a) for CO, 40 T/a for NO_x, VOC and SO₂, 25 T/a for total particulate. In the limiting case for a "small" major source of 100 T/a, these thresholds represent significant increases on a percentage basis. For instance, modifications increasing site annual emissions by up to 40% for NO_x, VOC and SO₂ are possible without triggering a new source review and an analysis of best available technology (BACT).

For facilities located in air quality non-attainment areas of the US, the more severe the ambient air quality problem, the lower the threshold levels are that define a modification to be a major one. These limits are:

Table _ - Major Modification Emission Levels

Emission Type	Air Quality Area	Emission Level
CO, NO _x , VOC	Serious CO and O ₃ non attainment	50
NO _x , VOC	Severe O ₃ non attainment	25
NO _x , VOC	Extreme O ₃ non attainment	10
PM ₁₀	Serious PM ₁₀ non attainment	70
Any combination of HAP	-	25
Any single HAP	-	10

Major modifications (and new sources) in these areas must comply with the Lowest Achievable Emission Rate (LAER) control technology which can be very costly. In addition, sources locating in these areas must purchase offsets for pollutants emitted by the facility for which the area is classified as non-attainment. Offsets are defined as an equivalent or greater emission

reduction obtained from another source. Such offsets provide a mechanism whereby the emission load to an air shed are reduced.

Although an operating permit will usually specify the production capacity of the facility, if increased production can be accomplished without an associated increase in air emissions, then the increased production will not trigger additional regulatory review. Using annual emissions rather than production as the basis for defining a major modification has the advantage of allowing production growth at lower specific emission rates.

In France, the regulations come into effect in the event production increases 25% or emissions increase by 10%. The regulations do not state what averaging time is used, but presumably the period is long term, such as one year.

In Sweden, any modification where the "character, extent, or amount of the discharge may change in such a way that may be of significant detriment to the environment or public health will trigger a permit review for that source". Also, any change "whereby the activity is conducted or the establishment configured in a different way from that defined in a permit decision" will require a permit review. There are no numerical limits set as to what is considered a significant detriment.

In Finland, there are no defined limits as to what production output would require a permit review; production is mentioned in the permit as a nominal mill capacity and no maximum limit is assigned. It is possible that a mill could increase capacity by at least 20 - 25% if not 30 - 50% before the air emission authorities would demand a permit renewal.

In Germany, the regional permitting authorities have a degree of latitude in determining if a modification is major and requires a new permit. The determination would take into account the local ambient air quality, the current emission levels and the nature of the modification and is therefore somewhat arbitrary. Thus the need for a new permit may vary from one case to another and one region to another.

In addition to the foregoing methods of tying air emission permit review to the size of a modification whether by emission quantity, production increase, or an assessment of significance by an authority of a change, a number of jurisdictions have mechanisms in place or planned to require existing mills to reduce limits in operating permits.

In Quebec, existing kraft pulp mills operating before 22 October 1992, have air emission standards that come into effect on 31 December 1996 (§58). These standards are less demanding than those for new mills which applied after 22 October 1992 (Gazette Officielle du Quebec; Regulation (Amendment) October 7, 1992).

In the US, Title V of the Clean Air Act requires states to adopt an operating permit program acceptable to Federal requirements for all mills. These permits are to be renewed after 10 years. Many issues, however, remain outstanding such as (a) the degree to which fugitive emissions must be identified and quantified, (b) what the minimum level sources have to be identified (de minimis emissions), (c) permit modification procedures and (d) the USEPA requirements for enhanced and periodic monitoring.

In Sweden, permit renewal frequency every 10 years respectively allows the opportunity to review and adjust permitted limits in the light of new national initiatives or local issues. In Sweden, a permit decision for an activity that may be harmful to the environment, the permitting authority must give a detailed account of the environmentally harmful activity covered by the permit, as well as the conditions that shall apply for erecting and operating the facility. The limit values stipulated in the permit remain in force for ten years, but they may be reconsidered at an earlier date, e.g. if unforeseen problems of non-compliance arise, if the local situation changes substantially, or if new technology has made considerable improvements feasible. The capacity stated in the permit is the ceiling for yearly production. A small increase in a good year requires a permit modification, but is usually turned down.

The problem with acidification of the environment in Sweden has focused the environmental control effort on the discharge of SO_x and NO_x . The Swedish Parliament decided in 1988 that the results of regulations so far were not sufficient. Air emissions from domestic sources are to be reduced by 80 percent for SO_2 between 1980 - 2000 and by 30 percent for NO_x between 1980 - 1995.

However, the Swedish national air emission guidelines have not been formally revised since 1973, and some of the values have become obsolete through technical progress. In a new approach SEPA publishes action plans that contain their views on some pollutants. Implementation of such plans will be through the operating permit system

In the United States, the EPA HAP emission standards for both new and existing mills will be based on best demonstrated control technology and practices and must be as stringent as the average emission limit achieved by the 12 percent best performing mills.

These MACT standards will apply to kraft, sulphite, semi-chemical, and soda pulp mills. The regulation is expected to be promulgated by late 1995 or early 1996 for non combustion sources. New or modified sources must meet the MACT limits as soon as they are set; existing sources have three years to comply. This regulation covers only non-combustion sources at the present time. It is unique because it simultaneously sets air and water regulations or multi-media standards for the industry.

In principle, MACT standards for the pulp and paper industry will not require specific technologies. However, a combination of process changes and add-on controls will be required in order to control HAP emissions and comply with a either a specific percent reduction or mass of pollutant emitted per ton of product.

Standards for combustion sources within kraft, sulphite, semi-chemical, and soda pulp mills are due to be published in late 1995.

6 - CONCLUDING REMARKS/SUMMARY

(TO COME)