

Case studies: Cluster Rule impact assessment

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Based on a study of several bleached and unbleached chemical pulp mills, a typical 1000-tons/day bleached kraft mill could expect to spend up to US\$ 80 million to comply with the EPA's Cluster Rule.

The Cluster Rule is the Environmental Protection Agency's (EPA) first attempt at combining air and water requirements into an ecosystem-wide approach to regulate the pulp and paper industry. To measure the impact of the Cluster Rule, Rust Engineering and Rust Environment & Infrastructure conducted assessment studies at nine mills: five bleached kraft, three unbleached board (two unbleached kraft and one semi-chemical), and one newsprint.

Nonchemical pulp mills (e.g., newsprint mills) are faced with more stringent conventional pollutant requirements [i.e., five-day biochemical oxygen demand (BOD) and total suspended solids (TSS)]. The chemical pulp mills (bleached kraft and unbleached board mills) are faced with a tough uphill battle to meet even more wastewater requirements: COD limits, AOX and color limits (bleached kraft mills only), organic chemical limits (bleached kraft mills only), and the Best Management Plan.

The chloro-organic chemical (i.e., dioxins, furans, etc.) limits are to be measured in the bleach plant effluent. The BOD, TSS, COD, and AOX limits are to be measured in the final effluent.

Additionally, the chemical pulp mills must comply with more stringent process air pollution requirements, which may include: NCG systems, HVLC/LVHC, pulp mill wastewater treatment, bleach plant vent gas scrubbing (bleached kraft mills only), and sulfur dioxide controls.

The emphasis is on controlling the hazardous air pollutants (HAPs) in the pulp mill, which include methanol and chlorine. The noncondensable gas (NCG) systems are composed of both high-volume low concentration (HVLC) and low-volume high concentration (LVHC) gas streams from the digesters, washers, evaporators, steam strippers, and spent pulping liquor tanks. Foul condensates from the evaporators, turpentine recovery system, and digester condenser make up the pulp mill wastewater. The bleach plant vents originate from not only the bleach towers, but also each stage's filtrate tanks and washer hoods. Sulfur dioxide (SO₂) controls may be required

for the destruction devices's gas emissions, which are treating the NCGs.

Chemical pulp mills will also be faced with further air pollution requirements for the process combustion sources. The requirements potentially include: reduced particulate limits; HCl scrubbing (DCE recovery boilers), and black liquor oxidation (BLOX) controls.

Hydrochloric acid (HCl) scrubbing may be required only for the direct-contact evaporator equipped (DCE) recovery boilers and for new recovery boilers. The BLOX controls involve capturing and incinerating the emissions from it.

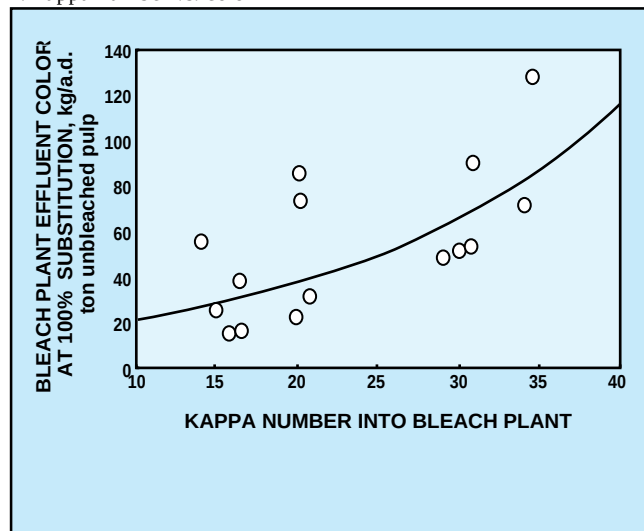
The key areas covered in the Cluster Rule assessment studies were: current operation analysis, water pollution control needs, air pollution control requirements, support area impacts, and compliance cost.

Current operation analysis

The analysis of a mill's operation involves:

- Trend analysis, used to pinpoint differences between the periods, involves plotting a rolling average (typically of 10 days duration) of pollutant data over a calendar year. For example, a trend analysis for the secondary influent BOD at one of the study mills showed a decrease or a downward trend in the BOD attributed to a change in personnel and emphasis on pollutant losses during the period. Conversely, another mill's secondary influent COD trend analysis moved upward during the last half of the analysis period because of the startup of another bleaching operation at the mill.
- In-mill pollutant breakdowns are also helpful in determining the control emphasis needed for each area. In observing in-mill BOD breakdowns for both unbleached and bleached kraft mills, the analysis revealed the differences in the nature of the pollutants between the two types of mills. The unbleached kraft mills show minimal losses from the pulp mill with the majority of the losses coming from the recov-

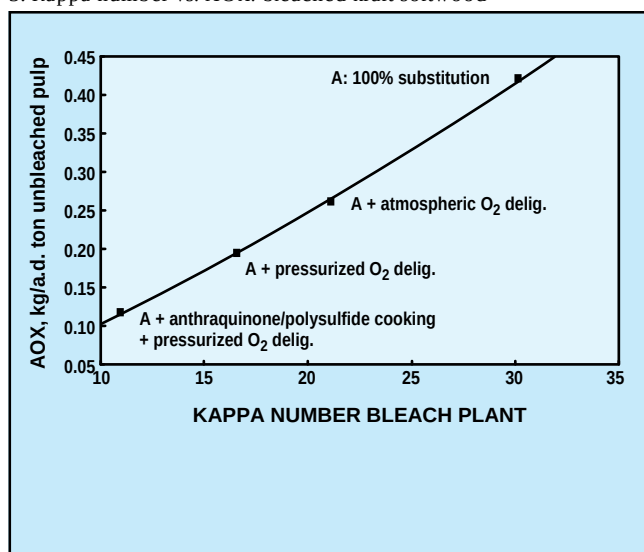
1. Kappa number vs. color



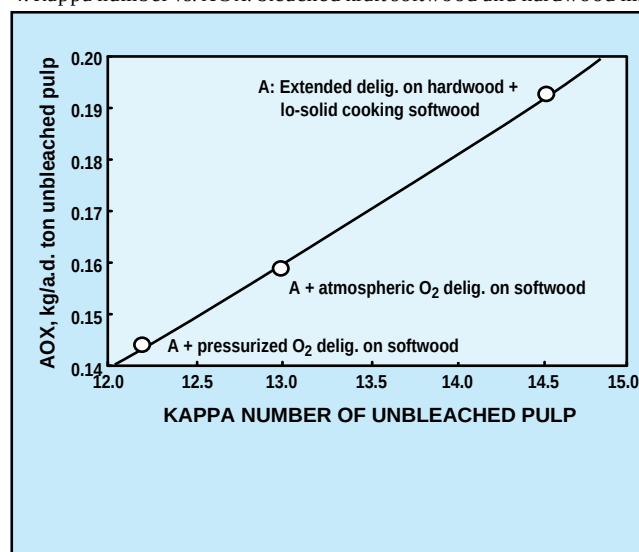
2. AOX control schemes

✓ 100% chlorine dioxide substitution	✓ Digester and bleach plant DCS controls
✓ Oxygen delignification • Atmospheric • Pressurized	✓ Improved washing and screening
✓ Polysulfide cooking	✓ Chip thickness screening
✓ Addition of anthraquinone	✓ Reduced kappa factor in bleach plant

3. Kappa number vs. AOX: bleached kraft softwood



4. Kappa number vs. AOX: bleached kraft softwood and hardwood mix



ery area (i.e., foul condensates) and the paper mill. Since the paper mill losses originate from unwashed spent pulping liquor being removed at the fourdrinier, one mechanism to reduce the pollutants at an unbleached mill is better washing. Also, treatment of the foul condensates and adequate spill controls can reduce the pollutant loadings from the recovery and pulp mill areas.

On the other hand, the bleached kraft mills' high pulp mill losses reflect the reuse of combined condensates within the process and the impact of the bleach plant losses. The lower paper mill BOD impact is the result of a clean, essentially BOD-free stock being sent to it with the only contribution generally coming from starch losses at the paper machine.

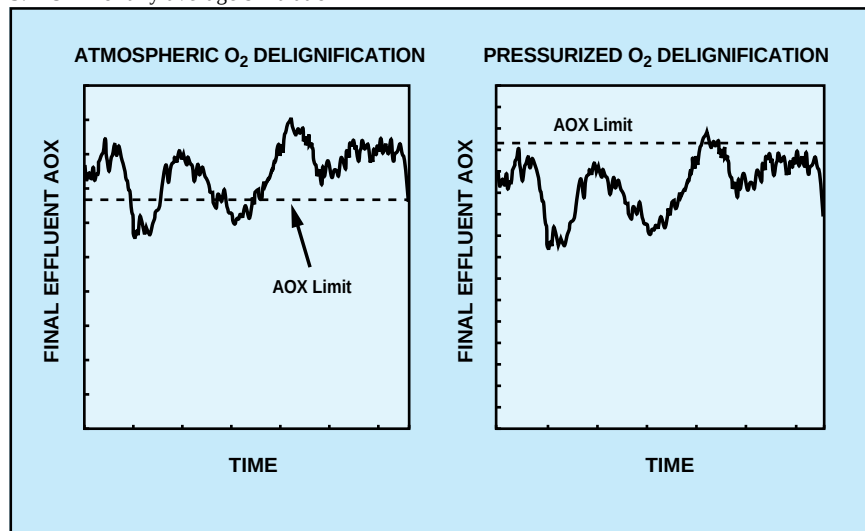
- Pollutant comparisons with other mills demonstrate the relative effectiveness of in-plant and end-of-pipe control

schemes. In a comparison of the BOD and TSS removal across a primary clarifier for similar mills, the poor pollutant removals across the primary clarifier were found to be from unequal flow distributions across the outlet weirs and poor sludge management within the clarifier.

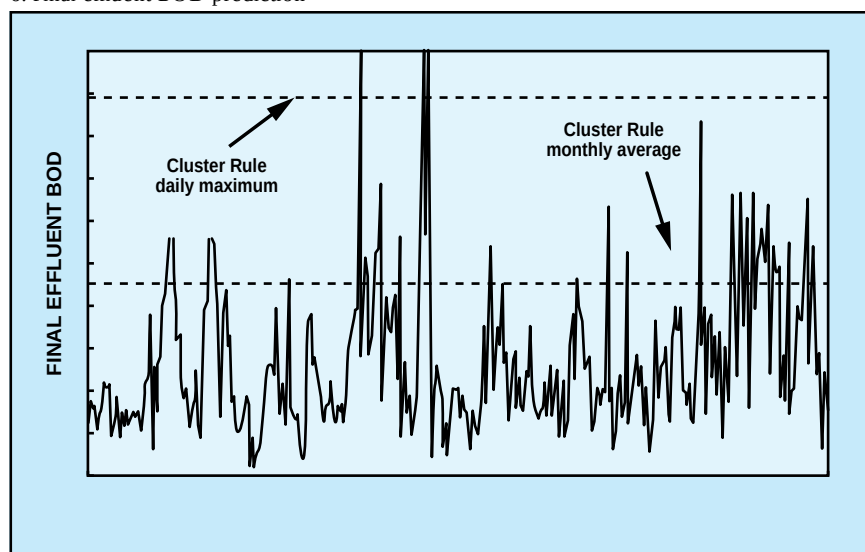
In a comparison of the secondary treatment influent BODs for the bleached kraft mill studied, the data reflects the degree of in-plant pollutant measures employed by the mills from a high to low degree of control. Although only five mills were studied, they represent a good cross-section of bleached kraft mills.

- In a correlation analysis, the degree of in-plant control can also be determined by the COD and BOD relationship for the secondary influent. For example, high pollutant loss mills show both a higher slope and lower intercept (i.e.,

5. AOX monthly average simulation



6. Final effluent BOD prediction



value of BOD when COD is zero) than for low pollutant loss mills. This possibly reflects increased spent pulping liquor loss at the high pollutant loss mills, which will tend to yield a good relationship between COD and BOD. With decreased spent pulping liquor losses at the low pollutant loss mills, the COD losses explain only a portion of the BOD losses.

- A spill potential analysis completes the analysis of a mill's operation by determining the type of pollutant losses—whether baseline or spill related. It separates in-plant data between baseline or normal operations and spill related losses from minor and major spills. In a spill potential analysis for four of the study mills, two were high pollutant loss mills where the losses occur primarily from both baseline and moderate spills. The low major spill contributions

indicate the mills are plagued with recurring, probably every other day type spills of an hour to two hours duration.

The other two mills had problems with both moderate and major spills. This necessitates a larger spill control system to handle the major spills, and reflects a need to increase the evaporate capacities at the mills.

Water pollution control needs

The impact of the additional wastewater requirements, both end-of-the pipe (i.e., BOD, TSS, COD, AOX, and color) and bleach plant effluent (i.e., dioxins, furans, etc.) is explored for both bleached and unbleached kraft mills:

Bleached kraft mills

AOX is the primary pollutant of concern at bleached kraft mills. AOX generally fell between 0.3 and 0.8 kg per air dried unbleached metric ton for final effluent data from mills using at least 50% chlorine dioxide (ClO_2) substitution and further delignification prior to bleaching. The lower numbers in the range reflect hardwood bleaching, while the higher numbers reflect softwood bleaching.

Unbleached kappa number is another AOX indicator. Control of effluent color and AOX are similar—they both require reduced kappa numbers entering the bleach plant. Figure 1 shows the relationship between effluent color and unbleached kappa number. The control techniques looked at during the bleached kraft studies are recorded in

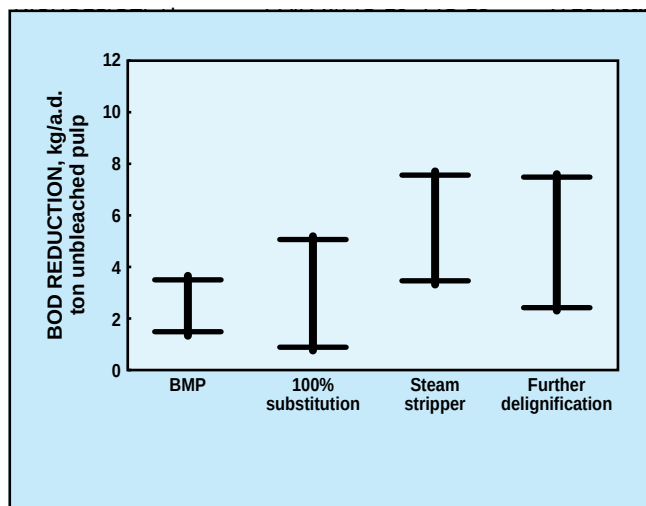
Fig. 2. The long-term average AOX values were estimated by the AOX computer model developed by the National Council for Air and Stream Improvement (NCASI).*

Figure 3 reflects the results of such an analysis for a bleached softwood mill. The data shows a kappa number of approximately 11 is required to meet the proposed standard of 0.156 kg/a.d. metric tons unbleached pulp.

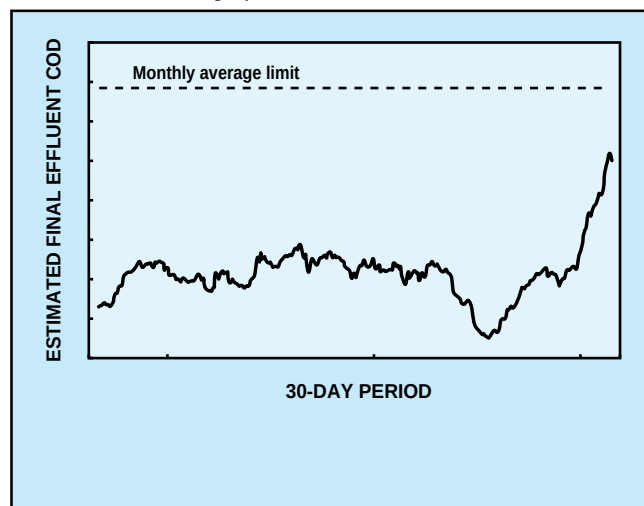
Figure 4 shows the results of a similar analysis for a mill producing both bleached softwood and hardwood. However, the long-term average needs to be factored into a Monte Carlo

*NCASI, "Regression Models to Estimate Adsorbable Organic Halide (AOX) Levels in Bleached Kraft Mill Wastewaters," Technical Bulletin No. 654, October 1993.

7. BOD reduction breakdown



8. Final effluent COD projection: unbleached kraft mill



simulation to determine the compliance with daily maximum and monthly average limits. The Monte Carlo simulation uses:

- A range of anticipated secondary influent AOX values on a kg/metric ton basis.
- A year's worth of mill production data (which can be factored to higher future production levels, if necessary).

From the data generated, a cumulative frequency distribution can then be developed to determine the amount of the data that is below any given AOX value. Thus, the degree of compliance with varying AOX values can be determined. Figure 5 shows a 30-day rolling average plot of the computer simulation of the AOX values for the above atmospheric and pressurized oxygen delignification cases for the bleached kraft hardwood and softwood mill. Although the long-term average for the atmospheric oxygen delignification (OD) was close to the proposed standard of 0.156 kg/a.d. metric ton, the projected monthly average compliance was poor. On the other hand, the pressurized OD demonstrated excellent compliance with the proposed AOX limits.

The final effluent BOD, COD, TSS, and color can also be projected based on modeling the projected process reductions and wastewater treatment removals for each. All of these tend to follow the same trend as the AOX—with spent pulping liquor losses also impacting the COD, color, and BOD compliance and high flows impacting TSS compliance. The spent pulping liquor losses are minimized with implementation of the best management practices (BMP) plan.

Figure 6 illustrates a BOD simulation run after implementation of the AOX controls (i.e., pressurized OD followed by 100% ClO_2 substitution), implementation of the BMP plan, and installation of a steam stripper on the pulp mill wastewater.

Figure 7 shows a typical breakdown of the influent BOD reductions. The COD compliance follows the same general pattern as for BOD with the northern mills realizing lower

secondary treatment COD removals (25–30%) than the southern mills (70–80%).

The projected TSS compliance tracked well with the BOD compliance for the southern mills. However, for several of the northern mills, either in-plant flow reductions or further clarification was required to comply with the projected TSS limits.

The bleach plant organic chemical compliance requirements were projected to be achieved by 100% ClO_2 substitution.

Unbleached kraft mills

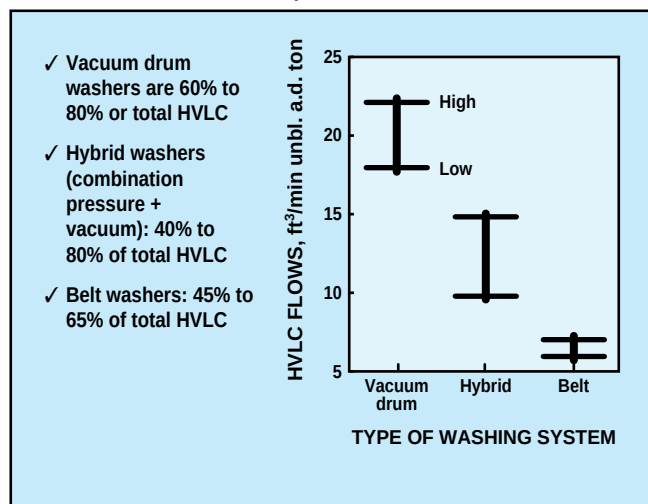
The key parameter for unbleached kraft mills is COD. The implementation of the BMP plan and installation of a steam stripper have been found to move the mill into a significant compliance situation with COD, as is illustrated in Fig. 8. The BOD and TSS requirements for the unbleached kraft mills track the COD requirements.

BMP implementation

The BMP plan implementation at unbleached and bleached mills has the following common characteristics:

- Pulp mill spill containment system (including sumps and equipment for fiber recovery)
- Evaporator and recovery boiler area spill containment system (including sumps)
- Automatic diversion of dirty evaporator condensate to spill collection system
- Shoring up diking and adding diversion walls around existing liquor/filtrate tanks
- Additional weak liquor storage capacity to accommodate reclaimed spills
- Increased evaporator capacity

9. HVLC NCG volumes at study mills



- Additional spill storage of between 750,000 and one million gallons per 1000 air dried unbleached tons.

Air pollution control needs

The air pollution control needs are split between process and combustion sources. The process source requirements have been formally proposed by EPA, while the combustion source limits have only been informally proposed.

The process sources consist of NCG controls, pulp mill wastewater treatment, and bleach plant vent scrubbing (bleached kraft mills only). The combustion sources consist of HCl scrubbing of recovery boiler flue gases, and BLOX controls.

NCG controls

NCGs take two forms: HVLC (e.g., liquor tank and wash hood vents) and LVHC (e.g., evaporator and digester vents). The Cluster Rule proposed treatment requirements for NCGs are as follows:

1. Reduce total HAP emissions by at least 98% by weight, or, if an incinerator is used, reduce total HAP emissions by at least 98% by weight, or, meet an outlet concentration of 20 ppm by volume of total HAP
2. Route all emission point gas streams to an incinerator designed and operated at a minimum residence time of 0.75 seconds and at a temperature above 1600°F
3. Route all emission point gas streams to a boiler, lime kiln, or recovery furnace, which introduces all emission point gas streams with the primary fuel or into the flame zone.

The major concerns with the NCG system are installing properly sized condensers, brownstock washer hood selection, and selection of incineration source—ideal LVHC: lime kiln/ideal HVLC: bark boiler.

10. Proposed Cluster Rule particulate limits

	Existing	New
Recovery boiler	0.044 gr/dsft ³	0.01 gr/dsft ³
Lime kiln	0.02 gr/dsft ³	0.01 gr/dsft ³
Smelt tank	0.12 lb/ton	0.12 lb/ton

Note: Smelt tank basis: per ton of black liquor solids.

The HVLC system cost is driven by duct size and length. By properly sizing the condenser(s), the minimum economical duct size can be determined for the gas streams collected.

The total volume of the HVLC system is driven by the brownstock washer filtrate tank and hood emissions. The NCG volumes from the brownstock washers and their filtrate tanks vary as follows:

- Vacuum drum washers: 1500–4000 ft³/min per washer
- Pressure washer: 600–1000 ft³/min per washer
- Belt washer: 4000–6000 ft³/min per system.

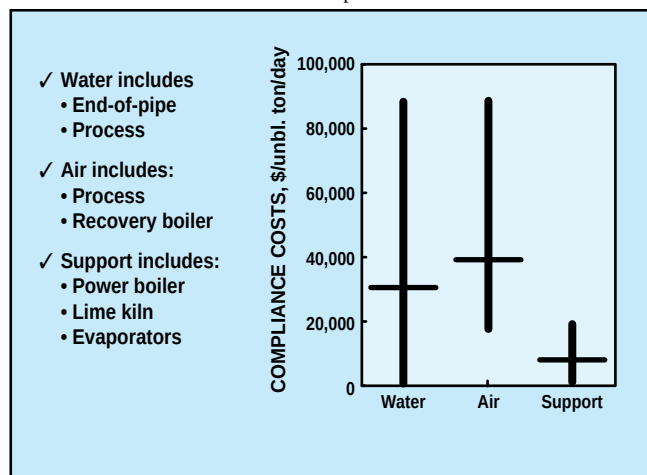
The use of pressure washers or belt washers is one way to reduce the size of the HVLC system. Figure 9 illustrates the range of estimated HVLC volumes realized at the study mills. The LVHC systems at most of the mills were adequate or required only minor modifications to comply with the proposed Cluster Rule.

The choice of the primary and backup destruction devices for the NCGs has run the gamut from lime kilns to power boilers to dedicated incinerators. Ideally from an air pollution control viewpoint, the lime kiln is best able to treat the LVHC NCGs for both destruction of methanol and removal of sulfur dioxide. The power boilers are generally the best choice as a backup device. The HVLC NCGs are best handled in a bark or multi-fuel boiler with the bark effectively treating the low sulfur dioxide levels generated in the destruction of the HVLC. If the mill has multiple power boilers, these can back up each other. Other choices are dedicated incinerators and recovery boilers (least favored choice).

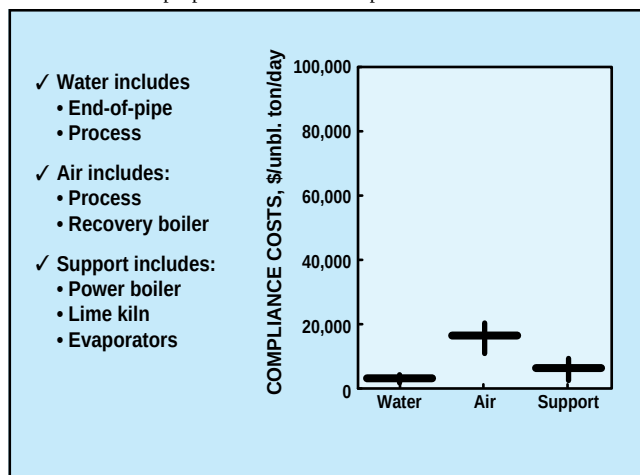
Pulp mill process wastewater

The pulp mill process wastewater consists of the following streams: foul condensates from multiple effect evaporates, turpentine condensers, NCG system condensates, and blow heat recovery system condensates.

11. Bleached kraft Cluster Rule compliance costs



12. Unbleached pulp Cluster Rule compliance costs



The wastewater is to be treated to remove >90% of the HAPs contained in the system. The current proposed minimum HAP level is 500 ppm-volume basis (ppmv), with some considerations given to increasing that to 1000 to 3000 ppmv. The recommended treatment technology is steam stripping and thermal destruction of the stripper off-gases (SOG) in the same device that is generally used for the LVHC NCGs. Alternatives to steam stripping that can be considered are:

- Transport the wastewater streams above the minimum level using an enclosed pipe ("hard pipe") to the wastewater treatment system. The wastewater treatment system should be able to remove >90% methanol from these streams.
- Transport the wastewater streams above the minimum level using an enclosed ("hard pipe") to be re-used in enclosed processes (i.e., the wastewater streams can be returned via a hard pipe to a process application that is completely enclosed or that vents to an incineration device).

The volume of pulp mill process wastewaters to treat varied. Pressurized steam strippers were recommended with a flux condenser used to recover the excess heat from the stripper. The recovered heat is used to supplement the steam feed to the evaporators.

The feed steam requirements for the stripper are 20% of the mass rate of the pulp mill wastewaters treated. Approximately 85% of the steam to the stripper can be recovered.

Bleach plant vent scrubbers

The proposed rule for bleach plants requires vent gas streams from the bleaching process above the minimum level to be treated to remove >99% of the HAPs present in the gases. Since the minimum level is relatively low (HAP flow of 0.23 kg/h or 0.001 kg HAP/mega gram of air dry pulp), essentially all the vent gases from the bleach plant would need to be controlled.

The air pollutants present in the bleach plant gases are volatile organic compounds (of which methanol is the pre-

dominant constituent), chlorine (Cl_2), and chlorine dioxide (ClO_2). Of these compounds, Cl_2 and methanol are defined by EPA to be HAPs. Several states also require the removal of Cl_2 and ClO_2 .

Cl_2 and ClO_2 can be scrubbed at >99% efficiency using caustic, weak wash, or white liquor in an appropriately designed packed scrubber. A scrubber designed for >99% Cl_2/ClO_2 removal can typically remove only 50–60% of the methanol by condensation. Therefore, to remove >99% of the methanol, alternate pollution control technologies must be considered.

EPA has specified the use of Cl_2/ClO_2 scrubbers as the floor technology for removing HAPs from bleach plant vent gases. EPA had rejected other technologies (such as incineration) as the floor, since these technologies were evaluated by EPA to be prohibitively expensive. EPA had assumed that high efficiency Cl_2/ClO_2 scrubbers would also achieve >99% methanol removal. At the time of the proposal, EPA was not aware that these scrubbers could not remove methanol at >99%. Therefore, the technology deemed by EPA to be the floor would not meet the removal requirement for methanol.

The American Forest & Paper Association (AF&PA) has submitted comments to the EPA requesting a reduction in the removal requirements for methanol. It is possible that EPA may provide this reduction, since EPA has acknowledged that alternate technologies (such as incineration) are too costly. However, this issue has not been completely resolved.

In conclusion, to meet the requirements of the proposed Cluster Rule, a high efficiency packed bed scrubber that removes >99% of the Cl_2 and ClO_2 is required. These scrubbers will not achieve high methanol removal efficiencies. If EPA requires >99% methanol removal, alternate technologies (such as incineration or the addition of a chilled water scrubbing state) may be required. However, no separate methanol treatment was investigated for any of the mills studied.

Sulfur dioxide controls

Another concern is the treatment of SO₂ formed from the combustion of the HVLC, LVHC, and SOG NCGs. The SO₂ generated will range from 0.25lb sulfur (S) per a.d. ton of pulp for the HVLC gases to 4 lb S per a.d. ton of pulp for the SOG gases. This means that under uncontrolled conditions the SO₂ generated would far exceed the 40 tons/year, which would trigger Prevention of Significant Deterioration (PSD) review. To avoid this, the mill would need to install SO₂ controls on the NCG destruction device. However, the current discussions between the AF&PA and EPA indicate that the 40-tons/year limit may be waived for the installation of the Cluster Rule-mandated NCG collection and destruction systems. Rust suspects that some proof will need to be supplied to show that ambient SO₂ standards will not be exceeded by the additional SO₂ emissions.

The SO₂ issue is mitigated if the LVHC and SOG NCGs are treated in the lime kiln and the HVLC is treated in a bark/wood-fired boiler. The chief concern with this approach is the amount of time the backup thermal destruction device will be on line and whether it has SO₂ controls.

Reduced particulate limits

Figure 10 presents the preliminary limits proposed by the EPA for the particulate loadings from process combustion sources. To meet these standards, Rust has generally recommended a dry bottom precipitator for the recovery boilers and a precipitator for the lime kiln. For most of the cases, Rust does not believe a wet bottom precipitator for the recovery boilers and a wet scrubber for the lime kiln will consistently meet the proposed standards.

HCl scrubbers on recovery boilers

HCl scrubbers probably will be required on new sources and existing direct contact evaporator recovery boilers. The requirements for the HCl scrubber is either 99% removal or 5 ppm in the controlled flue gas. Also, a low-odor conversion of the recovery boiler eliminates the need for HCl scrubbing.

Black liquor oxidation controls

The black liquor oxidation vent gases may need to be treated for methanol. Thus, these would need to be included in the HVLC NCG system. This would significantly increase the size of the HVLC NCG system and would either mean conversion to an oxygen versus air system or elimination of black liquor oxidation by a low-odor conversion of the recovery boiler.

Support area impacts

The implementation of the BMP plan and potential increased brownstock washing requirements may result in more evaporation capacity being required. The brownstock washing improvements result from the need to close the screen room (a requirement of the Cluster Rule), or from the need for cleaner pulp entering either bleach plant or the OD stage.

The recovery boiler may be affected by tighter controls and increased solids burning requirements from the addition of spill control, screen room closure, and OD. The tight controls include more stringent particulate requirements and HCl scrubbing for direct contact evaporator recovery boilers. Additionally, a low-odor conversion may be required either when the Cluster Rule is finalized or just to handle the increased solids loading to the recovery boiler.

The lime kiln is impacted from the previously mentioned tighter particulate controls, and the fact that more NCGs may be incinerated in it.

Modifications may be necessary to handle the additional steam loads from steam stripping and increased evaporation. Also, if SO₂ controls are required, and if the NCGs are primarily incinerated in the power boiler, SO₂ scrubbers would need to be added to the power boilers.

Compliance cost history

Figure 11 summarizes the Cluster Rule compliance costs for the bleached kraft mills studies. The process costs represented 93% of the total water compliance area costs. The recovery boiler modifications accounted for 60% of the air compliance costs.

Figure 12 illustrates the Cluster Rule compliance costs for the unbleached chemical pulp mills studies. The process costs represented 97% of the total water compliance costs. The recovery boiler expenditures were 38% of the air compliance cost totals.

Conclusion

The following are the key points from the Cluster Rule impact assessment studies:

- Data analysis can pinpoint operating abnormalities and differences with other mills, thus helping prioritize the pollution control efforts.
- AOX control is the driving force for the bleach kraft mills' compliance with the Cluster Rule additional wastewater requirements.
- Minimizing liquor discharges to the sewer is of primary importance to the unbleached kraft mills and second only to AOX for the bleached kraft mills.
- The key to minimizing the cost of an HVLC system is in properly sizing the condensers and choosing the tightest washer hood possible.
- The additional control for the recovery boilers offer the most uncertainties and thus the greatest potential for high costs. 

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