Economic benefits achieved from an odor reduction project

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ABSTRACT: Environmental regulations are requiring industrial facilities to commit scarce capital reserves for abatement systems in order to stay in business. Mills seldom evaluate projects to achieve environmental guidelines economically; instead, they are typically considered as "the cost of doing business." However, these projects can present an opportunity for achieving an economic benefit. Significant returns are often available, especially if the return is based on incremental capital only for doing the job right.

This paper presents the results achieved from a CAD 9 million (about US$ 5.76 million) environmentally justified project to reduce ambient TRS levels in the vicinity of Abitibi-Consolidated's kraft mill in Fort Frances, Ontario, Canada. The project, which was to have a net increase in operating costs, has in fact shown a significant savings on top of the anticipated reduction in ambient odor levels. The project, start-up, and benefits obtained are presented.

Application: Mills may use these findings to enhance similar environmental projects and obtain an improvement in mill operations.

Abitibi-Consolidated Inc. operates an integrated bleached kraft pulp mill with its paper operations in Fort Frances, Ontario, Canada. The kraft mill produces about 545 air-dried metric tons/day of bleached kraft pulp using seven batch digesters and an elemental chlorine free (ECF) bleach plant. The operation is located in the center of a highly populated area with the town of Fort Frances on three boundaries and the community of International Falls, Minnesota, USA, across the Rainy River to the south (**Fig. 1**).

In the early 1980s, the mill commissioned a concentrated noncondensible gas (CNCG) or low volume high concentration gases (LVHC) collection system with incineration in the kiln. In the late 1980s, the mill installed a foul condensate stripper, integrated with the evaporator train, to reduce odor emissions from the effluent treatment lagoon, which is located at the town boundaries across the street from a populated area. The proposed mode of operation was BOD reduction and the stripper off-gas (SOG) was incinerated in the lime kiln. This mode of operation (BOD) resulted in stripping high levels of methanol as well as TRS gasses. After a few months of operation, an explosion damaged the stripper feed tank and the mill shut down the system. In the mid-1990s, an extensively modified stripping system restarted. It included a sophisticated control system and improved safety features. The system operated for a few months with minor vents of SOG due to kiln reliability and control issues. A major system upset occurred when a kiln flame failure coincided with a reflux condenser level instrument failure that resulted in a complete purge of the stripper and reflux condenser to the environment. The system was again retired from service until the autumn of 1999 when the project discussed in this paper returned the foul condensate stripper to service.



1. A view of Abitibi-Consolidated's kraft pulp mill in Fort Frances, Ontario, Canada.

In 1995, the Ontario Ministry of Environment and Energy (OMOEE) requested that the mill provide a plan to reduce ambient odor levels. The mill formed a team to quantify and qualify emissions. The team concluded that the mill would need to reduce lagoon emissions to improve ambient odor. The team estimated that half the odor from the lagoon was due to foul condensate and the other half was due to organic decomposition. This dictated that the stripper would need to be modified to function reliably and a reliable method of incineration was required to treat existing CNCG odorous emissions and the future SOG produced. The mill retained NLK Consultants Inc. to assist the team in analyzing mill processes and prepare a construction budget. During this period, the team identified opportunities to enhance mill operations that would affect releases and abatement system cost and performance. Mill project management kept the team focused, and only those items that had a suitable return and could be directly related to ambient odor would be included in the project scope.

Project description

The project involved tall oil plant scrubbing and blow heat recovery system upgrades; evaporator, steam stripper, and foul condensate collection modifications; and a new incinerator and scrubber installation to handle both CNCG and SOG streams. The existing collection systems for incineration of CNCG and SOG

in the lime kiln were upgraded to serve as a backup for the new incinerator and scrubber installation.

NCG and foul condensate stripping systems require effective controls and logic to enhance operation and safety. These systems are auxiliaries to production processes and require additional instrumentation to enable trouble shooting and a degree of redundancy to ensure safe operation.

As with most environmental projects, Abitibi-Consolidated originally justified this project on the merits of meeting government imposed environmental guidelines. However, the approach taken by the team was to meet these guidelines while obtaining economic returns on process modifications, wherever possible. This involved not only minimizing process waste flows, but also enhancing by-product and waste heat recovery.

The project was very successful from an environmental standpoint. It also provided considerable savings to the mill. Benchmarking was performed before and after the project in areas where the effects would most likely be felt. The results show quantifiable savings that other mills may use to enhance similar environmental projects to obtain an improvement in mill operations.

TEAM / RESOURCES

A team was formed at the beginning of the project from mill engineering, maintenance, and operations staff (hourly and salaried), as well as outside consulting and engineering firms. External participants included the following companies:

- Paul Wentzell Associates Inc. provided controls design and distributed control system (DCS) configuration
- NLK Consultants provided system design, process and mechanical engineering
- Fransen Engineering provided electrical & instrumentation engineering
- KGS Engineering did structural engineering
- A.H. Lundberg supplied the incinerator and scrubber.

This team followed the project from concept to commissioning.

The project was considered from a process point of view and used HAZOP procedures. The team reviewed each stage of the project development to ensure that the resulting system could be operated safely with respect to people, equipment, maintenance, and the environment. This team also established a plan and protocol to integrate the new equipment with the existing operation effectively.

All kraft mill personnel received extensive training to enable an efficient and safe start-up and to ensure subsequent reliable operation of the system. Training included knowledge of all component gases of total reduced sulfur and related safety procedures. Personal protection, lockouts, alarms and response, routine maintenance, process isolation, and purging procedures (to incineration) were an integral part to the training. The team developed standard operating procedures (SOPs), troubleshooting guides, a preventative maintenance program, and a TRS manual, which were used in the training program. All operating and maintenance personnel received process and control training. Operators also received specialized training on a process emulator before start-up. The process emulator was configured in the actual project control equipment alongside the control strategies, and provided a process response for any given operator action. Although primarily used for operator training, the emulator also allowed evaluation of control strategies in a controlled environment before commissioning. The process emulator was considered an essential factor in the success of the project.

Solutions

The obvious problem that initiated the project was that excessive odor—total reduced sulfur (TRS)—was being released to the environment. The sources of the environmental excursions were identified as operational and maintenance related.

Tall oil plant scrubber

The tall oil plant had a packed bed scrubber using caustic to capture reactor emissions. Spent scrubbing solution was used to neutralize a batch before being pumped to the weak black liquor system. Control was manual and a common pump was used for wetting the packing and transferring the spent scrubbing solution. Stack testing revealed that TRS emissions were excessive during the initial stages of batch neutralization. Subsequent investigations showed that packing wetting was lost during the transfer of spent scrubbing solution for batch neutralization and much of the previously captured TRS in the spent solution was lost to atmosphere.

Performing the initial neutralization with fresh caustic, and subsequently raising the pH of the batch with a spent solution significantly reduced this discharge. The project provided an independent pump for increased scrubbing flow, improved scrubbing system controls, and increased instrumentation including solution recycle flow, pH, temperature and scrubber pressure drop. Subsequent testing has confirmed that this source of fugitive emissions has been eliminated and operations have adequate monitoring instrumentation to troubleshoot the system and schedule appropriate maintenance.

Blow heat recovery upgrade

The limited capacity of the blow heat recovery system led to frequent overpressurizing of the system. Safety vents would open as a result, allowing gases to be released to the environment. This venting caused numerous H_2S alarms in the plant and was causing serious safety related issues with all mill employees.

An audit of the blow heat recovery system showed that the heat removal capacity was inadequate and caused the following operating problems:

- Digester foul condensate volumes were excessive, far above values the existing steam stripping system could handle.
- During a blow, the hot water tank was often overflowing and temperatures were only moderate.
- The cold interface was driven to the top of accumulator between blows and the hot water tank that only has a 3 min retention time rapidly cooled.
- The hot water tank temperature was highly variable and when the tank cooled, blowbacks would occur in the chutes feeding bleach plant mixers.

Before the upgrade, the inefficient practices of adding cold water at strategic points and sewering hot water were

necessary to avoid fugitive emissions from the overloaded system.

This project increased the heat capacity of the system by adding indirect heat exchanger capacity, providing a pump to supply the secondary jet condenser with cooled foul condensate, and adding a new indirect tertiary condenser. Turpentine recovery was also included in the blowheat/recovery scope for both economic and safety protocols for the condensate stripping process. Controls were upgraded and a novel device—a 12 m averaging resistance temperature device (RTD)—was installed under the insulation on the surface of the accumulator tank to track the hot/cold interface. The increased heat capacity, improved controls, and the latter device have enabled the operators to effectively manage the accumulator interface level. This has greatly reduced hot water tank temperature drops and overflows and provides continuous hot water for mill operations.

Condensate stripper

The existing condensate stripper had been out of service for a number of years. The team decided to upgrade the stripper and return it to operation to remove total reduced sulfur (TRS) contaminants from the mill foul condensates prior to release to the aerated stabilization basin.

The original condensate stripper was integrated with the mill weak black liquor five-effect evaporators. The liquor flows 4-5-3-2-1 and the reflux condenser was used to pre-heat liquor from the fifth effect as it was transferred to the third. Discussions with operations indicated that evaporator train upsets caused severe stripper upsets and vice versa. To simplify control, the team decided to separate the two systems. The existing reflux condenser was incorporated in the evaporator train as an external liquor preheater. The net result from the upgrade is that less warm water is generated at equivalent evaporation rates, which has reduced warm water tank overflow rates and maintained evaporator efficiencies.

Modifications to the stripper included a new reflux condenser (to produce hot water from warm), a product condenser, and improved controls. The stripper was modified to operate in TRS mode to reduce steam consumption and to increase stripper foul condensate processing capacity. This mode of operation, as opposed to BOD mode, allows for efficient stripping of TRS gases, but reduces the amount of methanol volatization. Provision was added to make up the stripper feed tank level with 5th effect condensate. This condensate is not highly odorous, but has an elevated methanol content. This enables a constant feed rate to the column. Should the evaporators be down, provision was also made to recycle stripped condensate directly to the feed to maintain appropriate liquid rates. This latter feature has proven useful during upsets when steam is lost to avoid transferring non-stripped condensate to effluent treatment. The constant foul condensate feed with a constant steaming rate helps to stabilize column operation and in turn incineration.

The stripper can be bottled up during SOG collection system upsets or loss of incineration for extended periods with little deterioration in efficiency. This allows the mill to continue stripping condensates for a limited period while the incineration point is re-established. Higher temperature hot water is produced with the new reflux and product condensers, which, in turn, has reduced bleach plant steam consumption. Because the present steam stripper operates in TRS mode (about 10% steam), recovery area steam usage did not increase.

Because the previous system had two serious events, many of the operators felt the new system was doomed to failure. However, operator training, simplification of controls, and more than two years of trouble-free operation have satisfied even the most critical that the system is easy to operate and trouble free.

CNCG/SOG incineration

An investigation of the CNCG incineration system at the kiln showed that frequent blowbacks resulted from the rapidly varying fuel rates during a blow and a severe hot-end dust problem in the operating area was evident. Refractory maintenance costs were high and the poor flame stability while incinerating CNCG was believed to be the main cause of short refractory life. Additionally, the lime kiln was considered to be the major mill production bottleneck.

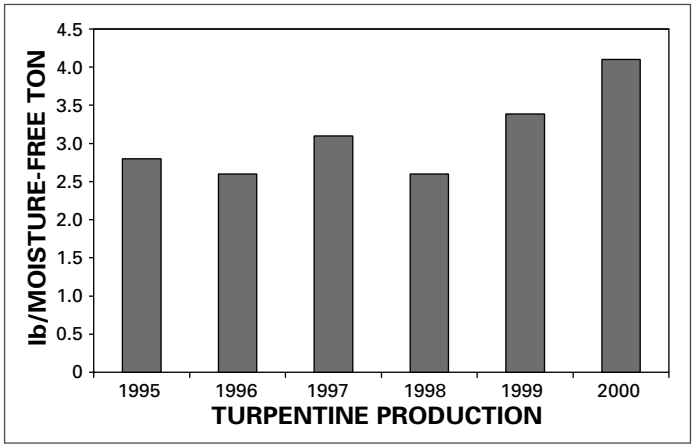
To improve operations in this area, the team felt it essential that an alternate point of incineration be provided for TRS treatment, especially if SOG also was to be handled. One reason that the condensate stripper was out of commission is that the only place the SOG could be burned was in the lime kiln. If the kiln was not operating, some of the gases had to be released to the environment. A second, more reliable place to burn the stripper off-gases was required. Because the mill does not have a suitable power boiler and the Black Liquor Recovery Committee (BLRBRAC) did not favor incineration in the recovery boiler at the time, a stand alone incinerator with SO_2 scrubber was considered the best approach.

To minimize the requirement for the kiln to serve as a backup incineration point, the design criteria were developed that would maximize incinerator uptime and reduce associated operating and maintenance costs.

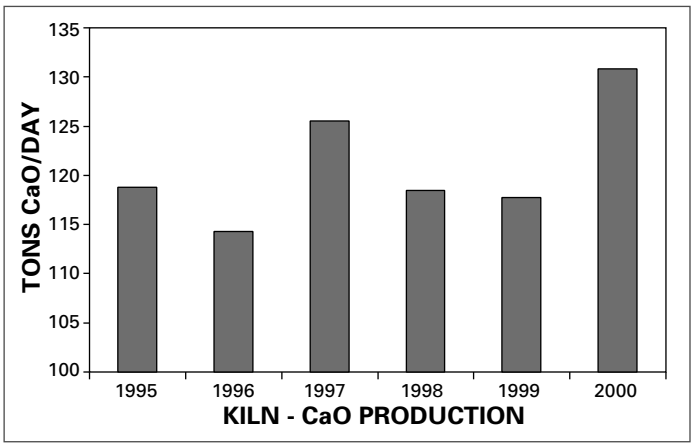
The incinerator and scrubber were installed on the upper floors of the recovery building, above the boiler induced draft (ID) fan. Because the incinerator and scrubber were located in a building extension, a unique design was possible. The incinerator combustion chamber was located above the quench so the exit gases could be discharged directly down, eliminating the need for a mitered refractory loop. A metallic quench and installed spare pump for scrubber and quench recycle were provided.

A key feature was triple redundancy for key control parameters. Three flame scanners, three incinerator temperature probes, and three quench outlet temperature transmitters were installed. Where redundant measurements are used, the process variable is calculated using some function of these three readings. An algorithm in the DCS can remove faulty signals from being included in the function and flag those signals for maintenance.

The new reflux condenser was located at the incinerator level to eliminate the need to pump reflux. The SOG firing train was located above the incinerator. Short lines eliminated the need to heat trace SOG lines. The associated moisture separator and flame arrester were rated for low pressure steam so no low pressure relief was required. A 60 psi(g) burst disc was provided at the incinerator should a flash back occur. The SOG collection system has no vent.



2. Turpentine production at Fort Frances.



3. Pebble lime production.

To minimize the use of prime natural gas fuel, the team specified a burner with a 20-to-1 turndown. The final design had major and minor air and natural gas controls to effectively meet the high turndown. At present, the average incinerator fuel usage is less than 10% of peak rating (less than 10 cfm of natural gas). The extra controls to effectively control low air/gas rates have proven to be justified.

The stand-alone incinerator is highly reliable. In fact, only once since start-up has CNCG been burned in the lime kiln due to operational problems (ejector steam flow instrument error). Monthly short-term transfers are performed to ensure the operators can effectively transfer gases should the need occur.

DISCUSSION OF RESULTS:

Tall oil plant

H_2S excursions during boil-outs have been negligible since the modification of the tall oil plant scrubber operation. The new alarms and upgraded instrumentation have allowed operations to dictate maintenance requirements before problems arise. This source of odor complaints has been eliminated.

Blow heat recovery

Improved control of digester blow gases has reduced pressure spikes in the CNCG collection header, which vented odorous gases within and outside the mill. The control strategy revision to the accumulator had a major impact on reducing in-plant hydrogen sulfide (H_2S) alarms by 97.0%. High-pressure CNCG vents to the mill recovery stack have been eliminated since the upgrade.

The elimination of raw water to the accumulator has enabled complete stripping of accumulator condensates. As well, the increased heat exchange capacity and improved interface controls have resulted in a substantial increase in hot water availability for the bleach plant. Before the upgrade, hot water availability was approximately 12 hours/day. Since the upgrade this availability is 22-24 h/day depending on blow schedules. Steam use in the bleach plant has been reduced by 70% and bleaching efficiency has improved by approximately 4%.

Another major cost benefit has been the increase in turpentine production (**Fig. 2**). The turpentine yield has increased by 69%. The benefits to the blow heat/recovery processes have resulted in total savings of over CAD 500,000 (US$ 320,000) annually.

CNCG system upgrade

Before the CNCG upgrade, in-plant H_2S alarms (exceedances of the threshold limit value of 10 ppm) averaged 500 per month. After the upgrade, only about 15 alarms occur month. Previously, the high number of exceedances was a significant safety concern as the monitors were going off so frequently that personnel were ignoring the alarms and walking through unsafe areas. Due to intensive training as part the TRS project and the significant reduction in alarms, personnel are no longer ignoring alarms and operators take proper precautions when troubleshooting events.

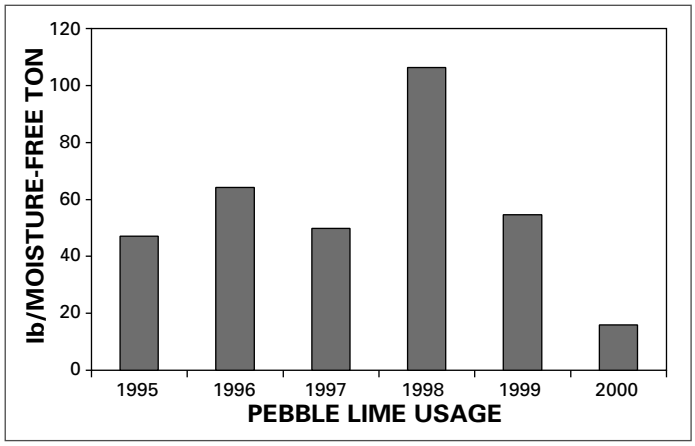
During blows and prior to the CNCG upgrade in 1998, the collection system would bleed off high-pressure spikes to the recovery stack. This meant that the high BTU and highly odorous gases from the digesters were only partially treated in the lime kiln. Once the system was closed, the true effects of the CNCG on the kiln performance became apparent. The reliability of the kiln for the first portion of 1999 was approximately 50%. Kiln combustion controls could not keep up to the varying BTU value of the CNCGs, which resulted in high temperatures and ringing. Twice the kiln was taken down and the refractory replaced. Large amounts of lime mud were sewered and the amount of purchased lime increased substantially. During these events production costs increased dramatically. Extra costs included increased dredging at the mill's primary settling basins and subsequent landfilling costs.

Once the incinerator started up the lime kiln process turned around dramatically. Ringing is now nonexistent and production curtailments due to recaust-related problems have been reduced. The production of CaO and the operability of the lime kiln have increased by 70% and purchased lime requirements are dramatically less (**Figs. 3 and 4**). Improved lime kiln operation has resulted in other benefits such as improved drainage at the mud filter and improved operation of recausticizing. With the reduction of purchased lime, the need for drainage aids has been eliminated. There has also been a decrease in the variability of white liquor strengths and decreased fouling of the pressure filter.

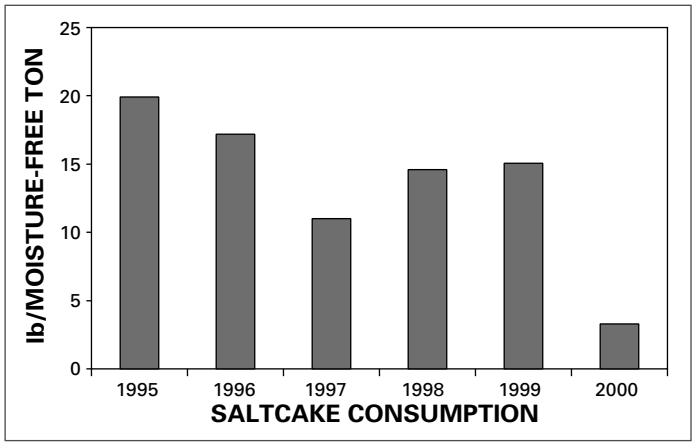
Gas usage at the kiln has increased, but the cost is more than offset with the improved efficiency of the kiln and the other benefits outlined above. All told, the mill has seen a savings in chemical costs of CAD 300,000 (US$ 192,000) annually. The reductions in refractory maintenance and improved uptime are indicating additional savings of CAD 200,000 (US$ 128,000) annually.

Condensate stripper/stripper off gas (SOG) upgrade

The start-up of the modified condensate stripper was essentially the third start-up



4. Kiln CaO use.



5. Saltcake consumption.

for this process. Operator confidence in this process was extremely low due to the difficulties with the initial two start-ups and associated environmental and in-plant gas releases. The system has run trouble-free since start-up with the odd trip related to steam swings due to boiler problems. Uptime on the stripper is >99% and operator confidence in the TRS system is extremely high. There have been no SOG discharges since start-up in mid 1999. The bottle-up design of the system allows for quick start-up after a trip and the stripper area within the plant is odor free.

The mill has found it necessary to caustic wash the column and preheaters three times per year to control fouling within the column. Originally, only one caustic wash per year was planned, but high pressure differentials through the two sets of packing dictated an increased frequency. The mill takes advantage of existing maintenance schedules to eliminate the need for discharging unstripped foul condensates to the secondary treatment facility.

Exceedances of the guideline limit of 27 ppb at the lagoon have been reduced from a high of 180 in 1990 to 54 in 2000. TRS levels are available through an Ontario Ministry of Environment ambient TRS station located approximately 50 ft. due south of the mill's lagoon.

Incinerator/scrubber

The addition of a dedicated incinerator and scrubber was the key to the entire TRS reduction project. It allowed for proper disposal and subsequent recovery of sulfur based gases and as stated prior in this report has allowed the lime kiln to run more efficiently.

Benefits from the installation of the dedicated incinerator/scrubber include an 80% reduction in saltcake addition due to the recovery of sulfur-based salts from the scrubber to the dissolving tank (**Fig. 5**). This has resulted in savings of over CAD 250,000 (US$ 160,000) annually. The mill is currently on a learning curve on when saltcake is required, such as after lengthy maintenance outages. Some saltcake was used in 2000 to eliminate hefty demurrage charges for rail cars on site. It was deemed more cost effective to bleed these cars into the process rather than sending them back to the supplier. The mill is working towards 100% elimination of saltcake makeup, which will eliminate the need to upgrade the saltcake unloading system, as there has not been the need to add saltcake since start-up of the new control facilities. (Note: The saltcake unloading station upgrade was an issue with the Ministry of Environment (MOEE) due to the number of saltcake upsets and spills within this area.)

Again, the stated effects to the lime kiln/recaust areas and the effects on the mill and community would not have been possible without the dedicated incinerator. In fact, the effects of SOG gases on the kiln and the tight CNCG system would have compounded the problems experienced at the kiln and subsequently throughout the rest of the mill.

The incinerator and scrubber have been in use >99.9% of the time, allowing continuous treatment of odorous gases, with no releases to the community. The installation has removed the recaust bottleneck from the process, even at higher pulp production rates.

General results discussion

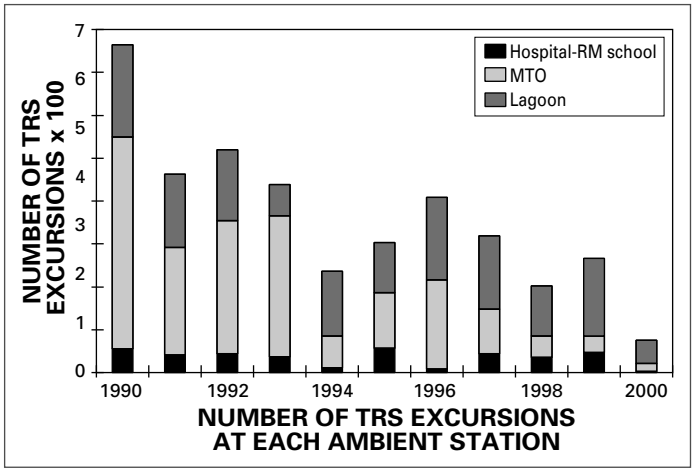
The TRS project team was together for 3 years from initial inception through to commissioning. The involvement of all mill forces and ownership by the mill for it's own process led to the success of this project. The design of the DCS system allows the operators to know and troubleshoot their own processes. The DCS was configured with first out annunciators for all system trips, which has in turn been incorporated into other mill operations. The effects of this project on operations throughout the mill are still being measured. The community was involved through a communication taskforce, which provided project updates and addressed concerns of key stakeholders. These included members of the towns of Fort Frances and International Falls, as well as the medical, health, sportsman's club members, and the public at large. The support from the community became apparent during discussions with these groups. An independent consultant carried out a health and safety report on TRS gases and the results were made available to the public at large. The mill has also recognized that even with the substantial reduction in odors it must continue to close up the sulfur cycles within the mill for the elimination of odorous compounds. Future plans include dilute CNCGs and removal of organic degradation H_2S formation in the mill's primary clarifier and secondary treatment facility.

The OMOEE currently operates three TRS monitoring stations at the mill—one adjacent to the secondary treatment facility, one at about ¼ mile from the mill at Robert Moore School, and one adjacent to the mill property. These monitors have been used to gauge the reduction in TRS exceedances of the 27 ppb OMOEE guideline. The monitors are slightly affected by another kraft mill located in International Falls, Minnesota,

depending on wind and atmospheric conditions. Exceedances of the guideline limit have been reduced from a high of 700 in 1990 to 76 in 2000 (Fig. 6). The vast majority of the exceedances are related to anaerobic H_2S formation at the mills secondary treatment facility. The mill has benchmarked odor complaints prior to the TRS project and a dramatic reduction has occurred since start-up. Complaints dropped from an average of 6.2 per month in 1996 to 0.4 in 2000.

CONCLUSIONS

The mill has estimated the TRS project is providing a yearly return of CAD 1.0-1.5 million (US$ 0.64-0.96 million). This type of project requires ownership by all mill personnel and complete support by mill management to ensure success. TRS emissions involve each and every operation within the plant. Without the understanding and involvement of mill forces in design through to implementation, the end product may not meet the mill's reduction targets. The Fort Frances mill is committed to further improvements in odor and other environmental reductions in future years. The standards set by the TRS project are being felt daily in mill operations and have extended to other projects within the mill. **TJ**



6. Number of TRS excursions at each ambient station.

ACKNOWLEDGEMENTS

We acknowledge the work of the TRS Taskforce Members and Doug Raoul, environmental coordinator for the Fort Frances mill, whose initial perseverance helped ensure project initiation. Bill Osterman, pulp production manager, and Gary Rogozinski, environmental and energy director, as management sponsors deserve special credit for their support and encouragement during the project execution. We also acknowledge the hard work and patience of Wayne Wilton, project manager for the TRS project.

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INSIGHTS FROM THE AUTHORS

We took on this project because the mill had an ongoing problem with odor and public complaints as well as a safety problem with H_2S in-plant. When it was completed, the results were so outstanding that we felt the information should be shared with others in the industry.

The TRS project and subsequent process implementation from design to start-up was developed site specifically for the Fort Frances mill. Previous projects in Fort Frances resulted in generic designs that did not fit well with the existing processes. The new designs incorporated as part of this project would be excellent fits in many other mills as well. The mill is currently studying the collection of dilute odor sources in the kraft mill and concentrating on biological odor control at its paper mill clarifier and secondary treatment facility.

The most difficult aspect of our research was measuring the impact of the project on existing kraft mill operations. We addressed this research through the TRS task force, which enabled us to draw knowledge from a broad cross-section of the kraft mill.

The biggest discovery as part of this project was that you can put in place environmental projects that not only help the environment but also save money. The biggest satisfaction the TRS Task Force had was going back to management and letting them know that the project they approved had in fact resulted in a significant dollar savings and reduced overall costs.

Any mill that is planning an odor reduction project can benefit from the knowledge gained as part of this capital project. Innovation was the name of the game when it came to design and implementation of the TRS project in Fort Frances.

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