

Low sludge yield biofilm activated sludge (BAS) upgrade – Quesnel River Pulp

ANNA RANKIN, MICHAEL VAN AERT, THOMAS WELANDER, AND ÅSA MALMQVIST

ABSTRACT: Quesnel River Pulp (QRP) began operating a low sludge yield biofilm activated sludge (BAS) treatment system at its bleached chemithermomechanical (BCTMP) pulp mill at Quesnel, British Columbia, in March 2005. AnoxKaldnes provided the technology. QRP upgraded the anaerobic/activated sludge treatment (AST) system to allow for both increased production rates, as well as production of higher load grades of pulp. The system increased treatment capacity from 110 tons soluble chemical oxygen demand (SCOD)/day to 140 tons SCOD/day with expansion capacity to 170 tons SCOD/day. In addition, the anaerobic system capable of removing 20 tons SCOD/day could be decommissioned since it had a low tolerance for peroxide and sulfur, and high maintenance and operating costs. Results of the upgrade included:

- 1) meeting all permit limits and effluent is nontoxic to trout under standard test conditions,
- 2) 80%–85% SCOD removal,
- 3) stable and reliable operation,
- 4) sludge yields between 0.12–0.17 net kg total suspended solids (TSS)/kg SCOD removed (compared to previous yields of 0.23 net kg TSS/kg SCOD removed), and
- 5) ~25% decrease in total effluent treatment costs per ton of pulp, despite a 30% increase in power requirements.

Application: The results of this study may interest mills looking for more treatment capacity, lower sludge production, reliability, and efficiency. The BAS low sludge yield process is especially suited to high strength wastewaters that have a wide organic loading range.

Quesnel River Pulp (QRP) ran an anaerobic/activated sludge treatment (AST) system from 1988 to 2005 (**Fig. 1**). The system included preclarification followed by a 6000 m³ pre-acidification tank, two 3000 m³ anaerobic reactors running in parallel followed by a 53,000 m³ AST. A 25.5 m diameter air flotation clarifier removes solids before discharge. Challenges associated with the system included

poor pond biology and final clarification upsets, poor tolerance to peroxide and sulfur, and insufficient treatment capacity for current and future production grades and rates.

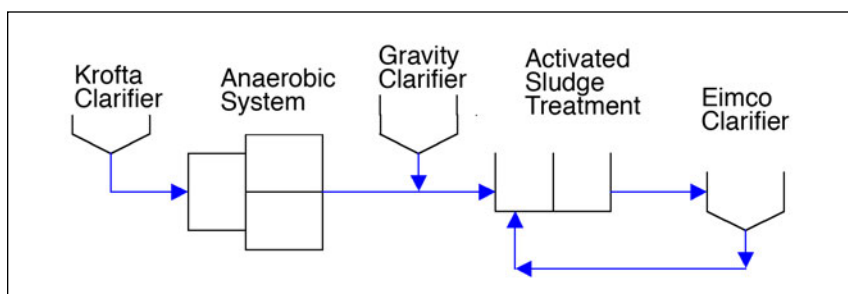
Initial costing was completed for two upgrade options: a) increased AST capacity (**Fig. 2**) vs. b) BAS (**Fig. 3**). Following a tour of a moving bed biofilm reactor (MBBR) and BAS operations in Sweden and a six-month pilot plant operated by

personnel on site, QRP opted to install a full-scale BAS treatment system. Results from the pilot system suggest that a full-scale system with a capacity of 140 tons/day might be constructed. The quality of sludge was very good based on sludge volume index (SVI). Sludge production was reduced 25% to 40%.

On March 15, 2005, the mill started up the BAS system. During the upgrade transition period (January 1 through March 15, 2005), QRP ran full activated sludge (AS) without anaerobic pretreatment. This provided a baseline of data to compare conventional AST full-scale with the anaerobic/AST configuration and the BAS system.

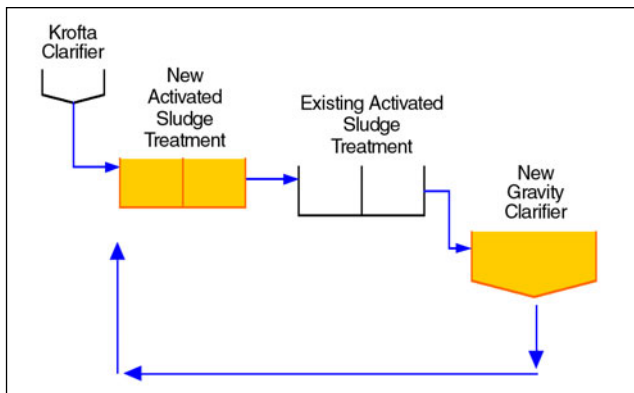
PROCESS

The BAS process is comprised of MBBR pretreatment, followed by conventional AST. The MBBR is a suspended carrier



1. Anaerobic/activated sludge system.

SLUDGE TREATMENT



2. Proposed activated sludge system.

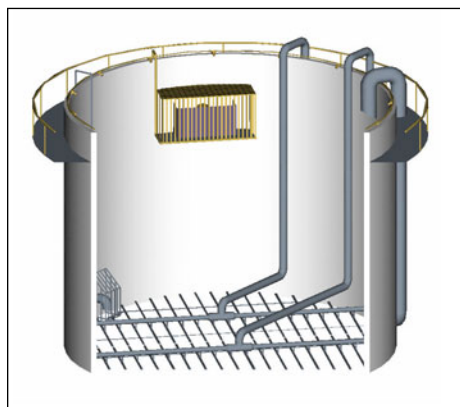
process based on plastic carrier media (**Fig. 5**). Microorganisms growing as a biofilm on the surface of the plastic media in the MBBR decompose organic matter in the wastewater, removing COD, BOD, and toxicity. Excess biomass sloughs off the media and washes out to the AST with partially treated wastewater.

Blowing air provided oxygen through a coarse bubble aeration grid at the bottom of the reactor (**Fig. 4**). Air mixes the reactor contents and keeps the carrier media suspended.

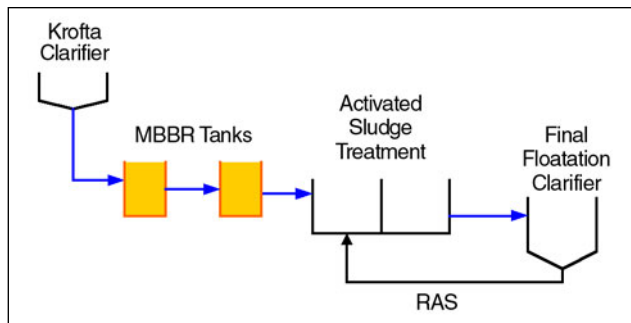
The effect of the two-stage system, where film-forming and dispersed bacteria in the first stage remove the readily biodegradable organics, discourages the growth of filamentous bacteria in the AST, leading to a healthy floc structure. Limiting nutrients in the MBBR causes bacteria to exude polysaccharide slime, which provides easily digestible material for higher life forms to consume in the AST [1].

Installation

Two 3000 m³ tanks with an aeration grid were constructed. Three 800 HP blowers were installed. Tank 1 contained 800 m³ of media and Tank 2 contained 1200 m³ of media. The upgrade also included installation of two cooling tanks before and after the first MBBR. The process used existing tankage to build the spray coolers. Total cost of the upgrade was CAD



4. MBBR cutaway.



3. Biofilm activated sludge (BAS) system.

9.5 million. The daily amount of SCOD that could pass through the designed system was 140 tons/day, at an average flow rate of 11,500 L/min. A phase two upgrade to treat 170 tons/day of SCOD is possible with addition of more MBBR media and AST aeration capacity.

Start-up

The start-up plan used came from pilot plant operation and early successful testing. To start-up the BAS system, the mill partially filled the two MBBR tanks with influent. RAS passed to the MBBR tanks from the AST with applied air. The RAS acted as seed for the system. Target dissolved oxygen level in the MBBR's was >3 mg/l. Nutrient in the form of liquid fertilizer (22.6% nitrogen [N], 4.5% phosphorous [P]) was added to the first MBBR at a ratio of 300:3.0:0.6 SCOD:N:P.

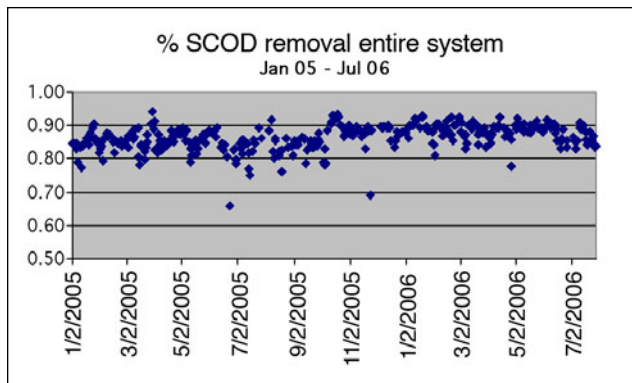
The two tanks accepted a split flow of RAS and the influent. Introducing RAS to the influent helped to limit the residual hydrogen peroxide, which may inhibit the growth of microorganisms. Within two days, a biofilm was visible on the carriers. SCOD removal was up to 25% over both reactors. The RAS flow was then routed to cell 1 of the biobasin.

There was no interruption in effluent treatment during the start-up. SCOD removal remained at >80% and effluent remained nontoxic. With an upper limit of 110 tons/day SCOD placed on loading from the mill, the AST had been treating effluent reliably for two months before start-up. Start-

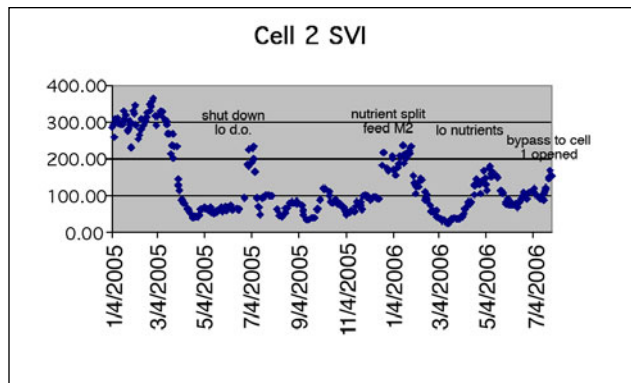


5. Plastic carriers (media) showing biofilm.

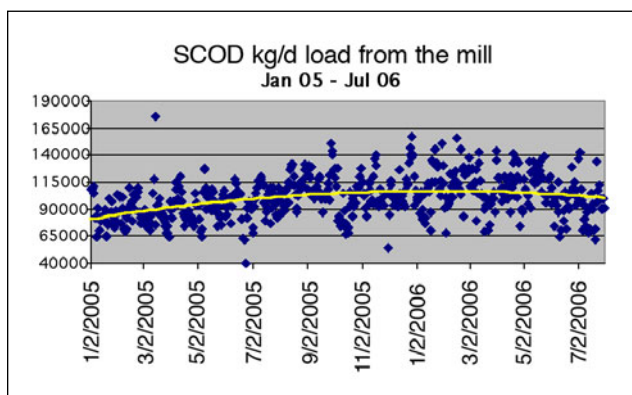
SLUDGE TREATMENT



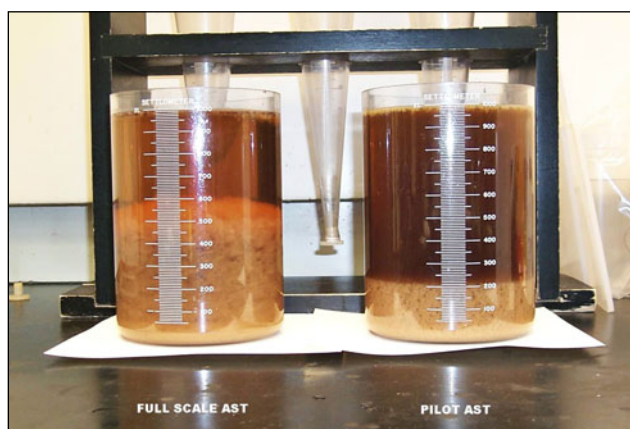
6. SCOD percent removal.



8. Sludge volume index (mL/g).



7. SCOD loading (kg/day).



9. AST settleability vs. BAS settleability.

up of the MBBR tanks immediately added capacity to the treatment system.

A discharge screen failure on the first MBBR tank two weeks after start-up caused the only interruption in treatment. Repairs were undertaken and screens checked on the individual offline tanks. There was no impairment in treatment performance during this time.

Performance

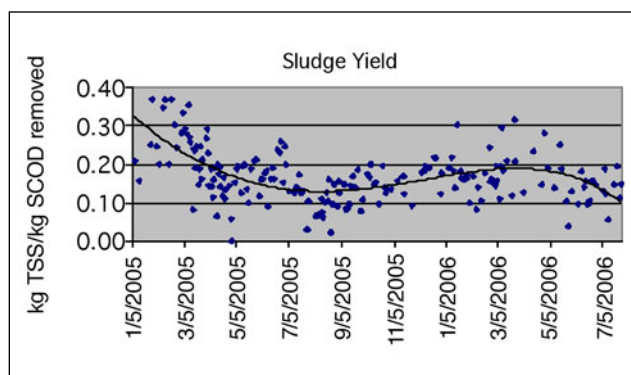
The system capacity increased immediately to the design level. SCOD removal remained at >80% through start-up and subsequently (**Fig. 6**).

Stability

Excellent treatment results demonstrate system stability despite frequent and extreme load swings. **Figure 7** shows loads from the mill varying between 61,000 kg/day to 151,000 kg/day and the steady increase in loading since the upgrade.

Sludge quality

SVI, which measures the degree of settleability of a given amount of sludge in a constant volume, averaged 300 mL/g before startup with and without the anaerobic system (**Fig. 9**) [3]. Within two days of BAS startup, the SVI began to drop



10. Sludge yield before and after start-up—kg net TSS/kg SCOD removed (AST vs. BAS).

(**Fig. 8**). It stabilized at ~70 mL/g within two weeks. A mill shutdown on June 21 caused the SVI to climb, but it quickly recovered once normal operation resumed.

Figure 11 shows dispersed bacterial growth in the MBBR. This material has high polysaccharide slime content due to the low nutrient targets. Microscopic analysis of the AST shows the effect of the two-stage system and the healthy floc structure associated with BAS (**Figs. 12 and 13**).

SLUDGE TREATMENT

	Anaerobic/ AST	Activated Sludge	BAS
Influent Load tons/day SCOD capacity	110	110	140
Flow L/min	14,000	14,000	11,500
SCOD concentration mg/L	5500	5500	6950
SCOD removal %	>80	>80	>80
Sludge yield kg TSS/kg SCOD	0.23	0.28	0.16
Chemicals CAD/admt	6.95	6.52	4.22
power CAD/admt	1.35	1.40	1.89
total costs CAD/admt	8.30	7.92	6.11

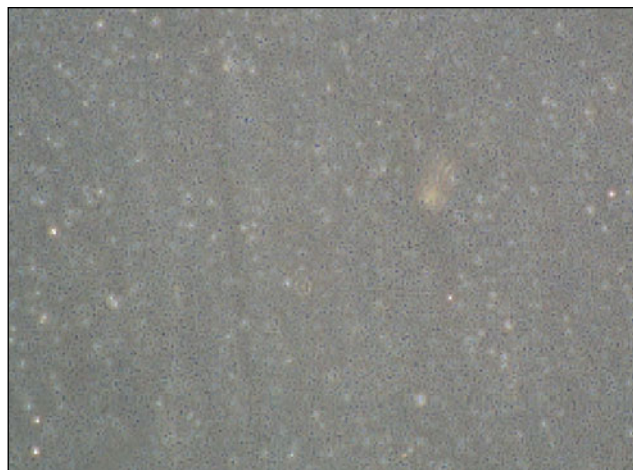
I. Performance and cost comparison of three configurations.

Sludge quantity

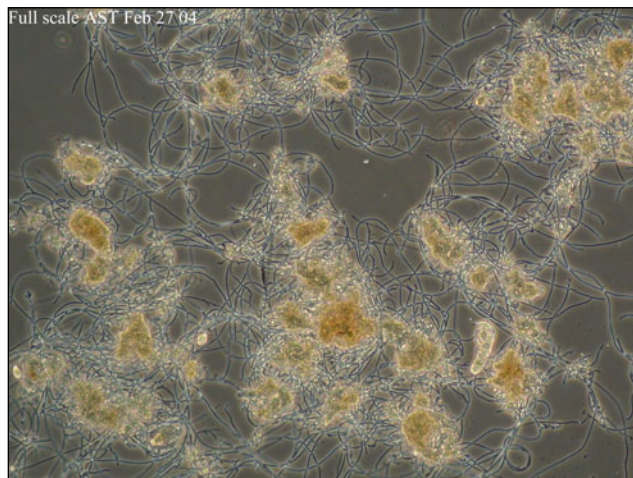
Very quickly after start-up, the sludge yield dropped from 0.28 kg TSS/kg SCOD removed to 0.17 kg TSS/kg SCOD removed, reducing the volume of secondary sludge produced by 11 tons/day on 96,000 kg of SCOD removed (**Fig. 10**). Completed pilot work led to this expected result. The pilot work also indicated that as nutrients are limited further, sludge yield would drop more. During a two-week period during the pilot study, nutrients were added at a SCOD:N:P ratio of 300:2.0:0.6. The sludge yield during this period averaged 0.11 kg TSS/kg SCOD removed. It was possible to reduce the full-scale nutrient ratio gradually to 300:2.3:0.6 around five months after startup. Sludge yield dropped to 0.15 kg TSS/kg SCOD removed. QRP is continuing to optimize nutrients to achieve full SCOD removal and minimum sludge production.

Cost improvements

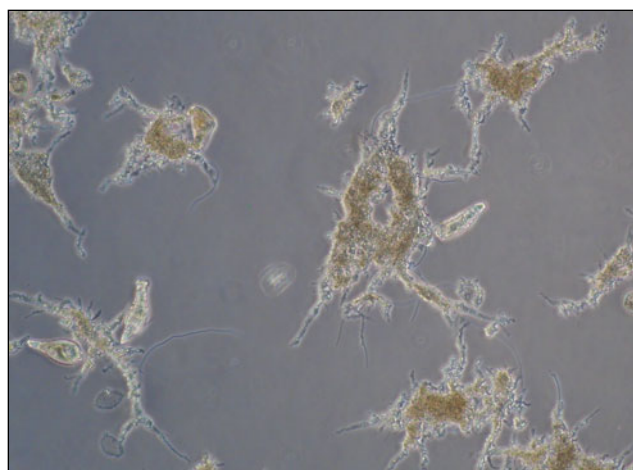
QRP compared the performance and costs of three configurations, before, during, and after the upgrade (**Table I**). Before the upgrade, the anaerobic/AST configuration could treat ~110 tons SCOD/day at a cost of CAD 8.30/air-dried metric ton (ADMT) pulp. The treatment capacity at the mill running AST only during the construction phase of the BAS was optimized to treat 110 tons SCOD/day. As expected, sludge yield during this period increased compared to the anaerobic/AST system. Eliminating caustic used for pH control resulted in a savings of CAD 0.38/ton. The anaerobic system required caustic to buffer the pH after pre-acidification and before the anaerobic reactors.



11. MBBR bacteria stage one of BAS (four h HRT dispersed growth).



12. AST before upgrade (100X).



13. AST after upgrade—stage two of BAS (100X).

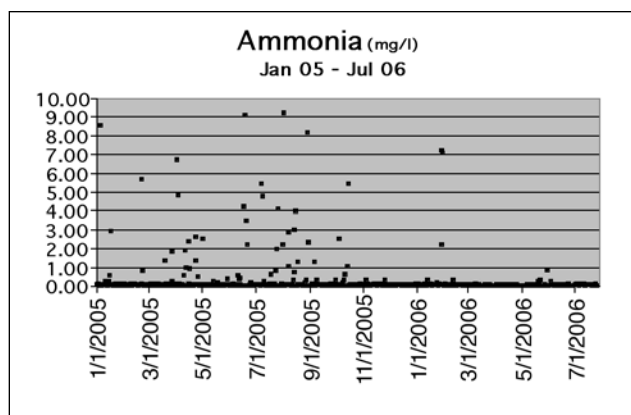
Installation of the spray coolers allowed for elimination of cooling water, causing total flows to drop, but the concentration of SCOD to rise. After start up of the BAS system, treatment capacity rose to 140 tons SCOD/day and costs dropped to CAD 6.11/air-dried metric tons pulp. Limiting nutrients further and optimizing power consumption can lead to additional cost reduction.

Power usage

Before the upgrade, the mill fully employed two 800 horsepower (HP) blowers and 750 HP from three small blowers, which were usually running, for 2350 HP. After the upgrade, average power consumption on MBBR #1 was 680 HP, MBBR #2 was 580 HP, and the pond used 1700 HP, for a total of 2960 HP. The dissolved oxygen (DO) target is 2.2 mg/L $\pm$ 0.4, but DO has averaged almost 3.0 mg/L across the system. There is room to optimize energy consumption.

Ammonia release

As anticipated based on pilot work, there have been challenges with ammonia release full scale (**Fig. 14**). Release of ammonia is a risk in the BAS process due to the high level of endogenous respiration. Endogenous respiration accounts for the reduced sludge production. Ammonia residuals have



14. Ammonia concentration in AST (mg/L).

to remain below 2 mg/L since there is a monthly requirement to pass rainbow trout toxicity tests. Excursions beyond this level happened both before and after the upgrade, but more frequently after the upgrade. Ammonia release frequency has been targeted for reduction by implementing several strategies.

It is possible to reduce the SCOD:N:P target ratio whenever levels of ammonia exceed 1.5 mg/L in the discharge stream. After a series of ammonia excursions in August, the

INSIGHTS FROM THE AUTHORS

Quesnel River Pulp Co. needed more effluent treatment capacity. We looked at conventional activated sludge treatment, but we were very interested in the promise of full treatment with low sludge yield. We looked at AST compared to BAS very carefully. This upgrade differs from other treatment installations in North America because of the small footprint, high SCOD removal capacity, and very low secondary sludge production. It should be of interest to BCTMP mills running AST, that produce low volume, high concentration effluent.

The most difficult aspect of this research was resolving the ammonia release issue because ammonia is toxic to rainbow trout, which is a monthly bioassay requirement. We addressed this by carefully reducing nutrient add rates (which also improves sludge yield) to the point where ammonia is nondetectable. This paper also outlines some other developed strategies.

One of the most interesting aspects of this project was the fact that our engineering consultants knew very little about this technology and were very skeptical about the promise of reduced sludge yield. We worked hard on our own to investigate the process by meeting with AnoxKaldnes reps, then traveling to Sweden to see installations, and finally running our own pilot plant here at the mill. We convinced ourselves that this relatively unknown technology (in North America) would work for us, and it has.



Rankin



Van Aert



Malmqvist

Other mills will benefit from the technology if they require more treatment capacity without additional sludge production. We were able to avoid a dewatering upgrade, even though we increased our SCOD treatment capacity by almost 50%. This process is also very stable and we have eliminated sludge bulking issues and other clarifier problems. Much lower chemical costs offset the additional blower power requirements necessary for endogenous respiration.

Rankin is environmental coordinator and van Aert is technical manager at the Quesnel River Pulp Co., British Columbia, Canada; Welander is associate professor and CEO, and Malmqvist is chemical engineer at AnoxKaldnes; email Rankin at anna.rankin@westfraser.com.

SLUDGE TREATMENT

mill reduced the nutrient ratio to 300:2.8:5 from 300:3.0:0.6 and reduced it again to 300:2.3:0.5 on September 22, 2005. Additionally, when the load from the mill drops suddenly, as happens regularly due to frequent grade changes, the mill directs some of the untreated effluent around the MBBRs directly to the AST. This provides some food for the bacteria, which would otherwise increase the rate of endogenous respiration to provide for their energy requirements. It has also been possible to automate nutrient addition and track loading. When the mill load drops, nutrient addition drops.

SUMMARY

Compared to anaerobic/AST and pure AST the BAS system has outperformed on many fronts. Operation is now sim-

plified, process control is better, capacity is higher, sludge separability is better, sludge yield is 30% lower, and overall costs are 25% lower. The system is very tolerant to interruptions in load caused by grade changes and shutdowns. Improved sludge quality has virtually eliminated final clarifier upsets.

The frequency of ammonia spikes is reduced with the automation of the nutrient add-rate. The dropping of the target SCOD:N:P ratio showed further improvements. Using a bypass option during excursions to use the available ammonia quickly improved the management of high ammonia residual. **TJ**

Submitted: November 1, 2005

Revised: October 24, 2006

Accepted: October 24, 2006

LITERATURE CITED

1. Welander T., Olsson, L.-E., and Fasth C., *TAPPI J.* 1(4): 20(2002).
2. Comeau Y., Petersen B., Stuart P., et. al., *Environ. Sci. Eng.* 104(8): 40(2002).
3. Jenkins D., Richard M.G., and Daigger G.T., *Manual on the Causes and Control of Activated Sludge Bulking and Foaming*, 2nd Edition, Lewis Publishers, London, England, 1993, p 11.

This paper is also published on
www.tappi.org
and summarized in the May
issue of Paper360° magazine.



2007 International Conference on Nanotechnology for the Forest Products Industry

JUNE 13-15, 2007 | KNOXVILLE CONVENTION CENTER
KNOXVILLE, TENNESSEE, USA

Presented by TAPPI and the Forest Products Society



Join peers and experts to explore current state-of-the-art applications as well as the promise of nanotechnology for the future of the forest products industry!

Save the Date!

The 2007 Conference Program Committee is developing a program agenda that will address topics such as:

Health and Safety
Nanofibrillar Cellulose
Self-Assembly/Biomimicry
Nanofibrillar Cellulose
Surface Modification and Characterization
Reinforced and Interfacial Structures
Hierarchical Structures from Lignocelluloses
Nanobiorefinery and Renewable Resources
Nanotechnology Programs and Funding
Nanostructure/Optical, Mechanical, Thermal and Electrical Interactions/Nanosensors
Future Directions
...and much more

For More Info:

For more information, visit www.tappi.org/07NANO.
Or call TAPPI Registration at
1.866.850.0999 or +1.404.760.8177.

