Diagnosing and solving the problem of poor activated-sludge settleability

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ABSTRACT: Effluent quality at a bleached kraft pulp mill was compromised by the combined effects of high summertime temperatures in the aeration basin and the growing load of secondary fiber in the waste stream. The mill solved the problem by increasing the capacity of its wastewater treatment plant.

KEYWORDS: Activated sludge, aeration tanks, effluent treatment, paper mills, problem solving, pulp mills, settling, sludge, suspended solids, temperature, troubleshooting, Virginia.

Chesapeake Corp. owns and operates an integrated bleached kraft mill in West Point, VA. Daily pulp production at the mill is 2500 tons/day, composed of 1500 tons/day virgin pulp and 1000 tons/day secondary fiber. The waste streams from both processes are combined and conveyed to a primary and secondary wastewater treatment system.

Primary treatment consists of gravity settling. The secondary treatment consists of a cooling tower, nutrient and antifoam addition, a pure-oxygen activated-sludge system (UNOX®), and discharge to the Pamunkey River. The activated-sludge system consists of two parallel trains. Each aeration basin is three staged and 15 m wide and 60 m long with a 3.2-m side-water depth. Secondary clarifiers are 39 m in diameter, with a side-water depth of 5 m.

In 1986, the mill started up its 1000-ton/day secondary-fiber plant and shifted one paper machine from virgin pulp to secondary fiber. An additional primary clarifier and air-activated-sludge basin were added to accommodate this production change. Soon after startup of the secondary-fiber plant, it became apparent that poor mixed-liquor settleability was contributing to high biological solids in the effluent. **Figure 1** shows effluent TSS (total suspended solids) from June through August 1987.

Treatability studies were begun in September to determine the cause of the sludge-settleability problem and solve it. Microscopic examination of the sludge revealed that a highly filamentous floc was associated with the poor sludge settleability. Previous efforts to control filamentous growth by chlorinating the return sludge had proved ineffective. Chemical addition also did not adequately enhance sludge settleability. Evaluation of the existing secondary clarification capacity indicated that conditions frequently limited solids flux at the operating MLSS (mixed-liquor suspended solids) concentrations and sludge settleability.

The treatability study was designed to investigate and solve the sludge-settleability problem under both existing and projected production scenarios. At the time of the study, the average daily pulp production from secondary fiber was approximately 500 tons/day, with an estimated future production of 1200 tons/day. The mill also was planning to switch from a three-stage (DC)OD bleaching process to a four-stage O(DC)(EO)D bleaching process. The study took into account the anticipated increase in secondary-fiber pulp production and evaluated performance under both bleaching operations.

The treatability investigation involved segregation of three production waste streams, importation of wastewater to simulate the modified bleaching operation, installation of pilot-scale heat exchangers for cooling and primary clarification, reconstitution of the waste streams, addition of nutrient and anti-foam, and bench-scale secondary biological treatment. The study objectives were accomplished via a two-phase on-site wastewater-treatability investigation. Phase I focused on problem definition. Phase II was carried out to evaluate alternative biological treatment systems and confirm that the recommended systems would be viable under modified bleaching operations. The two-phase approach successfully defined and solved the activated-sludge settleability problems at the mill's wastewater treatment facility under both existing

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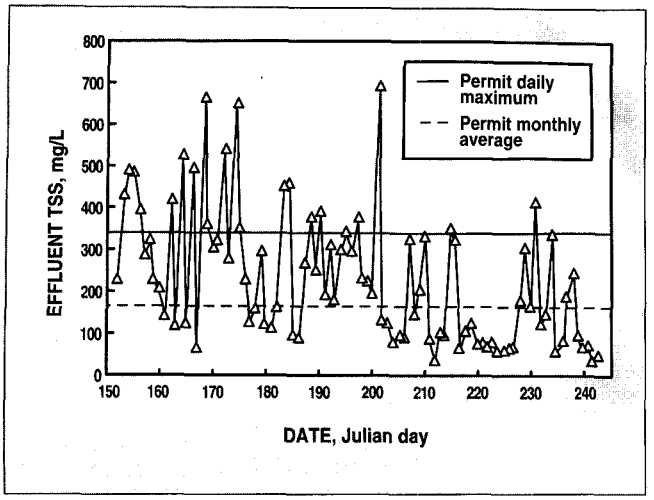
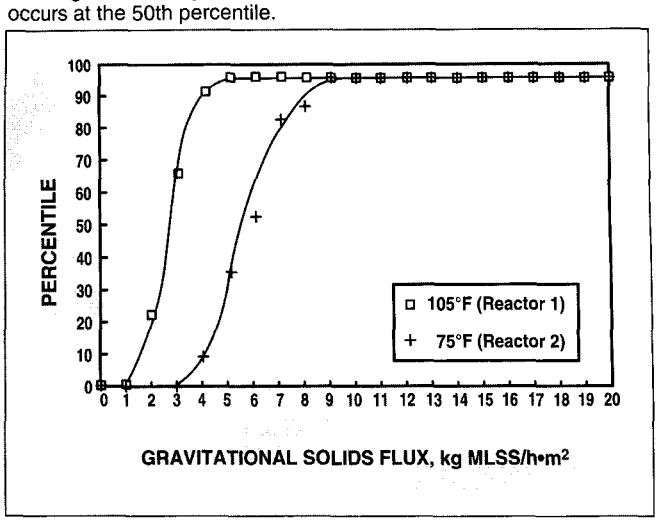
1. Effluent TSS, June–August 1987



2. Sludge settleability at two aeration-basin temperatures. Median flux occurs at the 50th percentile.



I. Average operating conditions and sludge settleability for the four reactors used in Phase IA study

Reactor no.	Influent wastewater[a]	Operating conditions: MLSS, mg/L	HRT[b], h	Temp., °F	F/M[c], day⁻¹	Gravitational solids flux[d], kg MLSS/h·m²: 10th percentile	Mean
1	Existing	6840	2.3	105	1.1	1.5	3.0
2	Existing	7660	2.3	75	0.95	4.0	6.0
3	Minimum	6850	2.3	75	1.1	5.5	7.5
4	Design	7270	2.3	75	0.99	2.5	4.0

[a]Secondary-fiber waste stream contribution based on "existing" (500 tons/day), "minimum" (50 tons/day) and "design" (1200 tons/day) production rate
[b]Hydraulic retention time, expressed as influent flow divided by aeration-basin volume
[c]Food to microorganism (F/M) ratio, calculated based on influent total BOD (biochemical oxygen demand), MLVSS (mixed-liquor volatile suspended solids), and aeration-basin retention time
[d]Aeration basin MLSS (mg/L) x ZSV (m/h) x 0.001. ZSV = zone settling velocity.

and projected operating conditions.

Phase I—problem definition

A review of the plant records and interviews with mill personnel identified two probable causes for the poor sludge settleability:

- High temperature in the aeration basin (105°F)
- The waste stream from the secondary-fiber pulp mill.

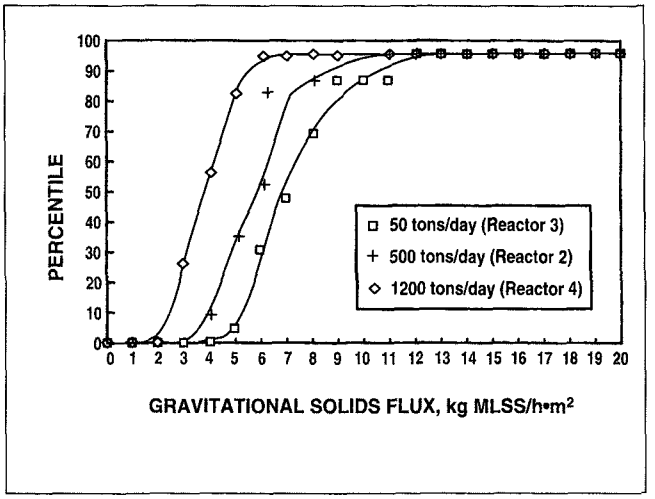
The high summertime temperature in the aeration basin was due to fouling of the cooling tower and biological oxidation. Secondary fiber in the waste stream became a factor in 1986 following startup of the secondary-fiber pulp plant. These potential causes were evaluated by designing a study matrix consisting of four bench-scale treatability reactors. **Table I** describes the average operating conditions and settleability results for Reactors 1–4.

Reactors 1 and 2 were operated at the mill's current secondary-fiber waste-stream loadings (500-ton/day pulp production rate) at aeration-basin temperatures of 105°F and 75°F, respectively. These conditions simulated the actual basin temperature and the projected basin temperature following expansion and/or upgrading of the cooling tower. Reactors 3, 2, and 4 were operated over a working range of secondary-fiber production rates from 50 tons/day to 500 tons/day to 1200 tons/day equivalent waste-stream loading. The comparative performance of these reactors indicated the effect of secondary-fiber production rate on sludge settleability at the projected lower aeration-basin operating temperature of 75°F.

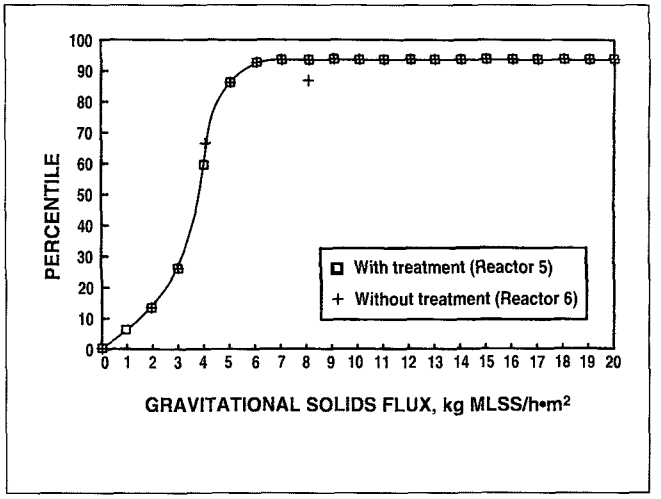
Phase IA results are summarized in **Figs. 2 and 3**. Figure 2 shows that the high temperature of the aeration basin (105°F) retarded sludge settleability. Figure 3 shows a similar effect for increased load of secondary fiber in the waste stream. Based on these results, the following recommendations were made:

- Expand the existing cooling tower to reduce aeration-basin tempera-

3. Sludge settleability at three secondary-fiber waste-stream loadings. Median flux occurs at the 50th percentile.



4. Sludge settleability with and without DAF pretreatment of secondary-fiber waste stream. Median flux occurs at the 50th percentile.



II. Average operating conditions and sludge settleability for the two reactors used in Phase IB study

Unit no.	Operating conditions: MLSS, mg/L	HRT[a], h	F/M[b], day⁻¹	Gravitational solids flux[c], kg MLSS/h·m²: 10th percentile	Mean
5	3690	3.3	1.4	1.5	4.0
6	3950	3.4	1.3	1.5	4.0

[a]Hydraulic retention time, expressed as influent flow divided by aeration-basin volume
[b]Calculated based on influent total BOD, MLVSS, and aeration-basin retention time
[c]Aeration basin MLSS (mg/L) x ZSV (m/h) x 0.001

tures to less than 90°F under "worst reasonable case" operating conditions. Conduct remaining treatability studies at 85°F.

- Conduct additional treatability studies to evaluate dissolved-air flotation (DAF) pretreatment of the secondary fiber waste stream.
- Add a complete three-stage pure-oxygen treatment train in parallel with the existing two trains.

The recommendation for DAF pretreatment was based on microscopic evaluations, batch settling tests, and treatability study results, which indicated that the secondary fiber was inhibiting activated-sludge settleability. DAF pretreatment offered several potential benefits, including improved activated-sludge settleability, improved dewaterability of primary–secondary sludge mixture, decreased fiber load on the existing primary clarifier, reduced amount of inert fiber in the mixed liquor, and reduced solids flux on the existing secondary clarifiers at an equivalent amount of active biomass in the system.

The addition of a third treatment train would increase the hydraulic retention time (HRT) from 2.4 h to 3.6 h at the design wastewater flow rate of 16 million gallons/day. The recommendation for additional aeration-basin tankage was based on the lack of process redundancy in the existing secondary facility. If one aeration train was taken out of service for maintenance, the remaining train did not have adequate capacity to handle the design waste load. A major outage at the wastewater treatment facility would require a reduction in mill production and waste load. This condition was not a cost-effective production scenario, and a redundant basin was recommended.

In Phase IB, the impact of DAF treatment of secondary-fiber wastewater was evaluated. A slip stream of the secondary-fiber wastewater was passed through a pilot-scale DAF unit achieving 94% fiber recovery and 80% removal of stickies. (The quantity of stickies was determined by extracting the material with Freon and analyzing it by infrared spectrophotometry at a wave number of 2930/cm and 1-cm light path against a hexadecane-isodecane-chlorobenzene standard.)

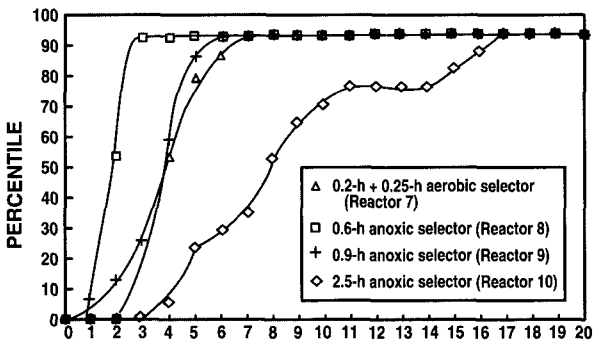
DAF-pretreated secondary-fiber wastewater simulating production of 1200 tons/day was fed to Reactor 5 with other background wastewaters. Reactor 6 received unpretreated secondary-fiber wastewater along with the same background wastewaters. **Table II** describes the average operating conditions and settleability results for Reactors 5 and 6. **Figure 4** illustrates the settleability results for the two reactors. DAF treatment had no effect on sludge settleability, indicating that the

III. Average operating conditions and sludge settleability for the four reactors used in Phase IIA study

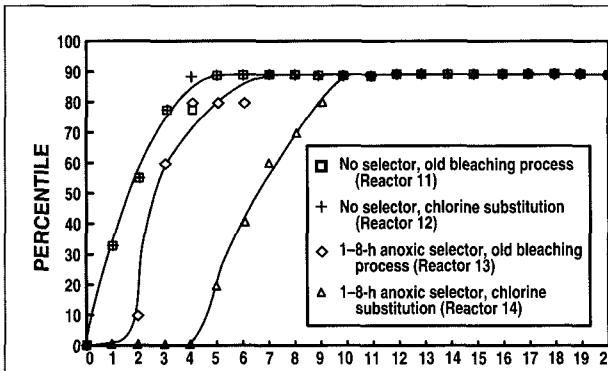
Reactor no.	Type selector	Operating conditions: MLSS, mg/L	HRT[a], h: Aerobic	HRT[a], h: Anoxic	MCRT[b], days	Gravitation solids flux[c], kg MLSS/h·m²: 10th percentile	Gravitation solids flux[c], kg MLSS/h·m²: Mean
7	0.2-h aerobic + 0.25-h aerobic	4600	3.6	0.0	4.7	2.5	4.0
8	0.6-h anoxic	4640	2.8	0.6	3.2	1.0	2.0
9	0.9-h anoxic	4400	2.6	0.9	5.6	1.5	4.0
10	2.5-h anoxic	4210	2.3	2.5	2.8	4.5	8.0

[a]Hydraulic retention time, expressed as forward flow rate divided by aeration-basin volume
[b]Mean cell-residence time
[c]Aeration basin MLSS (mg/L) x ZSV (m/h) x 0.001

5. Impact of biological selector configuration on sludge settleability. Median flux occurs at the 50th percentile.



6. Impact of bleaching process chlorine substitution on sludge settleability. Median flux occurs at the 50th percentile.



adverse impact of secondary-fiber wastewater is due to its soluble component rather than to the presence of fiber. Further evaluations indicated that DAF treatment of secondary-fiber wastewater could not be economically justified.

Phase II—evaluation of treatment alternatives

Based on Phase I results and on past experience, biological selectors were thought to be the solution for the mill's sludge settleability problem. Phase IIA of the treatability study addressed the issue of which selector operation and configuration would provide a reliable and consistent solution.

Biological selectors suppress filamentous microorganisms by creating an environment in which floc-forming bacteria have a competitive advantage. The Phase II studies evaluated two selection mechanisms:

- Increase the substrate profile throughout the aeration basin.
- Expose the biomass to prolonged anoxic conditions.

Biological selectors were evaluated by designing a study matrix consisting of four bench-scale reactors. **Table III** describes the average operating conditions and settleability results for Reactors 7–10. The results are illustrated in **Fig. 5**, which show that the best selector configuration used extended anoxic-zone exposure. Furthermore, results indicated that filament suppression was directly related to the length of anoxic-zone exposure. With the extended anoxic zone, the activated-sludge system could be operated with only two secondary clarifiers in service. The other configurations would require three secondary clarifiers.

Phase IIB also evaluated the impact of bleaching-process chlorine substitution on sludge settleability with and without an extended anoxic-zone selector in service. Unit configuration, average operating conditions, and settleability results are described in **Table IV**. Settleability results are illustrated in **Fig. 6**.

Sludge settleability was poor for the reactors without anoxic-zone selection (Reactors 11 and 12). Because settleability was so poor, chlorine substitution in the bleaching process showed no observable effect on sludge

IV. Average operating conditions and sludge settleability for the four reactors used in Phase IIB study

Reactor no.	Type selector	Bleaching process chlorine substitution	Operating conditions				Gravitational solids flux[c], kg MLSS/h·m²	
			MLSS, mg/L	HRT[a], h		F/M[b], day⁻¹	10th percentile	Mean
				Aerobic	Anoxic			
11	None	No	4450	3.6	0.0	0.35	0.2	2.0
12	None	Yes	4380	3.1	0.0	0.32	0.2	2.0
13	1.8-h anoxic	No	4390	3.6	1.8	0.52	2.0	3.0
14	1.8-h anoxic	Yes	4080	3.1	1.8	0.35	4.0	6.5

[a]Hydraulic retention time, expressed as forward flow rate divided by aeration-basin volume
[b]Calculated based on influent total BOD, MLVSS, and aeration-basin retention time
[c]Aeration basin MLSS (mg/L) x ZSV (m/h) x 0.001

settleability. This does not mean that differences would not exist, only that the method of detection was inadequate. In activated-sludge processes with an extended anoxic zone, chlorine substitution is not expected to have an adverse impact on sludge settleability. Nevertheless, comparison of the two reactors with anoxic-zone selection (Reactors 13 and 14) shows that sludge settleability was better for the reactor with chlorine substitution (Reactor 14). The reason for this improvement is unclear.

Conclusion

Causes of poor activated-sludge settleability were defined and a solution developed through a methodical and thorough treatability study. The mill opted to increase the capacity of the wastewater treatment plant to obtain the redundancy needed to maintain production during wastewater treatment plant outages. The plant can operate in a fully aerobic mode or in an extended anoxic zone/aerobic mode based on need. The mill has operated the last two years in consistent effluent TSS compliance by operating in the fully aerobic mode and utilizing three secondary clarifiers.

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