OVERVIEW OF EFFECTS OF DECREASED RELEASE OF BOD/COD & TSS

Introduction

Water that is used and recycled in pulp and paper manufacturing processes until it can no longer be reused in the process is called wastewater***.*** Wastewater is treated on-site or off-site in treatment systems. Once treated, the resulting effluents are, in most cases, discharged to surface waters. While there are some exceptions, wood products operations do not generally produce or discharge wastewater.

Wastewater treatment systems are designed to remove oxygen-demanding substances (as measured by five-day biochemical oxygen demand, BOD_5, or BOD) and solid particles (measured as total suspended solids, or TSS). Chemical oxygen demand (COD) is a measure of all oxygen-demanding substances, including those not amenable to biological treatment, and these, too, are reduced through wastewater treatment. No reasonably constant relationship exists between COD and BOD values for either untreated or treated kraft wastewaters (Bryant and Wiseman 2003). Wastewater may also contain toxic and non-conventional pollutants such as chlorinated organic compounds.

Industry Performance

There has been significant reduction in the global pulp and paper industry's production-normalized releases of BOD and TSS since the 1970s. The evolution of BOD and TSS reductions in the U.S. is shown in Figure B1. In Canada, federal government data show reductions of BOD and TSS between 1970 and 2008 to be 97% and 90%, respectively (Environment Canada 2012). Improvements to effluent quality since the mid-1970s have resulted from a combination of wastewater treatment system improvements and in-process improvements that have reduced the load on wastewater treatment systems allowing them to operate more efficiently. Examples of the latter include

- manufacturing process control measures taken to reduce the formation and release of chlorinated organic compounds, and
- best management practices applied to prevent or contain losses of spent pulping liquor and other process streams that might interfere with treatment plant performance or contribute to the discharge of pollutants.

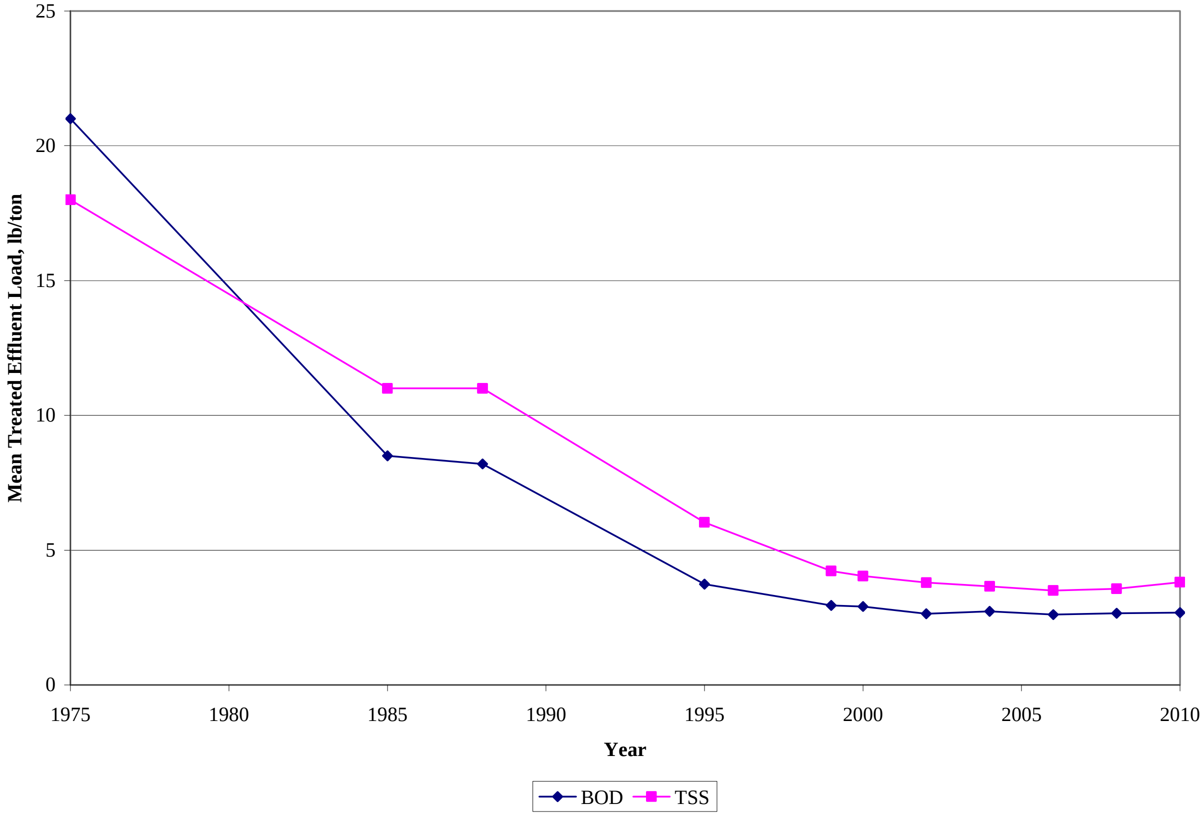

Figure B1. U.S. Industry Production-Normalized BOD and TSS Discharges (Source: NCASI 2012; AF&PA 2012)

Methods for reducing discharges to water take two general forms: a) reducing the loading of constituents delivered to the wastewater treatment system, also known as source reduction; or b) installing additional treatment system capacity or components. The potential environmental benefits and trade-offs for each method can be quite different, and for this reason, each method is presented separately in this section.

In its evaluation of appropriate controls for toxic and non-conventional pollutants, the U.S. Environmental Protection Agency expressed the view that "the most environmentally beneficial approach is to combine process technology changes which reduce or eliminate the formation of pollutants of concern with best available end-of-pipe treatment" (USEPA 1993a). As much might be said for such conventional pollutants as BOD and TSS.

Environmental Significance of BOD and TSS

The dissolved oxygen (DO) content of a waterbody is among the most important water quality characteristics necessary for protecting fish and aquatic life. Low DO levels can induce fish kills and reduce reproduction rates in aquatic biota. Industrial and municipal wastewater discharges, as well as stormwater runoff associated with urban, industrial, agricultural, and silvicultural sources, contribute oxygen-demanding substances (measured as BOD) to receiving streams and can diminish dissolved oxygen levels.

Suspended matter discharges (measured as TSS) may also be implicated in the depletion of DO, as well as other adverse aquatic impacts. Suspended matter, if settleable, can blanket the stream bed, damage invertebrate populations, block gravel spawning beds and, if organic, remove dissolved oxygen from the overlying water column. Suspended matter that does not settle may obstruct transmission of light into the water column, impairing aesthetics, as well as diminishing photosynthetic activity and the abundance of food available to fish and aquatic life.

History of Regulation of BOD and TSS Discharges

Historically, regulatory limitations on mill discharges of BOD and TSS were unevenly established on a site-specific basis in response to perceived local water quality imperatives. In the U.S., the regulatory landscape was altered in 1972 with a national legislative mandate that required the uniform application of technology-based standards except where water quality needs compelled even greater stringency. Significant improvement in effluent and receiving stream quality followed.

Regulatory standards responsive to the 1972 legislative mandate were adopted in 1977. They were derived on the basis of the average of the best existing performance by well operated plants within each production category. The best performing population of mills represented about 30% of the industry at the time (Ryan 2003). Deliberations involved consideration of the cost-effectiveness of alternative treatment practices, as well as a balancing of numerous engineering factors and non-water quality related environmental impacts including energy trade-offs. EPA has twice reviewed these initial standards for BOD and TSS, most recently in 1998 (*Federal Register* 1998). In each case, the original standards were left essentially unchanged for existing sources, a judgment based upon cost versus effluent reduction benefits.

In Canada, uniform standards were similarly enacted in 1992 to replace earlier (1971) regulations that had not required broad application of secondary biological treatment. By 1995, these types of secondary treatment systems were installed and operating at virtually all pulp and paper facilities in Canada.

Effluent limitations for BOD and TSS in North America have been largely driven by the demonstrated performance of external treatment systems. This stands in contrast to countries such as Sweden, where regulators going back to the 1970s had pressed the pulp and paper industry to adopt internal process changes rather than end-of-pipe treatment common in North America (Harrison 2002). The initial in-process focus gave the Swedish industry the advantage of having to treat smaller raw waste loads when biological treatment systems were installed two decades later.

Wastewater Treatment of BOD and TSS

Conventional wastewater treatment systems are capable of removing more than 90% of BOD and virtually the entire settleable portion of TSS. Further reducing discharges to water by installing additional treatment system capability involves capital improvements and/or the addition of new technologies to wastewater treatment systems. Because pulp and paper mills treat large volumes of wastewater, treatment system upgrades frequently require substantial capital investment. Costs escalate dramatically with the application of advanced treatment measures to remove the small increments of BOD and TSS that remain after conventional treatment.

Conventional Treatment: Conventional wastewater treatment systems in the pulp and paper industry most often employ primary clarification for removal of settleable material followed by secondary treatment for removal of biodegradable organic matter. Secondary treatment processes most often involve biological treatment. The process involves biological conversion of organic matter, either to energy required to sustain the biomass, or to growth and accumulation of additional biological solids. The solids are subsequently separated from the wastewater prior to its discharge. The most common secondary treatment configurations are aerated stabilization basins (ASBs; see Figure B2) and activated sludge treatment (AST). Both are capable of achieving high degrees of treatment.

Figure B2. Photo of Conventional Wastewater Treatment via Aerated Stabilization Basin

For North American pulp and paper mills, ASBs are the most frequently applied wastewater treatment technology, representing about 60% of U.S. and nearly 30% of Canadian mills practicing on-site wastewater treatment (i.e., excluding those who discharge indirectly via a publicly owned treatment works (POTW)). The remaining direct dischargers employ ASTs. In the aerated stabilization basin (ASB) configuration, most of the biosolids generated by the process settle within the aeration basin, or in subsequent polishing ponds. To a large extent, these biosolids subsequently decompose within the basin sediments. In the alternate activated sludge configuration, the biosolids are separated in dedicated tanks. Most of the solids collected in the tanks are returned to the system as needed to sustain the process. The remainder are dewatered and discarded or burned for energy recovery.

Conventional secondary treatment performance is, in part, dependent upon the settleable nature of the biological solids essential to the process. Sustaining that settleable quality is among the more sensitive aspects of activated sludge treatment and in some cases, chemical coagulants and settling aids may be intermittently used to enhance settling as circumstances require.

Wastewater treatment systems operating at pulp and paper mills are quite efficient at removing oxygen demanding substances (i.e., BOD) and solids (i.e., TSS). At many mills, average treatment system efficiencies exceed 95%. Table B1 shows data for activated sludge treatment systems. Aerated stabilization basin treatment systems perform in these ranges as well.

Table B1. Wastewater Treatment by the Activated Sludge Process (Source: Hynninen 1998)

	BOD removal, %
Sulfate (kraft) pulp mill	92 - 98
Mechanical paper	92 - 98
Recovered fiber-based paperboard	91 - 98

Given this high level of treatment efficiency, in-plant source reductions in the amount of BOD, TSS, and other treatable substances usually have a small incremental impact on treated discharges. For example, achieving a 50% reduction in raw waste load sent to a treatment system capable of achieving 95% BOD reduction would result in only an incremental 2.5% reduction relative to the original raw waste load. Wastewater substances that are not so amenable to removal in conventional wastewater treatment systems are, however, better dealt with by manufacturing process control measures. Wastewater color associated with chemical pulping is an example.

Effects of Decreased Release of BOD/COD & TSS

General Overview

The U.S. Environmental Protection Agency, as part of the extensive and systematic analyses that accompany its rulemaking, has examined the merits of more aggressive manufacturing process measures and unconventional external treatment approaches. The agency concluded that going beyond what is now required by its best conventional technology (BCT) and best available technology (BAT) requirements could not be justified by the relative effluent quality benefits.

There are potential environmental trade-offs in going beyond current regulatory requirements. These potential trade-offs must be reconciled with the incremental water quality benefits associated with further small reductions in discharges of BOD and TSS to receiving streams.

Opportunities for Improvement and Challenges to Further BOD/COD and TSS Reduction

Internal process measures at both integrated and non-integrated mills are capable of improving raw waste loads. Tertiary treatment can be applied to further reduce BOD/COD and TSS; however, it carries with it the potential for environmental trade-offs that may not justify the additional increment in effluent quality. Conventional wastewater treatment practices remain the workhorse in reducing BOD and TSS discharges to receiving waters.

In-Plant Reduction of Wastewater Discharges: In-plant source reduction necessitates changes in the wood, pulp, and/or paper processing systems to reduce the loss of usable raw or intermediate materials, thereby reducing the need to treat these materials in wastewater treatment systems and, assuming treatment efficiency remains constant, reducing discharges to water. Such opportunities are mill-specific. A detailed review of alternative process options is beyond the scope of this document, but literature on the topic is available (USEPA 1993b; NCASI 2012).

In their consideration of options that comprise the best available technology (BAT) for bleached kraft pulp mills, the European Commission (EC) gave recognition to the European industry's historic focus on process-integrated measures (Suhr 2000; IPPC 2001). Among them were the measures shown below that have potential benefits for raw waste load reduction.

- Dry debarking of wood
- Modified (extended) cooking
- Closed-cycle brown stock screening
- Highly efficient brown stock washing
- Elemental chlorine-free (ECF) or totally chlorine-free (TCF) bleaching
- Some, primarily alkaline, process water recycling from the bleach plant
- Purification and reuse of condensates
- Effective spill monitoring, containment, and recovery system
- Sufficient black liquor evaporation plant and recovery boiler capacity to cope with the additional liquor and dry solids loads due to collection of spills, etc.

The effect of these various options on wastewater quality and other environmental measures is qualitatively characterized in Table B2.

Table B2. Effects of Application of In-Plant Reduction of Wastewater Discharges (Source: IPPC 2001)

Techniques to Consider in the Determination of BAT	Effects on the Consumption and Emission Levels (Cross-Media Effects)				
	Chemical Consumption	**Energy**	**Emission to Water**	**Emission to Air**	**Solid Waste**
Dry debarking	n.e.	↑ in debarking	↓ COD, ↓ TSS, ↓ flow	n.e.	n.e.
Extended modified cooking to a low Kappa Continuous (c) or batch (b)	↑ in cooking ↑ lime demand ↓ in bleaching	(↑) cooking (c), ↓ cooking (b) (↑) evaporation, (↑) lime kiln	↓ COD ↓ AOX	↑ odor	n.e.
Closed screening	n.e.	n.e.	↓	n.e.	n.e.
Oxygen delignification	↑ in O_2-stage ↓ in bleaching	↑ O_2-stage, ↑ white liquor oxidation, ↑ caustic.& lime kiln	↓	n.e.	(↑) dregs
Ozone bleaching	↑ in O_3-stage ↓ in bleaching	↑ O_3-stage, ↑ O_3 generation ↓ in bleaching	↓	n.e.	n.e.
ECF bleaching technique (vs. TCF)[1] (at same incoming low Kappa)	(↑/↓)	(↑/↓)	↑ AOX, ↑ ClO_3^- -	↑ Cl_2	n.e.
TCF bleaching technique (vs. ECF)[1] (at same incoming low Kappa)	(↑/↓)	(↑/↓)	(↓ COD) ↓ AOX ↑ N Chelat.	n.e.	n.e.
Part closure of the bleach plant + increased evaporation	↑ bleaching	↑ evaporation	↓	(↑)	(↑) dregs
Collection of almost all spillage	n.e.	↑ evaporation	↓	n.e.	n.e.
Efficient washing and process control	↓ bleaching ↓cooking	↑ washing (electr.)	↓	n.e.	n.e.
Stripping and re-use of condensates	↓ bleaching	↑	↓ COD, N	↓ odor	n.e.
Buffer tanks for concentrated liquids	n.e.	n.e.	↓	n.e.	n.e.
Aerobic biological treatment	(↑)	↑	↓	n.e.	↑
Chemical precipitation	↑	↑	↓	n.e.	↑

NOTES: n.e. = no (or negligible) effect; ↑ = increase; ↓ = decrease; (↑/↓) = may or may not have an effect/little impact depending on the conditions.
[1] Assumed that there is efficient wastewater treatment.

EPA identified a similar array of options in its consideration of best available technology for bleached kraft mills. Though the agency's focus was on reduction of toxic and non-conventional pollutants, they nevertheless acknowledged the coincident BOD reduction benefits associated with the application of ECF bleaching and best management practices for containing liquor losses.

Effects of Decreased Release of BOD/COD & TSS

General Overview

Even greater improvements were anticipated with the application of other process modifications that advanced measures that further closed up the fiber line, improved water reuse within the bleach plant, and recycled bleach plant effluent. A common thread here is the capture of pulping liquor solids and other wood extractives that if lost to wastewater would add to raw waste load. To the extent that they are routed back through the liquor recovery system, they represent a source of cooking chemicals and energy (NCASI 2012).

Internal process measures of the potential benefits of raw waste load reductions are not restricted to pulping operations. The European Commission addressed some in their reference *Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Pulp and Paper Industry* (IPPC 2001), as shown in Table B3.

Table B3. Effects of Application of Other In-Plant Measures to Reduce Wastewater Discharges (Source: IPPC 2001)

Techniques to Consider in the Determination of BAT	Effects on the Consumption and Emission Levels (Cross-Media Effects)				
	Chemical Consumption	**Energy (E) & Water (W) Consumption**	**Emission to Water**	**Emission to Air**	**Solid Waste**
Water Management and Minimizing Water Usage	(0)	(↓)E (↓)W	↓	0	0
Control of Potential Disadvantages of Closing Up Water Systems	↑	0	(↓)	0	0
In-Line Treatment of White Water by Use of Membrane Filtration	0	(↑)E (↓)W	(↓)	0	0
Reduction of Fiber and Filler Losses	↑	↓	↓	0	(↓)
Recovery and Recycling of Coating Color Containing Effluent	(↓)	0	↓	0	↓
Separate Pre-Treatment of Coating Wastewater	(↑)	0	↓	0	(↑)
Measures to Reduce Frequency and Effects of Accidental Discharges	0	0	(↓)	0	0
Measurement and Automation	(↓)	↓	↓	0	0
Equalization Basin and Primary Treatment	0	0	↓	0	0
Aerobic Biological Treatment	(↑)	(↑)E	↓	0	↑
Chemical Precipitation	↑	(↑)E	↓	0	↑

NOTES: The positive and negative side effects are also given. ↑ = increase; ↓= decrease; 0 = no (or negligible) effect;(↑) or (↓) = low influence depending on conditions.

Tertiary Treatment Approaches: Tertiary treatment measures have been evaluated for effectiveness in further removing BOD and removing non-settleable material, but they have not often been applied.

Chemically Assisted Clarification (CAC), as one option, involves the routine use of chemical coagulants, polyelectrolytes, and polymer combinations. Achieving relatively modest incremental improvement in the discharge levels of TSS requires large chemical additions. More problematic is the associated generation of disproportionately large quantities of gelatinous, difficult to dewater sludge, especially with pulp mill wastewaters.

Filtration is another option that has been explored. Studies by NCASI and others have demonstrated that significant reduction in treated effluent TSS and turbidity could be achieved with filtration. Performance was dependent upon the type of wastewater being treated. Consistently high performance, however, required chemical addition. The corresponding BOD reduction represented a significant portion of the residual BOD after secondary treatment. However, the fraction removed was only a minor portion of the initial wastewater BOD introduced into the treatment system (NCASI 1973).

Past attempts to improve pulp and paper mill effluent quality through granular media filtration of biologically treated effluents have not proven to be successful (NCASI 2008). Among the obstacles is management of the filter backwash that is generated when the accumulated solids that would ultimately plug the filter are flushed from it. That backwash must be routed back through treatment, resulting in an additional hydraulic load. Any portion of the solids in the backwash that remain unsettleable will impose a continually increasing "dead load" on the system. Where separated, the solids represent an additional solid waste burden. If chemicals are employed to enhance filtration, sludge volumes and management difficulty will be all the greater. Mixed media filtration was among the technologies considered by EPA in its effluent guidelines review and judged not to be cost-effective.

There are other rarely applied advanced treatment options that might be considered, such as membrane systems, ozonation, carbon adsorption, and others. Like the tertiary treatment measures described above, the incremental reductions beyond conventional practices are seldom justified based upon other environmental trade-offs and what, in most cases, is little or no water quality benefit. Equal gains, if necessary, may be more constructively achieved with internal process measures than by pushing external treatment beyond the point of cost-effectiveness. The proper balance of internal and external approaches is a very mill-specific judgment.

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