1 TASK 2.4: EXPECTED EFFLUENT QUALITY FOLLOWING TREATMENT BY THE PROPOSED TECHNOLOGY

1.1 FOCUS REPORT TASK DESCRIPTION

Submit a complete physical and chemical characterization of NPNS's expected effluent following treatment by the proposed technology. To assess the efficacy of the proposed treatment technology, the following must be included:

a) Data from laboratory trials on NPNS's raw wastewater that were conducted at Veolia/AnoxKaldnes in Lund, Sweden in May 2018;

b) Modelling results using the raw wastewater parameters and quality;

c) A comparison of the effluent characterization results from the laboratory trials and modelling work, against appropriate regulations and/or guidelines.

The basic questions that will be addressed in the following document are:

a) Will the proposed treatment technology effectively treat the raw wastewater based on the effluent characterization parameters and the proposed ETF specifications?

b) Will the proposed treatment technology meet appropriate regulations?

c) How was the effluent quality brought forward in the RWS determined?

1.2 INFLUENT (UNTREATED) EFFLUENT CHARACTERIZATION USED TO DEVELOP DESIGN SPECIFICATIONS

KSH performed a statistical analysis of a full year of NPNS untreated effluent quality data from the TME (total mill effluent) for the calendar year 2016 in order to develop design specifications for the new ETF. The design specifications can be found in the attached request for quotation (RFQ No: 10-1113-A000-09400). A statistical analysis was performed on the mill data to determine the average, median, standard deviation and 90% percentile confidence level for flow, BOD, TSS and COD. All data was presented to prospective vendors so they could evaluate the normal process variation in their design proposals. Both average (first case: TME Avg.) and design (second case: Design) specifications were developed for the data set. As concentrations of pollutants vary by effluent flow and/or pulp production rate, ranges based on the highest load divided by lowest flow and lowest load divided by highest flow were developed. These wide ranges provide an added level of comfort in the ETF design.

Two additional columns of data were developed. The third column representing untreated influent quality after an Oxygen Delignification system is installed (third case: After O_2 Delig.). Bidders were asked to demonstrate that their proposed system could adapt to the organic load reduction without compromising system performance. This project is further discussed in Addendum 1. The fourth column considers a future production increase at the mill (fourth case: Future). NPNS has no current plans for expansion in the next few years. Bidders were not asked to design to this future case, but rather to demonstrate that their system could be upgraded or expanded in the future. This future production increase was assumed to occur after the O_2 Delignification was implemented.

The design specification also provides monthly average Expected Treated Effluent Quality that bidders were expected to meet for all four cases outlined above. These are to be used as the basis for vendor performance runs for the system.

The full physical and chemical untreated and treated effluent characterization was undertaken in Section 2.3 of the Focus Report based on a more up to date annual data set for 2018. Table 1-1, below, presents the data for comparison purposes for those parameters that are of interest to designers of a new ETF system. The 2018 data used for untreated effluent characterization falls well within the range provided in the TME Avg. with the exception of AOX. AOX is not a routine test for untreated effluent, meaning that averages had to be deduced from a much smaller sample set for the design specification. The average and design values for AOX in untreated effluent were artificially raised in the design specification to add a margin of safety to the design. The effluent characterization AOX of 1.2 mg/l is more typical of the NPNS data available.

Table 1-1 – TME Avg. Design Specifications vs 2018 Effluent Characterization in Section 2.3

Point A – Untreated Effluent	Production (ADt/d)	Flow (m^3/day)	TSS (mg/l)	BOD (mg/l)	Colour (TCU)	AOX (mg/l)	COD (mg/l)	P (mg/l)	N (mg/l)
TME Avg. Design Specifications	802	64,150	325	200	860	6.0	875	1.6	2.3
2018 Full Effluent Characterization	777	63,582	365	209	735	1.2	723	1.5	4.7

1.3 VEOLIA/ANOXKALDNES BAS™ (BAS) TREATMENT SYSTEM PROCESS

The selected process for the new ETF is the Biological Activated Sludge process (BAS) provided by AnoxKaldnes (a division of Veolia Water Technology). The BAS process was chosen for the ETF project for its flexibility and advantages in process design as well as its extensive reference list in the pulp and paper industry. The system is also extensively used in municipal wastewater treatment applications. There are over 800 municipal and industrial systems installed globally. Similar system configurations are currently in operation at 52 pulp and paper facilities worldwide, including over 20 chemical pulp mills (60–75% of all the biological effluent treatment plants in the pulp and paper industry use activated sludge systems). The following provides a brief discussion of the main components of the treatment system to discuss how sizing of the components was determined for the NPNS ETF. Refer to the attached simplified BAS Treatment Flowsheet that was presented in the EARD.

1.3.1 Primary Clarifier

Sedimentation, also known as primary treatment, is the first stage in the treatment process where solid particles or suspended solids are removed from the effluent by means of gravity in relatively large open circular tanks. In properly designed clarifiers, the velocity of the water is reduced so that gravity is the predominant force acting on the water/solids suspension. The key factor in this process is time to allow the particles to fall out of the effluent stream. The primary clarifier is designed as a settling tank where effluent passes through at low velocity (high retention time) to promote settling. Particles settle to the bottom of the clarifier, while “clear” effluent leaves the basin over an effluent baffle or weir at the top of the clarifier. The solids, primarily wood fibres and lime, collect at the bottom of the clarifier and are continuously removed and sent for further thickening and will be burned along with biomass in the power boiler. Sizing of the clarifier is further discussed in Section 3.1.

1.3.2 Effluent Cooling

The design specifications indicate that raw effluent leaving the mill can be as high as 55 °C. Effluent cooling will be necessary to reach temperatures appropriate for biological requirements. Cooling towers, located after the primary clarifier, will be needed to control the temperature of effluent entering the biological stage of the process. To maintain the proper biological conditions for the living organisms, year-round control of effluent temperature is required. Most, if not all, mills with AST technology require effluent cooling. The optimum temperature range for efficient operation of 25 – 39 °C will be discussed further in Section 3.1. The standard industry practice uses direct-contact cooling towers usually after primary treatment. NPNS opted to install a more elaborate indirect-contact cooling system designed to eliminate the potential of odorous emissions from this stage in the process. Cooling towers use evaporation to achieve heat transfer. In this case the evaporative medium is raw water from Middle River. The operation of the cooling towers will result in additional evaporative water losses at the mill. Care will be taken the ensure that the cooling towers stay clean and free of naturally occurring legionella bacteria by employing biocides if and when necessary.

1.3.3 BAS Biological Treatment (combined MBBR with AS)

The BAS process utilizes a combination of technologies, Moving Bed Biofilm-Reactor (MBBR) and conventional Activated Sludge (AS). The upfront MBBR stage offers protection for the downstream AS system by protecting it from upset conditions. The two stages can be controlled separately by the operators (e.g. air and/or nutrient addition) allowing for a much higher degree of control over the entire process. There are many advantages of utilizing MBBR technology up front of an existing AST, including:

- Extending the capacity of an existing AST;
- Protecting an AST system from high organic loads;
- Improving the efficiency of an AST; and
- Improving the AST effluent sludge characteristics.

MBBR technology is known for providing efficient, stable and robust treatment in a small footprint. The MBBR is a smaller vessel that is filled with engineered polyethylene carriers (media) to create a large surface for biofilm bacteria to attach. The large surface area created by the media provide more treatment capacity in a smaller volume compared to the downstream AS stage. Aeration keeps the media in constant motion and knocks off biological flocs that are created thereby freeing up surface area for more bacteria to adhere to. In some of the earlier BAS systems, keeping the media from leaving the MBBR basin with the effluent was a problem. Design improvements over the years have effectively eliminated that problem. There is a series of screens between the MBBR and the AS that prevent the loss or carry-over of media to the AS stage.

The downstream activated sludge system (AS) is a conventional, fully aerobic design in a single-train aeration tank. The aeration system is a coarse bubble aeration system, connected to high efficiency turbo blowers for energy efficiency. This combination provides for minimal maintenance and high energy efficiency. The AS stage also uses aeration to further promote the biological flocs and continue to remove organic pollution from the effluent. The term “activated” comes from the fact that a good portion of the settled biological flocs, after treatment and settling in the downstream secondary clarifiers, is returned to the beginning of the AS process to increase the active bacterial concentration and begin the process again. For this reason, AS system are designed for a high concentration of solids and active bacteria, expressed as Mixed Liquor Suspended Solids (MLSS), typically in the range of 2,000-5,000 mg/l. The high bacterial concentration is the main reason that AS systems can treat effluent in a much shorter time frame compared to the existing BHETF ASB system which does not incorporate recycle of bacteria.

1.3.4 Secondary Clarifier and Recycle

The two secondary clarifiers provide settling after the biological treatment (AS) stage in a similar manner to that of the clarifier in the primary treatment stage. As mentioned above, some of the settled, thickened material at the bottom of the clarifiers (still active bacteria able to perform more treatment) are recycled back to the aerated basin (Return Activated Sludge or RAS) to increase the efficiency of organic reduction. A portion of the settled sludge is wasted (Waste Activated Sludge or WAS) and will be burned along with biomass in the power boiler following a thickening stage. The WAS is almost entirely made up of organic bacteria.

Liquid/solids separation in the secondary clarifier is critical to produce clarified effluent (final treated effluent to be discharged to the receiving environment) that is low in organics and TSS. The biological bacteria or “bugs” contain water in their bodies which make them harder to settle compared to the fibres and lime that settle in the primary clarifier. For this reason, the flow will be split to two clarifiers both equal in size to the primary clarifier. Sizing of the clarifiers is further discussed in Section 3.1.

1.4 SUITABILITY OF PROPOSED TREATMENT SOLUTION

For wastewaters that are nutrient limited, such is the case at Northern Pulp, using the AnoxKaldnes BAS principle enhances overall treatment efficiency, effluent quality and sludge characteristics. The performance of the AS stage is improved by the fact that the MBBR is operated under nutrient-limited conditions, which results in a biofilm that limits bacterial reproduction and instead produces extracellular polysaccharides (EPS). The EPS-rich biomass passes through the MBBR and becomes a readily available food source for the microorganisms in the activated sludge step. Consumption of EPS-rich biomass has been shown to improve sludge characteristics as well as reduce the sludge production, when compared to conventional AST systems.

The development of EPS-rich biomass is a result of the readily biodegradable organic fraction being removed by the fast-growing biomass in the MBBR pre-treatment. Keeping the downstream activated sludge away from the MBBR is key, since the readily biodegradable COD present in a standard AS design normally causes filamentous growth in the active sludge with a strong negative impact on secondary clarification. In nutrient-limited conditions, the bacteria produce EPS which is a food source for bacteria in the downstream AS system instead of developing filamentous bacteria.

The MBBR system is designed to remove roughly 40% of the easily or readily biodegradable soluble COD present in the untreated effluent and provide 2.2 hours of retentions time. The AS stage is designed for a solids retention time (SRT) of 7 days, the time that activated sludge solids (bacteria) remain in the system. The AS stage is expected to remove up to 30% of the soluble COD.

The BAS process is designed for a soluble COD removal efficiency of up to 70% overall. This is a broad assumption based on the vast experience of Veolia with BAS in the pulp and paper market. The biodegradability of effluents vary depending on the mill processes, so a lab trial was undertaken to determine the fraction of soluble COD in NPNS effluent from which the process performance was finalized.

1.4.1 Future Considerations – Oxygen Delignification

It is anticipated that after the Oxygen Delignification Project is installed that the amount of readily biodegradable COD in untreated effluent will decrease as well as the total amount of COD entering the system will be less. Veolia considered this likelihood when designing the BAS system and allowed for a wide range of air flow options when splitting between the two reaction vessels. Both vessels will have Dissolved Oxygen (DO) control based on air supply. Three blowers will be in operation splitting the flow with a fourth as an installed spare. Refer to Addendum 1 for further details on this project and its expected benefits.

1.4.2 Future Considerations – Expansion (post-Oxygen Delignification)

Future expansion would bring the pollutant levels back to similar level used for the current design. Veolia has concluded that any modifications required to the new ETF would not be significant. If a future production expansion is undertaken at the mill system operating parameters may change and more aeration could be required. These modifications would be looked at in more detail at the time, but would not involve sizing changes to main process equipment.

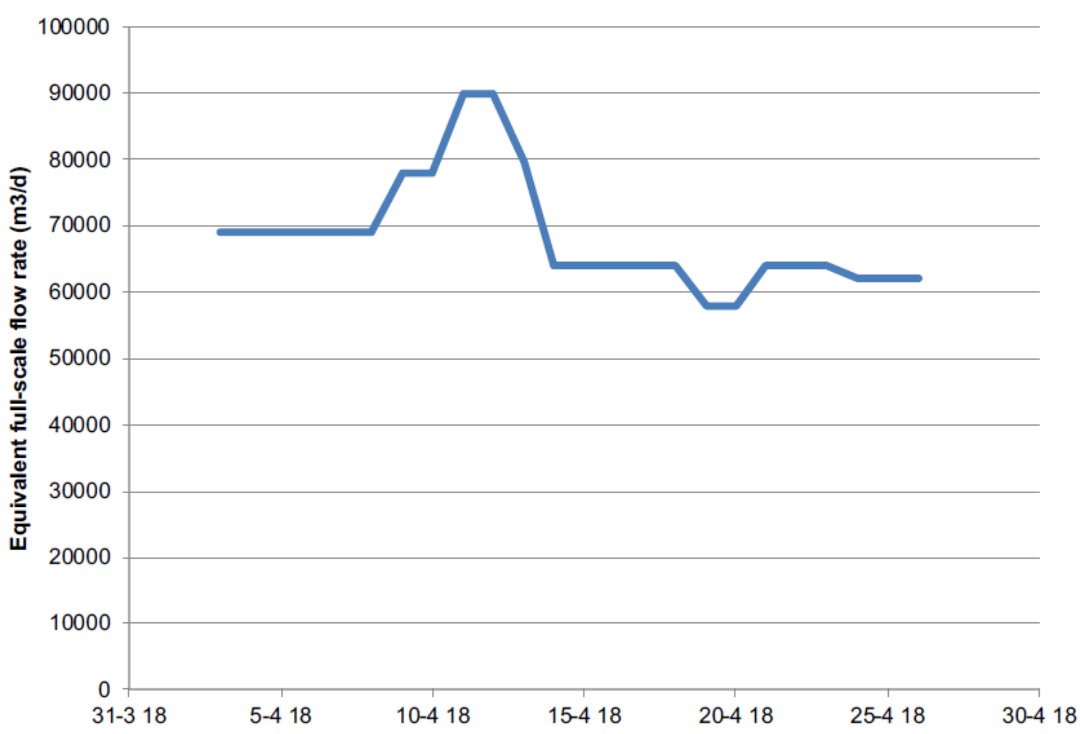
1.5 VEOLIA/ANOXKALDNES LAB TRIAL – LUND, SWEDEN

A lab trial to determine the biological treatability of NPNS untreated effluent, taken at Point A, was conducted at the Veolia/AnoxKaldnes facility in Lund, Sweden in May 2018. Results are attached. The lab trial, which was seeded with 4,000 mg/l of MLSS (mixed liquor suspended solids) active biomass or microorganism population from a nearby Swedish Kraft pulp mill, ran continuously over a three week period allowing time to evaluate the effect of process changes on treatability while simulating both average and design conditions.

Chemical oxygen demand (COD) is a measurement of the oxygen required to oxidize soluble and particulate (solids) organic matter in water. Many organic compounds, including colour compounds and fibres, which are not easily biodegradable, along with any inorganic chemicals will show up as particulate organic matter (pCOD). The soluble organic matter (sCOD) is more representative way to assess the effect of effluent on a receiving environment. Laboratories filter the samples through a 0.45 mm filter before analysis to remove the interference from the solids. This filtered, or soluble, sCOD has been found to be a better representation of the actual biochemical oxygen demand of the wastewater than the unfiltered, or total test result. sCOD is a more accurate representation of the expected or actual performance of a biological wastewater treatment system. Total COD is the typical industry measurement in Canada, referred to as tCOD in the lab report, which is a combination of the biodegradable sCOD fraction and the not easily biodegradable pCOD. The main focus of the laboratory trial was the removal of sCOD at different flow rates and loadings.

Untreated effluent flow rate was varied in the lab apparatus to determine its effect on the treatment efficiency. Flow rates corresponding to equivalent full-scale flow rates of 58,000 – 90,000 m^3/day were simulated during the experiment as shown in Figure 1-1**.** The system was tested above the design flow of 85,000 m^3/day to confirm the system robustness.

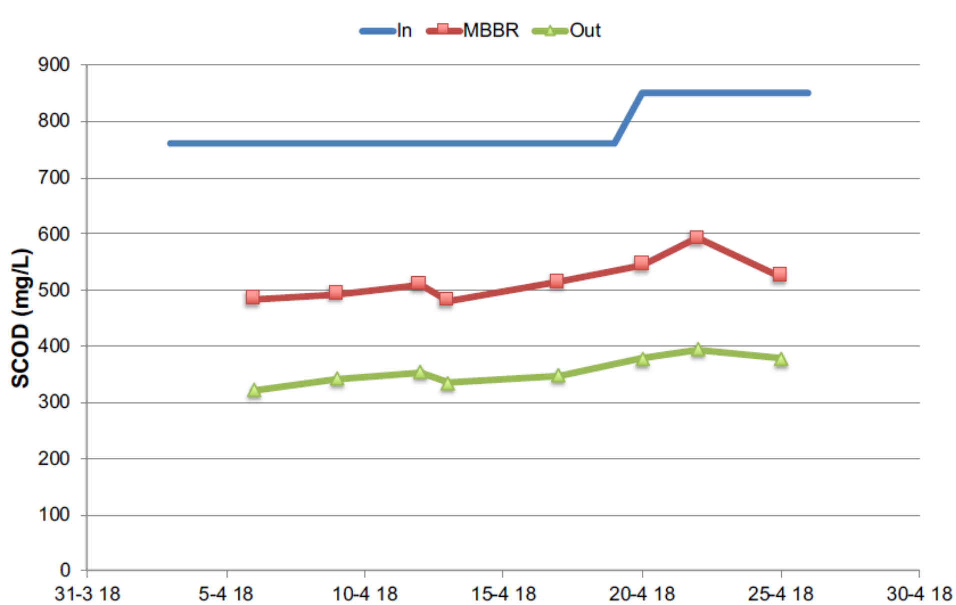
Figure 1-1: Equivalent Flow Rates Used During Laboratory Trial



Higher TSS loading entering with the untreated effluent in the full-scale system was simulated by reducing MLSS from 4,000 mg/l to 2,000 mg/l during the trial. Reducing MLSS has the same effect on the treatment system as increasing TSS of the incoming effluent. In both cases the amount of active bacteria in the system is reduced. Considerably higher simulated TSS loading did not negatively affect the treatment within the study range. Results indicate that the BAS system has the capacity to effectively treat the effluent with considerable dilution of the active biomass, or microorganism population, by inert materials such as lime.

A sCOD of 760 mg/l in untreated effluent was reduced through the BAS system to less than 350 mg/l in the treated effluent. A test with a higher sCOD of 850 mg/l was reduced to less than 400 mg/l in the treated effluent. Both of these tests were in line with conditions identified in the KSH design criteria. The removal of sCOD across the system averaged 55% and was independent of flow rate and loading within the study range. Refer to Figure 1-2 for the fate of sCOD concentrations during the laboratory trials. This is a strong indication that the maximum sCOD removal was achieved for all operating conditions. A biodegradability of 55% sCOD is representative of normal kraft mill effluent and is at a level expected for a mill without oxygen delignification. The very low residual BOD_5 tested on treated effluent on the last day of the trial, less than 3 mg/l, further verifies that the maximum biodegradation of the organic content had been reached. It should be noted that at the present time Canadian mills are not regulated for COD even though most mills test it internally. In Canada it is more common, as is the case with NPNS, that mills test the unfiltered sample (tCOD or COD) which produce a higher number than sCOD.

Figure 1-2: **sCOD Removal during Laboratory Trial**



AOX was measured on the last day of the trial in addition to BOD_5. An AOX removal of 52% was achieved. It was however noted that there is normally a very unstable fraction of AOX in bleach plant effluent that decomposes spontaneously with time and should be gone during the length of time samples were in transportation and storage. Higher removal rates would be expected, in the range of the current AOX rates currently achieved at the BHETF.

Another component of the experimental work was dedicated to nutrients present in untreated and treated effluent. Results show that there is considerable excess of phosphorus in the untreated effluent without nutrient addition, and a large part of it remains as soluble phosphorus after biological treatment. A lot of variation was also observed in the untreated effluent phosphorous content (0.12 to 5.8 mg/l). It will be difficult for NPNS to reach very low discharge concentrations for phosphorus even if it is not added as a nutrient. Total phosphorous in the treated effluent is the sum of soluble phosphorus and phosphorous in the outgoing TSS. The treated effluent total phosphorous is highly dependent on the level present in the initial untreated effluent. Veolia has concluded that the expected treated effluent quality as outlined in the KSH Design Criteria of ≤0.5 mg/l for phosphorous is likely unattainable. Existing data for Point C at the BHETF (1.5 mg/l) was used for design purposes for the 2018 RWS.

Nitrogen can exist as either inorganic nitrogen fractions available to the microorganisms or organic nitrogen fraction that may or may not be available to the microorganisms. Testing of nitrogen fractions in the untreated effluent determined that there exists a considerable inert fraction of soluble organic nitrogen (around 2.0 mg/l) that is not available to the microorganisms during treatment and will remain after treatment. Total nitrogen in the treated effluent will be made up of the inert fraction, any excess available nitrogen and nitrogen in the outgoing TSS. Due to the inert fraction, discharge levels around 5.0 mg/l were measured in the trials. Veolia has concluded that the expected treated effluent quality as outlined in the KSH Design Criteria of ≤3 mg/l for nitrogen is unattainable. Based on lab trial results, the nitrogen concentration was increased from 3 to 6 mg/l as the design in the 2018 RWS.

1.5.1 <u>Veolia Performance Run</u>

The Veolia expected performance numbers below were based on the KSH design specifications, the laboratory trial results from the Veolia/AnoxKaldnes facility in Lund, Sweden and Veolia's extensive experience designing more than 800 BAS™ systems globally. For performance (acceptance) run purposes, indicated mass per day (kg/day) values in the design specification prevail over concentration values (mg/l). All values are expressed as a monthly average based on daily composite samples.

Table 1-2: Performance Run Guaranteed Effluent Quality

Specific Parameter	Guaranteed Effluent Quality	Units
BOD_5	≤ 1,875	kg/day
COD (TCOD – total)	≤ 37,500	kg/day
TSS	≤ 1,875	kg/day

Table 1-3: Performance Run Expected Effluent Quality

Specific Parameter	Expected Effluent Quality	Units
AOX	≤ 225	kg/day
Nitrogen	≤ 450	kg/day
Phosphorus	Dependent on untreated effluent phosphorous levels	kg/day

1.6 REGULATORY REVIEW OF OTHER JURISDICTIONS

The replacement ETF was designed using BATEA (Best Available Technology Economically Achievable) principles and by review of other Canadian jurisdictions where mills of similar age and design operate. Industry standard limits are mass-based limits, different from municipal wastewater standards where concentration limits are typical. The Province of Quebec offers some of the best written regulations in Canada and differentiates between new and existing mills (defining post 1992 mills as new mills). Regulations are based on monthly averages and written with the understanding that unusual days occur, hence additional daily limits are also employed and are derived as multipliers of monthly limits.

The framework of the regulations follow the same methodology as the Federal Pulp and Paper Effluent Regulations (PPER) in using Reference Production Rate (RPR) and multipliers for daily versus monthly limits. As an example, Quebec multipliers employed were: BOD_5 Daily Max = 1.6 x Monthly Average and TSS Daily Max = 2.0 x Monthly Average. Quebec completed a review of their regulations in December 2016. The limits in Quebec are more stringent than the current Federal PPER regulations and were the starting point for the replacement ETF design.

The new ETF system capability was designed with a margin of safety to ensure NPNS can consistently run below the monthly and daily regulatory limits. Since the ETF project commenced, ECCC announced in September of 2017 their intent to modernize the current 1992 PPER. ECCC made public the first draft of the proposed changes in May 2019. The regulations are not finalized and may undergo changes before coming into effect.

Based on the current NPNS reference production rate of 938.5 ADt/day (90th percentile production) defined under PPER, the maximum allowable pollutant loadings for BOD and TSS that are regulated in other Canadian jurisdictions were calculated and are presented in Table 1-4, below.

Table 1-4: Calculated Regulatory Limits in Canadian Jurisdictions vs Veolia Expected Performance

	BOD				TSS			
	Daily Max		Monthly Avg		Daily Max		Monthly Avg	
	kg/t	kg/day	kg/t	kg/day	kg/t	kg/day	kg/t	kg/day
Canada								
PPER (1992 current)	12.5	11,731	7.5	7,039	18.75	17,597	11.25	10,558
PPER (2019 first draft)[1]	4.5	4,223	2.6	2,440	6.3	5,913	3.75	3,519
Quebec (existing mills)	7.1	6,663	4.5	4,223	7.1	6,663	4.5	4,223
Ontario	10.0	9,385	5.0	4,693	13.4	12,576	7.9	7,414
British Columbia	7.5	7,039	7.5	7,039	18.75	17,597	11.25	10,558
Alberta (existing mills)	5.0	4,693	2.5	2,346	8.0	7,508	4.0	3,754
New Brunswick	4.3 -13.4	11,731[2]	2.7-8.0	7,039[2]	18.75	17,597	11.25	10,558
Nova Scotia	12.5	11,731	7.5	7,039	18.75	17,597	11.25	10,558
Manitoba	10 - 32	11,731[2]	10 - 32	7,039[2]	5.0	4,693	5.0	4,693
Newfoundland	12.5	11,731	7.5	7,039	18.75	17,597	11.25	10,558
NPNS								
Veolia ETF Performance	---	---	2.0	1,875	---	---	2.0	1,875

[1] The values shown are speculative and are based on discussions between ECCC and Industry representatives
[2] Calculated at Canadian limit, as discharge limits in this province are permit-specific.

This analysis shows that the new ETF would not only continue to meet the existing PPER limits and be in compliance in every Canadian province, but would also be in compliance with the first draft of the 2019 PPER regulations. COD is not currently a regulated parameter anywhere in Canada, but some provinces require mills to report their discharges for data collection purposes only.

1.7 RWS EFFLUENT LOADING

The 2018 RWS for the Caribou outfall presented daily maximum effluent water quality expressed on a concentration basis. Based on a peak flow of 85,000 m^3/day, pollutant loadings in kg/day can be calculated for comparison to both current operation at the BHETF as well as the expected performance of the new ETF. The RWS, with far-field modelling conducted over a period of one month, assumes that the maximum daily effluent quality occurs every day of that month and, therefore, can be thought of as a monthly average with peak flow of 85,000 m^3/day occurring every day.

Table 1-5 shows a comparison of Northern Pulp's current effluent loadings at Point C and the proposed ETF's expected performance run from Veolia, against the pollutant loadings that were brought forward to the RWS. For all parameters presented below, the loadings brought forward to the RWS are greater than both current and future expected effluent quality and hence extremely conservative. It should be noted that actual operating parameters in the new ETF are expected to be below the maximum performance run values from Veolia.

Table 1-5: Effluent Loadings Comparison

	2018 Point C Treated Effluent Loading (kg/day) [3]	Veolia Expected Loading (kg/day) [4]	RWS Loading (kg/day)
BOD	1,526	≤ 1,875	4,080
TSS	1,717	≤ 1,875	4,080
COD	39,521	≤ 37,500	61,625
AOX	87	≤ 225	663
Nitrogen	299	≤ 450	510
Phosphorous	95	95 [5]	128

[3] Based on annual average production rate of 777 ADt/d
[4] Based on RPR of 938.5 ADt/d
[5] Expected to remain similar in new system

CONCLUSIONS

The purpose of this screening and evaluation was to establish whether the treated effluent characteristics found at Point C were representative of the future treated effluent characteristics with the new ETF. A comparison of the untreated (Point A) and treated (Point C) effluent components against published effluent composition data showed that the mill's effluent shows no appreciable difference from effluent characteristics from other bleached kraft mills operating either ASBs or ASTs. An analysis of the current system's performance shows that it provides effective treatment and is comparable, performance wise, to other mills in Canada. Based on Veolia's expected performance, the future ETF would also be expected to provide performance that is comparable to other mills. It is therefore quite reasonable, since current and future systems have comparable performance, that Point C can be used as an accurate representation of what the effluent from the new ETF will resemble.

The Northern Pulp data collected at Point A for untreated effluent entering the BHETF in Section 2.3 falls well in line with the typical pollutant loadings found in other bleached kraft effluents. Based on this, and the large number of systems already in operation worldwide that successfully treat an effluent of similar composition and characteristics, the proposed technology will effectively treat Northern Pulp's effluent to levels consistent with other bleached kraft mills worldwide. The new ETF would not only continue to meet the existing PPER limits and be in compliance in every Canadian province, but would also be in compliance with the first draft of the 2019 PPER regulations.

The Veolia Expected Loadings represent maximums for the plant acceptance run. It is anticipated that the plant will operate somewhat below the maximum plant acceptance run performance. Loadings brought forward to the RWS are greater than both current and future expected effluent quality and hence are extremely conservative. Results of the modelling from the updated RWS are presented in Section 4.2 of the Focus Report.

1.8 SIGNATURES

Signature	Signature
Name: Ken Frei (OIQ #123617)	Name: Guy R. Martin (OIQ # 040521)
Title: Principal Consultant, Process & Environment	Title: Vice-President, Consulting Services

NORTHERN PULP NOVA SCOTIA CORPORATION
A PAPER EXCELLENCE COMPANY
ABERCROMBIE POINT, NOVA SCOTIA, CANADA

RFQ NO: 10-1113-A000-09400

EFFLUENT TREATMENT PLANT REPLACEMENT PROJECT ABERCROMBIE POINT, NOVA SCOTIA, CANADA

for

SUPPLY, FABRICATION, TESTING, INSPECTION, PACKAGING, GUARANTEE AND DELIVERY

of an

EFFLUENT TREATMENT PLANT

REV B
05 FEBUARY 2018

Rev	Date	Status	Description	Prepared By	Checked By	Approved By
A	26-jan-2018	For bid	Effluent Treatment Plant	KF	GRM	BZC
B	5-feb-2018	For bid (corrected)	Effluent Treatment Plant	GRM	`GRM	BZC

3.2 Design Criteria

The main input and output parameters are as follows: More detailed data analysis of the mill's raw effluent is shown in the attached Appendix 5 – Design Criteria. Ranges for mg/L are based on highest load divided by lowest flow and lowest load by highest flow.

Raw Total Mill Effluent (TME) Data

Parameter	Units	TME Avg.	Design	After O_2 Delig.	Future
Production	*ADMT/a*	280,000 *(280,000 – 300,000)*	280,000	280,000 – 300,000	320,000 – 380,000
	ADMT/d	802 *(700 - 900)*	802	802	900 – 1,100
Flow rate	*m^3/d*	65,000 *(55,000 – 85,000)*	85,000	55,000 – 85,000	60,000 - 85,000
	m^3/hr	2,710 *(2,300 – 3,333)*	4,000	2,300 – 3,333	2,500 – 3,333
pH units	-	8.0 *(6.0 – 10.0)*	8.0	8.0	8.0
Temperature					
Raw effluent	°C	43 *(40 - 55)*	55	43 *(40 - 55)*	40 – 55
After cooling	°C	35 *(28 - 37)*	35	35	28 - 37
AOX	*mg/L*	6.0 *(2.0 – 14.5)*	12	5.4 *(2.5 – 10.2)*	3.2 – 11.5
	kg/d	400 *(100 - 800)*	800	350 *(230 – 560)*	260 – 650
BOD_5	*mg/L*	200 *(75 - 575)*	350	180 *(68 – 520)*	160 – 600
	t/d	13 *(6.5 – 32)*	23	12 *(6 – 30)*	14 – 36
COD	*mg/L*	875 *(400 – 2,000)*	1,250	650 *(270 – 1,270)*	385 – 1,820
	t/d	60 *(35 - 100)*	90	42 *(23 – 71)*	33 – 101
TSS	*mg/L*	325 *(35 - 2300)*	800	250 *(35 – 870)*	42 – 715
	t/d	22 *(3 - 100)*	55	16 *(3 – 48)*	3.6 - 43
Total Nitrogen	*mg/L*	2.3 *(0.2 – 5)*	0.5	2.3 *(0.2 – 5)*	0.2 – 5.0
	kg/d	150 *(15 - 300)*	35	150 *(15 - 300)*	15 – 300
Total Phosphorus	*mg/L*	1.6 *(0.125 – 5.8)*	0.5	1.6 *(0.125 – 5.8)*	0.14 – 5.3
	kg/d	100 *(10 - 320)*	35	100 *(10 – 320)*	10 – 320
Total Colour	*TCU*	860 *(400 – 2,500)*	1,500	603 *(190 – 1,820)*	270 – 2,580
	t/d	55 *(25 - 160)*	98	40 *(15 – 101)*	22 – 145

3.2.1 Comments

- As a separate project, NPNS intends to implement an oxygen delignification system, which will reduce the organic loading, both chlorinated and non-chlorinated, of the raw effluent. This system is expected to be on-line after the start-up of the new effluent treatment facility: the Bidder must demonstrate that the proposed system is able to adapt to this organic loading reduction while still maintaining the system's performance;

- Design numbers: these numbers represent the 90th percentile process value for the majority of the parameters listed (COD, BOB, TSS, AOX, Colour). Design flow value represents the maximum hydraulic loading to be treated in the ETP while nutrient design values show the lowest nutrient content in the untreated effluent.

- Future scenario: the data shown in this column should be used to demonstrate the potential expandability of the proposed system to compensate for mill expansion. It is assumed that any mill expansion would occur after the implementation of O_2 delignification;

- Daily production rates are based on 354 days of operation per year;

- Summer effluent flows average 70,000 m^3/day while winter flows average 60,000 m^3/day;

- AOX=Adsorbable Organic Halides;

- BOD_5=Biochemical Oxygen Demand (5-day);

- COD=Chemical Oxygen Demand (total);

- TSS loadings are variable but can often exceed 200 mg/l. 30% of all TSS is inorganic lime;

- Total Nitrogen includes Nitrates, Nitrites and Ammonia (NH_3).

Expected Treated Effluent Quality

The values shown below are based on average conditions and represent the performance levels expected of the system. These limits are to be used as the basis for the system performance guarantees.

Bidder to indicate likely performance, as compared to the required effluent quality parameters listed below or state the expected system performance if it is felt that the proposed performance levels are not achievable. Unless otherwise mentioned, the performance levels shown are at current production rates and irrespective of the implementation of oxygen delignification.

Parameter	Units	Amount
BOD_5	kg/day	≤ 1,875
	mg/L	≤ 25
COD (without O_2 delig)	kg/day	≤ 37,500
	mg/L	≤ 500
COD (with O_2 delig)	kg/day	≤ 30,000
	mg/L	≤ 400
TSS	kg/day	≤ 1,875
	mg/L	≤ 25
AOX (without O_2 delig)	kg/day	≤ 225
	mg/L	≤ 3
AOX (with O_2 delig)	kg/day	≤ 170
	mg/L	≤ 2.3
Nitrogen	kg/day	≤ 225
	mg/L	≤ 3
Phosphorus	kg/day	≤ 35
	mg/L	≤ 0.5
pH		6 – 9

APPENDIX 4

DESIGN CRITERIA

5.1 Raw Total Mill Effluent (TME) Data

Parameter	Units	TME Avg.	Design	After O_2 Delig.	Future
Production	*ADMT/a*	280,000 *(280,000 – 300,000)*	280,000	280,000 – 300,000	320,000 – 380,000
	ADMT/d	802 *(700 - 900)*	802	802	900 – 1,100
Flow rate	*m^3/d*	65,000 *(55,000 – 85,000)*	85,000	55,000 – 85,000	60,000 - 85,000
	m^3/hr	2,710 *(2,300 – 3,333)*	4,000	2,300 – 3,333	2,500 – 3,333
pH units	-	8.0 *(6.0 – 10.0)*	8.0	8.0	8.0
Temperature					
Raw effluent	°C	43 *(40 - 55)*	55	43 *(40 - 55)*	40 – 55
After cooling	°C	35 *(28 - 37)*	35	35	28 - 37
AOX	*mg/L*	6.0 *(2.0 – 14.5)*	12	5.4 *(2.5 – 10.2)*	3.2 – 11.5
	kg/d	400 *(100 - 800)*	800	350 *(230 – 560)*	260 – 650
BOD_5	*mg/L*	200 *(75 - 575)*	350	180 *(68 – 520)*	160 – 600
	t/d	13 *(6.5 – 32)*	23	12 *(6 – 30)*	14 – 36
COD	*mg/L*	875 *(400 – 2,000)*	1,250	650 *(270 – 1,270)*	385 – 1,820
	t/d	60 *(35 - 100)*	90	42 *(23 – 71)*	33 – 101
TSS	*mg/L*	325 *(35 - 2300)*	800	250 *(35 – 870)*	42 – 715
	t/d	22 *(3 - 100)*	55	16 *(3 – 48)*	3.6 - 43
Total Nitrogen	*mg/L*	2.3 *(0.2 – 5)*	0.5	2.3 *(0.2 – 5)*	0.2 – 5.0
	kg/d	150 *(15 - 300)*	35	150 *(15 - 300)*	15 – 300
Total Phosphorus	*mg/L*	1.6 *(0.125 – 5.8)*	0.5	1.6 *(0.125 – 5.8)*	0.14 – 5.3
	kg/d	100 *(10 - 320)*	35	100 *(10 – 320)*	10 – 320
Total Colour	*TCU*	860 *(400 – 2,500)*	1,500	603 *(190 – 1,820)*	270 – 2,580
	t/d	55 *(25 - 160)*	98	40 *(15 – 101)*	22 – 145

Note: Raw Data Ranges are wide, but within statistically collected data. See Section 5.4

5.2 Expected Treated Effluent Quality

* Values are based on average conditions, these limits should be respected on a monthly average *

Bidder to indicate likely performance.

Parameter	Units	Amount
BOD_5	kg/day	≤ 1,875
	mg/L	≤ 25
COD (without O_2 delig)	kg/day	≤ 37,500
	mg/L	≤ 500
COD (with O_2 delig)	kg/day	≤ 30,000
	mg/L	≤ 400
TSS	kg/day	≤ 1,875
	mg/L	≤ 25
AOX (without O_2 delig)	kg/day	≤ 225
	mg/L	≤ 3
AOX (with O_2 delig)	kg/day	≤ 170
	mg/L	≤ 2.3
Nitrogen	kg/day	≤ 225
	mg/L	≤ 3
Phosphorus	kg/day	≤ 35
	mg/L	≤ 0.5
pH		6 – 9

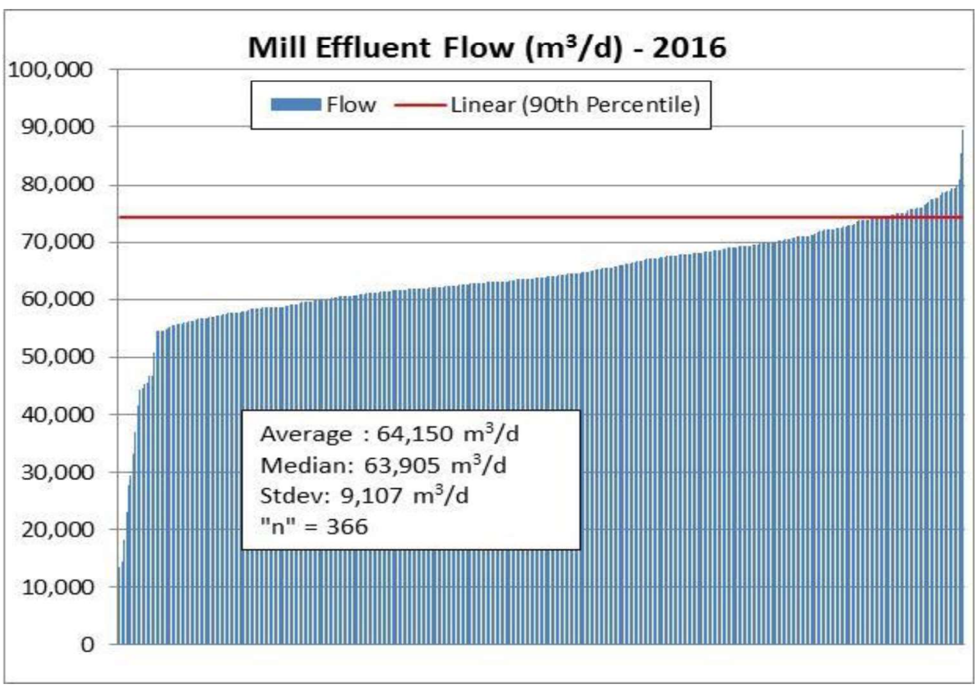
5.3 Sludge Treatment

Condition	Units	Amount
Minimum sludge cake dryness required: (primary only)	% OD	40
Minimum sludge cake dryness required: (biological sludge only)	% OD	15
Minimum sludge cake dryness required: (mixed sludge consistency)	% OD	26

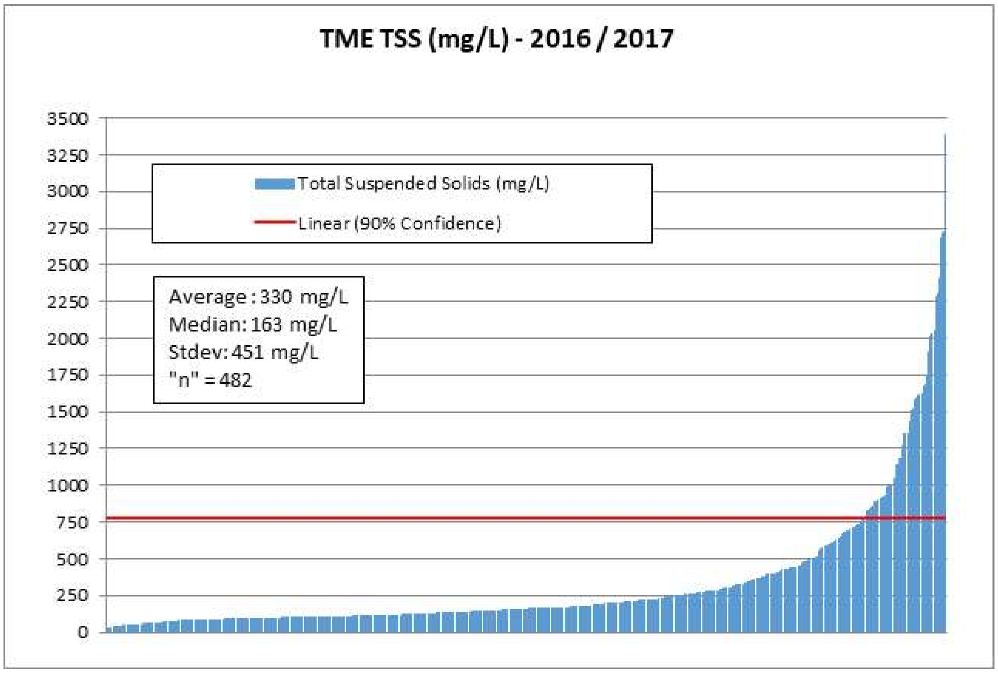
5.4 – Raw Data Statistics

Data shown below is for the mill's Total Mill Effluent (TME) station. These graphics are to provide the Bidder with an understanding of the mill's raw effluent characteristics for the 2016 year.

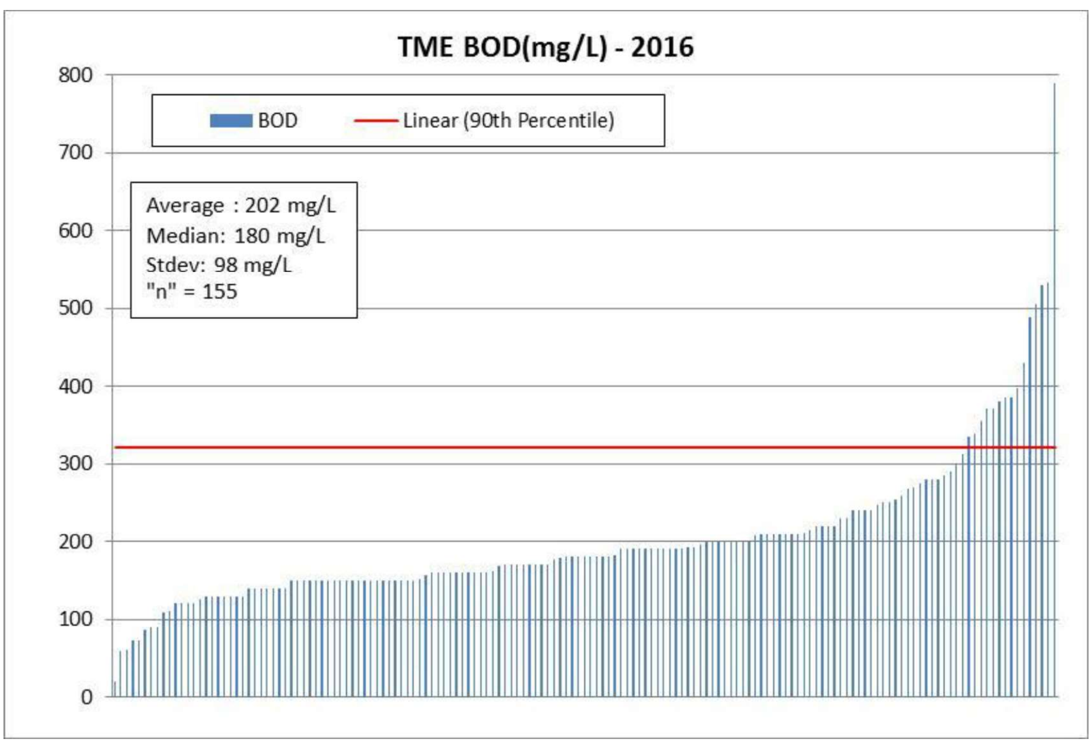
Mill Effluent Flow:



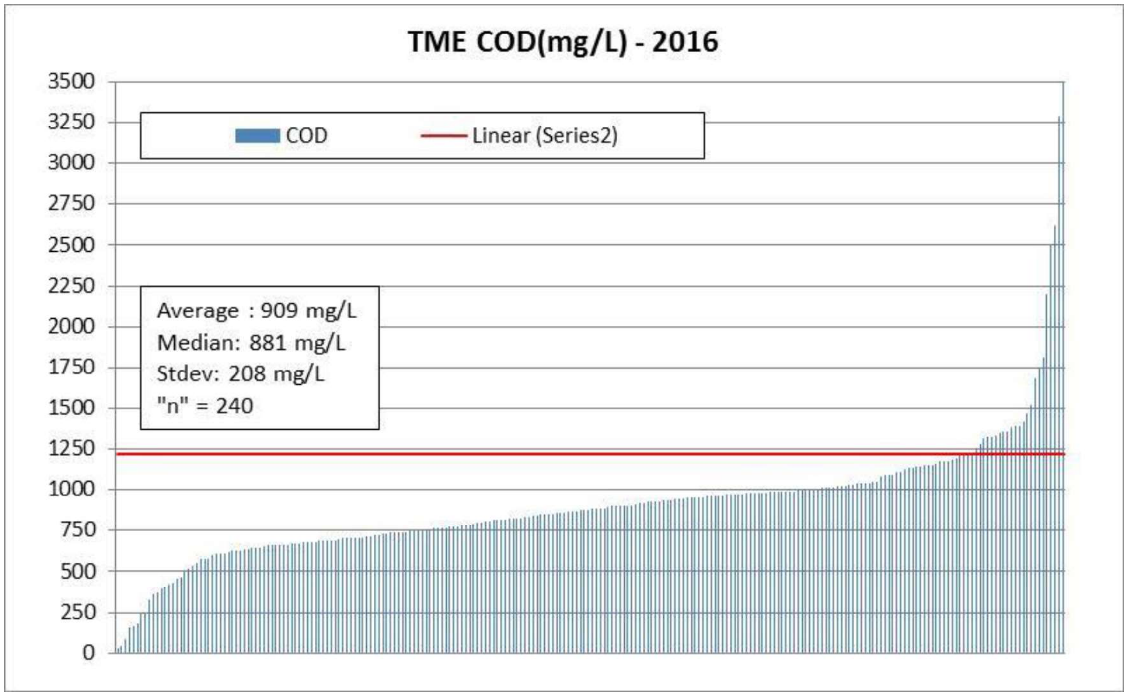
Total Suspended Solids



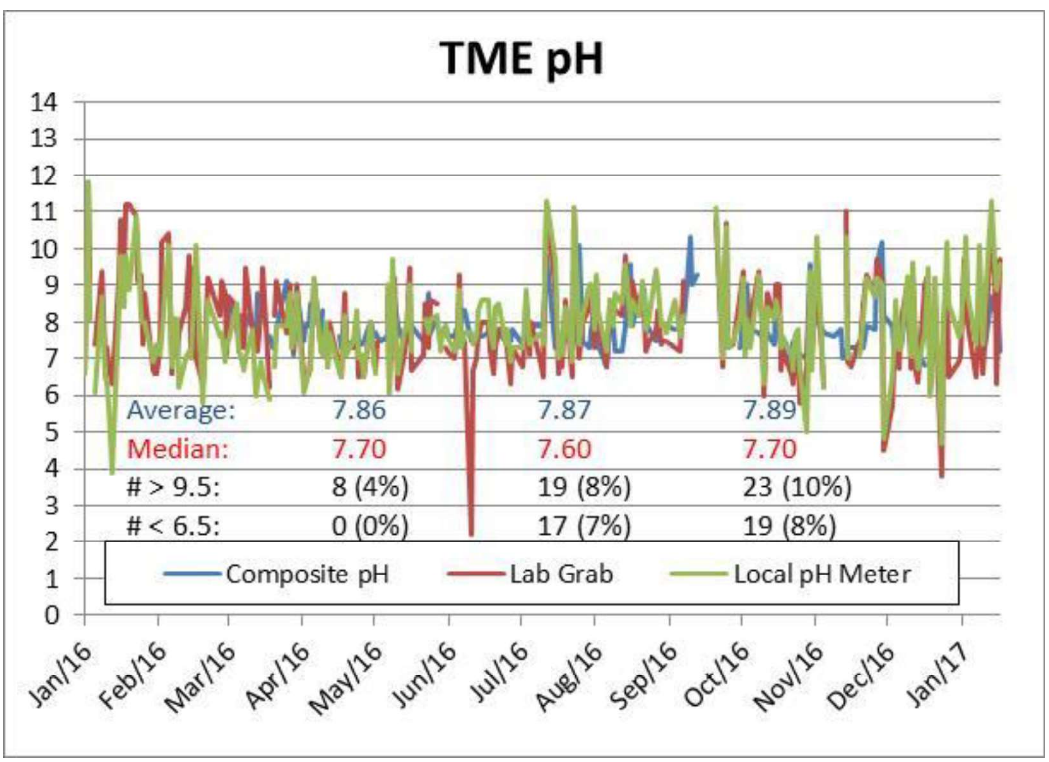
<u>Biological Oxygen Demand (BOD₅)</u>



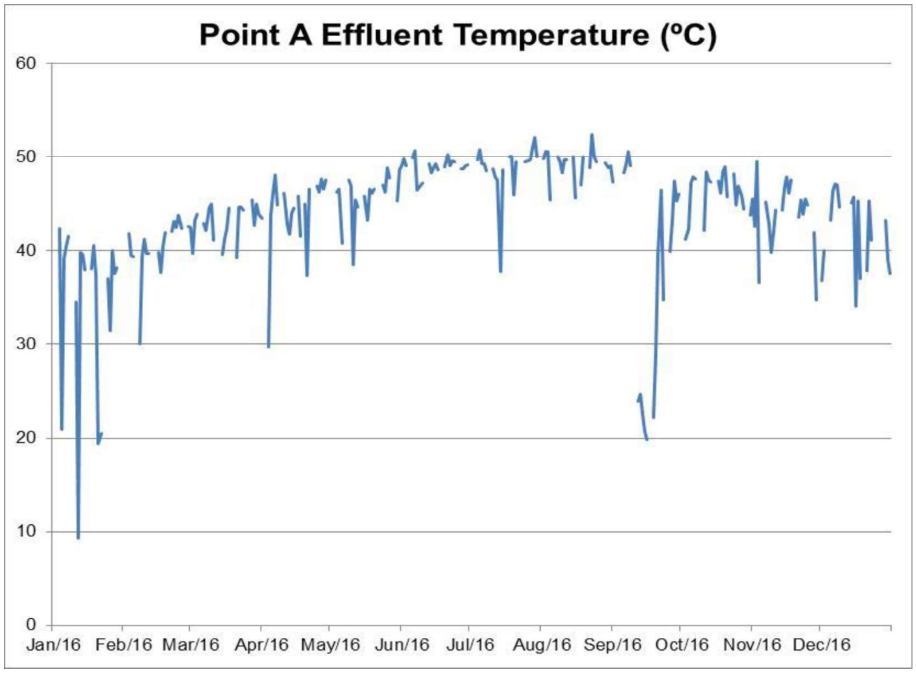
Chemical Oxygen Demand (COD)



pH (raw, before CO_2 Addition)



Temperature (shown for a downstream point known as Pt. A) Representative.



A STUDY ON THE BIOLOGICAL TREATABILITY OF EFFLUENT FROM NORTHERN PULP

Background

Northern Pulp in Nova Scotia are to replace an existing ASB treatment system with a new up-to-date biological treatment system. The new system is expected to reach a maximum removal of biodegradable COD in the effluent. However, the biodegradability of COD in the effluent in question is unknown. It is expected to be lower than for mills with oxygen predelignification (typically showing 65-75% SCOD biodegradability), but at least somewhat higher than the degradation achieved in the present ASB system (present discharge COD somewhat above 500 mg/L). The lab test presented in this report was carried out to determine the expected biodegradation of COD in a biological system representing best available technology, which should be very close to the maximum biodegradability of the COD. Some studies of other discharge parameters, i.e. N, P, AOX, BOD and TSS were also included although the short study did not allow optimization in respect to all those parameters.

Experimental

The lab test was carried out at Veolia Water Technologies – AnoxKaldnes laboratories in Lund Sweden. Effluent from Northern Pulp was received in three 20 L containers on 3 April 2018 and was stored refrigerated (2°C) pending use. The test was started the same day and was carried out in a lab-scale set-up simulating a full-scale design of a BAS-system for Northern Pulp. The temperature was controlled to 37°C Dissolved oxygen in the reactors was controlled manually with hand-held instruments as was the pH on a number of occasions. No adjustment of the pH was necessary to keep it within optimal biological range in the reactors.

The reactor volumes were chosen to simulate the full-scale design The reactor carriers were already colonized with biofilm from a previous pulp and paper study. The activated sludge reactor was filled with approximately 4000 mg/L of MLSS from a nearby kraft mill using a similar waste water treatment process. Starting with effective seeding material and shortening the adaptation period is a precondition to get maximum results in a short experimental time.

The system was operated at varying flow-rates in the range of 2,0 to 3,1 L/d, corresponding to full-scale flows of 58.000 to 90.000 m^3/d.

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COD, Tot-N, Tot-P, PO_4-P, NH_4-N, NO_3-N and NO_2-N were all analysed using Hach-Lange analytical kits. TSS was analysed according to Standard Methods, while AOX and BOD_5 were analyzed by an external accredited lab.

Results

Analytical data on the untreated effluent

The raw effluent contained a rather high concentration of TSS. During transportation and storage, TSS had to a large extent settled out and formed fairly big clumps. This is normal, but makes it difficult to get representative measures of TSS as well as TCOD. To get estimates, one of the containers (No 3) was shaken vigorously after which samples were taken and analysed for TCOD, TSS and SCOD. The results were as follows:

TCOD ≈ 1300 mg/L
SCOD = 850 mg/L
TSS ≈ 600 mg/L

As the effluent was very well settled when fed to the lab system, the difference between settled and soluble COD was rather small <50 mg/L.

The other two containers (No 1 and 2) were analysed for SCOD and showed a somewhat lower value of 760 mg/L.

Other analyses carried out on the effluent (container 3) showed the following results:

AOX: 4,6 mg/L
TN (settled): 3,4 mg/L
TN (soluble): 2,0 mg/L
NH_4-N: 0,1 mg/L
NO_3-N: 0 mg/L
NO_2-N: 0 mg/L
TP (settled): 1,1 mg/L
TP (soluble): 0,8 mg/L
PO_4-P: 0,5 mg/L

It can be noted that a very small part of total N in the effluent was found in the form of available inorganic N fractions.

Operation and COD-removal

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The system was started on effluent from container 1. The feed was switched to container 2 on 11 April and to container 3 on 19 April. In the first part of the test, nutrients in the form of NH_4-N and PO_4-P were added in excess (12,5 mg/L N and 2,5 mg/L P) to avoid any risk of limitation and secure the determination of maximum biodegradability. Focus was on SCOD-removal at different flow rates/loadings. The flow through the system, for simplicity translated to equivalent flow rate in the full-scale plant, is shown in Figure 1. As can be seen, flow rates corresponding to 58000 - 90000 m^3/d were tested in the experiment.

During the second half of the test, focus was put on nutrient discharge as well and nutrient dosage was reduced as described below.

Throughout the test, dissolved oxygen was kept on a level of 3 mg/L or above in both the MBBR and the activated sludge reactor.

SCOD in to and out from the reactors in the set-up is shown in Figure 2. SCOD was decreased from 760 mg/L (container 1 and 2) to around 500 mg/L in the MBBR and down to <350 mg/L in the activated sludge reactor. For container 3, the higher feed SCOD of 850mg/L was reduced to between 500 and 600 mg/L in the MBBR and to less than 400 mg/L by the total BAS system. Figure 3 presents the % SCOD removals in the system. The removal over the MBBR was around 35% and the removal over the total BAS process was around 55% throughout the test. The removal showed not to depend on flow rate/loading within the studied range, which is a strong indication of maximum SCOD-removal being achieved. The MLSS, starting at 4000 mg/L, was decreased to 2000 mg/L on 9 April to simulate a full-scale situation where more TSS is entering the system, diluting the active biomass with more inert organic/inorganic material. This did not affect the treatment negatively, showing the capacity of the BAS plant is enough also with considerable dilution of the biomass with inert material.

Settled COD out from the system (30 min settling of BAS effluent) was measured on a few occasions and was always <20 mg/L higher than SCOD. This is somewhat better than what can be expected out from the full-scale system as the lab settling procedure is very efficient.

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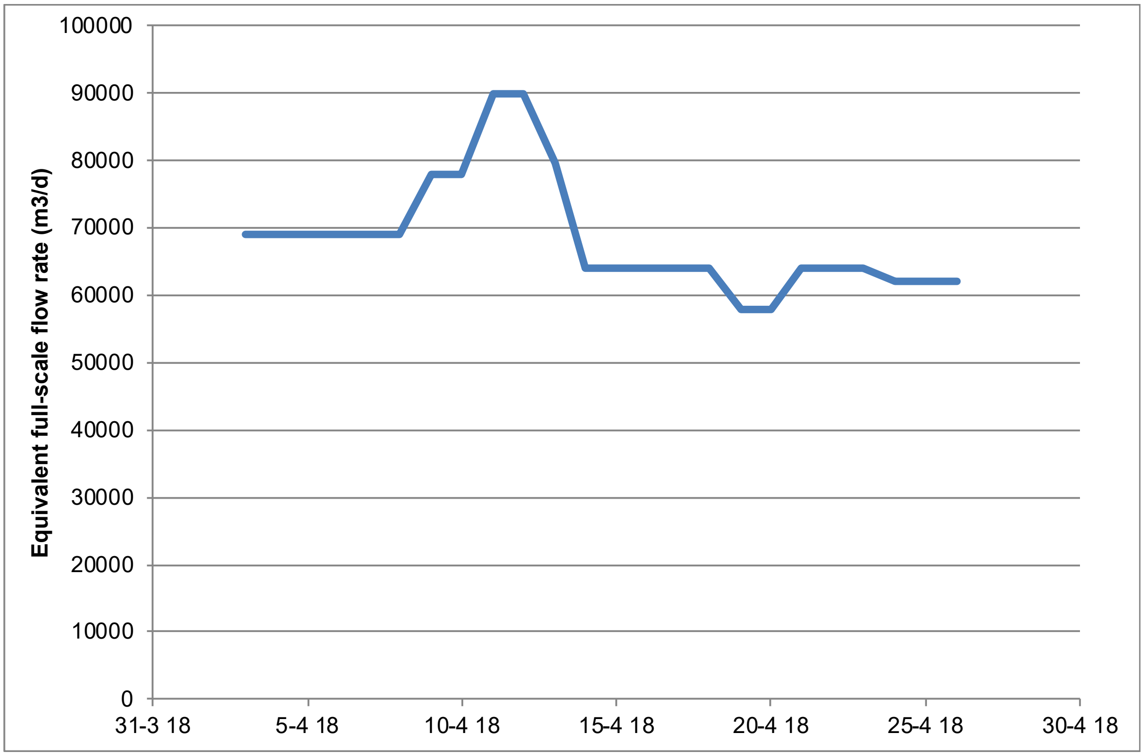

Figure 1. Flow-rates applied in the test expressed as equivalent full-scale flow rate

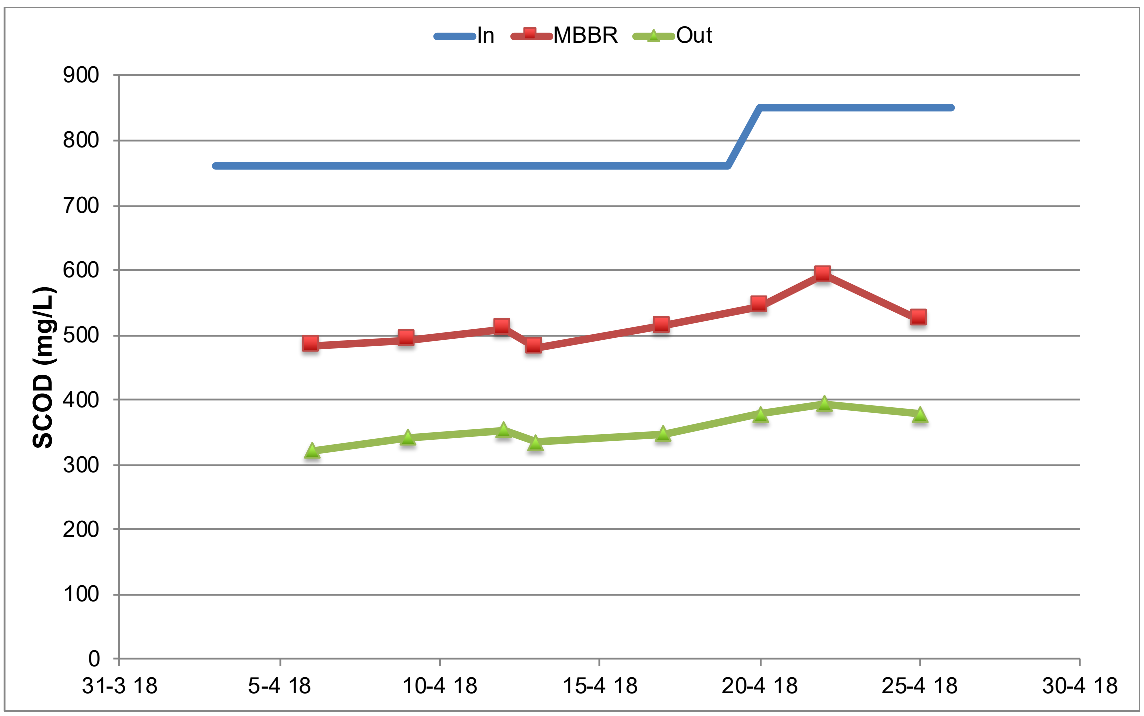

Figure 2. SCOD in to and out of the reactors in the BAS set-up

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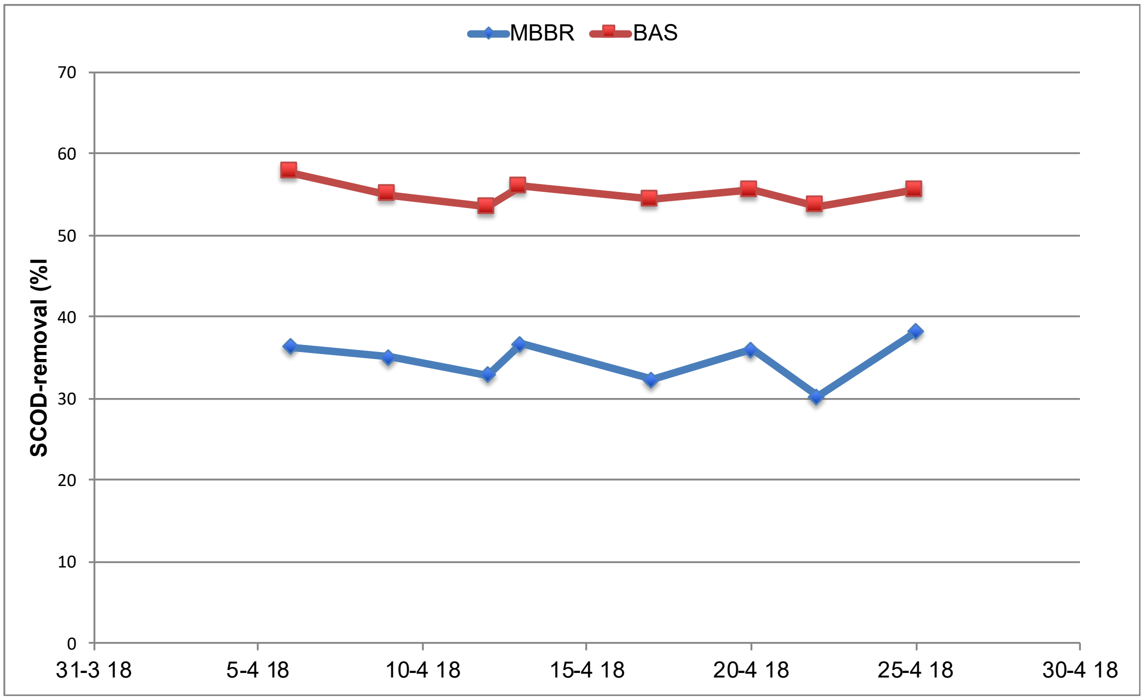

Figure 3. SCOD-removal over the MBBR and the total BAS during the test

Other treatment parameters

AOX was measured on untreated effluent (container 3) and outlet from BAS on 25 April (last day of experiment):

AOX in: 4,6 mg/L
AOX out: 2,2 mg/L

This means AOX-removal was 52%, similar to the removal of SCOD. It should be noted though that the original AOX of the effluent, when collected at the mill, was likely higher than 4,6 mg/L. There is normally a very unstable fraction of AOX in bleach plant effluent that decomposes spontaneously with time and should be gone after transportation and storage in this case. AOX removal performance should be similar to what is achieved with the current location system.

BOD_5 in the outlet from BAS was measured on the last day of the test (25 April) and was found to be <3 mg/L.

N and P were initially dosed to the effluent in considerable excess to secure non-limiting conditions. However, as analyses showed untreated effluent P to be well in excess to demands without dosage, no P was added from 17 April. On the same day, N addition

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was lowered to 6 mg/L. Discharge nutrient analyses were then carried out with results as presented in Table 1 below.

TABLE 1. Nutrient analyses on BAS effluent. All concentrations in mg/L

Date	TN (sed)*	TN (S)	NH_4-N	NO_3-N	NO_2-N	TP (sed)	TP (S)	PO4-P
20 April		2,5					0,80	
23 April	5,0	3,7	0	0,80	0,15	0,8	0,61	
25 April	4,6	2,7	0	0,41	0,16	0,73	0,59	0,45

*(sed): settled through 30 min sedimentation out from BAS

The results show that there is a considerable excess of P in the untreated effluent and a big part of this remains in the effluent as soluble P (mostly PO_4-P) after biological treatment. This makes it difficult to reach really low discharge values for P.

Analyses of N-fractions on the untreated effluent showed almost all N to be present in other forms than inorganic available N, most likely organic N. Depending on the organic N-containing molecules, that N may be available (if molecule degraded) or unavailable (if molecule not degraded). The discharge analyses indicate that this N (around 2 mg/L) seems not to be available and will remain as an inert soluble N fraction after treatment. The total N discharge will then be made up of this inert N + any excess available N + N in outgoing TSS. With very well settled outgoing samples, a discharge level around 5 mg/L TN was achieved in the tests. This is probably somewhat better than what can be achieved in practice with some more TSS in the treated effluent and varying load leading to occasional increases in available N discharge.

Separability of biomass

The small scale of the lab set-up did not allow simulation of full-scale clarification in continuous mode. Instead, the separability of the biomass was judged through microscopy of the biomass and small-scale batch settling of the outgoing water. The short term of the present lab study did not allow any study of the biomass development in the long run, but separability remained very good throughout the test, showing good compactability of the biomass and a very clear supernatant after settling.

Discussion and conclusions

The test was run in a flow-rate interval covering both average and design conditions in the "Design criteria" for the full-scale plant. The total COD content of the studied batch seems to be close to "design" (1300 and 1250 mg/L respectively) and thus higher than "average" (875 mg/L). Given that wood raw material as well as pulping and bleaching conditions will be similar to those applied when collecting the sample, the biodegradability of the sample, around 55% of SCOD, should be representative of the normal mill effluent. It is on a level expected for a mill without oxygen delignification and the very

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low residual BOD_5 after treatment further verifies that the maximum biodegradation of the organic content has been reached. The less than 400 mg/L SCOD achieved in the test means that TCOD below 500 mg/L should be achieved in full-scale even at average conditions and with TSS above 20 mg/L in the final effluent.

AOX of the untreated sample (4,6 mg/L) was lower than specified as the average AOX (6 mg/L). However, as AOX is typically decreasing spontaneously with time in this kind of effluent, it is likely that the original AOX when the sample was collected was on the level of average or higher and consequently the total removal from collection to after treatment higher than the 52% achieved based on “old” influent.

Nutrient discharge control is made complicated for this effluent. Phosphorus is available in the raw effluent in higher concentrations than needed by the biological process, which is a limiting factor for how low P discharge can be achieved. For the sample in question, influent P without dosage was 1,1 mg/L, which could be reduced to around 0,8 mg/L over the process. P seems to vary a lot in the effluent (0,125 to 5,8 with an average of 1,6 mg/L according to the design criteria), which means phosphorus levels of 0.5 mg/L are unlikely attainable. N is present in concentrations less than needed, so dosage will most likely be required. Most N in the raw effluent seems to be inert and will result in an increased discharge level to which any residual available N and N in the solids will be added.

Lund 17 May 2018

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