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I am writing this letter in relation to the Focus Report on Northern Pulp's Proposed Replacement Effluent Treatment Facility Project. I have grave reservations about the underlying scientific basis of the Focus Report and the subsequent reasoning and rationales based upon it. I would like to make a brief presentation about my concerns as they relate to the proposed effluent treatment plant.

Background

I am a retired computer systems and network engineer with a background education in organic and theoretical chemistry; my CV is attached for further review. My wife and I moved to Three Brooks to retire near my wife's family who live in the area. We have visited the greater Pictou over the past 30 years, and part of the reason we chose this locale is water borne lifestyle the area provides; fishing, boating, kayaking, paddleboarding and so on. I was enchanted by the waterways in and around Caribou, Pictou and the Northumberland Strait.

My brother-in-law has fished from the wharf in Caribou since the early 1980's. He has built a livelihood which has provided he and his wife a modest lifestyle which allowed them to raise their three children into successful adults. Both of his sons have followed him into careers in fishing from Caribou after witnessing the quality of life the fishing can provide someone willing to work for and invest in themselves and their families.

As I implied above, my wife and I make use of the Caribou waterways for recreation. We live next to a tributary river to Caribou Harbour and during the warmer seasons we swim, swim our dogs, kayak, stand-up paddleboard. We bike along Caribou Island, out to the lighthouse for exercise and to enjoy the pristine environment that the Northumberland Strait provides. We also motorboat in the area, particularly across Caribou Harbour to Pictou Island where my brother-in-law's family has a small piece of land and to visit other friends that have multi-generational family retreats on the Island as well. Our passages there and back takes us right across the outfall area for the proposed Northern Pulp-NS (NPNS) effluent treatment plant.

My family uses of this area for work and recreation and thus I became interested in what was coming out the end of that pipe into Caribou Harbour and what impact it will have upon my family and our way of life.

Introduction

I have read the NPNS Focus Report. I have focused my attention on Sections 2.3 and 2.4 and the associated appendices of the Focus Report (FR) as I have some relevant scientific background. [see CV attached]

The Focus Report is clearly a supporting document, designed to buttress proposals made in the previously submitted Environmental Assessment and allay the concerns raised by the regulatory review process. The effectiveness of this document thus is dependant on the sturdiness and cohesion of the presented discussions and the relevance of the data used to support them.

Regrettably, I did not find the arguments and supporting data convincing. The presentation is a tangled logical confusion in which the authors mix the contexts and subjects of their arguments and seemingly use an over-abundance of jargon to confound the reader's understanding of the issues at play.

But I am not writing to complain about the style and format of the authors' scientific presentation - after all, writing scientific documents for public consumption is hard and distilling a jumble of technical issues to a straight-forward, cohesive line of thought ready for digestion by the public is a challenge.

Instead, I am writing to address what I see as fundamental flaws in the logical constructs of the presented arguments. These flaws make the arguments upon which they are based suspect and in need of thoughtful consideration within the context of the overall proposed project. Because, if the justification of a large and likely impactful public work leans heavily upon complex and technical studies then the regulatory bodies and the public should have confidence that these studies and the arguments based upon them are sound. I'm afraid that this is not the case here.

Review of Focus Report

Dilution through the diffuser of the effluent pipe is not an effective mitigation

A main thrust of the justification for releasing the treated effluent and all it contains into the receiving waters of Caribou Harbour is that once mixed with a sufficient amount of water the effluent's contents are no longer of concern, i.e. "Dilution is the Solution for Pollution". This approach rests upon the flawed impression that once 'stuff' is diluted below a threshold concentration that the 'stuff' is no longer there. This is just not true. The 'stuff' is still there.

To give a numerical example, If a flask contains one litre of a 100 mg/L concentration of a 1000 Dalton pulp byproduct, then there are ~859 billion molecules of that compound in the flask.[1] Pouring in another litre of water into the flask reduces the "concentration" of this compound to 50 mg/L but there is still 859 billion molecules in the flask. Dilution doesn't

[1] 100 mg of X at 1000 g/mol = 0.000001 moles of X contains 859 billion molecules of X.

destroy the byproduct. Dilution doesn't degrade the byproduct. Dilution doesn't necessarily even reduce the impact that those billions of molecules can have.

The regulatory limits are, after all, just arbitrary thresholds hopefully based upon the science of the day. In this case thresholds were set some 30 years ago. It has to be remembered the early 1990's was a time when the consequences of even dilute 'stuff' weren't broadly considered as having an impact by the public.[2] The times have changed and we, as a society, have come to understand that dilution isn't, in of itself, a remedy but merely a disposal strategy and this should be kept in mind.

Rather than a "*complete … characterization of NPNS' raw wastewater*" as directed by the Terms of Reference, the authors have "*... completed a characterization of the raw effluent…*" [NPNS FR, 2.3.1, p 63]

The Terms of Reference require:

> ***Terms of Reference*** [NS TOR, p 3]
>
> *2.3 Submit data regarding the complete physical and chemical characterization of NPNS' raw wastewater (ie., influent at Point A for the Project)*...
>
> *2.4 Submit a complete physical and chemical characterisation of NPNS's expected effluent following treatment by the proposed technology….*

The Focus Report authors have chosen to set aside the task of "complete physical and chemical characterization" of the raw and treated effluents as requested in the Terms of Reference [TOF, p. 3]. The authors have substituted the more convenient approach of creating a list of compounds, minerals and elements that they anticipate from the proposed treatment process and then search for these in the raw wastewater from Point A, the 'treated' wastewater from Point C and then water sampled from Caribou Harbour. [NPNS FR, App 2.3] One must conclude that technically the authors have not presented a "complete characterization" as directed by the Terms of Reference.

My general concern with this approach is that it is subjective in nature; the analyses depend entirely upon the authors' choices, rather than allowing the observations themselves to drive the studies. And so we are dependent upon the authors' competence, expertise and motives regarding what is important and what is not. Thus to take this report at face value then we have to lean upon the goodwill, credibility and veracity of the authors and *their employers*.

Regrettably, as has reported, NPNS hasn't always been transparent nor have their statements regarding possible dangers to the public from their operations or impacts to the

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[2] 30 years ago, smoking in public places was common. One could smoke in restaurants, bars and other public commons - one could still smoke in airplanes in flight! Today the public broadly understands that cigarette smoke, even diluted by the vast volumes of air around us, does have an impact. Every public building is marked with signs limiting where smoking in public can be done.

environment earned the trust of the public. [Hoffman, et. al.] The result of this process is that the reader must keep in mind that the author might well not have studied all the relevant byproducts of the bleach Kraft pulping processes that would impact the receiving waters of Caribou Harbour.

High molecular weight molecules of bleach Kraft pulping process are a significant byproduct and their impacts should not be dismissed merely because they are difficult.

A more specific concern of mine with the authors' strategy of characterization is that the chemical analyses focus on the smaller molecules typically found in bleach Kraft pulp effluent. These molecules are the chiefly components of the effluent that the proposed process has been shown to work well upon.

The authors don't address the challenging characterization of the higher molecular weight byproducts of pulping, beyond a general description of their makeup. These are largely made of incomplete breakdown products of the lignin biopolymers found in the source wood. The proposed processes don't work as well on these effluent components and, as a result, these larger molecules would out into the receiving waters of Caribou Harbour. See Endnote 1 for a brief, general overview of lignin and its breakdown via bleaching.

Afterall, as pointed out by the authors, these hIgh molecular weight compounds make up ~ 40% of the effluent load organic material (COD) [NPNS FR, App 2.3, p4] which works out to ~21,000 kg of the organic matter in the raw effluent every day.[3]

It has also been determined that most of the organic halides AOX found in pulp effluent are contained within the high molecular weight components. [Hewett, Bullock, Borton] These are the chlorinated byproducts of the bleaching process[4]. The broad scientific consensus is that many organic halides resulting from the bleach Kraft pulping process can be long-lived and possibly deleterious (see discussion of organic halides below).

Thus, the physical & chemical properties, rates of degradation and impacts on the flora and fauna of the receiving water from the high-molecular weight components of effluent are important information as we try to understand what impacts are to be expected from their introduction into the receiving waters and what mitigation, if any, is possible.

The Veolia expected performance of the proposed ETF are overly optimistic given the results of the lab study presented in the Focus Report.

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[3] In 2018, the annual average COD in the raw effluent was 723 mg/L. [NPNS Focus Report, Add 2, p4] Assuming an average effluent flow of 72,500 m^3/day [NPNS EA, App C, p 12] then the daily effluent flow will contain 52,418 kg/day of COD load, 40% of which is ~21,000 kg/day.

[4] The organic halides formation are a side reaction in the bleaching process, primarily due to the in situ formation of hypochlorous acid and its competitive reaction with the phenolic subunits that make up lignin.

In discussing the Veolia Report [NPNS FR, Add 2.4 p 8-11], the authors explain that their working model for the proposed BAS portion of the effluent treatment system looks only at the digestion of the soluble organic material or sCOD. The particulate organic material or pCOD is filtered out beforehand, 29% of the total organic matter in the effluent. The rationale given is that the particulate organic matter comprises biopolymers from lignin breakdown ('colour compounds') & biopolymers from hemicellulose degradation (fibres) and that these are "not easily biodegradable". [NPNS FR 2.4.2, p 34]

The model system found a maximum of 55% digestion of the soluble organic matter, leaving the undigested remainder of 45% to pass through the rest of the ETF system. But the authors then continue their numerical and physical analyses of the ETF using this remainder as the total amount of organic matter going through the system, the 'COD load', ignoring the pre-filtered particulate matter.

Clearly, in the real world system, both soluble and particulate organic material will flow through the BAS system to be treated. The particulate organic matter, being 'hard to digest' would most likely then flow through this process unchanged. And so, this omission of ~1/3 of the COD load in their calculations yields over estimation of the total efficiency of the digestion process in cleaning the effluent that flows into the system. This omission from their calculations also underestimates the amount of organic matter that will flow into the receiving waters of Caribou Harbour.

Doing the math and adding the filtered-out particulate COD back to the soluble matter wasn't digested by the BAS system, would result in more than a doubling of the total COD leaving the treatment system[5] and into the receiving waters. This wide discrepancy is not addressed in analysis of the bench-top, model system's performance, yet these overly optimistic results are used to project the efficiency of the entire proposed effluent treatment system.

The authors incorrectly imply that organic halides from bleach Kraft pulping processes are short-lived contaminants in the environment. [NPNS Focus Report, 2019, p1]

This position is in stark contrast to a broad swath of the published literature on the use and remediation of adsorbable organic halides (AOX) in this context. A brief review of the literature dealing with pulp and paper effluent resulting from bleaching processes yielded the common motif that organic halides so produced are long-lived (persistent), difficult to degrade (recalcitrant), candidates for bioaccumulation (concentration) and potentially toxic.

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[5] Given the sample's initial measured organic material or COD of 1300 mg/L, their model system processed only the soluble 760 mg/L, with the 540 mg/L non digestible organic matter filtered out. The model effluent treatment system yielded a maximum efficiency digestion of 55% resulting in a reduction of soluble COD to 350 mg/L. Adding the 540 mg/L of pCOD back to the effluent stream would a total COD leaving the BAS system as 890 mg/L, instead of the reported 350 mg/L.

In fact, the general agreement upon this is so broadly held that the deleterious characteristics of AOX are common points in the preambles of numerous papers on pulp effluent streams. A quick sampling of statements about this consensus regarding chlorinated byproducts of the bleaching of wood pulp is provided in Endnote 2.

Furthermore, the goal of degradation and/or removal of organic halides produced during the bleaching process is a topic of active research and interest for tertiary treatment protocols. See a list of published work over the last 5 years on this topic in Appendix 1. The NPNS Focus Report claims that

> "*chlorinated compounds formed during ECF pulp production technology will neither be recalcitrant with respect to breakdown in the environment nor resistant to biodegradation.*" [NPNF Focus Report, 2019, p6]

If this statement were accurate then there would be no need for all of the research listed in Appendix 1. Yet dozens of researchers are investing a good deal of hard-won money and years of their lives to designing technologies that remove organic chlorides from effluent streams.

Clearly these compounds are seen by others as a problem and there is an active effort to reduce their impact on receiving waters. The author's positions on soluble organic halides disagrees with much of the scientific literature in this area of study.

The Focus Report purports that the organic halides created as a by-product of the bleached Kraft pulping process are readily degraded by 'natural' processes.

The authors' assert [NPNS Focus Report, 2019, p5]

> *"Chlorinated organic compounds are synthesized and degraded in the environment by natural biological and chemical processes..."*

The existence of natural processes that use and degrade specific organic chlorides, even one quite similar to those produced in the bleach Kraft pulping process, in no way justifies the author's conclusion

> *"...chlorinated compounds formed during ECF pulp production technology will neither be recalcitrant with respect to breakdown in the environment nor resistant to biodegradation."*

The processes of degradation are quite specific and not necessarily amenable to rapid adaptation to new, albeit similar molecules. As discussed in the literature on microbial removal of organic halides from pulp mill effluent streams, [Bajapi 2001, Savant 2006], the use of very specific bacterial species in very specific conditions shows promise. But in general, microbial degradation is limited in the scope of molecules consumes and the efficiency varied depending upon reaction conditions and the wood source of the effluent streams. Similarly, Bhatt, et. all [Bhatt 2007] review a number of specific organic chlorides

and the specific processes, organisms and conditions via which these particular compounds are biologically degraded. These authors conclude

> "*Many of the chloro-organics that are not degraded by bacteria and fungi have the potential to persist in the environment and express their toxicity over extended periods of time.*"

The literature provides no evidence of generic or rapidly evolving natural processes that degrade organic halides. In fact, the detail, variation and specificity of the many literature discussions suggests that suitable natural processes for breakdown of organic chlorides are rare and that there are few, if any, general pathway exists or that organisms can readily adapt to different compounds.

The authors are much too optimistic that a natural process is readily available in the receiving waters to degrade the organo-halides produced by the proposed bleach Kraft pulping process. Their optimism is not supported by the broad body of scientific knowledge nor by any evidence presented in either the EA or the Focus Report.

The authors incorrectly imply that the compounds resulting from bleached Kraft pulp mills are well characterized and their extent of chlorination is known.

> "*Most of the reported compounds are either non-chlorinated or have low degrees of chlorination and are expected to be readily biodegradable.*" [Focus Report, NPNS 2019, Appendix 2.2, p1]

As has been repeatedly reported in the literature, the constituent make-up of bleached Kraft pulping effluent is complex and not well characterized in general. [Hewitt et.al, Karat] It has been found that the high-molecular weight components of the bleaching process represent a good deal of the measured organic halides and these fractions are not well characterized, [Hewett, Bullock, Borton] as discussed above. For example, from "Effluents from Pulp Mills Using Bleaching" [Priority Substances List Assessment Report No. 2, 1991]

> "*The chemical composition of bleached pulp mill effluents is variable and not well characterized. Approximately 250 compounds have been identified in bleachery effluents but many more remain unidentified. Thus, substantial quantities of chlorinated organic compounds, both of known and of unknown composition, enter the Canadian aquatic environment from bleached pulp mill discharges.*"

Thus, I would conclude that the Report's position regarding characterization of organic halides in pulp effluent are overly optimistic.

The logic by which the authors dismiss the persistence of organic chlorides is in conflict with the Focus Report thesis that the effluent is immediately diluted to insignificant concentrations within the receiving waters.

The authors' statement that

> "*Pulp mill AOX will ultimately be mineralized through photochemical and biological processes.*" [NPNS Focus Report 2019, Appendix 2.3, p 6]

conflicts with the logical presumption of the report's theme that the effluent is quickly diluted to 'legal insignificance'. Such a dispersal in the receiving waters of Caribou Harbour would preclude any further biological degradation, either aerobic or anaerobic, if we assume the dilution proceeds as predicted by the simulation models. As discussed above, the known biological degradation pathways have specific conditions and organisms involved. The chances that the specific organisms and the organic halides would be brought into proximity with appropriate reaction conditions is vanishingly small.

Similarly, degradation relying upon photodegradation would be similarly unlikely as relatively little of the water volume is at/near the surface at any time given the volume of the water body as a whole. The efficiency of photodegradation is fundamentally dependant upon the amount of high energy (shorter wavelength) light that reaches the molecule and the intensity of the UV radiation decreases with increasing depth in the water body. Shorter wavelengths have a far more deleterious effect on photosensitive materials than longer wavelengths and the total energy of shorter wavelengths tends to be absorbed within a few millimetres of the surface. [Broughton 2012]

If dilution is as efficient as suggested by the simulation results, then neither the biological nor photochemical processes are likely. The authors are in conflict with themselves here; either the dilution is complete - as proposed - or there are natural processes which will degrade the organic halides - as proposed. But these two positions are not compatible.

Discussion, Conclusion and Opinion

To my mind, the arguments presented in sections 2.3 and 2.4 of the Focus Report can be summarized as follows:

- everything is natural and thus harmless
- harmful things that do arise are not a problem
- problematic things are instantly diluted and are unimportant

That something is found in nature does not rule out that it's concentration through industrial processing and subsequent disposal are without concern. For example, lignin is a naturally occurring biopolymer, resistant to natural breakdown in the forest environment. Its concentration and chemical modification during the bleach Kraft pulping process results in an enormous quantity, some 20 tonnes per day, of byproducts whose disposal is a grave concern as discussed above.[6] Naturally occurring components of trees might be harmless as they stand in nature but the concentration of even seemingly harmless things by the

[6] One could just as readily say that Uranium is a naturally occurring element, found in vanishingly small amounts within pitchblende whose concentration and subsequent disposal presents a staggeringly complex and dangerous problem for humanity. The underlying premise is the same.

marvelous efficiency of industrial processing can create problems when we seek to return them to the environment in a manner for which the environment has not evolved.

Much of the authors' attempt to downplay the impacts of the various pulping process byproducts is undermined by their scientific presentations and the arguments based upon them, as discussed above. I won't belabour the points here, merely conclude that the problematic components in the effluent could well remain a problem after being released into the environment.

And, as discussed above, dilution is not in of itself a 'mitigation' for the release of these pulping byproducts into the receiving waters. Releasing tons of not-easily-digestible paper byproducts into Caribou Harbour each and every day is very likely to have impacts. This has consequences, consequences that are likely to be expensive for the locality, its economy and the province. These points should be kept in mind when reviewing NPNS's proposal.

My goal of understanding "what was coming out of the pipe and into Caribou Harbour" has been confounded by an admixture of baffling detail with curious omissions within the NPNS Focus Report. To my mind, the presentation in those parts of Focus Report on which I've focused make more of a sales document crafted to salve the conscience of those who would approve and regulate the proposed project. It would appear the authors hope that the sheer volume of printed paper will provide the reader with the calming sense that something of consequence has been done and that the conclusions thus presented must be sound or at least 'sound-ish' enough to support. Regrettably, these are conclusions I cannot reach based upon what has been presented.

What I can conclude is that the authors of the Focus Report are overly optimistic about the efficiency of their proposed system and overly dismissive of the likely impacts of the by-products that would be released into Caribou Harbour. The 'scientific' information as presented does little to assuage my concerns.

Next, the technology in the proposed effluent treatment place is now over 20 years old and has roughly the same efficiencies as the present Boat Harbour effluent treatment facility. While well established, the process does not include the modern tertiary processes that have been shown to significantly reduce the organic matter released into the receiving waters. As was discussed above, a number of such technologies have been shown to be effective at production scale. In fact, the Focus Report admits as much by suggesting that oxygen delignification might be added in the future.

Why should the province or the public accept a technology known to be technically deficient in light of the present modern scientific body of knowledge? Doesn't Nova Scotia deserve the best available technology? The province and its people have invested a good deal into the operations now owned by NPNS and will spend a good deal more in the near term to clean up after these operations. The public, in return, deserves that the proposed project at least makes every effort to reduce its impact using known technology.

Finally, I see the proposed solution as a tremendous risk to the regional economy. Pulp is not the only economic driver from this area. The area's "receiving waters" contribute substantially to the provincial economy. [See Endnote 3] Lobster is the largest single commodity shipped by both value and volume from Stanfield Airport, some $216 million and 11.5 metric tonnes respectively in 2018. The growth of seafood exports is a large reason for the construction of the new $36-million cargo handling facility to ease the freight bottleneck at the Halifax Stanfield International Airport.

And to forestall the idea that impacts on the province's fisheries would be localized, I remind the reader that in 2003 a single breeder cow in northern Alberta tested positive for bovine spongiform encephalopathy (BSE), more commonly known as mad cow disease. Within hours, most nations had imposed a ban on all Canadian beef products[7,8] costing, at its peak, $11 million dollars a day.[9]

This is all the more relevant considering that foreign governments are now searching for possible 'rationales' - real or not - to punish other governments that have disagreeable policies or actions; for example, the recent targeting of Candian soybeans.

Similarly, seafood is a product whose 'locality of origin' is going to be difficult to demonstrate in the marketplace. Once a reputation is formed, say "Nova Scotia has 'pulpy lobster'", it is going to be long-held and stubborn in a world dominated by social media. One need only consider the impact of one repeatedly discredited study linking autism to vaccines and its ramifications to see the risks.

As a result of my reading of the NPNS Focus Report, my conclusions regarding its last than robust scientific foundations and my reservations about the wisdom of risking one of the province's more lucrative economic activities to support a portion of another, I would council NS Environment to decline the approval of the NPNS ETF as proposed.

[7] https://www150.statcan.gc.ca/n1/daily-quotidien/031105/dq031105a-eng.htm
[8] https://globalnews.ca/news/1830438/timeline-canadas-2003-mad-cow-disease-crisis/
[9] https://edmontonjournal.com/news/local-news/a-brief-history-of-mad-cow-disease

Endnotes

1) Lignin are polymers important in the formation of cell walls, especially in wood and bark. Lignins lend rigidity and do not easily rot in natural conditions. These are big molecules within wood that routinely reach molecular masses in excess of 10,000 Dalton or 10 times the size of the industry's standard cutoff between light and heavy molecules.

As a biopolymer, lignin is unusual because it lacks uniformity in its linear makeup, being made up from a number of somewhat different building block molecules. In contrast, cellulose - the desired wood pulp - is a biopolymer chain made up entirely from the same molecule. Lignin is cross-linked haphazardly between the links in the chain of the polymer as a result, lignin forms a dis-ordered mesh. This mesh-like material fills the spaces in the cell wall between the uniform and rod-like cellulose, hemicellulose (a tree-branched structures of a few sugars that make up the cell walls), and other components, especially in vascular and supporting tissues within the plant.

Lignin is relatively hydrophobic (insoluble in water solutions) and rich in aromatic subunits, or chromophores, which leads to its 'colouring' of yellow to brown in solution and, indeed, within the pulp. The delignification process uses chlorine dioxide solutions to chemically 'attack' the aromatic regions of polymer. This 'bleaching' of the molecules alters the chromophores' ability to absorb light, making the molecule colorless in the visible spectrum.

Note that this is the same basic thing that happens to one's color dyed clothing when bleach is spilled upon them. The chromophores within the dye molecules attached to the fabric in your clothes are altered and so no longer absorb light in the visible part of the spectrum and the color fades

This bleaching process has the added benefit of breaking down the large lignin polymers into smaller polymers and molecules made up of only a few subunits, known as ' lignans'. The process ends up adding alcohol units into the polymers at the points of breakdown - among others. Adding in the 'water-like' alcohol groups increases the solubility of the smaller resulting polymers in water.

But this process is nowhere near 100% efficient. It leaves a random collection of various still large biopolymers, some in solution and some still attached to the cellulose pulp. Some of the smaller biopolymers have added alcohol units and some can have chlorine inserted into them - the later of these makes up much of the recalcitrant organic halides found in

2) A few examples of authors discussing the broad concern regarding chlorinated byproducts of the pulp bleaching process:

> *"Chlorinated organic molecules constitute the largest single group of compounds on the list of priority pollutants compiled by the U.S Environmental Protection Agency… The ability of chlorinated compounds to impart toxicity, bioconcentrate, and persist*

and consequently their ubiquitous distribution in the biosphere has caused public concern over their possible effects on the quality of life." [Bhatt 2007]

"*Adsorbable organic halides (AOX) are generated in the pulp and paper industry during the bleaching process. These compounds are formed as a result of reaction between residual lignin from wood fibres and chlorine/chlorine compounds used for bleaching. Many of these compounds are recalcitrant and have long half-life periods. Some of them show a tendency to bioaccumulate while some are proven carcinogens and mutagens.* " [Savant 2006]

"*Adsorbable Organic Halides (AOX) are among the toxic constituents generated from the recycled paper industry. The problems associated with AOX in the environment are their accumulation in the food chain and their persistence in nature.*" [Muhamad 2011]

"*Effluents originated in cellulose pulp manufacturing processes are usually toxic and recalcitrant, specially the bleaching effluents, which exhibit high contents of aromatic and halogenated organic compounds (e.g. residual lignin derivatives).*" [Chaparro 2010]

3) Receiving waters contribute substantially to the provincial economy:

In 2018, Nova Scotian caught lobster is the largest single commodity shipped by both value and volume from Stanfield Airport, at $215.7 million and 11,495 metric tonnes respectively, while total seafood export value equates to $232 million. ["Halifax Stanfield Helps Propel Nova Scotia Seafood Industry Exports to Record Volumes", News Release March 20, 2019]

"*With the recently ratified CETA agreement, demand for Nova Scotia seafood continues to grow in Europe. We also continue to see strong growth in Asia, particularly for live lobster exports," says Bert van der Stege, Halifax International Airport Authority (HIAA) Chief Commercial Officer. "In fact, China is our top market for live Nova Scotia lobster, with the volume of exports to this country increasing by 63 per cent over the previous year, double the average growth of all export destination countries.*"

https://halifaxstanfield.ca/2019/03/halifax-stanfield-helps-propel-nova-scotia-seafood-industry-exports-record-volumes/

The importance of seafood products to the Nova Scotian economy is readily apparent in that construction this August on a new $36-million cargo handling facility to ease the freight bottleneck at the Halifax Stanfield International Airport — another sign of the growing volume and importance of fresh seafood exports from Nova Scotia. [CBC News, "Booming seafood exports leads to $36M cargo expansion at Halifax airport", Nov 15, 2018]

https://www.cbc.ca/news/canada/nova-scotia/new-cargo-logistics-park-halifax-airport-1.4906860

As Premier Stephen McNeil said the new cargo facility will play a key role in helping Nova Scotia businesses bring more of their world-class products, including live lobster, to international markets. ["Breaking New Ground: Halifax Stanfield Begins Construction on Air Cargo Logistics Park to the Benefit of the Region", News Release August 20, 2019]

https://halifaxstanfield.ca/2019/08/breaking-new-ground-halifax-stanfield-begins-construction-air-cargo-logistics-park-benefit-region/

References

P Bajapi “Microbial Degradation of Pollutants in Pulp Mill Effluent” Advances in Applied Microbiology, AI Laskin, JW Bennet, G Gadd, eds, 2001, Academic Press, 48, 79-134.

TA Barr, JM Taylor, SJB Duff Water Research “Effect of HRT, SRT and temperature on the performance of activated sludge reactors treating bleached kraft mill effluent” 30, (4), 1996, 799-810.

P Bhatt, MS Kumar, S Mudliar, T Chakrabarti “Biodegradation of Chlorinated Compounds—A Review” Critical Reviews in Environmental Science and Technology, 2007, 37, 165–198.

DL Borton, T Hall, R Fisher, J Thomas “Pulp & Paper Mill Effluent Environmental Fate & Effects“, 2004, DEStech Publications, Inc.

W Broughton “Assessing the moisture resistance of adhesives for marine environments” Adhesives in Marine Engineering, 2012, Woodhead Publishing Series in Welding and Other Joining Technologies pp 155-186.

CM Bullock, PA Bicho, JNSaddler “The influence of the high and low molecular weight fractions of a bleach kraft mill effluent on the microbial activity of activated sludge” Water Research 1996, 30, 1095-1102.

TR Chaparro, CM Botta, EC Pires “Toxicity and recalcitrant compound removal from bleaching pulp plant effluents by an integrated system: anaerobic packed-bed bioreactor and ozone” Water Science Technology, 2010, 61, 199-205.

LM Hewitt, JL Parrott, M. McMaster “A Decade of Research on the Environmental Impacts of Pump and Paper Mill Effluents in Canada: Sources and Characteristics of Bioactive Substances”*Journal of Toxicology and Environmental Health*, 2006, 9, 341–356.

E Hoffman, M Bernier, B Blotnicky, P Golden, A Kader, J Janes, R Costa, S Pettipas, S Vermuelen, T Walker “Assessment of Public Perception and Environmental Compliance at a Pulp and Paper Facility: A Canadian Case Study” *Environmental Monitoring and Assessment* 2015 10 1007/s10661-015-4985-5.

I Karat “Advanced Oxidation Processes for Removal of COD from Pulp and Paper Mill Effluents A Technical, Economical and Environmental Evaluation” M. Sc. Thesis, Royal Institute of Technology, Sweden, 2013.

AB Mohamad, R Rahman, AA Kadhum, S Siti & Sudin S Zakiah “Removal of Adsorbable Organic Halides (AOX) from Recycled Pulp and Paper (P&P) Mill Effluent Using Granular Activated Carbon–Sequencing Batch Biofilm Reactor (GAC-SBBR).” Modern Applied Science, 2009, 2, 37-45.

MH Muhamad, SRS Abdullah, AB Mohamad, RA Rahman and AAH Khadum “Treatment of Adsorbable Organic Halides from Recycled Paper Industry Wastewater using a GAC-SBBR Pilot Plant System”, Journal of Applied Sciences 2011, 11, 2388-2393.

Northern Pulp Nova Scotia - Focus Report 2019.

Nova Scotia Environment - Terms of Reference 2019.

WH Osman, SR Abdullah, AB Mohamad, AA Kadhum, RA Rahman. “Simultaneous removal of AOX and COD from real recycled paper wastewater using GAC-SBBR.” J Environ Manage. 2013, 30, 121, 80-86

Priority Substances List Assessment Report 2, Canadian Environmental Protection Act, “Effluents from Pulp Mills Using Bleaching” 1991, ISBN 0-662-18734-2.

DV Savant, R Abdul-Rahman, DR Ranade “Anaerobic degradation of adsorbable organic halides (AOX) from pulp and paper industry wastewater.” Bioresource Technology, 2006, 97, 1092-1104.

R.Sridhara, V.Sivakumar VP Immanuel JP Maran “Treatment of pulp and paper industry bleaching effluent by electrocoagulant process” Journal of Hazardous Materials, 2011, 186, 1495-1502.

Appendix 1: Studies related to degradation of adsorbable organic halides in the effluent of bleached pulp and paper mill effluent.

I have listed, in reverse chronological order, the results of a search in Google Scholar for scientific papers published limited to the period 2015 - 2019 with the keywords "*degradation+adsorbable+organic+halides+pulp+paper+effluent+bleach+kraft*".

This is not an exhaustive survey. It is meant to demonstrate the prevalence of studies in the scientific literature regarding efforts to reduce organic halides in pulp effluent.

Vashi, H, Iorhemen, OT and Tay, JH. "Aerobic granulation: A recent development on the biological treatment of pulp and paper wastewater." *Environmental technology & innovation* Elsevier, 2018

Zhang, H, Nie, S, Qin, C, Zhang, K and Wang, S. "Effect of hot chlorine dioxide delignification on AOX in bagasse pulp wastewater." *Cellulose* Springer, 2018

Farooqi, IH and Basheer, F. "Treatment of Adsorbable Organic Halide (AOX) from pulp and paper industry wastewater using aerobic granules in pilot scale SBR." *Journal of Water Process Engineering* Elsevier, 2017

Yao, S, Nie, S, Zhu, H, Wang, S, Song, X and Qin, C. "Extraction of hemicellulose by hot water to reduce adsorbable organic halogen formation in chlorine dioxide bleaching of bagasse pulp." *Industrial crops and products* Elsevier, 2017

Chen, T, Li, Y, Lei, L, Hong, M, Sun, Q and Hou, Y. "Influence of residual black liquor in pulp on wastewater pollution after bleaching process." *BioResources* ojs.cnr.ncsu.edu, 2017

Toczyłowska-Mamińska, R. "Limits and perspectives of pulp and paper industry wastewater treatment–A review." *Renewable and Sustainable Energy Reviews* Elsevier, 2017

Yao, S, Gao, C, Zhu, H, Zhang, Y, Wang, S and Qin, C. "Effects of additives on absorbable organic halide reduction in elemental chlorine-free bleaching of bagasse kraft pulp." *BioResources* ojs.cnr.ncsu.edu, 2016

Dai, Y, Song, X, Gao, C, He, S, Nie, S and Qin, C. "Xylanase-Aidued chlorine dioxide bleaching of bagasse pulp to reduce AOX formation." *BioResources* ojs.cnr.ncsu.edu, 2016

Song, X, Pei, Y, Su, J, Qin, C, Wang, S and Nie, S. "Kinetics of Adsorbable Organic Halides (AOX) Reduction in Lactase-Aided Chlorine Dioxide Bleaching of Bagasse Pulp." *BioResources* ojs.cnr.ncsu.edu, 2016

Pei, Y, Wang, S, Qin, C, Su, J, Nie, S and Song, X. "Optimization of lactase-aided chlorine dioxide bleaching of bagasse pulp." *BioResources* ojs.cnr.ncsu.edu, 2016

Fiskari, J, Kakkonen, A, Pakkanen, H and Alén, R. "A comparative study of advanced oxidative processes. Degradation of chlorinated organic compounds in ultrafiltration fractions of kraft pulp bleaching effluent." *Environment Protection …* infona.pl, 2016

Fiat, TM, Dahl, O, Master, E and Meyer, T. "Biochemical methane potential of kraft bleaching effluent and codigestion with other in-mill streams." *Tappi Journal* researchgate.net, 2016

Kamali, M, Gameiro, T, Costa, MEV and Capela, I. "Anaerobic digestion of pulp and paper mill wastes–An overview of the developments and improvement opportunities." *Chemical Engineering …* Elsevier, 2016

Nie, S, Wang, S, Qin, C, Yao, S, Ebonka, JF, Song, X and .... "Removal of hexenuronic acid by xylanase to reduce adsorbable organic halides formation in chlorine dioxide bleaching of bagasse pulp." *Bioresource …* Elsevier, 2015

Larsson, M, Truong, XB, Björn, A, Ejlertsson, J and .... "Anaerobic digestion of alkaline bleaching wastewater from a kraft pulp and paper mill using UASB technique." *Environmental …* Taylor & Francis, 2015

Kumar, S, Saha, T and Sharma, S. "… of pulp and paper mill effluents using novel biodegradable polymeric flocculants based on anionic polysaccharides: a new way to treat the waste water." *Int Res J Eng Technol* researchgate.net, 2015

Nie, S, Yao, S, Wang, S and Qin, C. "Absorbable organic halide (AOX) reduction in elemental chlorine-free (ECF) bleaching of bagasse pulp from the addition of sodium sulphide." *BioResources* (2015)

Kamali, M and Khodaparast, Z. "Review on recent developments on pulp and paper mill wastewater treatment." *Ecotoxicology and environmental safety* Elsevier, 2015

Hossain, K and Ismail, N. "Bioremediation and detoxification of pulp and paper mill effluent: A review." *Research Journal of Environmental …* pdfs.semanticscholar.org, 2015

Ashrafi, O, Yerushalmi, L and Haghighat, F. "Wastewater treatment in the pulp-and-paper industry: A review of treatment processes and the associated greenhouse gas emission." *Journal of environmental …* Elsevier, 2015

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