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Feasible policy development and implementation for the destruction of endocrine disruptors in wastewater

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HIGHLIGHTS

- Endocrine disrupting chemicals mimic some of the body's natural hormones.
- The treatment of certain EDCs can be handled in the activated sludge process.
- Endocrine disruptors, can be treated using the denitrification process.

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ABSTRACT

Endocrine disruptors when introduced to waterways have many adverse health effects on wildlife and humans. These health effects vary from neurological, immune, carcinogenic and reproductive disorders. Currently, there are few wastewater treatment facilities that are purposefully treating endocrine disruptors as part of the normal wastewater treatment process. Current literature has shown that endocrine disruptors can be treated using conventional methods. These conventional methods are centered around the denitrification process, which is rarely adopted in Canada. This paper investigates the current wastewater effluent regulations and guidelines in Canada, Ontario and the European Union. The research identifies a policy strategy that would include denitrification in the wastewater treatment process to help eliminate endocrine disruptors and acutely toxic nitrogen based compounds. Our emphasis here is on action possible in the Province of Ontario Canada, give the context of the Great Lakes basin and the potential for early action to stimulate other jurisdictions to follow. Our recommendations while aimed at one jurisdiction, have broad application globally.

1. Introduction

In Canada, endocrine disruptors are a very topical issue in wastewater effluent quality. We define endocrine disruptors as chemicals that can interfere with the endocrine or hormone systems in wildlife and humans. Results can vary from different forms of cancer, birth defects and developmental disorders (National Institute of Environmental Health Sciences, 2010). Since these substances are considered to represent a chronic toxicity issue, and since federal wastewater treatment regulations have focused acutely toxic substances such as ammonia, nitrates/nitrites, suspended solids and carbonaceous biochemical oxygen demanding matter (BOD) (Ministry of Justice, 2017), their treatment has been not been overtly considered since they do not cause acute toxicity at the end of the pipe. This paper investigates three hormonal endocrine disruptors that we consider "important" based on the United States Environmental Protection Act. We describe these pollutants, 17alpha-Ethinylestradiol,17beta-Estradiol and Estrone based on their sources, attributes and effects, to better illustrate the need for treatment.

Discoveries made in the late 1990s and 2000s have determined that17alpha-Ethinylestradiol, 17beta-estradiol and estrone can be treated using conventional wastewater methods that are meant to treat the acutely toxic ammonia/ammonium and their byproducts, specifically the nitrates/nitrites (Andersen et al., 2003; Ternes et al., 1999; Andersen et al., 2003; Ternes et al., 1999). The collateral benefits of treating these toxins simultaneously with the acutely toxic substances reveal the potential for a policy shift. We also review two future technologies for treating endocrine disrupting pollutants, photocatalysis for UV systems and membrane nanofiltration.

These treatment discoveries highlight an opportunity to review current Canadian wastewater effluent regulations for improvement and inclusion of endocrine disruptors, and too review the requirements of Ontario's Treatment for Sewage Treatment Works. In this research, the European Commission's regulations have been reviewed for comparison.

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When reporting on endocrine disruptors (EDCs) and potential treatments, we decided to target specific compounds. EDCs come from a variety of sources such as industrial run-off, personal care products, hormone based contraceptives, leachate from a variety of plastics and even medicine from hospital waste (NIEHS, 2010; National Institute of Environmental Health Sciences, 2010). Therefore, due to the varied sources and types, it is unlikely that there would be a catch-all solution for treating all the endocrine disrupting pollutants. Importantly, certain chemicals have different concentrations in wastewater effluent and different potencies. We targeted those endocrine disruptors that have high concentrations and high potency to research potential EDC treatment methods and policy responses.

The United States Environmental Protection Agency (USEPA), considers the following ten endocrine disruptors to be the most concerning, based on their studies of bioactivity (Endocrine Disruptor Screening Program (EDSP) Estrogen Receptor Bioactivity, 2015). Note that the Estrogen Receptor Bioactivity (ER Bioactivity) uses 17alpha-Ethinylestradiol as the denominator, to which the other compounds are compared. Numbers in Table 1 that are >1.000 are more potent than 17alpha-Ethinylestradiol and those <1.000 are less potent.

Despite the greater estrogen receptor bioactivity of 17alpha-Estradiol, the ability to feminise is significantly less than that of 17beta-Estradiol (Moos et al., 2008). Moos et al. determined that 17alpha-Estradiol can be 2 to 200 times less potent in its ability to feminise organisms, specifically in humans.

Wastewater effluent from the Boulder WWTP in Boulder, Colorado (Vajda, 2008) (Vajda AM1, 2008) had high concentration offenders of 17alpha-Ethinylestradiol, 17beta-Estradiol and Estrone. These three offending compounds are considered the most likely to cause reproductive damage in fish (Vajda, 2008). Based on the Boulder WWTP study, the USEPA data and further reasons we describe below, we focus on 17alpha-Ethinylestradiol, 17beta-Estradiol and Estrone for treatment possibilities and policy responses.

2. Sources and attributes

17beta-Estradiol (E2) is a synthetic and naturally occurring steroid hormone. As a medication, E2 is frequently used in hormone replacement therapy and for birth-control (PubChem, 2004a, 2004b). E2 is also produced in women and men naturally. For women, this is largely during the developmental stages and during fertile adulthood. Production in women is roughly an order of magnitude higher than men. This compound usually enters the wastewater stream through normal bodily functions. 17alpha-Ethinylestradiol (EE or EE2) is a synthetic form of Estradiol. It is used in the same applications as E2 (PubChem, 2005). EE2 is not naturally occurring. Entrance to the wastewater stream is through normal bodily functions from a user of EE2. Estrone (E1) is a naturally occurring steroid hormone which enters the wastewater stream through normal bodily functions (PubChem, 2004a, 2004b). In the past there was a synthetic version of Estrone, it has been discontinued from use due to the superior effectiveness of synthetic E2 and EE2.

Table 1
US-EPA top 10 endocrine disruptors by estrogen receptor bioactivity (Endocrine Disruptor Screening Program (EDSP) Estrogen Receptor Bioactivity, 2015).

Chemical name	ER Bioactivity
17alpha-Estradiol	1.06
17alpha-Ethinylestradiol	1
meso-Hexestrol	0.993
Diethylstilbestrol	0.943
17beta-Estradiol	0.935
Equilin	0.822
Estrone	0.807
Estriol	0.786
Mestranol	0.742
Zearalenone	0.71

2.1. Effects on fish

EDCs can have very serious effects on fish, both behaviourally and physiologically (Thorpe, 2003). The effects may range from reproductive issues to evidence of intersex fish (Vajda, 2008). Testing on small fish types such as the Japanese medaka, has shown the negative effects of EDC exposure to EE2 in concentrations as low as 63.9 ng/L (Seki, 2002). Hormonal EDCs, such as E1, E2 and EE2, exist in concentrations on the order of 1–1000 ng/L, which impact fish that are in direct contact with the wastewater effluent (Sigreist, 2005). The effect of EDCs on larger fish such as smallmouth bass in the Potomac River has been inconclusive (Blazer, 2007).

There is evidence that exposure to E1, E2 and EE2 additive and thus exposure even at low levels can produce the same effects on fish over time because the exposure is from multiple present hormones. By exposing rainbow trout to known constant low dose of EDCs (<63.9 ng/L) and measuring the hormonal responses in fish, Thorpe (2003) found that the vitellogenic (VTG) response was found to be is directly related to the feminization of male fish Over the 14-day exposure, the trout had an increasing VTG responses.

2.2. Effects on humans

The human body's normal endocrine system is affected by very small changes in hormone levels. EDCs can mimic these hormones and exposure can cause dramatic changes in these hormone levels in humans (NIEHS, 2010). When absorbed these EDCs can decrease and increase certain hormone levels, mimic some of the body's natural hormones and even alter natural hormone production, thereby reducing male fertility, reducing the number of males being born, interfering with male reproductive organs, causing female reproductive issues, increasing mammary, ovarian and prostate cancer and increasing autoimmune diseases (NIEHS, 2010). These effects seem to be greatest during key development stages in humans. Greater detail on these impacts is detailed by the National Institute of Environmental Health Sciences[1]:

Having briefly summarized the ecological and human health threats of these substances, we now examine technological options for their destruction before they leave the wastewater treatment plants and enter the receiving water.

3. Current technology

3.1. Activated sludge treatment

Activated sludge treatment is a commonly used secondary treatment method in wastewater treatment that uses a biological process to treat ammonia and remove the biological oxygen demand (BOD). Activated sludge treatment or secondary treatment is the bare minimum level of treatment required by the EU and Canada through their respective wastewater effluent regulations (European Commission, 2016a, 2016b, 2016c; Ministry of Justice, 2017) Importantly, E1, E2, EE2 can be treated by the activated sludge treatment process (Siegrist, 2005). There are certain modifications that can remove additional pollutants. Fig. 1 shows the evolution of the activated sludge processes including advances in the types of contaminants treated.

The most common activated sludge treatment in Ontario, in large scale wastewater treatment plants are aeration basins or aeration tanks. In reference to Fig. 1, the most common installation in Ontario

[1] http://www.niehs.nih.gov/health/topics/agents/endocrine/index.cfm

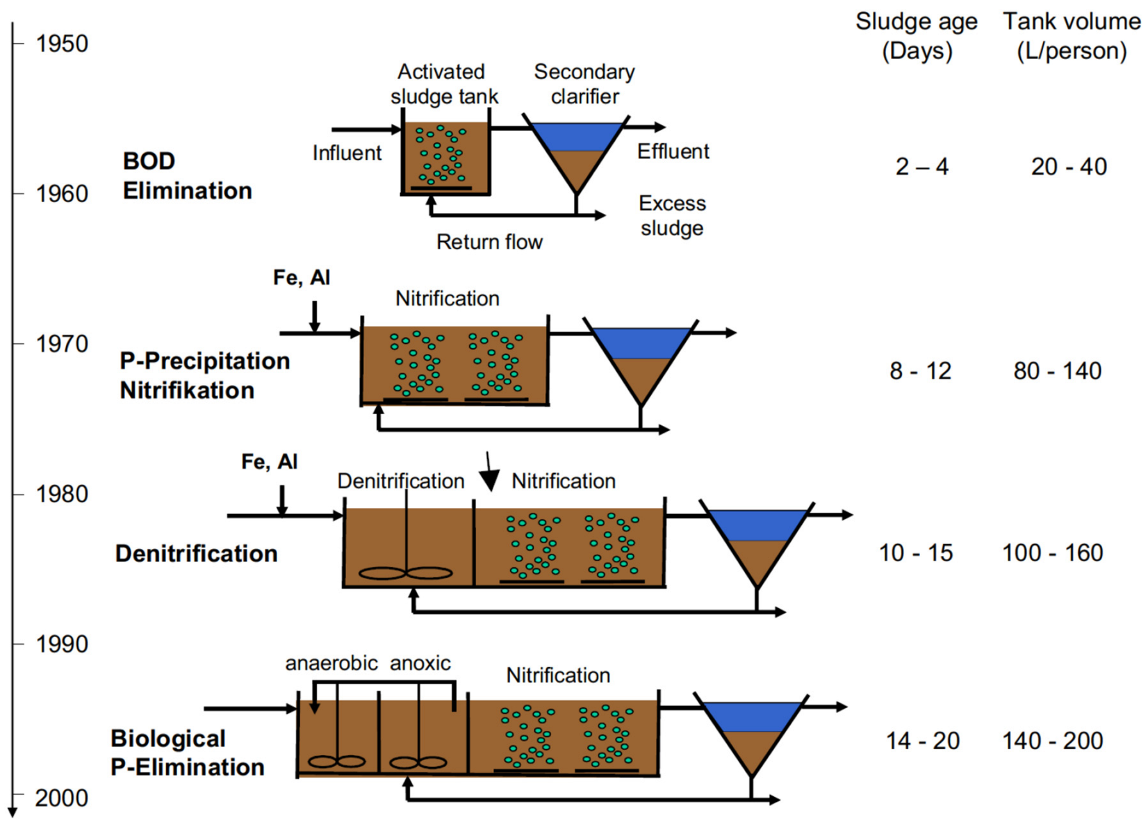

Fig. 1. Evolution of activated sludge processes 1950–2000 from: (Siegrist, 2005).

is the phosphorous precipitation and nitrification option, a technology dating from the 1970s (Siegrist, 2005). This process removes ammonia from the effluent of the wastewater plants to address acute toxicity. It does not treat the resultant nitrite and nitrates, the by-products of the ammonia breakdown process (The Fondriest Staff, 2010).

Research from 1999 and 2003 has shown that the treatment of certain EDCs can be handled in the activated sludge process (Andersen et al., 2003; Ternes et al., 1999). During the activated sludge process the offending EDCs are mineralized in lieu of absorbing into the sludge. This is done by creating a situation in which the bacteria inhabiting the wastewater treatment process break down the pollutant as a carbon and energy (food) source (Andersen et al., 2003). The efficiency was found directly related to the sludge age, that is with increasing sludge age the percent reduction of E1, E2 and EE2 increases (Andersen et al., 2003; Ternes et al., 1999).The pollutants break down in different stages of treatment and under different conditions and can be degraded with an upgraded activated sludge treatment system, as seen in Fig. 1.

Andersen et al. (2003) determined that EE2 degraded up to 90% if the sludge retention time reaches 11–13 days. E1 and E2 are broken down during the anaerobic denitrification process and aerobic nitrification process, found in some secondary treatment facilities. This occurs with sludge ages of 5 days or less (Ternes et al., 1999). There are additional benefits to upgrading to a denitrification or biological phosphorous removal process. Depending on the hydraulic capacity of the plant, the change can be an upgrade of existing facilities instead of constructing a new facility. This can be done by adding baffle walls and mixers to the front end of an existing aeration tank system. The process can be made more efficient when upgraded to a fine bubble aeration system. Fine bubble aeration provides a significant energy savings over the alternative systems by reducing the demand on the aeration blower system. The aeration blower systems can account for up to 50% to 65% of a wastewater treatment plant (USEPA, 1999).

3.2. Future technologies

There are several newer technologies that can be used for EDC removal. We briefly discuss the photocatalysis and membrane nanofiltration technologies. These forms of treatment are typically classified as tertiary treatment and are currently not mandatory as part of the wastewater treatment, per the current regulations for wastewater treatment in Canada (Ministry of Justice, 2017).

3.3. Photocatalysis

Photocatalysis is a future means to treat endocrine disruptors. The process is based on adding TiO2 during the disinfection phase and irradiating the wastewater with UV light (Sin, 2011). This causes the formation of OH radicals which react with organic pollutants, such as hormonal EDCs. Treatment of endocrine disruptors by catalysis is in the early stages of development and has yet to pass the pilot stage. This UV treatment is often seen in the disinfection of drinking water, but is relatively new in the wastewater industry. The process is energy intensive and therefore rarely used unless required for regulatory purposes. AECOM Canada Ltd., has designed a system for UV disinfection for the City of Toronto, where construction will begin in early 2018 (City of Toronto, 2014). The current design does not include a catalysis process. Details on wastewater treatment by photocatalysis are provided by Sin (2011).

3.4. Membrane nanofiltration

Membrane nanofiltration (NF) is a recent pressure driven system that forces water through a filter with pore sizes to the single order of nanometers (~1 nm) (Shon, 2013). Due to the small pore size, NF can remove viruses, demineralize chemical compounds for specialized industries, metal recovery from wastewater and even separate pharmaceuticals (Shon, 2013). This allows NF to be a near catch-all treatment for endocrine disruptors as seen in the research by Yoon (2005). The limitation of the membrane nanofiltration is related to its inability to treat large volumes of wastewater. A full-scale treatment train can handle a flow of 7 ML/D (Wilf, 2008). In comparison, a large wastewater facility, such as Ashbridges Bay Treatment Plant in the City of Toronto, Ontario, has an average flow of 550 ML/D (Toronto Water, 2016). As such, we classify this as a future technology, due to constraints on scaling up the process and to the need to potentially create new facilities to manage the large flows.

4. Policy context

In July 2014, the European Commission voted on an EU policy on endocrine disruptors. They advanced the first regulatory system in the world with legally binding criteria to define what an endocrine disruptor is. Once implemented, any active substance identified as an endocrine disruptor for people or animals can be assessed and withdrawn from the market. The adopted criteria will provide a stepping stone for further actions to protect health and the environment by enabling the Commission to start working on a new strategy to minimise exposure of EU citizens to endocrine disruptors (European Commission, 2017b, 2017c).

South Korea's regime is closest to the EU's. The country's chemicals legislation (K-Reach) came into force in January 2015, partly as a response to a major chemical incident in the city of Gumi in 2012. "Like EU Reach, K-Reach proposes to assess, evaluate and restrict chemicals before import, use or manufacture. It already requires all new substances to be registered before they can be introduced to the market, while existing substances will be assessed in batches. The first batch includes 510 ‘priority’ substances that the government considers to be particularly hazardous. These must be registered before July 2018. The registration process is also like the EU's. It requires companies to elect a lead registrant and submit joint registrations, and use an online platform similar to the EU's substance information exchange forums" (Niemiec, 2017).

The current Canadian Government Wastewater Systems Effluent Regulations falls under the Fisheries Act and regulates the following substances (Ministry of Justice, 2017):

- carbonaceous biochemical oxygen demanding matter (BOD)
- suspended solids
- total residual chlorine
- un-ionized ammonia

The goal of the effluent regulations is to ensure there is no acute toxicity in wastewater effluent for the protection of fisheries and aquatic life. To execute these regulations, a timeline has been setup with milestone dates for wastewater facilities to upgrade to meet these regulations. The extent of effluent regulations is specific to a facility's effluent quality and the timeline is based on the severity of the processes requiring upgrades to meet the new mandated effluent quality for that facility (Ministry of Justice, 2017).

Key dates taken from the Wastewater Systems Effluent Regulations are presented in Table 2.

The regulations have encouraged the City of Toronto, Ontario, to produce a pilot project in denitrification, as a result of high ammonia and nitrate levels in the effluent water (Toronto Water, 2016). The current installation is a single aeration basin upgraded with mixers and fine bubble aeration to improve energy efficiency and destruction of nitrogen based contaminants. As noted earlier, these upgrades could concurrently remove 90% of three “important” endocrine disruptors. There are currently no regulations through the Wastewater Systems Effluent

Table 2
Key dates for the wastewater systems effluent regulations (Ministry of Justice, 2017).

Date	Important information
January 1, 2013	Effluent quality and quantity monitoring begins; Combined Sewer Overflow (CSO) recording begins; record keeping and reporting requirements are in force. Application for ammonia temporary authorizations may be submitted.
January 1, 2015	Effluent quality standards and limits in TAs are in force **Exception:** Total Residual Chlorine (TRC) standard for <5000 m^3/day wastewater systems. Application for temporary bypass authorizations may be submitted. Acute lethality monitoring begins for wastewater systems that already meet the effluent quality standards.
December 31, 2040	Deadline for wastewater systems with TA expiry date of December 31, 2040 to meet effluent quality standards for CBOD and SS.

Regulations which dictate acceptable endocrine disruptor concentrations. This is because EDCs have chronic, rather than acute toxicity. Canada is currently focused on acutely toxic compounds (Ministry of Justice, 2017). Exemptions from having to correct these acutely toxic pollutants can occur until 2040, per the Wastewater Systems Effluent Regulations timeline.

In the Province of Ontario, there are two documents associated with wastewater treatment and more specifically wastewater effluent design goals. The first document is the “Design Guidelines for Sewage Works”, which was conceptualized and written as a guideline for engineers designing or reviewing sewage works (Province of Ontario, 2016). This document sets the standard for the designs of wastewater treatment facilities in Ontario, and references the ‘Guideline F-5, Levels of Treatment for Municipal and Private Sewage Treatment Works Discharging to Surface Waters (1994)’. The “Design Guidelines for Sewage Works”, was developed by professionals in the wastewater treatment industry, a consortium of members of various government and industry groups (Province of Ontario, 2016).

The second document is the ‘Guideline F-5, Levels of Treatment for Municipal and Private Sewage Treatment Works Discharging to Surface Waters (1994)’, and more specifically within that guideline the ‘Procedure F-5-1, Determination of Treatment for Municipal and Private Sewage Treatment Works Discharging to Surface Waters’ (Province of Ontario, 1994). Guideline F-5-1 details the effluent design objectives for various treatment levels and processes for BOD, suspended solids, total phosphorous, ammonia/ammonium and the effluent guidelines for BOD and suspended solids. The levels of treatment described are secondary treatment or better. As a comparison, aside from residual chlorine, these guidelines are in line with the Wastewater Systems Effluent Regulations for offending contaminants and minimum level of treatment. Within the guidelines all ammonia/ammonium treatment requirements are considered not applicable except for conventional activated sludge with nitrification. Neither endocrine disruptors nor nitrates/nitrites are considered for treatment.

Annex 3 of The Great Lakes Water Quality Agreement (GLWQA, 2012) commits Canada and the United States to prepare and issue Binational Strategies to reduce the release and impact of Chemicals of Mutual Concern (CMC). The 2012 Great Lakes Water Quality Agreement requires the United States and Canada to identify Chemicals of Mutual Concern that are potentially harmful to human health or the environment and that originate from anthropogenic sources. Annex 3 (CMC) requires that the parties target these chemicals of mutual concern for action by preparing binational strategies and coordinating the development and application of domestic water quality standards, objectives, criteria and guidelines. Further, Canada and the US commit to reduce anthropogenic releases of chemicals of mutual concern and products containing chemicals of mutual concern throughout their entire life cycles. The first group of Chemicals of Mutual Concern have been identified through a binationally agreed upon multi-stakeholder process. Canada and the United States are designating the following chemicals as the first set of Chemicals of Mutual Concern under the Agreement (in alphabetical order):

- Hexabromocyclododecane (HBCD)
- Long-Chain Perfluorinated carboxylic acids (LC-PFCAs)
- Mercury
- Perfluorooctanoic acid (PFOA)
- Perfluorooctane sulfonate (PFOS)
- Polybrominated Diphenyl Ethers (PBDEs)
- Polychlorinated Biphenyls (PCBs)
- Short-Chain Chlorinated Paraffins (SCCPs)

We suggest that the next set of CMCs include the EDCs we discuss herein, to "contribute to the achievement of the General and Specific Objectives of this Agreement by protecting human health and the environment through cooperative and coordinated measures to reduce the anthropogenic release of chemicals of mutual concern into the Waters of the Great Lakes." (GLWQA, 2012).

As noted above, the European Commission (EC), has adopted a strategy to address the health and environmental effects of endocrine disruptors since 1999 (European Commission, 2016a, 2016b, 2016c). Using the precautionary principle, the strategy has placed endocrine disruptors under several sets of regulations, namely, the Plant Protection Product Regulation, the Biocidal Product Regulation, REACH, and the Cosmetics and the Water Framework Directive (European Commission, 2017a, 2017b, 2017c). These regulations contain specific details on how endocrine disruptors are to be treated, and based on their toxicity, whether they are banned or regulated. While few other jurisdictions have acted, using Ontario as a case study, policy breakthroughs are possible.

The endocrine disruptors of concern to our research are also discussed by the Water Framework Directive. EDCs were added to the list of main pollutants in October 23, 2000 (European Commission, 2000). The EC has had recent issues in implementation caused by debate over the criteria that identifies endocrine disruptors. Two draft legal documents have been presented as part of the Biocidal Products and Plant Protection Products, issued on June 15, 2016, to set the criteria for identifying endocrine disruptors (European Commission, 2017a, 2017b, 2017c). As of July 4, 2017, the EC has amended the identification of endocrine disruptors to include those with relevant scientific evidence on the effects on animals (European Commission, 2017a, 2017b, 2017c). Based on the heavy adoption of tertiary treatment, despite not being required by the EC regulations, the EU has put in to place infrastructure to treat EDCs and other chronically toxic pollutants (European Commission, 2016a, 2016b, 2016c).

5. Policy recommendations

Our recommendations consider the principles of Best Available Technique (BAT) as outlined in the European Union's IPPC Directive (Table 3) (96/61/EC) (European Commission, 1996):

Table 3
The European Union's definitions/criteria for the terms of BAT (European Commission, 1996).

Term	Definition/criteria
Technique	Shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned
Available	Techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator,
Best	Shall mean most effective in achieving a high general level of protection of the environment as a whole, this can include reduction, substitution or even elimination.

As shown above, since 90% of the "important" endocrine disruptors, E1, E2 and EE2, can be treated using the denitrification process, we suggest their treatment be considered in amending existing policy. The Wastewater Systems Effluent Regulations can be updated to include endocrine disruptors as a fifth target. The justification is that from based on BAT, a currently available technology handles both the acutely toxic un-ionized ammonia, and by-products, in addition to treating the EDCs E1, E2 and EE2. As such the regulation could presently be amended to require treatment for:

- carbonaceous biochemical oxygen demanding matter (BOD)
- suspended solids
- total residual chlorine
- un-ionized ammonia
- endocrine disruptors, E1, E2 and EE2

Based on the Effluent Regulations January 1, 2013 effluent monitoring, some facilities are required to upgrade to denitrification. An example is the Ashbridges Bay Treatment Plant in Toronto, Ontario, which was required to install a pilot project for an eventual full upgrade. If endocrine disruptors were added to an amendment to the Wastewater Systems Effluent Regulations, linked to the acute toxicity of nitrogen compounds, this could require most larger scale municipal wastewater facilities to put in a denitrification system to also treat endocrine disruptors.

The advantages to including endocrine disruptors as part of effluent regulations are:

- Encourages installation of denitrification processes to existing wastewater facilities, thus reducing the nitrogen contamination of the effluent (even if not necessary under the current regulations).
- Future proofing of the facility – Eventually the effluent regulations will require lower quantities of nitrogen in the effluent. The processes would then be upgraded to meet future stricter effluent quality standards to simultaneously treat EDs.
- Reduction in energy consumption – While performing the upgrade it would be necessary to move to a fine bubble diffuser system which would include an energy cost savings.
- Upgrade over building new – When the ability to retrofit is present there is a significant cost savings.

The disadvantages to including endocrine disruptors as part of effluent regulations are:

- Capital Cost – Outside of the upgrades mandated by the current regulations, there will be a need for capital expenditure to make the upgrades at all relevant facilities.
- Some smaller facilities will require different solutions to provide the added sludge retention time (SRT) to treat endocrine disruptors.

Implementation would require having each wastewater facility acquire baseline effluent concentrations of E1, E2 and EE2. In Ontario, for example, the Ministry of Environment and Climate Change would require a reduction in the baseline concentrations. Since the 90% reduction is based on experimental data and not from a trial facility, a smaller percentage may be mandated to start. A chosen target of 50–70% reduction could be acceptable, and tuning of this value could be done as installations proceed and more data becomes available.

The current timeline for the effluent regulations allows no further exemptions beyond December 31, 2040 (Table 2). This date could be accelerated to address destruction of endocrine disruptors. The timeline from initial design proposal through to construction of these upgrades per installation is more than adequate for all major facilities to upgrade their activated sludge processes. The recommendation would be to accelerate the December 31, 2040 for final compliance for all facilities. Once the Wastewater Systems Effluent Regulations have been updated, it would be necessary for the Ontario Government's Guideline F-5 and other provincial guidelines to be updated as well. Guideline F-5 will need to have levels added for acutely toxic nitrite and nitrate and also include levels for endocrine disruptors. Finally, on a regional scale, including EDCs in the next round of CMCs under Annex 3 of the GLWQA could accelerate domestic programs and policies regarding their destruction in wastewater treatment plants.

6. Conclusion

Based on the work by Andersen et al. (2003), and Ternes et al. (1999), the treatment of EDCs E1, E2 and EE2 can be achieved using an upgraded conventional activated sludge system By upgrading traditional aeration basin systems to include denitrification processes, removal of E1, E2 and EE2 are possible, in addition to ensuring compliance with the Wastewater Systems Effluent Regulations for acutely toxic nitrogen based pollutants and the Guideline F-5 of the Province of Ontario (Ministry of Justice, 2017; Province of Ontario, 1994). This satisfies the need to treat both sets of pollutants, in addition to adding potential energy saving benefits to wastewater facilities.

We intend to stimulate the discussion on allowing the policy amendments to update the Effluent Water Regulations and the Ontario Guideline F-5. We recommend a future study using, for example, the City of Toronto's Aeration Tank 2 Pilot Project (AT2) to study the reduction of EDCs in a denitrification process for a large municipal wastewater plant (Toronto Water, 2016). As this is a single train of denitrification within a system of 11 nitrifying trains, one could study the effectiveness in removal comparing the trains. If there is noticeable removal of EDCs in AT2 based on the flows to the tank, this would provide much needed full-scale plant data to provide further validity to the policy recommendations in this paper.

We further intend to stimulate discussion on listing EDCs and Chemicals of Mutual Concern under the Great Lakes Water Quality Agreement based on their impacts to human and ecosystem health, and the feasibility of their destruction wastewater plant as detailed above.

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