

# Liquid Waste Management Plan

## Technical Memorandum



### LWMP Technical Memorandum #8

**TO:** Wastewater Advisory Committee

**SUBJECT:** Emerging Contaminants

**DATE:** January 17, 2018

**Prepared By:** Troy Vassos

**Reviewed By:** Paul Nash, Project Coordinator

## 1.0 EMERGING CONTAMINANTS

Historically, the primary focus wastewater treatment plant designs was to reduce the concentration of readily biodegradable organic contaminants in the treated wastewater effluent so that the residual organic content could be consumed by aerobic bacteria in the environment without the risk of depleting dissolved oxygen to the extent of affecting fish and other aquatic species. Emerging Contaminants refers to a growing awareness that there are other contaminants, that are typically present at very low concentrations, that can have a chronic or long term detrimental impact on the environment, aquatic and wildlife species and humans. These include micro-plastics formed when plastic degrades and breaks down into microscopic particles that enter the food chain, contaminants from nano-technology such as carbon nano-fibres that can penetrate cell walls and immobilize bacteria in the environment, and a group of chemicals that have been found to affect the hormone and reproductive systems of aquatic organisms, wildlife and even humans referred to as Endocrine Disrupting Chemicals or EDCs.

## 2.0 ENDOCRINE DISRUPTING CHEMICALS (EDCS)

Commonly used medications, birth control hormones, cleaning chemicals, fragrances, personal care products, anti-bacterial hand-wash lotions, and various other organic and inorganic pollutants are released to municipal sewers either as a result of direct disposal (e.g. poured down drains and flushed down toilets), application (e.g. shampoos contributing to shower and bath greywater drainage), or indirect release as part of urine and feces discharged to sewer through sanitary fixtures (e.g. toilets and urinals). Either individually, or in combination, over 800 chemicals have been found to exhibit or cause hormone and reproductive disruption and DNA damage in aquatic organisms, as well as being responsible for declines in wildlife populations and loss of species, and are referred to as “endocrine disrupting chemicals” or EDC’s. Some metals and organometallic compounds, for example cadmium, lead, mercury and tributyl tin (TBT), have also been identified as EDCs. EDC’s include well known persistent organic pollutants such as PCBs and DDT, and brominated flame retardants used in electronics, phthalates used in plastics and personal care products, and perfluorinated compounds. Some EDCs are persistent and can bioaccumulate to toxic levels within the food chain long after the chemical has ceased to be actively used (e.g. PCBs). Consequently, EDC’s not only affect aquatic species and wildlife, they have also been shown to affect humans.

The ways in which EDC’s interfere with hormone function is varied. The chemical can either affect hormone receptors or it can modify the production, transport, metabolism or secretion of hormones. EDCs can also interfere with other endocrine systems, including the immune system and fat development, and most EDCs interfere with several physiological systems simultaneously (Bergman et al, 2013).

*Bergman, A., J. J. Heindel, S. Jobling, K. A. Kidd, R. T. Zoeller. (2013). State of the Science of Endocrine Disrupting Chemicals - 2012. WHO (World Health Organization)/UNEP (United Nations Environment Programme).*

As a consequence of the increasing awareness of the ecological damage that EDC's are causing, there is a greater awareness that wastewater effluent discharges to the environment are a significant source of these chemicals. These contaminants enter the environment largely through human or personal activity and use, rather than contamination caused by industry. Unfortunately, wastewater treatment technologies have been primarily focussed on reducing the concentration of readily biodegradable organic matter in wastewater, and the technologies employed have limited effect on reducing the amount of EDC's in wastewater. While EDCs have been labeled as an "Emerging Substance of Concern" by the Canadian Council of Ministers of the Environment (CCME), the lack of technologies to remove these chemicals, and the fact they have a detrimental impact even at very low concentrations, make them difficult to target from a treatment perspective. What reduction that does occur is primarily through adsorption ("sticking") to biosolids – bacterial growing in the treatment process. When the bacteria are wasted from the treatment process, depending on how the biosolids are managed, the EDC's associated with the biosolids can be released to the environment.

There are presently no Canadian standards for the treatment/removal of EDC's from wastewater, or acceptable levels in receiving environments. The CCME is looking at this and have recently released the first draft of a standard for the pharmaceutical Carbamazepine in aquatic environments, but other countries such as Australia have already developed guidelines on EDC's in receiving waters.

### 3.0 TREATMENT TO REMOVE EDC'S

#### **EDC Treatments**

The wide range of EDC's that can be present in wastewater, their low concentrations, and their different chemical and physical characteristics makes them difficult to treat and remove. Treatment approaches that have been researched include:

- Biological treatment over long periods of time enable bacteria to slowly and gradually break down the typically complex and long-chain organic structures. Attached growth or fixed film wastewater treatment processes have characteristically extremely long biosolids retention times and are expected to be better suited to adsorbing and breaking-down complex organic compounds. However, many of the EDCs are toxic or are inorganic and not suited to biological treatment, and can take extended periods of time to biodegrade.
- Advanced oxidation using ozone and/or generated hydroxyl radicals to chemically oxidize and break down complex organic molecules. However, advanced oxidation technologies are typically very expensive and imprecise in terms of being able to target EDCs – and a great deal of the treatment capacity is spent reducing or removing non-EDC contaminants at considerable cost. Finally, some of the oxidation products may harmful in themselves, and effort must be taken to remove them, typically by an adsorption type process.
- Adsorption to chemicals and organic compounds for subsequent removal and targeted treatment/destruction. Activated carbon is a well known and effective contaminant adsorption substance that can remove both organic and inorganic contaminants. While adsorption can be highly effective at

removing EDCs from water, the contaminants have not been treated or destroyed, but merely partitioned from the liquid to a solid particle, or biosolids, and requires further treatment.

## 4.0 ATTACHED-GROWTH FIXED-FILM PROCESSES

As noted in Section 3.0, attached growth or fixed film processes are generally considered to be superior to suspended growth processes in the ability to adsorb and break-down complex organic molecules. This adsorption and long-term retention characteristics is expected to allow such systems to achieve significant reductions in EDC contaminant levels in wastewater. An example of a fixed film process is a Reed Bed which consists of support media with reeds growing on the surface of the media and the plant roots providing additional attached growth surface area for bacteria.

As noted, while some of the biodegradable organic EDC contaminants that become adsorbed to the bacterial biofilm can be gradually broken down and digested, other EDC contaminants may be more difficult or impossible (e.g. inorganic contaminants) to treat and can buildup in the biosolids that eventually have to be removed and disposed of. Consequently, the attached growth process has an indefinite ability to degrade some EDC's, and a finite ability to adsorb and treat certain others.

## 5.0 USE OF BIOCHAR

The filtering of water through charcoal is an ancient method of water purification, and carbon adsorption using activated carbon filters is a common method of treating drinking water to remove inorganic contaminants (metals), and organic contaminants that can affect taste and odour. and is still used today in many water and food applications. Some of this work has focused specifically for advanced wastewater treatment for organic micropollutant removal by biological activated carbon filtration. Although activated carbon has displaced charcoal for many specialized purposes, it is much more expensive to manufacture than charcoal, and is impractical to manufacture on a small scale. Consequently, over the last five years, there has been extensive research focused on using biochar as a sorbent for contaminant management in soil and water.

Biochar is a specialized form of charcoal, made primarily for use as a soil amendment, or filter media. It has an advantage over activated carbon in that it is relatively easy to make, especially at small scale, and can be made from a wide variety of carbonaceous materials, including wastewater biosolids. There have been many studies on making biochar from various feedstocks, including from wastewater biosolids. Biochar can be made easily at small scale, and there are a few emerging systems for small scale continuous production.

In summary, biochar offers the potential to;

- Effectively remove EDC's from reclaimed water
- Removes EDCs at least well as activated carbon
- Can be made locally from available waste-carbon feedstocks
- Is a cheaper alternative to commercial Activated Carbon

As noted, many of the organic contaminants and EDCs removed during the water treatment process end up in the biosolids. Making biochar from the biosolids represents an alternative method of treatment compared to conventional methods such as composting, heat drying or lime stabilization. Biochar, made from wood waste, has

also been found to be a beneficial aid to the composting of biosolids, leading to numerous improvements in the process and product.

There are currently no biosolids treatment processes that specifically target trace organics, including EDC's. Some charring processes can be operated in a way to destroy the organic contaminants, thus the biochar process has the potential to destroy all the organic contaminants in the biosolids.

Biochar, when applied to as a soil amendment, is also carbon negative – it is actually sequestering solid carbon into the ground. Various studies have shown charcoal can be stable in the soil, for hundreds to thousands of years. Protocols have been developed in other countries to quantify the use of biochar as a carbon sequestration methodology, though there is not one yet for BC or Canada. This is an area for future study with biochar, but the proposed project can quantify the fixed carbon contents of produced biochar.

The ability of biochar to remove EDC's was evaluated at the District of Sechelt Water Resources Centre. Table 1 illustrates the variation in concentration of various pharmaceutical compounds present in tertiary effluent from the Sechelt wastewater treatment facility after one hour of contact with wood-pellet biochar – with 1 gram of wood pellet biochar mixed with 1 L of tertiary treated wastewater effluent. While the tertiary treatment process was able to decrease the concentration of about half of the targeted analytes to less than the analysis detection limits, contact with the biochar resulted in adsorption and further significant reductions

**Table 1 Pharmaceutical reductions after 1 hr contact with biochar (1gm wood pellet biochar with 1L tertiary effluent)**

Analyte	Use	Detection limit (ug/L, or parts per billion)	Influent	Tertiary Effluent (reclaimed water)	Biochar Treated Tertiary Effluent	Tertiary Treatment Removal %	Tertiary + Biochar Removal %
Carbamazepine	anti-epileptic	0.001	0.334	0.347	0.083	0%	75%
Trimethoprim	antibiotic	0.005	0.138	0.213	0.017	0%	88%
Warfarin	blood anti-coagulant	0.001	0.009	0.007	0.004	22%	56%
Diclofenac	anti-inflammatory	0.01	2.82	0.899	0.427	68%	85%
Sulfamethoxazole	antibiotic	0.005	0.733	0.146	0.086	80%	88%
Triclosan	anti bacterial agent	0.05	0.637	0.064	<0.05	90%	100%
Naproxen	anti-inflammatory	0.025	10	0.388	0.104	96%	99%
Acetaminophen	pain killer	0.005	62.9	0.075	<0.005	100%	100%
Caffeine	coffee	0.02	73	<0.02	<0.02	100%	100%
Fuoxetine (Prozac)	anti-depressant	0.02	0.038	<0.02	<0.02	100%	100%
Sildenafil (Viagra)	erectile dysfunction	0.025	0.246	<0.025	<0.025	100%	100%
Triclocarban	anti bacterial agent	0.05	0.214	<0.05	<0.05	100%	100%
Bisphenol A	plasticiser	0.01	0.22	<0.01	0.012	100%	95%
17a-Ethinylestradiol (synthetic estrogen)	birth control	0.01	<0.01	<0.01	<0.01	n/a	n/a
Gemfibrozil	cholesterol control	0.005	<0.005	<0.005	<0.005	n/a	n/a

## 6.0 SYSTEMS IN FULL SCALE USE

There are a few examples worldwide of wastewater treatment system that have components specifically intended to remove EDC's. Most of these are plants that are producing high quality reclaimed water, or are discharging into a river that is subsequently used as a source for drinking water.

A well-researched example is a study on three advanced wastewater treatment plants in Australia using ozonation and "Biological Activated Carbon (BAC) filtration to produce high quality reclaimed water.

["Biofiltration for Advanced Treatment of Wastewater" Reungoat et al, Urban Water Security Research Alliance Technical Report No. 73 , 2012](#)

From the executive summary, with emphasis added:

BAC filtration without prior ozonation is capable of significantly improving the quality of the WWTP effluent. BAC filtration proved more effective than sand filtration and ***ozonation before BAC filtration did not significantly improve the performance***. BAC filtration is therefore suggested as a simple and cheap option for the upgrade of WWTPs with advanced treatment in order to improve effluent quality before discharge. Further research is required to better understand the parameters influencing the performance of BAC filters and to provide information for the design of full scale units.

Several other research and field studies have shown that activated carbon and charcoal produce good performance in degradation long after their adsorptive capacity has been exhausted. It is interpreted that it is the biofilms that are responsible for this performance.

Since the carbon and biofilms are reducing the dissolved organic carbon content, the clarity of the water is increased, which can be measured by the Ultra Violet transmissivity, and more simply, it is often commented that the water is "sparkling". This represents getting closer to the state of "fresh" water.

While the long term "fixed bed" systems perform well, the systems that have the media replaced more often perform slightly better due to the adsorption characteristic

That said, where the highest performance is not critical, the simplicity and cost efficiency of a single charge of media in long term service is operationally a better choice.

## 7.0 COMBINED FIXED FILM AND BIOCHAR PROCESS

The concept of a treatment by a Reed Bed (an engineered constructed wetland) was proposed in 2016 as polishing step for the Cumberland wastewater treatment system. Reed beds are normally built with inert gravel media simply because it is cheap and free draining. By adding biochar to the media within a reed bed, the adsorptive capacity of the reed bed to remove EDCs from the treated wastewater effluent can be significantly increased, and the carbon from the biochar can also be used to support bacterial growth within the reed bed. Charcoal is well known as a successful plant growing media in horticulture and hydroponic operations.

The media within the reed bed could also be further enhanced to remove phosphorus from the effluent by incorporating zero-valent iron (e.g. iron filings or shavings) into the media, as well as removing ammonia through nitrification by ensuring the support media is aerated and aerobic conditions are maintained.

This system would have adsorption, biofilm and plant based biological process happening, and is a promising, and potentially simple, means of providing treatment for emerging contaminants. The concept of combining the features of adsorption and fixed film biological treatment process into a reed bed will be discussed further in TM #9.

