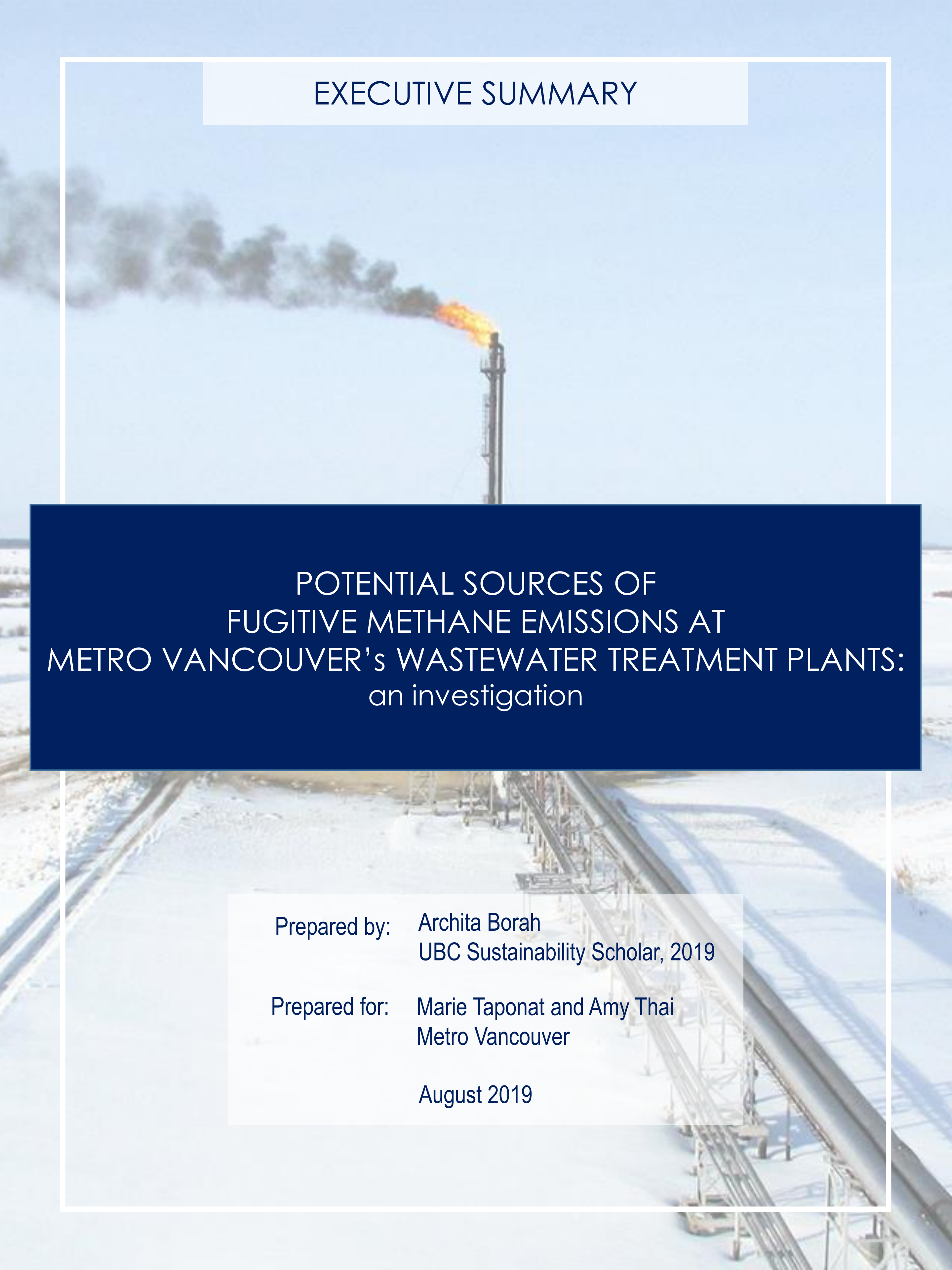

EXECUTIVE SUMMARY

POTENTIAL SOURCES OF FUGITIVE METHANE EMISSIONS AT METRO VANCOUVER's WASTEWATER TREATMENT PLANTS: an investigation

Prepared by: Archita Borah
UBC Sustainability Scholar, 2019

Prepared for: Marie Taponat and Amy Thai
Metro Vancouver

August 2019

DISCLAIMER

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organisations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region.

This project was conducted under the mentorship of Metro Vancouver's staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of Metro Vancouver or The University of British Columbia.

ACKNOWLEDGEMENTS

The report was made possible thanks to the support and guidance of Marie Taponat and Amy Thai, my mentors from Metro Vancouver. I would also like to take this opportunity to thank a few individuals: Vince Chiu, Yehan Chen, all my fellow scholars and Karen Taylor at the UBC Sustainability Scholars Program.

PROJECT BACKGROUND

Wastewater has an image problem[1]. However, careful planning coupled with modern wastewater treatment technologies have been successful in alleviating many concerns related to wastewater disposal and reuse. In addition to this, resource recovery from wastewater has paved the way for sustainable water management. Some of the common resources recovered from wastewater include carbon in the form of energy, and phosphorus and nitrogen in the form of fertilizers[2]. Wastewater treatment plants (WWTPs) are instrumental in deriving these resources from wastewater. Metro Vancouver treats about 400 billion litres of wastewater each year and operates five wastewater treatment plants in the region[3]. The Annacis Island Wastewater Treatment Plant (AIWWTP), located in Delta, B.C, is the largest wastewater treatment plant in Metro Vancouver[4].

Figure 1. Annacis Island Wastewater Treatment Plant (AIWWTP) located at Delta, British Columbia, the largest wastewater treatment plant operated by Metro Vancouver, and treats wastewater from 14 municipalities in the Lower Mainland to safely discharge the same into the Fraser River[4].

At AIWWTP, the organic matter present in the incoming raw wastewater is broken down into smaller compounds, which can be consumed by bacteria through a variety of biochemical processes in order to derive energy in the form of biogas and useful materials like Class A biosolids that can be used as fertilizers (Nutrifor™)[*] .

However, WWTPs can be significant sources of greenhouse gas (GHG) emissions globally[5]. Emissions of methane, a potent GHG, are possible from WWTPs. Methane, a colourless and odourless gas, and has a global warming potential (GWP) of 28-36 over a 100 year horizon, which means that despite a shorter lifetime (almost 12 years), methane is more destructive than CO_2, because it can trap more energy (heat) and slow the rate at which energy can escape into space, thereby contributing to global warming[6].

In 2017, emissions from the Waste category in Canada were 19 Mt CO_2 eq (2.6% of Canada's total GHG emissions) as compared to 20 Mt (2.8%) in 2005, wherein emissions from Wastewater Treatment and Discharge were 1.2 Mt CO_2 eq or 6.3% of the total emissions from the waste sector[7]. For the wastewater sector, the IPCC (2006) defines emissions as a function of the organic waste generated and emission factors as representative of the extent to which this waste generates methane[8]. In a WWTP with Anaerobic Digestion (AD), GHG emissions are basically of two types: direct and indirect. Direct emissions include emissions from combustion of fuel, fugitive gas losses from the reactors, utilization of biogas in gas engines at the facility, and conversion of

---

1 J.S. Guest, S.J. Skerlos, J.L. Barnard, M.B. Beck, G.T. Daigger, H. Hilger, S.J. Jackson, K. Karvazy, L. Kelly, L. MacPherson, J.R. Mihelcic, A. Pramanik, L. Raskin, M.C.M. Van Loosdrecht, D. Yeh, N.G. Love. A new planning and design paradigm to achieve sustainable resource recovery from wastewater. Environ. Sci. Technol., 43 (2009), pp. 6126-6130

2 Shaddel, Sina. "RECOVER – Resource recovery from wastewater", Norwegian University of Science and Technology (NTNU), 2017

3 Metro Vancouver (2019). How wastewater is treated. Accessible online at http://www.metrovancouver.org/services/liquid-waste/treatment/treatment-plants/how-wastewater-treated/Pages/default.aspx

4 Metro Vancouver (2019). About the project. Accessible online at http://www.metrovancouver.org/services/liquid-waste/consultations/annacis-island-wwtp/about-project/Pages/default.aspx

* Metro Vancouver (2019). About Biosolids. Accessible online at http://www.metrovancouver.org/services/liquid-waste/innovation-wasterwater-reuse/biosolids/about-biosolids/Pages/default.aspx

5 Climate Central (2016). Sewage Plants overlooked sources of CO2. Accessible online at https://www.climatecentral.org/news/sewage-plants-overlooked-co2-source-20840

6 EPA (2019). Understanding Global Warming Potentials. Accessible online at https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

7 Government of Canada (2019). Greenhouse gases and sinks: Executive Summary 2019. Accessible online at https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/sources-sinks-executive-summary-2019.html

8 IPCC (2006). Guidelines for National Greenhouse gas Inventories: Chapter 6: Wastewater Treatment and Discharge

biogas to motor vehicle fuel, whereas indirect emissions occur from associated activities outside the facility (like the application of biosolids as fertilizers (downstream avoided emissions))[9]. But, emissions from biogas conversion are biogenic in origin and these avoided (downstream) emissions offset the energy use within the facility through recovery of energy, and include emissions from the treatment of rejects, usage of the digestate (including its transportation and application on land), carbon sequestration in soil and fertilizer substitution[9]. In WWTPs, fugitive methane emissions are expected to occur at the process units where anaerobic conditions prevail[10]. Unintentional releases of methane like leaks can occur from pipes, valves or other instrumentation units transferring the produced methane gas to the storage units also fall under the category of fugitive emissions[8]. Despite the documented presence of fugitive methane emissions in WWTPs, the literature lacks consensus on the percentage of expected fugitive emissions in a WWTP. The estimation of direct emissions from a WWTP is relatively uncomplicated, but it is rather difficult to estimate the amount of fugitive emissions from the plant, mostly since they are unintentional and require a thorough understanding of the production mechanisms of the GHG itself and manual measurements of the same. Currently, the IPCC acknowledges the presence of fugitive emissions in the Oil and Gas industry but accepts that these emissions are uncertain and reliable data is unavailable from many countries[8]. The IPCC suggests that a wide range of 1 to 10% of the total methane production in a WWTP is lost as fugitive methane emissions, but also adds that for WWTPs where unintentional or excess methane is flared, these emissions can be zero[11]. However, other sources have reported average fugitive methane emissions of 3% of the produced methane in the WWTP[12]. Also, poor operational and management practices can increase the amount of methane lost to the atmosphere[13].

SCOPE

Fugitive methane emissions, which may occur due to leaks, loose valves, or venting of methane gas do not find place in the current methodologies for estimation of methane emissions in the wastewater sector and hence aren't included in the GHG inventory for assessment. This project opens a discussion into the presence of fugitive methane emissions in a wastewater treatment plant to allow for appropriate mitigation measures and ultimately adoption of best practices in the field. For the purposes of this project, the largest wastewater treatment plant operated by Metro Vancouver—the Annacis Island wastewater treatment plant (AIWWTP) was chosen for study. A literature review of all potential sources of fugitive methane emissions was conducted to obtain clues on which treatment processes to focus on at AIWWTP. Some of the areas identified as possible sources of methane emissions include the Influent Pumping and Screening (IPS) room, Sedimentation tanks, Anaerobic Digesters and the Gas management system and lastly, the Biosolids storage of AIWWTP. In addition to identifying the sources, a review of methane detection, measurement and mitigation techniques were also included.

KEY FINDINGS

The main deliverables for the project included a list of potential sources of fugitive emissions at Metro Vancouver's wastewater treatment plants, a summary of the available detection, measurement, and mitigation techniques for fugitive methane emissions,

[9] Møller J, Boldrin A, Christensen TH. Anaerobic digestion and digestate use: accounting of greenhouse gases and global warming contribution. Waste Manag Res. 2009 Nov;27(8):813-24. doi: 10.1177/0734242X09344876. Epub 2009 Sep 11.
[10] Kosse P., Knoop O., Lübken M., Schmidt T.C., Wichern M., Methane emissions from Wastewater Treatment Plants: Assessment and review of quantification methods. Water Solutions (2018).
[11] Eggleston, S., Buendia, L., Miwa, K., Ngara, T. & Tanabe, K. (2006) IPCC Guidelines for National Greenhouse Gas Inventories. Vol. 5 Waste. IPCC National Greenhouse Gas Inventories Programme, Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan. Accessed February 2009 from: http://www.ipcc-nggip.iges.or.jp/public/2006gl/
[12] Reeh, U. & Møller, J. (2001) Evaluation of different biological waste treatment strategies. In: Proceedings of NJF Seminar No. 327, Urban areas - rural areas and recycling - the organic way forward? The Royal Veterinary and Agricultural University of Denmark. Aug. 20-21, 2001. NJF, Stockholm.
[13] Yoshida, H., Mønster, J., Scheutz, C., 2014b. Plant-integrated measurement of greenhouse gas emissions from amunicipal wastewater treatment plant.Water Res. 61, 108–118.

and a primary estimation of the possible fugitive methane emissions at the plants. Listed below are the key findings associated with the deliverables. The full report submitted to Metro Vancouver includes further discussion on each topic.

Potential sources of fugitive methane emissions at Annacis Island wastewater treatment plant

The key concept used to determine which parts of the plant could be potential sources of fugitive methane emissions was the biochemistry of methane formation and its behaviour in the liquid phase. Understanding the optimal conditions required by methanogenic (methanogenic archaea (MAs)) bacteria to be able to produce methane was instrumental in identifying the locations in the plant where such optimal conditions of temperature, substrates, and environmental conditions existed. Some of the potential sources of fugitive methane emissions have been listed below:

1. Influent Pump Screening (IPS) room

Fully filled pressurized sewers like the ones used by Metro Vancouver to transport wastewater from various locations in the region to AIWWTP can be sites of methane production. The anaerobic zones formed inside the sewer allow for methanogenesis to occur and thereby result in methane formation. Furthermore, this methane can be dissolved in the wastewater allowing the gas to travel through sewers to the WWTP. When this raw wastewater with dissolved methane gets exposed to a ventilated environment like the IPS room, some of the methane can get stripped off into the atmosphere under the turbulent flow conditions[14]. It is estimated that the amount of methane dissolved in the influent can be quantified as 1% of the chemical oxygen demand (COD) of the raw wastewater[15]. The amount of dissolved methane present in the influent wastewater will also depend on the 'age' of the wastewater. It has been observed that for 'older' or aged sewage from locations far from the wastewater treatment plant (usually upstream pumping stations), the amount of dissolved methane recorded at the influent pumping station can range between 1-2 mg/L, whereas for 'newer' sewage from nearby locations, it is close to zero[15]. At AIWWTP, gas detectors (Ultima® X Series) are situated on the east and west wall of the IPS room to monitor the methane concentration of the area[16]. The data received from these gas detectors did not record any significant concentrations of methane in the IPS room (constant at 117 ppm, safe limit for working personnel is 500 ppm)*.

2. Primary Sedimentation Tanks

Unstripped dissolved methane in the wastewater can flow into the sedimentation tanks from the IPS room. In the sedimentation tanks, wastewater is exposed to the natural environment (temperature fluctuations) and a phenomenon called ebullition can occur. Ebullition is the efflux of methane rich bubbles from the organic sediments' porewaters supersaturated with methane resulting in the rapid release of methane from the sediments and is one of the major ways in which methane is released into the atmosphere[17,18]. During the site visit to AIWWTP (July 17, 2019), some bubbles were observed in sedimentation tank 3 and 4 of the plant. It is a possibility that one of the causes of such bubbles could be the degassing of the dissolved methane into the atmosphere. Because there were no gas detectors near the tanks, it cannot be said for certain if there are methane emissions. For the formation of methane, an anaerobic environment along with a suitable hydraulic retention time (HRT) or solids retention time (SRT) (variable for HRT and SRT) and high temperature (30 or 36 degrees C or higher) is required amongst other factors[19]. The sludge deposited by gravity settling on the bottom of the tanks is also regularly scoured off by conveyor belts[16]. Considering these requirements, it is highly unlikely that the sedimentation tanks can provide sites for methane formation. Considering these

---

[14] Liu Y., Measurement and understanding of methane emission from sewers. University of Queensland, Australia (2015).

[15] Daelman M.R.J., Voorthuizen E.M.V., van Dongen U.G.J.M., Volcke E.I.P., van Loosdrecht M.C.M., Methane emission during municipal wastewater treatment. Water Research 46 (@013). 3657-3670

[16] Metro Vancouver, 2019

*ppm: Parts per million

[17] DelSontro T., McGinnis D.F., Sobek S., Ostrovsky I.S., Wehrli B., Extreme Methane Emissions from a Swiss Hydropower Reservoir: Contribution from Bubbling Sediments. February 2010Environmental Science and Technology 44(7):2419-25. DOI: 10.1021/es9031369

[18] Walter, B. P., M. Heimann, R. D. Shannon, and J. R. White (1996), A process-based model to derive methane emissions from natural wetlands, Geophys. Res. Lett., 23, 3731– 3734.

[19] Wastewater Engineering: Treatment and Resource Recovery, 5th edition, Metcalf and Eddy, AECOM, 2014

requirements, it is highly unlikely that the sedimentation tanks can provide sites for methane formation and unless manual sampling is conducted at this location, it cannot be said if these bubbles are a result of stripping off of methane.

3. Anaerobic digestion (AD) and gas management system

Anaerobic digestion is a process by which organic matter in wastewater is broken down for use by bacteria to produce valuable resources like biosolids and biogas (methane)[20]. The main sources of GHG emissions from an AD facility are mainly from use of fossil energy at the facility, emissions from the bioreactor and combustion of biogas, and from the digestate when applied to soil[9]. Fugitive methane emissions can be expected when the anaerobic digester is open for maintenance, or through leaks from pipes, valves, and fittings that transport the produced biogas (methane) to the gas engine or storage facility, and even from the dome of the digester[9,21]. Leaks can also occur through valves if there is an over-pressure in the reactor[9]. It has also been observed that emissions occur in the sludge thickener, exhaust of the cogeneration plant, buffer tank for the digested sludge and storage tank for the digested sludge (methane can be dissolved in the digested sludge)[15]. In a study done by Noyola et al. (2008), about 8% of the total methane production from 4 anaerobic digesters at the Dulces Nombres WWTP in Monterrey (MTY) was lost in leaks[21]. Estimation of these fugitive methane emissions is difficult and varies between plants. At AIWWTP, methane is produced in the 4 anaerobic digesters, and provides enough energy to satisfy all and half of the heat and electricity requirements at the plant[22]. It can be expected that due to leaks or during transfer of gases through pipes, some fugitive methane emissions occur at the plant. But, the lack of well defined quantification estimates in literature makes it difficult to assess the amount of fugitive emissions from the ADs at AIWWTP. The gas monitors located around the area did not detect any significant emissions as well.

4. Biosolids Storage

Biosolids are a valuable resource obtained from anaerobic digestion but can be a source of GHG emissions[23]. Biosolids stockpiles are usually kept at the WWTP site for a couple of days before being transported to the site of application. The occurrence of microbial decomposition and transformations of carbon and nitrogen in the anaerobic environment of the stockpiles result in the production of methane in addition to carbon dioxide and nitrous oxide[24]. However, emissions from biosolids depend on the characteristics of the organic matter present on the stockpile, the physical characteristics of the stockpile (height and shape), and environmental factors (moisture content and temperature)[25]. In case of shallow stockpiles, it becomes harder for anaerobic conditions to develop, and methanotrophic bacteria (if present in the biosolids and under aerobic conditions) can consume methane from the atmosphere (act as methane sinks)[24]. At AIWWTP, biosolids produced at the plant remain on site only for a couple of hours (half a day on average) and are taken trucked away for various applications[16] It is safe to say the fugitive methane emissions from the biosolids at AIWWTP are negligible, but could potentially be significant sources of GHG emission off site.

Detection and measurement of fugitive methane emissions

Methane is a colourless and odourless gas, which makes its detection complicated. Methane in gaseous phase can be successfully detected by sophisticated methods using optical telemetry (Fourier Transform Infrared (FT-IR) principle)[26]. Leaks can be detected in many ways, for example with the help of tools using relevant parameters (pressure or flow rates as surrogates

[20] UNFCCC (2017) Methodological tool: Project and leakage emissions from anaerobic digesters. Version 02.0.

[21] Noyola A., Paredes M.G., L.P.Güereca L.P., Molina L.T., Zavala M., 2018. Methane correction factors for estimating emissions from aerobic wastewater treatment facilities based on field data in Mexico and on literature review. Science of The Total Environment, Volume 639, 15 October 2018, Pages 84-91. https://doi.org/10.1016/j.scitotenv.2018.05.111

[22] Metro Vancouver (2009) Annacis Island (Delta). Accessible online at http://www.metrovancouver.org/services/liquid-waste/treatment/treatment-plants/annacis-island/Pages/default.aspx

[23] Wang H.L., Brown S.L., Magesan G.N., Slade A.H., Quintern M., Clinton P.W., Payn T.W. (2008) Technological options for the management of biosolids Environ. Sci. Pollut. Res., 15, pp. 308-317

[24] Majumder R., Livesley S.J., Gregory D., Arndt S.K., Storage management influences greenhouse gas emissions from biosolids. J Environ Manage. 2015 Mar 15;151:361-8. doi: 10.1016/j.jenvman.2015.01.007. Epub 2015 Jan 10.

[25] Boldrin A., Andersen J.K. , Moller J., Christensen T.H., Favoino E. (2009) Composting and compost utilization: accounting of greenhouse gases and global warming contributions. Waste Manage. Res., 27 (2009), pp. 800-812

[26] Gärtner, A., Hirschberger, R., Becker, A., Düputell, D., 2017 Widely distributed biogenetic emissions from wastewater treatment plants. Korrespondenz Abwasser, Abfall (11), 985 – 993

for methane concentrations), other hand held devices or automated tools (fibre optics or gas sensors) that do not require any human intervention. For large plants like AIWWTP, drones can also be used to detect plumes of gas leaks as already done in most oil and gas fields.

Figure 2. An unmanned gas leak detection system from ULC Robotics (2019). These drones-based leak detection systems can not only measure concentration of methane gas (ppb) in air samples using laser spectroscopy but can also offer information on the leaking sources and rate of leaks[27].

Other common methods used require manual sampling like atmospheric tracer release approach (A tracer like acetylene is used and the emission rate of the target gas can be obtained by a real time measurement of the concentration of the species of interest and acetylene with a known releasing rate located at the suspected emission source)[28]. For methane in dissolved form in a suspected location, the ability of this gas to easily vaporize is exploited[29]. The salt stripping method (headspace analysis) is commonly used, where dissolved methane escapes from the liquid phase to the headspace of the serum bottles and builds up a pressure in that area. Amount of methane in the headspace before expansion can be calculated from the concentration, measured volume of the headspace of the sealed bottle, and the headspace pressure after pressure build up (Calculated from the volume expansion of the headspace). This amount of methane was completely dissolved in the liquid sample before the sample was saturated with salt. The original methane concentration in the liquid can be established by dividing the amount obtained in the previous step by the sample volume (50 mL)[15].

Estimation of fugitive methane emissions is not included in the 2006 IPCC Guidelines for National Greenhouse gas inventories. It was only recently (May 12, 2019) that the IPCC acknowledged sewers as a potential methane emission source[30]. Various studies have also shown that the methodologies provided by the IPCC are not ideal for many WWTPs and require modification based on plant data and information[21]. Estimated percentages of fugitive methane emissions are quite varied and can often overestimate the actual amount of emissions. Hence, it is safe to assume that the most reliable method to accurately narrow down the sources of potential fugitive methane emissions is physical examination of the probable sources at AIWWTP.

---

[27] ULC (2019) Unmanned Aerial Gas Leak Detection Services. Accessible online at https://ulcrobotics.com/services/uav-gas-leak-detection/
[28] Delre A., Mønster J., Scheutz C. 2014. Quantification of Fugitive Methane Emissions from the Biogas Plant in Linköping (SE). Technical University of Denmark, DTU Environment, Kgs. Lyngby (2014) (15 pp.)
[29] Kosse P., Lübken M., Knoop O., Schmidt T.C., Methane emissions from wastewater treatment plants - Assessment and review of quantification methods (2010) https://www.researchgate.net/publication/323308510
[30] IPCC (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Mitigation measures for fugitive methane emissions

The most common mitigation measures to control and reduce fugitive methane emissions at a WWTP are covering the thickening sludge tanks and sludge disposal tanks to avoid gas leakages[29]. Gas detectors in suspected locations will help to monitor gas leaks and concentrations. One of the most significant sources to acknowledge at a WWTP is the influent wastewater that contains methane in dissolved form, although this dissolved methane can be oxidized in the subsequent process units (sedimentation tanks, solid contact tanks, activated sludge tanks)[29]. Regular monitoring like walk through with handheld devices around the plant can be very useful. Since there is evidence that higher temperatures can accelerate methane formation, the number of such inspections can be higher in summer[31].

CONCLUSION

Upon the successful completion of the project entitled "*Potential sources of fugitive methane emissions in Metro Vancouver's wastewater treatment plants: an investigation*", the deliverables of identifying the potential sources of fugitive methane emissions at AIWWTP and the suitable detection, measurement, and mitigation measures for the same were achieved.

It became evident during the study that certain gaps in knowledge need to be addressed to better understand the fugitive methane emissions at a WWTP. The first knowledge gap is the definition of fugitive emissions for the wastewater sector. IPCC does not offer any suggestion on which activities to consider as expected sources of fugitive emissions. Although defined for the Oil and Gas industry, it is not suitable or logical to apply the same to the wastewater sector. This was one of the key challenges faced during the project. Secondly, the lack of consensus in literature about the expected amount of fugitive emissions in a wastewater treatment plant made it difficult to quantify the estimate of fugitive methane emissions at AIWWTP. Thirdly, it became obvious from the literature explored during this study that the values of fugitive methane emissions differ between plants and cannot be generalized. Manual sampling or study of the key zones as identified in this report are needed to obtain more information on the potential estimate of fugitive methane emissions at Annacis Island Wastewater treatment plant.

Despite the various challenges, a significant amount of useful information on climate change in Canada, contribution of wastewater to global greenhouse gas emissions, and potential sources of fugitive methane emissions was obtained. This would allow Metro Vancouver to pursue further research into the study area and introduce action steps that will allow the federation to control GHG emissions from its wastewater treatment plants.

[31] Aben R.C.H., Barros N., van Donk E., Frenken T., Hilt S., Kazanjian G., Lamers L.P.M., Peeters E.T.H.M., Roelofs J.G.M., de Senerpont Domis L.M., StephanS., Velthuis M., Van de Waal D.B., Wik M., Thornton B.F., Wilkinson J., DelSontro T., Kosten S. Cross continental increase in methane ebullition under climate change. Nature Communications, 2017; 8 (1) DOI: 10.1038/s41467-017-01535-y

Cover Photo: Eremeychuk Leonid/Alamy. Retrieved online at: https://www.audubon.org/news/updated-gas-industry-leaks-enough-gas-power-three-million-homes-each-year