Fugitive Nitrous Oxide (N_2O) Emissions from Metro Vancouver Wastewater Treatment Plants

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Executive Summary

Nitrous oxide (N_2O) is a potent greenhouse gas, which accounted for 6% of the global anthropogenic greenhouse gas emissions in 2014. It is also determined to be the most dominant ozone-depleting substance in the twenty-first century. The lifetime of N_2O in the atmosphere is 114 years on average, and the impact of N_2O on warming the atmosphere is 298 times that of carbon dioxide. As N_2O is emitted during wastewater treatment, Metro Vancouver would like to take a step ahead and investigate if its wastewater treatment plants (WWTP) have substantial fugitive N_2O emissions. The report presents the results of a literature review of N_2O emissions at WWTPs in general, along with a preliminary estimate of N_2O emissions at Annacis Island WWTP (AIWWTP), as well as a survey of potential measurement techniques. For the purpose of this report, AIWWTP was selected from the existing wastewater treatment plants to be studied because it is the largest wastewater treatment plant in Metro Vancouver that also involves secondary treatment.

Wastewater treatment processes are designed to improve wastewater effluent quality. However, a by-product of some of the processes used can be N_2O. There are four pathways that are potentially responsible for N_2O formation. Chemical reactions include N_2O produced from the reaction of hydroxylamine and nitrite and decomposition of hydroxylamine. Biological reactions include nitrifier denitrification and heterotrophic denitrification that can contribute to N_2O emissions. Among these four pathways, nitrification and denitrification used to remove nitrogenous compounds from wastewater in biological nutrient removal (BNR) plants are believed to be primarily responsible for emissions of N_2O, and nitrifier denitrification is

determined to be the major contributor that can contribute up to 83% of the N_2O emissions from WWTP.

The current secondary treatment at AIWWTP is designed to reduce soluble biochemical oxygen demand (sBOD) and not for nitrogen removal at the current stage. Namely, nitrification and denitrification, may be taking place at AIWWTP at trickling filters and solid contact tanks spontaneously but not intentionally and is anticipated to be less than at BNR plants.

Methodologies from the Intergovernmental Panel Climate Change (IPCC) and Water Environment Research Foundation (WERF), as well as a mass balance method were utilized to estimate N_2O emissions from AIWWTP. Both IPCC and WERF approaches have shown that N_2O emissions from AIWWTP are not significant because the treatment processes do not incorporate BNR. Another approach was attempted using a closed-loop mass balance but failed because of the inaccuracy of the data available. The IPCC method uses population as the main factor that alters the N_2O emissions while it didn't consider the changes that different configurations, operating conditions, and processes may lead to. The WERF method only used TKN_{inf} as the only variable while it ignored the transition among ammonium, nitrite and nitrate. Neither one can fully represent the real N_2O emissions from AIWWTP.

A study was conducted by AECOM between 2015 and 2018 to identify if AIWWTP would require ammonia removal treatment to comply with the Fisheries Act, which updated the discharge standard that must be met by Canadian wastewater facilities. They also evaluated various ammonia removal technologies that could be used to achieve compliance. The study established some level of risk of non-compliance and recommended ANAMMOX ® be implemented at AIWWTP as a short-term sidestream treatment option, and nitrifying trickling filters (NTFs) as a longer-term mainstream treatment option. For the future phase of AIWWTP and new North Shore Wastewater Treatment Plant, more accurate methods, such as monitoring and measurement on site, may be necessary for future studies as more intensive nitrification and denitrification are taking place in the biological nutrient removal processes.

One reason N_2O emissions are difficult to estimate is that N_2O formation is different than N_2O emission. N_2O is predominantly emitted from the aerated zones although N_2O is an obligatory intermediate product in denitrification, which mostly takes place under anoxic or anaerobic conditions. A large percentage of N_2O formed under anoxic conditions will remain in liquid phase due to its high solubility, especially under cool stream temperatures. Liquid phase N_2O can be quickly stripped due to intensive aeration. Therefore, best locations for measurements at AIWWTP and any new WWTPs would likely be at trickling filters, and solid contact tanks, and in the future, at nitrifying trickling filters, and ANAMMOX process location where normal operation mode is under aeration. Static floating chamber and plastic bags are typically used to capture gas, and the gas is then analyzed using a gas chromatograph. However, these methods are not able to capture dynamic change in the system.

In conclusion, there are still uncertainties associated with N_2O emissions from a wastewater treatment plant. Due to these limitations and the different emissions results obtained from two methods, more research is need needed to define whether or not the emissions are significant for the current stage. With the construction of the future phase and other WWTPs that incorporate BNR, increases in N_2O releases are anticipated in the future, and thus more investigations will be necessary for a better understanding of the relationship between wastewater treatment processes and N_2O emissions.