Fall 12-12-2019

# Integrated Science 3002A: Proposal for Plumbing Initiative for Water Conservation in London

Rebecca Oeyangen
*Western University*, roeyange@uwo.ca

Jennifer Evans
*Western University*, jevan24@uwo.ca

Ali Coyle
*Western University*, acoyle5@uwo.ca

John Chepesiuk
*Western University*, jchepesi@uwo.ca

Nadia Aiaseh
*Western University*, naiaseh@uwo.ca

*See next page for additional authors*

Authors
Rebecca Oeyangen, Jennifer Evans, Ali Coyle, John Chepesiuk, Nadia Aiaseh, and Trystan Lee

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**CEL Project – City of London Water**

**Integrated Science 3002A**

December 5th, 2019


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|---|---|
| Jennifer Evans | 250973444 |
| Ali Coyle | 250957826 |
| John Chepesiuk | 250951042 |
| Nadia Aiaseh | 250956179 |
| Rebecca Oeyangen | 250974508 |
| Trystan Lee | 250958718 |

# Plumbing Initiative for Water Conservation in London, Ontario

December 5th, 2019

**Press Release**

This fall, a team of six Western Integrated Science students collaborated with the City of London to develop a groundbreaking plumbing proposal to reduce water conservation issues and address social inequalities.

Lower-income residents often cannot afford a plumbing service, and water leaks can go unfixed for years. The interdisciplinary team designed a solution to these common leaks in the City.

The proposal involves hiring a plumber to provide free plumbing service for applicants living in subsidized housing units.

The program pays for itself and more. Within a year of implementation, the program, the City will save the City $692,215.75 in water usage costs (for fixing 520 leaks/year, the savings are evaluated for one year of work at the end of two years) and pays for the plumbers' salary of $70 000.

"Our mutually rewarding relationship provides students with an opportunity to develop on the job skills for their future careers while advantageous for the City as it brings innovative ideas and creative solutions to the projects," says City of London, Water Engineering Community Partner, Jessica Favalaro (Supervisor).

After researching the economic impact of increasing climate change effects including; water quality decline, increased pollution, and worsening algae blooms, the students realized the dire need to conserve water.

The processes of filtering and preparing the water from Lake Erie and Lake Huron for daily usage will only become more expensive.

The multi-faceted report addresses water conservation, climate change and works towards increasing social equality. The future of London looks bright in the hands of ambitious and hardworking students.

## General Implications of Climate Change on Water Supply

For a sustainable ecosystem and socio-economic development, it is important to effectively manage water resources and to investigate the impacts of climate change on them. Climate directly interacts with watershed features such as size, slope, soils, vegetation, etc. Therefore, streamflow regimes are likely very sensitive to climate change and altered streamflow regimes will affect the ecological structure and function of freshwater ecosystems. In one study, it was found that rivers will become unsuitable for salmonids in the region of Rocky Mountain due to a lower magnitude and earlier onset of snowmelt runoff (Hauer et al., 1997). It was also predicted that because of climate change, the intensity of storms along with high flow fluctuation will increase. Intense flushing events and shorter periods of flooding in riverbanks cause loss of stream habitat (Mulholland et al., 1997). The streamflows will be ecologically affected more by climate change than by withdrawals and dams (Döll & Zhang, 2010). By 2050, it is expected that North America will experience an increase in winter runoff and a decrease in summer runoff due to climate change (Arnell & Gosling, 2013).

Access to fresh water is a precious commodity that is often taken for granted in developed countries. Climate change can lead to reduced precipitation in some areas, permafrost melt, and glacial mass balance, all of which can affect the morphology of river systems and consequently the availability of the water (Ashmore & Church, 2000). For Canada specifically, freshwater glacial and river systems are in wide abundance and 82% of freshwater monitoring stations across Canada show that water quality is described as “fair to excellent” (McKitrick et. al, 2018). For London’s water situation, poor or marginal water quality is typically related to river systems flowing into the Great Lakes and the St. Lawrence River basins. Soil erosion from deforestation can lead to further pollution and sediment buildup in river systems and source inputs, reducing water quality even more drastically (Coulthard & Macklin, 2001). On top of these areas in Southern Ontario, those with high urbanization and industrialization are of greatest concern for worsening water quality.

## City of London’s Water System’s Infrastructure

The cycle of drinking water in the City of London involves seven steps: water intake, pre-treatment, sedimentation, filtration, chlorination and fluoridation, storage, and distribution (Wibberley, n.d.). With 85% of daily water consumption from Lake Huron and 15% from Lake Erie, raw water flows into the intake screens and intake pipes that are approximately 2 kilometers offshore (Wibberley, n.d.). The intake screens stop fish, debris, rocks, and other items from flowing into the pipes/treatment system. The intake cribs are equipped with a chlorine solution which is diffused for Zebra Mussel control (May to October when the lake water temperature is above 12 degrees) (Wibberley, n.d.). After completing the treatment process the water travels to the City through an underground pipe.

**Chemical Reactions in Disinfection Process of City of London's Water System**

In the treatment plant, chlorine is added to lake water to eliminate most disease-causing microorganisms (Wibberley, n.d.). Alum (a coagulant and polymer) is added to fast-stirring mixers which cause very fine particles to clump together into larger particles called floc. Flocculation basin agitates the water to cause floc to be created quickly (Muruganandam, Kumar, Jena, Gulla, & Godhwani, 2017).

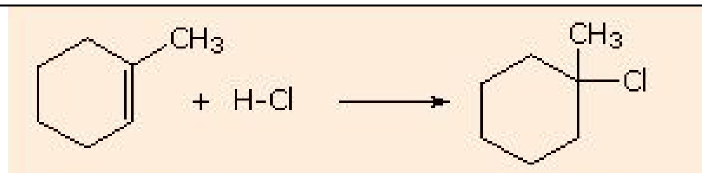
Additional chemicals include powered activation carbon (PAC) for taste and odour control as well as additional polymers that are required at Elgin treatment plant since they have a significant number of suspended solids at Lake Erie than Lake Huron (Wibberley, n.d.) Sedimentation tanks then slow the speed of the flowing water so that the larger suspended particles can settle out by gravity. At last, clean water on the surface spills over the top of the tank, on-route to the filters.

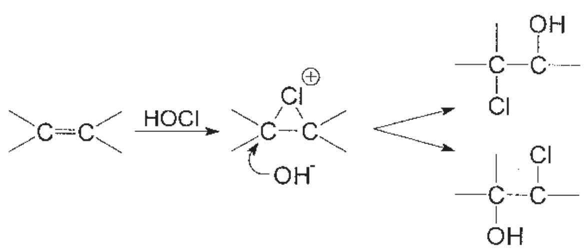
Filtration is the last step in removing particulate matter from the water. Layers of gravel, sand, and anthracite filter out remaining suspended particles including floc, algae, silt and other impurities (Wibberley, n.d.). Post-chlorination involves the addition of chlorine to remove any remaining disease-causing organisms and to sustain chlorine residual in the water, as the residual makes its way through the distribution system ("Water Fluoridation Additives | Engineering | Community Water Fluoridation | Division of Oral Health | CDC," n.d.). Chlorine residuals are necessary to prevent bacterial regrowth. Fluoride is added to the water specifically from Lake Huron to prevent tooth decay (as well to ensure fluoride levels are maintained throughout the city with the already fluoride-treated water from Lake Erie). This is done by the chemical Hydrofluosilicic acid (HFS) ("The Chemistry of Disinfectants in Water: Reactions and Products - Drinking Water and Health - NCBI Bookshelf," n.d.)

The chemical reactions with the main disinfectant Chlorine are done in the form of hypochlorous acid (HOCl) (Fig 2. b)). HOCl is a hydrolysis product that is formed from the reaction between the chlorine molecule and water (Fig 2. a)). Chlorine reacts in solutions of organic compounds by one of three basic mechanisms: addition in which chlorine atoms are added to the compound; oxidation; and substitution in which chlorine atoms are substituted for another atom that is present in the organic reactant (Fig 2. c), d), and e)) ("The Chemistry of Disinfectants in Water: Reactions and Products - Drinking Water and Health - NCBI Bookshelf," n.d.). Fluoridation, the addition of fluoride into the water, does the same chemical reactions as chlorine as they are both halogens in which they act as an electrophile in these reactions.

$$Cl_2\,(g) + H_2O\,(l) \longrightarrow HClO\,(aq) + HCl\,(aq)$$

$$HOCl \longrightarrow H^{+} + ClO^{-}$$




$$C_6H_5CH_3 + HOCl \longrightarrow C_6H_5CH_2Cl + HOH$$

*Figure 2*. Diagram of examples of chemical reactions described: a) Hydrolysis reaction of Chlorine and Water; b) Dissociation equation for hypochlorous acid (form of Chlorine that reacts with organic compounds); c) Addition reaction of Hypochlorous acid with organic compound, 1-methylcyclohexene; d) Oxidation reaction of Hypochlorous acid with organic compound, ethylene; e) Substitution reaction of Hypochlorous acid with organic compound, toluene ('hv' stands for high voltage, meaning the reaction needs to be done under high light).

**Climate Change and the Chlorination Process**

London's drinking water supply is centered on the efficiency of its disinfection processes. They are crucial to ensuring the water is clean and safe for the population. London's drinking water treatment system includes several steps from the physical sorting and the intake location to filtration through sand and smaller particles and finally chlorination to kill microorganisms and bacteria (Hua, Guanghui & Yeats, 2010). A study investigated the correlation between rising sea temperatures and carcinogenic Trihalomethanes (THMs) in drinking water (Valdivia-Garcia, Weir, Graham, & Werner, 2019). It was found that increased water temperatures caused increased dissolved organic carbon (DOC) in the water. This high DOC reacts with products of chlorination in the waste treatment process and creates disinfection by-products including THMs. Some carcinogenic THMs include chloroform, bromodichloromethane, dibromochloromethane, and bromoform. This has implications for the water system because it limits the ability of current treatment methods and creates more disinfection by-products. Currently, London Water's Maximum Acceptable Concentration for Trihalomethanes is 0.1mg/L, a value that could be exceeded soon.

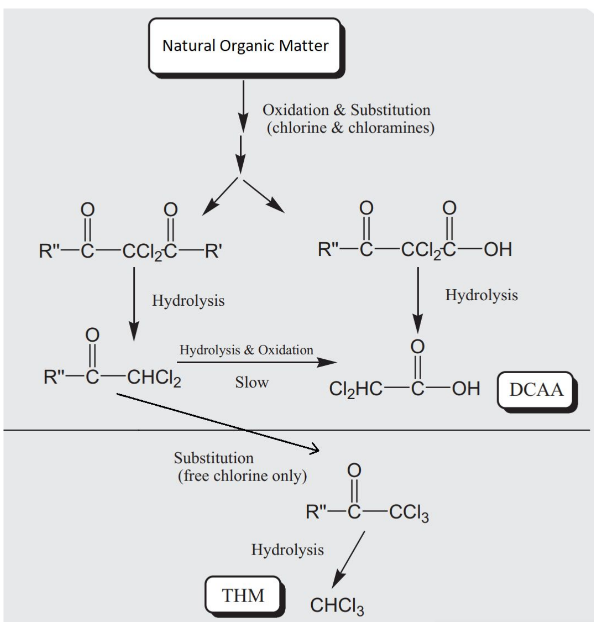



*Figure 3*. Formation pathways of THMs from chlorine and chloramines

**Climatic Change in London, Ontario**

In this case, triangular is used as it allows for two extreme bounds corresponding to the system's maximum and minimum capacities. Lake Huron Treatment facility has a capacity of 336 400 m3/day. Rainfall due to climate change is increasing in uncertainty and intensity. As for the results of this evaluation using fuzzy logic, Huron water seems to be more reliable and robust than Elgin water. The vulnerability-reliability index can change based on the shape of the membership function but the resilience index is independent of this shape. Fuzzy performance indices can tell us which components of the water system are weak and need to be improved upon.

**How Climate Change Affects London**

The City commissioned Professor Simonovic at Western University to carry a research project to answer part of this question. The report is based on simulations, raw local data, and local expert interviews. Climate change is impacting the climate at a faster pace than most Londoners realize. We cannot rely on the old infrastructure because they were built specifically for the climate before. What we can do, is to run simulations based on an upper bound and a lower bound for intensities the future climate will bring about. These bounds can be calculated. future climate. Based on these possibilities, the City can make changes to adapt to the current infrastructure in place to our rapidly changing climate. It is important to be aware that the simulations had to be rescaled to London's size and some were used as inputs for further simulations. Therefore, we shall recognize them as reliable possible scenarios, not concrete predictions of the future. There is over 520 km of primary and arterial roadways, 117 culverts, 99 bridges and 8 footbridges within the City of London, all of which are important infrastructures to think about an event of a climate-change-induced flood. About 94% of the buildings affected by the modeled flood is residential.

The methodology defines risk to be a product of hazard and vulnerability. The formula for which risk is used is dependent on:

- Probability of the hazard event occurring
- Economic loss for each impact category, infrastructure type, and element
- Impact multiplier

The latter represents the impact of the hazard event on the infrastructure post-interaction. The study considers three losses to determine impact multiplier: the loss of function, equipment, and structure. The latter loss refers to the degree of infrastructure's structural compromise in the event of a hazard. Qualitative considerations for this parameter include the current condition of the structure as it will determine how it will be affected by flooding; determining the structure's current condition is most accurately done through local expert interviews (qualitative). Fuzzy reliability index, based on fuzzy set theory, was then used to convert this qualitative information to measurable quantities.

The study was able to identify dissemination areas of higher risk, produce maps for each climate scenario considered that identifies the risk of each area through different shadings. It was recommended to increase the number of flow monitoring systems for real-time data and increased preparedness in the event of a flood. Other operational recommendations include regular inspection of pipe networks. Further investigations on a variety of subjects such as the response of bridges and pollution control plants, dynamic simulations and other climate scenarios were also recommended.

**Water Metrics - An Investigation of Other Municipalities**

Upon researching other municipalities for inspiration, Guelph's endeavors for water conservation seemed to be effective for them however too costly for London. Waterloo's Master Plan suggested professional partnerships that included teaching trades and sustainable plumbing (Lura Consulting & Econics, 2014, p. 18). High school students in London have to complete a certain number of volunteer hours to graduate. Making a program that would teach students would allow students to accumulate hours by learning basic plumbing techniques and residents would benefit from having quicker access to someone that can fix their leaks.

**RECOMMENDED WATER EFFICIENCY PROGRAM: 2015-2025**

| Sector | Continuing Activities | New or Enhanced Activities |
|---|---|---|
| **Residential Sector** | General Education and Awareness | Residential Water Savings Assistance Program<br>Toilet Flapper Program<br>Rainwater Harvesting Program |
| **Commercial, Industrial and Institutional (CII) Sectors** | Water Efficient Technology (W.E.T.) Program | CII E-newsletter<br>Restaurant Certification Program<br>Cooling System Program |
| **Partner Profession** | Trades Training | New Home Building Incentives<br>Plumber Sustainability Training |
| **Community-Wide** | Water Conservation By-Law<br>Pressure and Leakage Management | Enhanced Interactive Website and Communications |
| **Research and Development** | Water Softener Research | Residential Hot Water Recirculation System Research<br>Commercial Sub-Metering Education and Advocacy<br>Landscape Topsoil Depth Advocacy |

Figure 4. A collection of ideas presented from Waterloo's Water Efficiency Master Plan (2015-2025)

**Plumbing Proposal Summary**

The final proposal for the city of London Water sector involves a contract-based plumbing solution that provides economic, environmental, and social benefits for the city. The plan to be implemented includes the steady income for plumbing work while also providing a shadowing aspect for high school students. The city of London will hire a plumber for either part-time, full-time or contract work, and will focus mainly on disenfranchised residents of subsidized housing units. These units are typically not maintained properly in terms of leaks and other plumbing issues, and so having a plumber working to fix these minor issues on a more regular basis will aid in water conservation while also saving money in the process. Students shadowing this work will receive hours required for their community service record before graduating high school, while also learning applicable skills they can bring back home. The plumber will also be able to have access to a more steady source of clients than through private work. Only residents of subsidized housing will be allowed to apply to this program and can be easily monitored based on their address. They will also only be allowed to have one plumbing check-up per year to avoid misuse of the program. Depending on the success of this program for disenfranchised residents, it may be expanded in the future on a city-wide scale. This will thereby greatly reduce water conservation issues and economic loss, allowing for the expansion of other green initiatives within the city.

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