ANALYSIS OF DRINKING WATER DISTRIBUTION SYSTEMS USING THE ENGINEERING DESIGN PROCESS

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Abstract

Our research has identified that issues pertaining to distribution infrastructure are a leading cause of water safety vulnerability. These challenges are exacerbated within small communities which experience a disproportionate number of boil water advisories compared to larger communities. This study used the engineering design process to explore the root causes and potential solutions to water safety hazards within the water distribution system. A systematic literature review thoroughly examined data-backed evidence of issues causing potential threats to drinking water safety. Potential solutions involving the implementation of distributed treatment using UV LEDs installed at different points in the distribution system were identified through research and stakeholder consultation and compared to one another using EPANET software. The results of this analysis indicated that installing UV LEDs at the point-of-entry could potentially be used to reduce the impact of water safety hazards within the distribution system.

Dedication

This thesis is dedicated to my friends and family.

Acknowledgements

I would like to first and foremost acknowledge my supervisor, Dr. Stephanie Gora, who has shown me unwavering support over the past three years. She has provided nothing less of consistency and pushed me to accomplish more than I knew I could. I cannot show her enough gratitude, and I owe her all my academia and career success. She has taught me how to be a strong woman in a male dominated field.

I would like to thank Dr. Pulin Mondal and Dr. Thomas Cooper for their participation in my Oral Exam and for showing their support through my final steps of finishing my degree. They have dedicated their time and patience and provided me with very valuable support and feedback.

The Safe and Sustainable Water Research Group, for providing me with support and friendship as we all worked through graduate school.

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1 Chapter 1: Introduction to the Project and to the Engineering Design Process

1.1 Introduction

Drinking water safety is an important issue worldwide, and a growing concern for many areas of the world. The United Nations have identified clean water and sanitation as one of the 17 sustainable development goals, which were adopted by all United Nations Member States in 2015 [1]. Many communities throughout Canada have been faced with vulnerabilities associated with safe drinking water, particularly within smaller communities. Research has identified that issues within drinking water infrastructure, particularly issues pertaining to distribution infrastructure, are a leading cause of water safety vulnerability. Furthermore, exasperated impacts of climate change can cause further issues with drinking water infrastructure. These problems related to drinking water safety require immediate attention as well as goal-oriented, sustainable solutions to ensure long-term access to drinking water particularly within small communities.

Ultraviolet light-emitting diodes (UV LEDs) have been widely used for a number of applications, including drinking water treatment. UV LEDs are an emerging technology, with major technological advances and more projected advances in the coming years. While providing many advantages over traditional disinfection methods, UV LEDs are also cost-effective and low maintenance, making them an attractive option for small and remote communities.

This study provides an in-depth analysis of the engineering design process to provide solutions to problems within drinking water infrastructure and safety. This thesis combines numerous pieces of work, which have been broken down within the steps of the engineering design process. Within these steps, a systematic literature review of the impacts of climate change on boil water advisories in Canada was conducted; this review thoroughly examines data-backed evidence of issues causing potential threats to drinking water safety. This work was published in the FACETS Journal (Moghaddam-Ghadimi et al., 2023) and elements of this work are provided within this study. Findings from this work were used to further enhance the steps of the design process to present a solution of using UV LED devices within drinking water distribution systems to provide drinking water treatment outside of the treatment plant. The U.S. Environmental Protection Agency (EPA) provides a public domain software for the modelling of drinking water distribution systems, EPANET. This study utilizes extensions within the EPANET software that allow for multispecies analysis within the distribution system to create models that utilize UV LED reactors within the distribution system. These models are used to analyze the impacts of UV LEDs on various drinking water safety parameters, such as water age, *E. coli,* and planktonic bacteria concentrations, as well as the impacts of installing these reactors in various locations within the distribution system. Although various studies over the years have investigated the use of UV LED devices for drinking water treatment both inside and outside the treatment plant, this study is the first of its kind to utilize a modelling software to analyze the impact of UV LED treatment within the distribution network. The overall project objective is to utilize the engineering design process to identify water safety issues and their causes within small communities in Canada, provide solution(s) to the identified problems, and evaluate these solutions.

1.2 Research objectives

The research objectives of this project are as follows:

- Identify the impacts of climate change on boil water advisories;
- Utilize EPANET to create models that utilize UV LED reactors within drinking water distribution systems;
- Examine the impacts of UV LEDs on various drinking water parameters;
- Examine and discuss the necessary considerations for potential implementation of UV LEDs within distribution systems;
- Identify gaps and areas of future research associated with implementing UV LEDs within distribution systems.

1.3 Engineering Design Process

The engineering design process is a tool utilized by engineers to design practical solutions to problems. These problems may have many possible solutions, so the design process is used to seek the best solution out of various alternatives [2]. **Figure 1** shows the engineering design process, divided into phases:

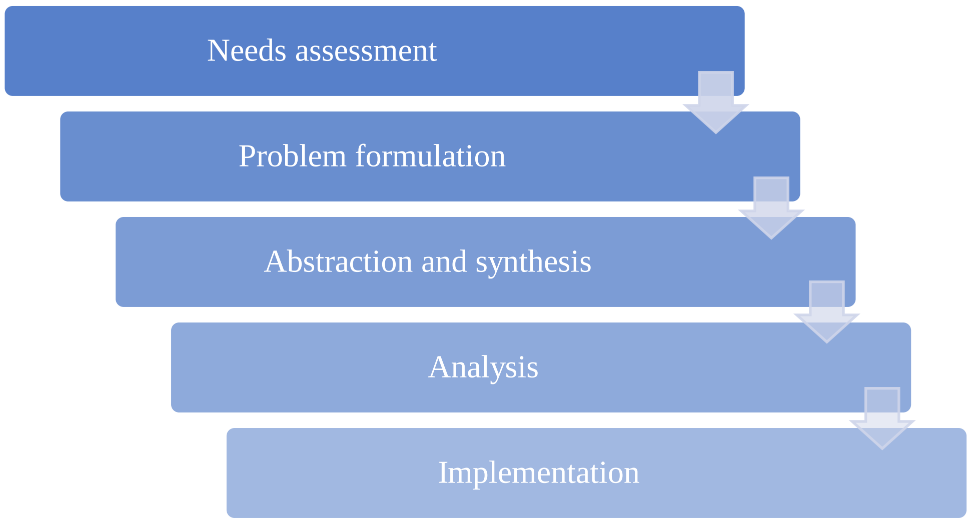

Figure 1: The Engineering design process (adapted from [1])

The initial stage of the engineering design process involves doing a thorough needs assessment to identify potential problems or opportunities [2]. This step consists of defining the objectives that need to be fulfilled, identifying who will benefit from the solution, and staying mindful of the ultimate objective [2]. The second step, problem formulation, consists of defining the actual problem that requires a solution by identifying the design objectives that need to be accomplished [2]. This step involves analyzing the original problem statement to pinpoint the source of the issue and assessing if the actual problem differs from the ones initially presented. The third step, abstraction and synthesis, consists of creating abstract and general concepts or approaches that can be applied to solve the problem, followed by generating a range of comprehensive and detailed alternative designs to further address the problem [2]. The fourth step of the engineering design process, analysis, consists of comparing and evaluating the alternative designs generated in the previous step [2]. Finally, the final step is implementation, where the chosen solution is developed into a final product and presented to the intended consumer or client [2].

1.4 Structure of the thesis

The stages of this project have followed the engineering design process and this is reflected in the structure of this thesis.

Table 1: Structure of thesis document

Engineering Design Process Step	Thesis Chapter
Introduction	Chapter 1: Introduction to the Engineering Design Process
Step 1: Needs Assessment	Chapter 2: Vulnerability and Resilience of Water Infrastructure and Implications for Water Safety
Step 2: Problem Formulation	Chapter 3: Analysis of Boil Water Advisory and Identification of Causes
Step 3: Abstraction and Synthesis	Chapter 4: Maintaining Water Safety using Primary and Secondary Disinfection
Step 4: Analysis	Chapter 5: Analysis and Comparison of Different Approaches to Maintain Water Safety in the Water Distribution System
Step 5: Implementation	Chapter 6: Considerations for Implementation and Future Research
n/a	Chapter 7: Conclusions

2 Chapter 2: Vulnerability and Resilience of Water Infrastructure and Implications for Drinking Water Safety (Needs Assessment)

The first step of the design process is to identify a need for an engineered solution to a problem. This need can arise from various situations such as concern for public health, safety, and quality of life [2]. Additionally, the need for a solution can arise from recognizing the existing product needs redesigning to address its current shortcomings, adapt to changing market needs, increase commercial viability, or reduce cost [2]. Finally, an engineer can determine a need for a solution based on personal experience using the product or performing a particular task to identify the need for a different or adjusted technical solution [2].

Studies show that small communities in Canada are particularly likely to experience repeat and long-term boil water advisories. Climate change has led to changes in precipitation and temperature patterns, leading to region-specific impacts such as increased frequency, severity, or variance in floods, forest fires, droughts, freezing rain, and sea water intrusion. In accordance with the first step of the engineering design process, a study was conducted to analyze the impacts of climate change on boil water advisories in Canada. Elements of this chapter have been published in FACETS, a peer reviewed journal [3].

2.1 Boil Water Advisories in Canada

Boil water advisories (BWAs) are public announcements advising users that they should boil their drinking water prior to consumption in order to eliminate any suspected or confirmed disease-causing microorganisms in the water [4]. BWAs are intended to be used as short-term public health interventions and repeat and long term BWAs can diminish users' trust of their drinking water [4], [5]. Common themes reported in previous water safety studies in Canada include the lack of consistent BWA reporting methods from one jurisdiction to the next, the challenge of compiling and completing accurate data sets, and inconsistent reporting formats across federal and provincial jurisdictions [6]. This results in gaps in data sets, making it difficult to accurately understand and address the problems that cause BWAs in Canada.

This study was the first to conduct a Canada-wide assessment of the potential impacts of climate change on water safety as indicated by the reasons, frequency, and length of BWAs and to conduct an in-depth statistical analysis of the seasonality of BWA reasons in Canada. A review and analysis of historical BWA records from the Canadian Network of Public Health Intelligence (CNPHI), a public health surveillance and alerting resource of the Public Health Agency of Canada (PHAC), was conducted to determine the leading causes of BWAs in Canada. The data was aggregated and analysed based on various parameters, such as population, reason for BWA, and water source, to identify trends and consistencies within each parameter and with each other. An in-depth review of academic and industry related literature related to water safety and climate change with a focus on factors relevant to Canada was conducted to analyze and identify the need for a solution.

Four major scholar databases (Omni, Scholars Portal, ProQuest, EBSCOhost) related to environmental science and engineering as well as a search engine (Google Scholar) were used to identify literature related to climate change, BWAs, and water quality. Various keywords were searched together, interchangeably, using the databases search method that allows for multiple terms to be searched in order of relevancy. The CNPHI data included information about BWAs issued from February 4, 2005, to July 8, 2021 in multiple Canadian jurisdictions and included 9,825 records, each of which represented a single BWA. Each BWA record included information about the drinking water supply type, status, water quality reason, operational reason, estimated population affected, the dates when the BWA was issued and rescinded, and the drinking water source type.

A total of 1,630 communities are represented in the database, but as a condition of the data sharing agreement with CNPHI the data was provided in an anonymized format and no information was provided about the location of the communities that experienced BWAs. According to the agency, anonymization was required because the data provided to CNPHI belongs to the individual agencies who collect and report it [7].

Primary reasons included measures of treated and/or distributed water quality such as turbidity, *E. coli*, total coliforms, and inadequate disinfection residual, as well as infrastructure-related reasons such as 'line break and pressure loss in distribution system', indicating a breakdown in the water distribution system (WDS) or 'significant deterioration of source water quality'. Some primary reasons, such as 'exceedance of maximum accepted concentration (MAC)' were open to interpretation. Secondary reasons included 'planned system maintenance', 'treatment unable to cope with source water deterioration', 'power outage resulting in system power loss or reduced storage of treated water', 'contamination during construction, repair, or operation', and 'inadequate disinfection residual in distribution system', among others. In 15% of cases, however, the primary reason was listed as 'not applicable', and in these instances, the secondary operational reason was assumed to be the primary reason for the BWA. Increased risk of contamination of distributed water is ultimately the underlying cause of all BWAs, whether they are called because there is evidence of microbial contamination (emergency BWAs) or when there is the potential for contamination (precautionary BWAs).

Drinking water source types were categorized as groundwater, surface water, cistern or holding tank, groundwater under the influence of surface water (GUDI), hauled water, high risk GUDI, potential GUDI, water pipeline, mixed (blended), unknown, and satellite system. GUDI is defined as a groundwater source that is located close enough to nearby surface water, such as a river or lake, to receive direct surface water recharge [8]. The formal definition of GUDI differs from one jurisdiction to the next, however, GUDI is usually defined as any water beneath the surface of the ground with significant occurrence of insects or other macro-organisms, algae, organic debris, or large-diameter pathogens such as *Giardia lamblia* or *Cryptosporidium*; or significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH that clearly correlate to climatological or surface water conditions [9]. A water pipeline system is one where water is transported via a water pipe from another community's water source. A satellite system is a drinking water system that receives water from another drinking water system through a service relationship or hub system. A cistern or holding tank is a waterproof receptacle for holding water. The provided dataset may have contained some variations in source water identification, particularly pipeline, region distribution systems, partial area advisories, area-wide advisories, or blended systems. Consultation with CNPHI confirmed that pipeline, regional distribution system, satellite system, and blended system all referred to water systems that were fully or partially supplied by a water pipeline from outside of the community. Due to the anonymity of the database, it is unclear which advisories are for partial areas or a full city or town.

Each BWA in the database was assigned an estimated population range by CNPHI. The smallest range was 0-100 people and the largest was >100,000.

The length of each BWA was computed by subtracting the date that the BWA was issued from the date that it was rescinded. In the case of BWAs that were ongoing at the end of the covered period (February 4, 2005, to July 8, 2021), the length of the BWA was assumed to be the difference between the date that the BWA was issued from July 1, 2021.

The impacts of these climate change phenomena on the factors that result in the issuance of BWAs (poor distributed water quality, damaged distribution infrastructure, malfunctioning treatment equipment) will be mostly indirect and often complex, requiring the use of holistic and multipronged strategies to ensure that water remains safe despite projected climate changes. The reviewed literature identified these climate change phenomena as increasing temperatures, flooding due to extreme wet weather and changes in snow and ice cover, changes in snow and ice cover, coastal flooding, drought, wildfire, and permafrost degradation. Table 2 summarizes the observed changes caused by the mentioned climate change phenomena, as well as their potential impacts on drinking water.

Table 2: Summary of potential impacts of climate change on drinking water safety

	Observed or Projected Changes	Impacts on Drinking Water
Increasing Temperatures	• Increase in annual mean surface temperature [10] • Arctic regions to warm above two times the global rate [10]	• 35% of waterborne outbreaks occurred between June and August [11] • Diminished surface and groundwater due to evaporation [12] • Warm temperatures increase chlorine decay [13]; [14]; [15]
Flooding due to Extreme Wet Weather and Changes in Snow and Ice Cover	• High probability of increase in frequency, intensity, and amount of heavy precipitation [16]; [10]; [17] • Increase in pluvial flooding, annual streamflow, and fluvial flooding [18]	• Waterborne diseases linked to heavy rainfall [19] [11] • Sewer overflow from heavy rainfall [20] [21] • Heavy precipitation increases the transport of soil and debris into surface water [22] • Increased turbidity, causing increase in contamination [20] • Changed both the quantity and character of NOM (Williamson) [23]
Changes in Snow and Ice Cover	• Changes in spatial and temporal distribution of snow and ice [24] [12] • Less snow accumulation, earlier melting of snow, more winter precipitation [24] [12]	• Flooding causing power outages impacting infrastructure [25] • Flooding can overwhelm water treatment and distribution infrastructure [11]
Coastal Flooding: **Sea Level Rise,** **Storm Surge and** **Convective Storms**	• Coastal flooding is expected to increase [26] • Coastal flooding caused by sea level rise or storm surge [26] • Sea level rise due to increasing liquid water volume due to melting glaciers [18] • Relative sea level expected to fall in Arctic Canada because of land uplift [26] • Increase in severity and magnitude of intense storms [27]	• Impacts on water infrastructure and additional effects on aquifers and surface water quality [28] • Sea level rise causing groundwater flooding [29] • Aquifers experiencing flooding can interact with buried infrastructure like sewage pipes and water mains [28] • Storm surge linked to vertical infiltration of saltwater and lateral saltwater intrusion into groundwater aquifer [30] and damage to drinking water systems [31] • Hurricanes and intense storms causing extensive flooding and damage to wastewater infrastructure resulting in contamination of surface water bodies [32] • High winds causing increased pipe failure and indirectly impact water treatment and distribution infrastructure through damaged electrical infrastructure [33] [34]

Drought	• Increased temperature and changing precipitation leads to droughts [35] [16] • Canadian Prairies and British Columbia will experience more severe and persistent droughts [17] [12] • Reduce moisture content and volume of soil, allowing for deeper frost penetration into soils [36]	• Post-drought rainfall events can deliver nutrients, organics, and turbidity into water sources (Mosley)(Kolijn) • Increased likelihood of pipe failure due to soil moisture [37] [36]
Wildfires	• Higher temperatures and prolonged droughts lead to larger and more severe wildfires [38] • Increase in FWI project increases the number of forest fires [10]	• Heavy rainfall post-wildfire impact water source and quality [39] • Ash, soil, sediment, nutrient, and NOM exposed from fire runoff into waterbodies [38] • Large amounts of gradually accumulated contaminants are released into streams, which can impact treatment facilities [39] [40] [38] • Increase in surface water sediment [41]
Permafrost Degradation	• Increase in permafrost degradation due to increased temperatures	• Changes in particulate, NOM, nutrients, and ionic species in surface water [42] [43] [44] [45] • Permafrost degradation linked to changes in chloride, conductivity, and hardness in source water [46] • Release of accumulated mercury and industrial chemicals into surface water [43] [47] [45] • Can cause increase in pipe breaks and pressure loss in distribution systems [34]

3 Chapter 3: Analysis of Boil Water Advisory and Identification of Causes (Problem Formulation)

The second step of the engineering design process is to search for and define the real problem. Rather than describing a problem based on a pre-determined solution, a problem statement should focus on the desired function to be performed by the solution [2]. Formulation of a problem statement is a critical step in the design process, determining which direction the efforts will continue [2].

3.1 Structuring the Search for a Problem

The first step of the ED process (Chapter 2) identified the need for a solution to water safety insecurities in Canada, specifically BWAs. This search was structured through a systematic literature review and data analysis. Our analysis of the CNPHI data explored the number and trends in BWAs in Canada from 2005 and 2020. Our central hypotheses were:

- Small and very small communities will be more likely to have experienced BWAs, repeat BWAs, and long term BWAs than larger communities.
- In keeping with common media narratives in Canada, most BWAs will have been linked to treatment failures and distributed water quality.

3.2 Structuring the Search for a Solution: Design Goals and Specifications

In order to develop a problem statement, structuring the search for a problem and the search for a solution are essential steps. One of the first steps in searching for a solution is to define the objective of the search; a problem statement does not always highlight the objective of a solution, nor does identifying the need for a solution. In this case, the objective is to find a solution and/or major causes of drinking water safety vulnerabilities in Canada. **Figure 2** illustrates the primary reasons for BWAs reasons in communities of different sizes, with aggregated results from across Canada. Smaller communities have a disproportionally higher frequency of BWAs, with communities of up to 100 and 500 residents experiencing more than 2,000

BWAs over the study period. Similarly, communities with up to 1,000 and 5,000 residents also have a relatively high occurrence of BWAs compared to larger communities.

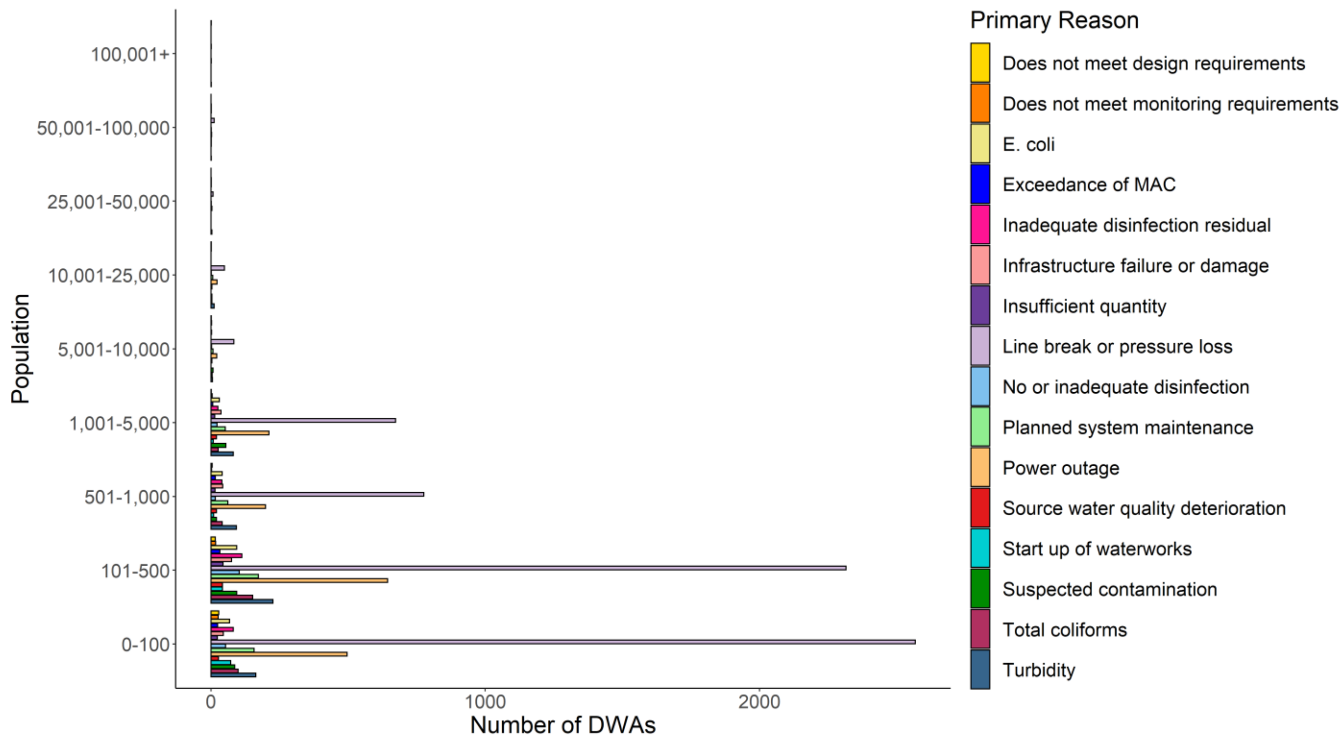

Figure 2: Primary reason(s) for calling BWAs in Canadian jurisdictions based on the population of the affected area.

Figure 2 shows that the most frequent primary reasons for the issuing of BWAs are "line break or pressure loss in distribution system", "planned maintenance", "equipment failure", "total coliforms detected", and "power outage". In small communities (up to, 100, 500, 1,000, and 5,000 residents), "line break of pressure loss in distribution system" count for the majority of the primary reason for BWAs, followed by "power outage". These advisories may be precautionary since a power outage can interfere with the treatment plant operation. This is in contrast to the common media narrative in Canada that BWAs are called because of treatment failures and/or that pathogens have been detected in distributed water.

Furthermore, **Figure 3** demonstrates that repeat BWAs are also common in small communities in Canada. The most common cause of repeat BWAs was a line break in the distribution system, with some small communities experiencing upwards of 40 repeat BWA due to line breaks during the 15-year span represented by the data. Other common causes of repeat BWAs included inadequate disinfection residual, turbidity, and total coliforms.

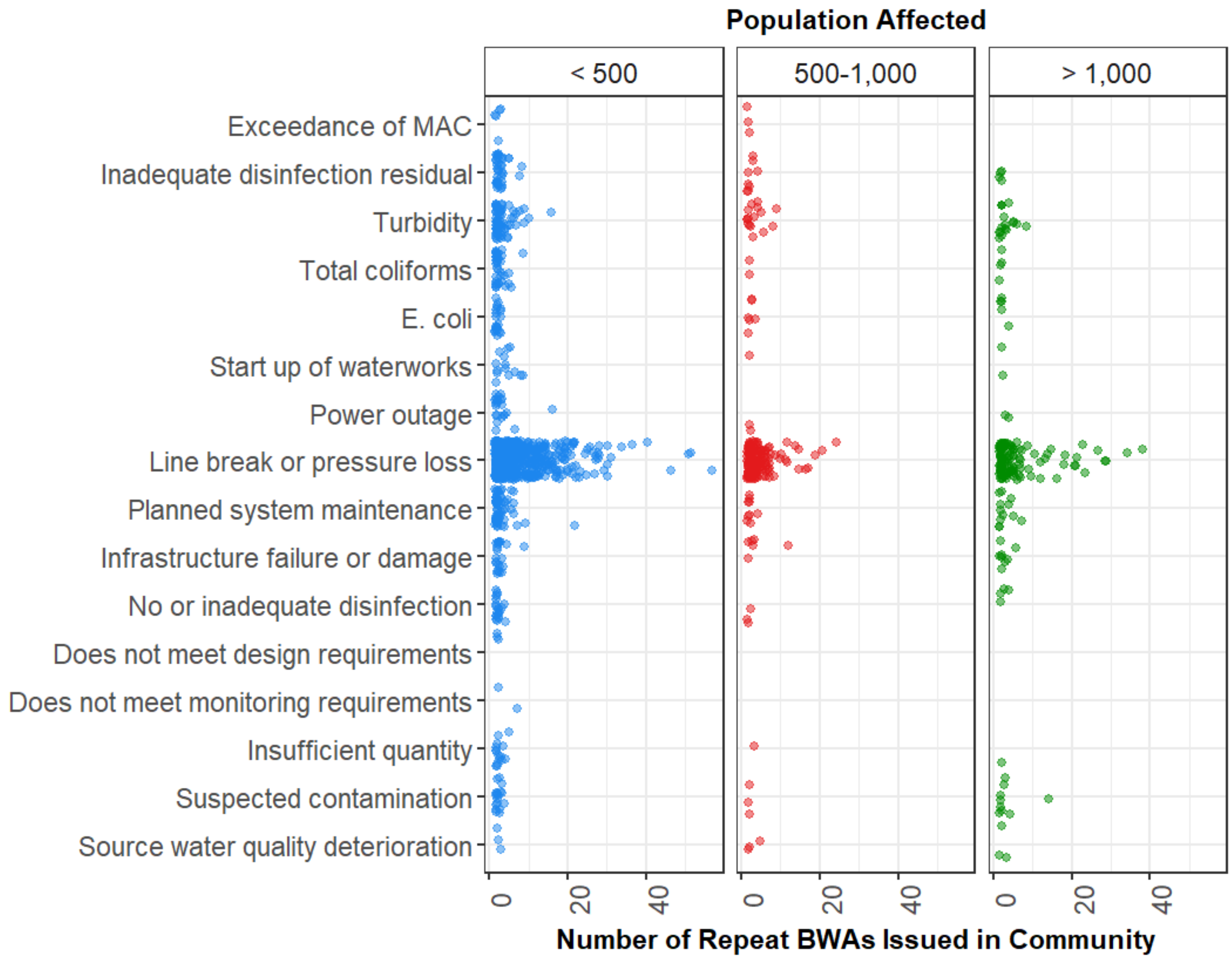

Figure 3: Number of repeat BWAs in each community broken out by primary reason and population size. Each dot represents the number of repeat BWAs that have been issued in a given community for a specific primary reason

Previous studies have identified that there are a large number of long-term and repeat BWAs, particularly in small communities [6] and that long term BWAs occur most often in small water systems [48]. Our findings are in-line with these observations, identifying and confirming that small communities are, in-fact, more heavily impacted by long-term and repeat boil water advisories as shown in **Figures 2 and 3**.

Many of the underlying causes of BWAs are influenced by temperature and other seasonal factors, so it was expected that some of the BWA reasons would show seasonal patterns. The following figure illustrates the number of BWAs issued during the study period due to *E. coli*, total coliforms, turbidity, and inadequate disinfection residual plotted by the month in which they were issued:

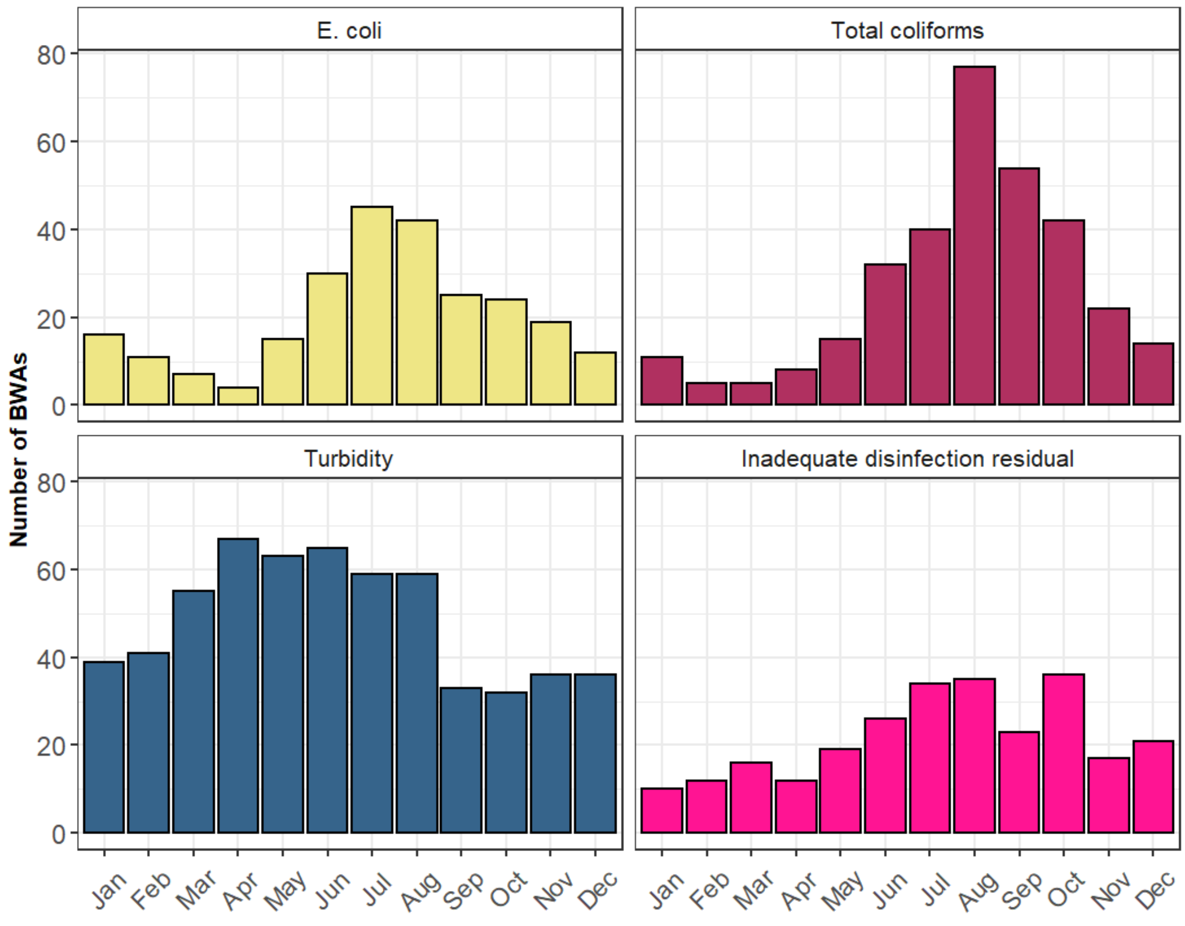

Figure 4: BWAs issued during the study period plotted by month which they were issued

The literature for this study found various reasons that small communities may be more vulnerable to water safety risks. Our analysis of the CNPHI database indicated that fewer than 5% of the BWAs issued in Canada between 2005 and 2020 were primarily linked to poor design or failure of water treatment unit processes. Systems that rely exclusively on chlorination are particularly vulnerable – previous research has linked these systems to higher incidence of acute gastrointestinal illness (AGI) [49]. Similarly, climate change phenomena are likely to impact water treatment plant equipment and operation in indirect ways. These findings further highlight the need to address drinking water safety in small communities, particularly within the distribution system.

3.2.1 General Design Goals

The general design goals for most engineering problem-solving efforts can include safety, environmental protection, public acceptance, reliability, performance, ease of operation, durability, use of standard parts, minimum costs, and minimum maintenance and ease of maintenance [2]. These are all important factors to consider when searching for and choosing a solution. Furthermore, the overall design objectives should be custom-tailored to thoroughly address the identified problem and need for solution outlined in the previous steps.

The current project's design goals include all of the previous stated examples. Firstly, safety, in the context of water safety; as discussed earlier, the objective of this design is to address potential water safety concerns, specifically pertaining to BWAs and distribution systems. Our analysis of the CNPHI data set clearly indicates that WDSs are the main source of water safety risk in Canada as indicated by the number of BWAs issued for distribution-related reasons. Precautionary BWAs are usually called when there is a line break or pressure loss in the system because there is the potential for the pipe and/or distributed water to become contaminated. This concern is well-founded – a systematic review of 20 studies linked increased incidence of acute gastrointestinal illness (AGI) to low pressure and interrupted tap water supply in water distribution systems [50]. This steers the direction of design goal formulation towards addressing the ultimate underlying cause, which has been identified to be increased risk of contamination of distributed water, and issues pertaining to the water distribution system.

Furthermore, public acceptance is also a key parameter for design consideration. Lack of trust in a community drinking water supply can push users to purchasing bottled water, or collecting water from streams and springs [51]; [52]; [53].

For small communities, reliability, minimum costs, minimum maintenance, and ease of maintenance are all crucial parameters to consider. Small water systems commonly lack access to funding, resources, and trained personnel [48]. In recognition of the interrelated logistical, operational, and financial capacity issues faced by small communities, very small water and/or remote systems are held to less rigorous treatment standards in some Canadian jurisdictions. For example, in the northern territory of Nunavut, 24 out of 25 communities have fewer than 5,000 residents and 50% of communities rely exclusively on chlorination (no filtration) for water treatment [46].

Table 3: Summary of design goals and justification for need to meet goal.

Design Goal	Need for Goal
Safety	Water safety; distribution systems and infrastructure are main causes of water safety vulnerability
Public Acceptance	Lack of trust in water sources, most communities do not prefer the taste/smell of chlorine (i.e. opt for less chemical treatment)
Ease of Operation/Reliability	Lack of access to trained personnel requires water sources/treatment that is reliable and easily operated
Minimum Maintenance/Ease of Maintenance	Lack of access to trained personnel and other resources requires a solution requiring minimum maintenance
Minimum costs	Lack of access to funding and resources requires solution with minimum cost

The challenge identified is to provide a solution to drinking water vulnerabilities within small communities, with a specific focus on addressing issues within the water distribution system. The current state of water distribution systems in these communities necessitates a comprehensive solution that ensures water quality, accessibility, and reliability meet established criteria and standards. Through an iterative engineering design process, the overall objective is to develop and implement a sustainable and effective solution. This solution should not only satisfy the identified design goals, but also align with the unique needs of the community.

4 Chapter 4: Maintaining Water Safety using Primary and Secondary Disinfection (Solution Formulation using Abstraction and Synthesis)

By following the engineering design process thus far, a potential solution can be identified to address the problem statement as well as satisfies the design goals and objectives using abstraction and synthesis. The abstraction phase of the engineering design process includes generating various approaches to a solution by creating models to represent different solutions and design scenarios [2]. The synthesis step involves the creative formation of the design solutions into tangible and practical forms [2].

Table 3 in the previous chapter identified the needs and justifications for these pre-determined design goals and objectives. The following section highlights the abstraction and synthesis phases, which consist of exploring potential solutions which satisfy the highlighted design goals and needs. In this chapter, three potential solutions to maintaining water safety in the distribution system were identified and elucidated using an in-depth literature review. Next, modelling (abstraction) and stakeholder consultation (synthesis) were conducted to establish potential distributed treatment approaches that could be explored in greater detail in the analysis stage of the project.

4.1 Maintaining water safety in the water distribution system

Secondary disinfection is widely used to ensure that the water that leaves the water treatment plant does not become contaminated as it travels through the water distribution system. Chlorine disinfection with free chlorine, chloramines, or chlorine dioxide is the default approach to secondary disinfection in North America, but some countries in Europe rely instead on maintaining a positive pressure in the distribution system using pumps with variable speed drives and regular water quality and operational monitoring to reduce the chance that bacteria will enter the WDS through cracks in distribution pipes [54]. An example of this is the Netherlands, one of the few countries in which chlorine is not utilized for any stage of drinking water treatment [54]. The production and distribution of drinking water without chlorine is done through prioritizing the following: using the best source water available, using various physical process treatment such as filtration and UV-disinfection, prevent contamination and microbial growth within the distribution system, and timely monitoring for system failures [54]. Furthermore, the Dutch drinking water regulations are more rigorous than that of the European Union; for example, the EU allows exceptions for smaller supplies of drinking water, while the Dutch regulations do not [54]. Dutch regulations do not include requirements for primary or secondary disinfection, but rather a health-based target system that is related to the size and demand of the system [54]. This allows for a treatment system that intensifies monitoring of the full-scale drinking water system, allowing for drinking water safety implementation to go further than the treatment facility [54]. A recent paper by Linden et al. (2019) suggested an alternative approach to maintaining water safety in the WDS using UV LEDs in storage tanks, water distribution pipes, or at the point of entry/point of use at individual building.

4.1.1 Secondary disinfection with chlorine

A small amount of free chlorine, chloramines, or chlorine dioxide is widely used to prevent microorganisms from reinfecting treated water as it travels through the distribution system [55]. Chlorine can interact with organic and inorganic species in the water to form disinfection byproducts (DBPs), some of which have been linked to negative human health outcomes [56].

DBPs are regulated in North America due to their potential health impacts on consumers; developing research is making it apparent that microbiological activity plays a role in these chemical parameters, such as DBPs [57]. The accumulation of oxidizable material at the pipe wall, such as corrosion by-products and biofilm, can increase disinfection residual demand [57]. Disinfection residual can also be impacted by increases in temperature, causing areas that experience high temperature for long durations to experience periods with little to no disinfection residual [58].

4.1.2 UV LEDs

Distributed treatment with UV LEDs provides a new approach to water treatment; this consists of water treatment to occur across the entire drinking water system. This includes in storage tanks, water mains, entries and even at the point-of-use. Ultraviolet (UV) disinfection has been proven to be an effective method for the inactivation of pathogens and microorganisms [59]. In the year 2000, the US Food and Drug Administration approved ultraviolet (UV) disinfection as an effective method for inactivation of pathogens and spoilage microorganisms in food, water, and beverages; ultimately, working as a disinfection mechanism [59]. UV light emitting diodes (UV LEDs) are a source of UV radiation that can emit a variety of wavelengths [60]. An LED is a semiconductor device that utilizes semi-conducting material to create a p-n junction; the electrons and holes recombine at the junction to emit radiation, with a wavelength that depends on the semi-conductor material [61]. They offer numerous benefits over conventional UV lamps, including fast start-up times, compact and durable, longer lifetime, and potentially less energy [61]. Furthermore, they carry the same advantage of efficient disinfection without the production of DBPs. As an emerging technology, LEDs are constantly improving in terms of power output, energy efficiency, life-span and economic viability, making them more practical for usage in water treatment [62].

The rapid development and advantages of UV LEDs give it the potential to be used along side secondary disinfection [57]. UV LEDs can also be applied for targeted treatment in regions prone to problems with microbial growth, or areas where consumers are at a higher risk of contracting infections [57].

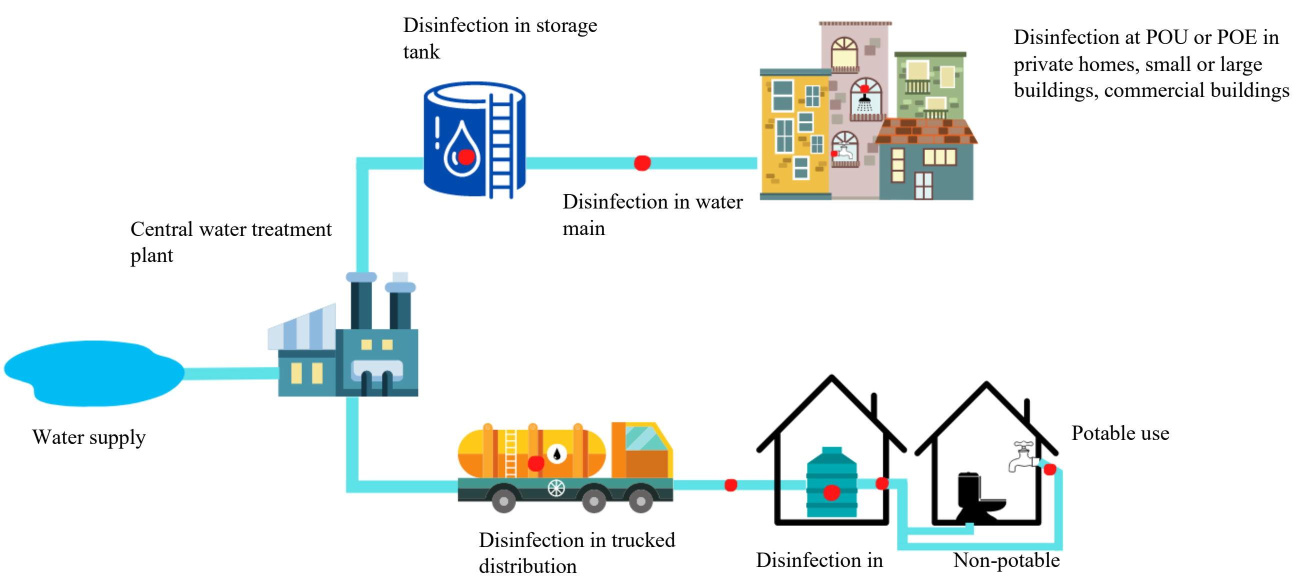

Figure 5: Diagram of conventional treatment distribution system. Red dots indicate potential locations for UV LED reactors. Figure adapted from Linden et al.

Applications of UV LEDs throughout the distribution system can include UV in storage tanks or in their inlets/outlets, LEDs along pipe walls, or point of entry/point of use treatment for buildings or homes [57]. Although UV alone has the potential as a chemical-free process for disinfection, it can also be integrated into existing systems to supplement current processes without the formation of DBPs [57].

There are three main specifications for each UV LED besides wavelength: the radiant power, the radiation profile and the spectral power distribution. Inaccurate measurements of the UV LED’s radiant power or improper operation of the UV LED’s may result in inaccurate recording of UV doses [60].

4.1.2.1 Wavelengths

Different wavelengths are emitted from different UV sources; conventional low pressure (LP) mercury lamps emit one color (monochromatic) of UV light at a wavelength of 254 nm and medium pressure lamps emit a multiple color (polychromatic) spectrum with various wavelengths [63]. UV LEDs make it possible to use a variety of wavelengths for disinfection rather than just the 254 nm offered by LP lamps, along with the many advantages of LED lamps over mercury lamps [63].

UV LEDs are comprised of UVC wavelengths, ranging from 200-280 nm, UVB wavelengths, ranging from 280-315 nm, and UVA wavelengths, ranging from 315-400 nm [59]. Various wavelengths can be manufactured using different semiconducting materials [61]. The most frequency used materials are III-nitride, including gallium nitride (GaN) and aluminum gallium nitride (AlGaN), and aluminum nitride (AlN) [64]. The germicidal efficiency of UV radiation is reported to be highly dependent on the wavelength, making the UV wavelength as essential factor for microorganism inactivation which varies between different microorganisms [61]. There are three main specifications for each UV LED: the radiant power, the radiation profile and the spectral power distribution; inaccurate measurements of the UV LED’s radiant power or improper operation of the UV LED’s may result in inaccurate UV doses recording [60]. DNA mainly absorbs UV radiation from 200 to 300 nm, with a maximum absorbance at around 260 nm [61]. UV LEDs with a wavelength around 260 nm have been found to be the most efficient for most microorganism inactivation [61]. However, the peak wavelength distribution is dependent on the target microorganism and wavelength should be investigated and adjusted depending on the target microorganism.

4.1.2.2 Inactivation Effectiveness

To evaluate and compare the effectiveness of disinfection, the log inactivation of each microorganism, UV dose (unit: mJ/cm^2), inactivation constant *k* (unit: cm^2/mJ) and the UV dose per log inactivation (unit: mJ/cm^2 per log inactivation) can be measured and compared. An inactivation constant refers to the rate constant that defines the rate of inactivation. Various studies looked at different UV wavelengths in the ranges of UVA, UVB, and UVC and applied them to various microorganisms to evaluate their inactivation by UV LED [65]; [66] [67]; [68].

The inactivation profile of *E. coli* by different UV LED wavelengths was completed by Nyangeresi, et. al. (2018). The 267 UV LED had a higher log inactivation than the other wavelengths, followed by the combined emission of 267/275 nm, 275 nm, and finally 310 nm UV LED having the lowest log inactivation. Furthermore, the 267 nm UV LED had a *k* value of 0.42 cm^2/kJ, 275 nm had a *k* value of 0.292 cm^2/kJ, and 267/275 nm had a *k* value of 0.391 cm^2/kJ [65]. The *k* values of the other single and combined wavelengths were the lowest of both the other single and combined wavelengths, but any combination of wavelengths that contained 267 nm had a slightly increased *k* value; this tells us that the 267 nm UV LED has an influence on the deactivation of microorganisms [65].

Hamamoto et al. (2007) applied 365 nm UVA-LED on *E. coli*, and achieved a UV dose response of 55,263 mJ/cm^2; this value is considered very high, considering the UV dose for a 254 nm mercury lamp achieves a UV dose of about 8 mJ/cm^2 for a 4 log inactivation of *E. coli* (2 mJ/cm^2 per log inactivation) [61]. Xiong and Hu (2013) established a photocatalytic (acceleration of a photoreaction in the presence of a catalyst) using titanium oxide and a 365 nm UVA-LED and achieved a UV dose of 229 mJ/cm^2 per log inactivation for *E. coli* inactivation; still, a significantly high dose [69].

Another study by Oguma et al. (2013) used 310 nm UVB-LEDs for *E. coli* inactivation and achieved a UV dose response of 94.8 mJ/cm^2 per log inactivation; this is lower than the results from UVA-LED radiation, however is still not highly efficient [68]. Again, we can see that UVB radiation is not effective enough for microorganism inactivation.

Aoyagi et al. (2011) used 280 nm UVC-LEDs to study the effects on ΦX174, Qβ and MS2; these are all types of bacteriophages, which are a type of virus that infect bacteria [70]. The achieved UV dose responses for the microorganisms were 2.8, 28.7 and 30.5 mJ/cm^2, respectively [67]. The experiment was repeated with 255 nm UVC-LEDs, and achieved 1.7, 12.5 and 12.8 mJ/cm^2, respectively [67].

Another study by Bowker et al. (2011) used UVC-LEDs at 255 nm and 275 nm on MS2, T7, and *E. coli*; the 255 nm radiation achieved a UV dose response of 26.1, 5.1 and 3.3 mJ/cm^2, respectively and the 275 nm radiation achieved 28.6, 4.3, and 2.4 mJ/cm^2, respectively [71]. The dose response for MS2 is slightly lower at 255 nm, indicating that 255 nm was more effective for MS2. However, the 275 nm was more effective for T7 and *E. coli* [71]. The higher effectiveness of 275 nm may be due to a higher fluence rate and shorter exposure time to reach the same UV dose [71]. UV inactivation is said to follow the Bunsen-Roscoe reciprocity law, which means the photochemical effect depends only on the total energy dose which is the product of fluence rate and exposure time [61].

4.1.2.3 Mechanism of Inactivation

Along with the effectiveness of microorganism inactivation using UV LEDs, the discussion of the mechanism of microorganism inactivation by UV LEDs is also of interest. It's known that UV radiation acts directly on the DNA of the microorganism, having direct germicidal effects [61]. DNA mainly absorbs UV radiation from 200-300 nm, with a maximum absorption reached at approximately 260 nm [59]. UV light induces damage to the genomes of bacteria, protozoa, and viruses, breaking bonds and forming photodimeric lesions in nucleic acids, DNA, and RNA [72]. These lesions lead to the inactivation of the microorganisms by preventing both transcription and replication [72]. However, direct damage to the DNA may be reparable through DNA-repair mechanisms; this is not ideal for microorganism inactivation [59]. Many studies have investigated the repair mechanisms of microorganisms undergoing UV radiation.

Nyangaresi et. al (2018) investigated the impact of coupling UV wavelengths of 267/275 nm, 267/310 nm, and 275/310 nm to view their inactivation profile of *E. coli* [65]. The 267/275 nm coupling achieved a log inactivation of ~ 4 using the same UV dose required for the ~ 2.1 log inactivation using a 267/310 nm wavelength, ~ 1.9 log inactivation using 275/310 nm, and ~ 0.4 log using 310 nm [65]. Beck et al. (2016) evaluated the inactivation of MS2 at lower UV wavelengths to understand more about the inactivation mechanisms at these wavelengths. There are few studies which measure the damage that occurs within the DNA or RNA because of the absorbance of UV irradiation; RNA is different from DNA due to its presence of uracil nucleotides instead of thymine [72]. MS2 is used as a surrogate for enteroviruses for reactor validation [72].

4.1.3 Evaluation of potential solutions to maintaining water safety in the water distribution system

UV LEDs address most, if not all, the previously stated design goals (see **Table 3)**. Chlorine disinfection produces disinfection-by-products (DBPs), whereas UV LEDs achieve disinfection without the formation of DBPs [57]. DBPs are formed when chemical disinfectants interact with natural organic materials in the water, and have the potential impacts on human health [73]. This satisfies the goal of public acceptance. Additionally, the durability, long lifetime, and less energy consumption of UV LEDs satisfies the design goals of reliability, low cost, and ease of maintenance. **Table 5** once again highlights the design goals, their need/justification, and how the proposed solution addresses these.

Table 4: Summary of design goals, need for goals, and proposed solutions.

Design Goal	Need for Goal	Distributed treatment with UV LEDs
Safety	Water safety; distribution systems and infrastructure are main causes of water safety vulnerability	Distributed treatment – treatment of drinking water within the distribution system to help address the potential causes of vulnerabilities.
Public Acceptance	Lack of trust in water sources, most communities do not prefer the taste/smell of chlorine (i.e. opt for less chemical treatment)	Implementation of UV LEDs as a disinfection mechanism to opt for treatment that does not require chemicals (i.e. chlorine) and does not have a taste, odor, or formation of DBPs.
Ease of Operation/Reliability	Lack of access to trained personnel requires water sources/treatment that is reliable and easily operated	Implementation of UV LEDs as a disinfection mechanism due to its ease-of-use and longer lifespan
Minimum Maintenance/Ease of Maintenance	Lack of access to trained personnel and other resources requires a solution requiring minimum maintenance	Implementation of UV LEDs as disinfection mechanism due to compatibility, ease-of-use, and low maintenance.
Minimum costs	Lack of access to funding and resources requires solution with minimum cost	Implementation of UV LEDs as disinfection mechanism due to economic viability and energy efficiency.

4.2 Abstraction with EPANET

The proposed high-level solution to address water safety concerns in distribution networks proposed in this thesis is to implement UV LED reactor devices along the WDS. There are a variety of methods and designs that can be employed to execute this idea, such as installing them in the watermain pipes, storage takes, at the points-of-use or points-of-entry. To analyze the impact and effectiveness of these various UV LED designs, EPANET can be used to model various simulations and scenarios.

4.2.1 Introduction to EPANET

The complex nature of WDSs can make them difficult to understand, especially in determining whether a compromised distribution system is leading to a contamination issue. Various computer-based tools, such as EPANET, are used to model these distribution systems to simulate responses to contamination events in the attempt to safeguard and understand the distribution system.

EPANET is a modelling software used to analyze hydraulic and water quality parameters in WDSs [74]. EPANET can be used as a stand-alone program, or alongside various toolkits of functions that can be incorporated outside the software interface to build custom applications. The quality analysis in the stand-alone program is limited to tracking single species, such as free chlorine used for secondary disinfection. The toolkit used in this study is EPANET-MSX; the MSX stands for Multi-Species Extension [74]. This toolkit extensions provides the capability to analyze the interaction and behaviour of multiple species in a WDS.

These tools are built on mathematical models and define the behaviour of contaminants in various forms throughout the distribution system. The following five governing rules should be considered when implementing mathematical modelling for accuracy and understanding of the system: 1) physical rules regarding the flow characteristics within the distribution network, 2) rate and duration of contamination, 3) physical, chemical, physicochemical, and biochemical mechanisms administering the contaminant's fate within the spatial domain of the system, 4) the dynamics of the supply and extraction of water at the source and demand points and 5) the network configuration [75].

There are two significant physical phases of species in a WDS; a bulk phase and a fixed surface phase [74]. The bulk water species are chemical or biological components that exist in the flowing or 'bulk' water travelling throughout the system at a certain velocity [74]. The chemical or biological species that are attached to the pipe wall are denoted as 'wall' species; they are attached or incorporated into the surface of the pipe wall and is assumed to not travel with the moving water [74].

4.2.2 Model Development

A model distribution system was built to simulate and compare secondary disinfection with free chlorine and distributed treatment with UV LEDs. To the author's knowledge, this is the first time that distributed UV LED treatment has been simulated with EPANET or any other WDS simulation software.

Most past studies focus solely on the biological activity of a single contaminant or disinfectant chemicals such as chlorine; these are single species models [75]. Multi-species models combine the exchange among various abiotic and biotic constituents to simulate and model the spatiotemporal distribution of microbiological and chemical water quality parameters [75]. There are a couple of challenges associated with multi-species models compared to single species models that should be considered, such as the conceptualization of the exchanges among multiple reacting constituents and developing a scientific description of these exchanges [75]. Various second-order kinetic equations were used in this study to illustrate the chlorine-Total Organic Carbon (TOC)/Bioavailable Dissolved Organic Carbon (BDOC) reactions and the chlorine decay and TOC/BDOC degradation, as shown in equations 1-3 [75]. It's important to note that these equations have been simplified to represent the interaction of bulk species.

$$\frac{dC}{dt} = -k_{cn} * N * C \quad (1)$$

$$\frac{dN}{dt} = -Y_n * k_{cn} * N * C \quad (2)$$

$$\frac{dS}{dt} = -Y_n * k_{cn} * S * C \quad (3)$$

Where C = concentration of residual chlorine (mg/L); N = concentration of TOC (mg/L); S = concentration of BDOC (mg/L); t = time (h); k_{cn} = second order rate constant corresponding to chlorine-TOC/BDOC reactions (L/mg/h); Y_n = yield coefficient for TOC/BDOC corresponding to chlorine-TOC/BDOC reactions (mg/mg) [75].

The THMs formation, a DBP formed from chlorine and TOC reactions, was modelling with a reaction yield coefficient in equation 4 [75].

$$\frac{dH}{dt} = Y_h * k_{cn} * N * C \quad (4)$$

Where Y_h is the reaction yield coefficient corresponding to THM formation from organic matter (µg/mg) and *H* is the concentration of THMs (µg/L).

Furthermore, the transfer of chlorine in the bulk flowing water to attached biofilm on the pipe walls and the consumption of chlorine by the pipe walls is modelled using equation 5 [75].

$$\frac{dC}{dt} = -\frac{k_w * k_f}{(k_w + k_f) * R_h} * C \quad (5)$$

Where k_w is the wall decay coefficient of chlorine, k_f is the mass transfer coefficient of chlorine, and R_h is the hydraulic radius.

The planktonic microbial regrowth and substrate consumption is modelled in equation 6 [75]. This equation also defines the impact of chlorine and temperature on the planktonic microbial growth. Biofilm growth against chlorine inhibition is also modelled in equation 7 [75].

$$\frac{dX_b}{dt} = \mu_{max,b} * \frac{S}{K_s + S} * \exp(-k_{inact} * C) * \exp\left[\left(-\frac{T_{opt} - T}{T_{opt} - T_i}\right)^2\right] * X_b \quad (6)$$

$$\frac{dX_a}{dt} = \mu_{max,a} * \exp\left(-\frac{k_{inact}}{k_r} * C\right) * \exp\left[\left(-\frac{T_{opt} - T}{T_{opt} - T_i}\right)^2\right] * X_a \quad (7)$$

Where X_b = planktonic microbial colony count (CFU/L); X_a = biofilm microbial density (CFU/ft^2); $\mu_{max,b}$ = maximum specific growth rate of planktonic microbes (1/h); k_{inact} = microbial growth inactivation constant (L/mg); T_{opt} = optimal temperature for microbial activity; T = water temperature; T_i = temperature-dependent shape parameter; $\mu_{max,a}$ = maximum specific growth rate of biofilm microbes (1/h); and k_r = resistance factor.

The inactivation rate of *E. coli* in the presence of free chlorine is modelled in equation 8 [76]:

$$dE/dt = -k_e * C * E \quad (8)$$

Where E = *E. coli* count (CFU/L); and k_e = *E. coli* inactivation coefficient (cm^2/mJ).

The UV inactivation kinetics of each species were derived mathematically from the fluence-response curves developed after each species was exposed to the respective UV LED fluence for various wavelengths (Equation 9) [77].

$$\frac{N_t}{N_0} = 1 - \left(1 - 10^{-kF}\right)^{n_c} \quad (9)$$

Where N_0 and N_t are the microbial concentration (CFU or PFU/mL) at times 0 and time t [77]. K is the inactivation constant (cm^2/mJ), which is specific to each species of microorganism. F is the UV fluence at time t, and n_c is the number of critical. If n_c is equal to 1, the equation can be reduced to a single target model as follows [77]:

$$\frac{N_t}{N_0} = 10^{-kF} \quad (10)$$

At bench scale, collimated beam apparatus applies the same UV fluence to the entire sample of water and the respective organisms; the beam is uniformly applied to the entire sample that is stationary and well stirred [78, pp. 42-45]. In the case of a UV reactor, or a UV system installed along a watermain, the water is flowing at varying velocities and can travel through the beam through a variety of paths. Because the paths vary, the UV doses or fluences are received differently by each microorganism, resulting in a UV dose distribution [78, pp. 42-45]. Using a mathematical model to calculate the irradiance or fluence rate throughout the reactor can calculate the volume averaged fluence rate [78, pp. 42-45].

To address this, the core equations used for UV fluence, irradiation, and UV disinfection were restructured to consider the velocity and diameter of the water flowing through the pipes. The irradiance value was chosen and inputted into the model.

The exposure time of the water as it passed was calculated using the following equation:

$$E_t = \frac{L}{U} \quad (11)$$

Where E_t is the exposure time (s), L is the length (ft) of the UV reactor lamp, and U is the velocity of the pipes (cm/s). The MSX extension uses the velocity in the observed pipe during the hour of calculation.

The fluence is calculated using the chosen irradiance value and exposure time using the following equation [79]:

$$F = I * E_t \quad (12)$$

It's important to note that the UV reactor equations have been simplified for modelling purposes, and the reactor shape and geometrical factors are not considered.

4.2.3 Model Parameters

4.2.3.1 UV LED Parameter Requirements

Products and materials used for drinking water treatment additives, devices, and system components are not currently regulated by the federal government [80]. The NSF/ANSI 55 documentation is used by Health Canada to develop health-based standards for using ultraviolet disinfection for water treatment systems [80].

The NSF 55 standard separates UV systems into two distinct classes: Class A and B. Class A devices are designed to inactivate and/or remove microorganisms such as bacteria and viruses; these devices are used at the municipal level and intended for regulated use, similar to a primary disinfectant [81]. Class B systems are designed for supplemental treatment of water that has been tested and deemed acceptable [81]; this is water that has already left the treatment plant and is undergoing UV exposure as a secondary disinfectant. Since this current study is evaluating the use of UV LEDs in the distribution system, i.e. after it has left the treatment plant, it is considered a Class B system. **Table 6** highlights the basic requirements of NSF/ANSI for POU/POE UV systems:

Table 5: Basic requirements for NSF/ANSI 55 for POU/POE systems - Table adapted from [37]

Requirement	Class A System	Class B System
UV dosage	40 mJ/cm^2 at highest achievable flow rate	16 mJ/cm^2 at highest achievable flow rate
UV sensor	Required	Not Required
Material safety	Formulation review for all drinking water contact	Formulation review for all drinking water contact
Structural integrity	Testing required based on product configuration	Testing required based on product configuration
Product literature	Installation, operation, and maintenance instructions, performance data sheets and replacement element packaging required to include specific information	Installation, operation, and maintenance instructions, performance data sheets and replacement element packaging required to include specific information

Since this study calls for a class B system, a UV dosage/fluence of 16 mJ/cm^2 will be used where applicable.

4.2.4 Microorganism Parameters

In order to assess the disinfection rate of specific microorganisms through UV treatment, a critical parameter to consider is the inactivation rate constant, denoted as k in **Equation 9**. The following table summarizes the inactivation rate constants that have been determined for two common test microorganisms, *E. coli* and *P. aeruginosa*, at various wavelengths. *E. coli* is one of the major pathogens associated with of waterborne diseases and used as an indicator of fecal contamination for food and water samples [82]. *P. aeruginosa* is a gram-negative biofilm-forming bacteria, commonly found in the environment such as in soil and water [83]. Both microorganisms are more vulnerable to inactivation by light in the UVC spectrum (200 nm – 280 nm).

Table 6: Inactivation rate constants using UV LED at various wavelengths as reported by [34]

Wavelength (nm)	**Inactivation rate constant *k* +/- 95% Confidence Interval (cm^2/mJ)**	
	E. coli	***P .aeruginosa***
254	(8.11 +/- 0.70) x 10^{-1}	(4.48 +/- 0.51) x 10^{-1}`
265	(8.05 +/- 0.55) x 10^{-1}	(7.74 +/- 0.49) x 10^{-1}
280	(5.61 +/- 0.39) x 10^{-1}	(5.11 +/- 0.53) x 10^{-1}
300	(0.63 +/- 0.04) x 10^{-1}	(0.59 +/- 0.06) x 10^{-1}

For the purpose of the MSX code, a UV LED device emitting light at 254-nm was assumed and *P. aeruginosa* was used as the planktonic bacterial species. 254 nm is currently the most widely used wavelength for water disinfection.

4.2.4.1 EPANET MSX Interface

The MSX extension is used for multi-species analysis and has not yet been integrated into the Windows version of the programs interface [74]. The EPANET MSX extensions is supplied in a compressed zip file called EPANETMSX.zip [74]. It supplies both a stand-alone console application (epanetmsx.exe) that does not require the use of additional programing languages, as well as a function library that can be used to customize the analysis using various programming languages [74]. Some users may opt to use MATLAB or C++ to customize analysis packages. Both methods require two input files to be used; one is a standard EPANET file of the network of study that is exported from EPANET as a network (.inp), and the other is a prepared MSX file (.msx) that describes the species being simulated and the respective governing equations [74].

The current study used the stand-alone console application to conduct a water analysis. The application (epanetmsx.exe), the network file (.inp), the customizes MSX file (.msx) and a new file to print results

(.rpt) were called in the Windows Command Prompt (CMD) interpreter. **Figure 6** illustrates these inputs in CMD to execute the water analysis. All files are prepared and written in Microsoft Notepad. The exported network file contains all the necessary information from the constructed network in the EPANET program. The customized MSX file contained specific information for the analysis under various headings such as [OPTIONS], [SPECIES], [COEFFICIENTS], [TERMS], [PIPES], [TANKS], [QUALITY], [SOURCES], [PARAMETERS], [PATTERNS] and [REPORT]. The EPANET MSX Manual ([74]) was utilized heavily as a guide and manual to executing water analysis simulations using EPANET MSX. This includes the mathematical equations highlighted, microorganism parameters**,** and model inputs. The inputted values and files for this study are available in the appendices.

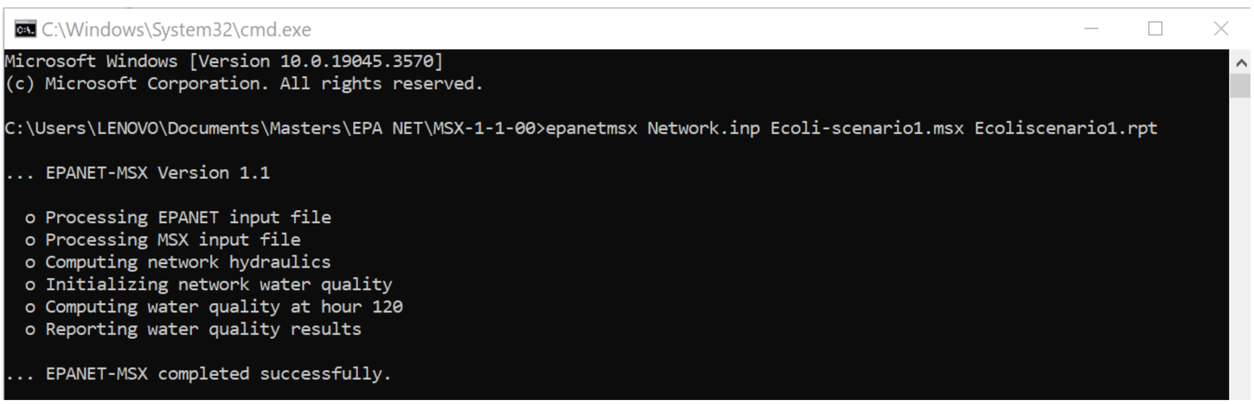

Figure 6: Windows Command Prompt running epanetmsx analysis

The following inputs are listed under the [OPTIONS] section to set the values of computational options.

Table 7: Computational option inputs and selected values

Input	Options	Selected value in this study	Definition of input
Area units	ft^2 m^2 cm^2	ft^2	Units used to express pipe wall surface area. Default is ft^2.
Rate units	Seconds Minutes Hour Day	Day	Units in which all reaction rate terms are expressed.
Solver	Standard Euler integrator Runge-Kutta 5th order integrator 2nd order Rosenbrock intergrator	Standard Euler integrator	Choice of numerical integration method used to solve the reaction system.
Timestep	-	300 seconds	Time step used to integrate the reaction system.
Coupling	Full None	None	Determines to what degree the solution of any algebraic equilibrium equations is coupled to the integration of the of the reaction rate equations. If the coupling is NONE, the solution to the algebraic equations is only updated at the end of each time step.
Compiler	None Visual C++	None	Determines if the chemical reaction system being modelled should first be compiled before the simulation begins.
Absolute tolerance	-	0.01	Default absolute tolerance used to determine when two concentration levels of a species are the same. Default is 0.01.
Relative tolerance	-	0.001	Default relative accuracy level on a species' concentration used to adjust time steps. Default is 0.001.

4.2.4.2 Model inputs

In the context of this analysis, there are two primary water sources, a lake and a river, for both Scenario's 1 and 2. While the water from these sources has already undergone treatment at a designated plant, to ensure the accuracy of the model, it is essential to provide specific input values that reflect the quantities of these variables as they enter the distribution system. **Table 9** presents an overview of these model inputs for both scenarios and both water sources. Note that many of these values from been adapted from a previous study completed by Abhijith et al. (2022) [75]. For more detailed model inputs, including inactivation kinetics and the full models, refer to **Appendix A.**

Table 8: Model inputs for Scenarios 1 and 2

Variables	Scenario 1		Scenario 2	
Source	**Lake**	**River**	**Lake**	**River**
Chlorine (C) (mg/L)	0.49	1.0	0.49	1.0
BDOC (S) (mg/L)	0.05	0.1	0.05	0.1
THMs (H) (μg/L)	20	20	20	20
TOC (N) (mg/L)	3.55	0.56	3.55	0.56
Planktonic bacteria (P.aeruginosa; Xb) (CFU/L)	1×10^{-4}	1×10^{-3}	1×10^{-4}	1×10^{-3}
Biofilm microbial density (Xa) (CFU/L)	0	0	0	0
E. coli (E) (CFU/L)	15	-	15	-
E. coli at Node 195 (E) (CFU/L)	15		15	
UV intensity (I) (mW/cm^2)	3.5		Defined by UV LED manufacturer	
UV dose (F) (mJ/cm^2)	Et*I		16	

4.2.4.3 Case Studies

The network used in this study was the **EPANET Example 3 Network**, which was originally designed to demonstrate the operation of a dual-source system over time. This network is based on the North Marin Water District WDS [75]. The two sources in this network are a lake and a river, and it has three storage tanks. Furthermore, the network contains two pumps, 92 junctions, and 117 pipes. **Figure 7** displays the percentage of River source water within each pipe at 76 hours, with percentage values distinguished by colour and shown in the figure legend.

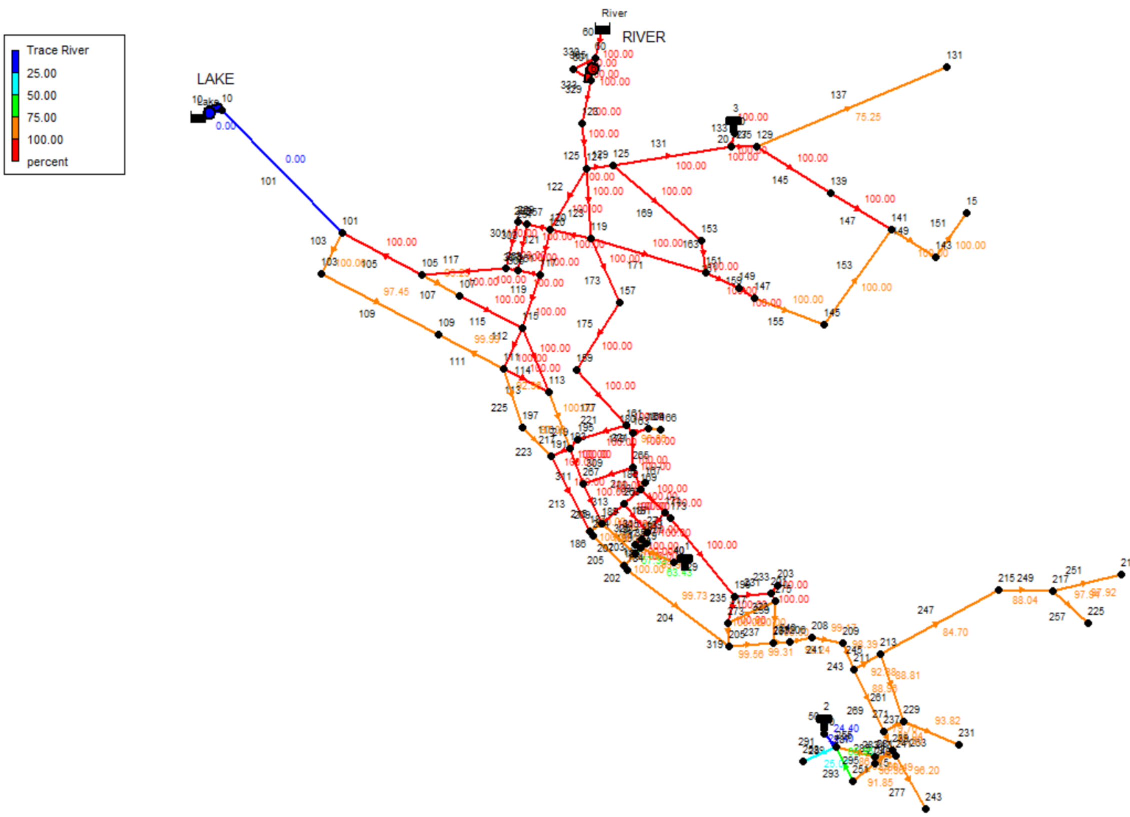

Figure 7: Network 1 at 76:00 hours

The model run time was chosen to be 120 hours (5 days). All the nodes have various base demands and demand patterns. **Table 10** summarizes the various base demands and demand patterns for the node analyzed in this study. Extended model parameters can be found in Appendix A.

Table 9: Analyzed node, base demands, and applied demand pattern.

Node	Base Demand (GPM)	Demand Pattern
15	1	3
219	41.32	N/A
253	54.52	N/A

Detailed demand patterns can be found in **Appendix B**.

As mentioned previously, the model contains 2 pumps, each of which is connected to each respective water source. Pump 10 (pump curve 1) is connected to the lake source, and pump 335 (pump curve 2) is connected to the river source. **Table 11** highlights the pump curves applied to each pump.

Table 10: Applied curves for pump 1 and 2

Pump Curve 1		Pump Curve 2	
Flow (GPM)	**Head (ft)**	**Flow (GPM)**	**Head (ft)**
0	140	**0**	200
2000	92	**8000**	138
4000	63	**14000**	86
Equation	104-1.69E-005(Flow)^1.77	**Equation**	200-0.003503(Flow)^1.09

The network contains simple controls as follows:

```
;Lake source operates only part of the day
Link 10 OPEN AT TIME 1
Link 10 CLOSED AT TIME 15

;Pump 335 controlled by level in Tank 1
;When pump is closed, bypass pipe is opened
Link 335 OPEN IF Node 1 BELOW 17.1
Link 335 CLOSED IF Node 1 ABOVE 19.1
Link 330 CLOSED IF Node 1 BELOW 17.1
Link 330 OPEN IF Node 1 ABOVE 19.1
```

4.3 Model Validation

The use of a pre-built, standard EPANET example network helps to ensure little to no errors or discrepancies within the model. However, various validation mechanisms should be used to verify the results and accuracy of the model results particularly that of results produced from the mathematical models. Firstly, the verification and accuracy of the pre-built model's interaction with the MSX interface was analyzed through the relationship between the chlorine residual and water age; this analysis was done for model validation as well as learning the impacts of water age and chlorine residual. These results are shown in **Figure 12.** Furthermore, the mathematical models were verified by analyzing the results and relationship of the different species. **Appendix D** provides the results of the chlorine, THMs, BDOC, and TOC concentrations produced by the MSX model. These results show us that the inputted mathematical equations and MSX model are working as expected. Ensuring the species results have a clear relationship with one another indicates that the input mathematical models are working correctly due to their calculated dependence on one another.

4.4 Synthesis using Stakeholder Consultation

To supplement the abstraction phase of this project, a focus group was conducted to gather awareness, knowledge, and ideas around the implementation of UV LEDs in water distribution networks. A focus group is a research method that consists of a meeting or discussion group to collect opinions, feedback, and ideas. This group can be used to provide feedback and consumer consensus of a product before its launch; it can also be used as a means of brainstorming and obtaining fresh perspectives. By bringing together diverse perspectives, a focus group can provide a collaborative and creative environment for generating innovative solutions to complex design challenges. This involves engaging a diverse range of knowledgeable individuals in the water industry, including professors, graduate students, and other industry professionals. The group was tasked with discussing various aspects related to the implementation of UV LEDs, including functionality, installation, electrical requirements, and other relevant design features and constraints. This synthesis phase of the design process goes hand-in-hand with the abstraction phase; the knowledge and insight gained during the focus group can be applied to the modelling and analysis of employing UV LEDs in WDS using EPANET's MSX extension.

Participants were selected based on their industry knowledge and experience within different areas of the industry to insure a diverse range of perspectives. The collaborative and open nature of this high-level discussion helped generate ideas and insights that informed the design and implementation of this research project.

To encourage participation and more focused discussions, participants were divided into two 'breakout rooms' and provided with Miro boards. These boards allowed them to visually map out and share ideas about potential opportunities or challenges associated with implementing a UV system in various depicted locations along the distribution system. This interactive approach to the focus group allowed participants to share their perspectives and ideas more effectively, providing high-level and valuable ideas and insights that will help guide the design and implementation of this research project.

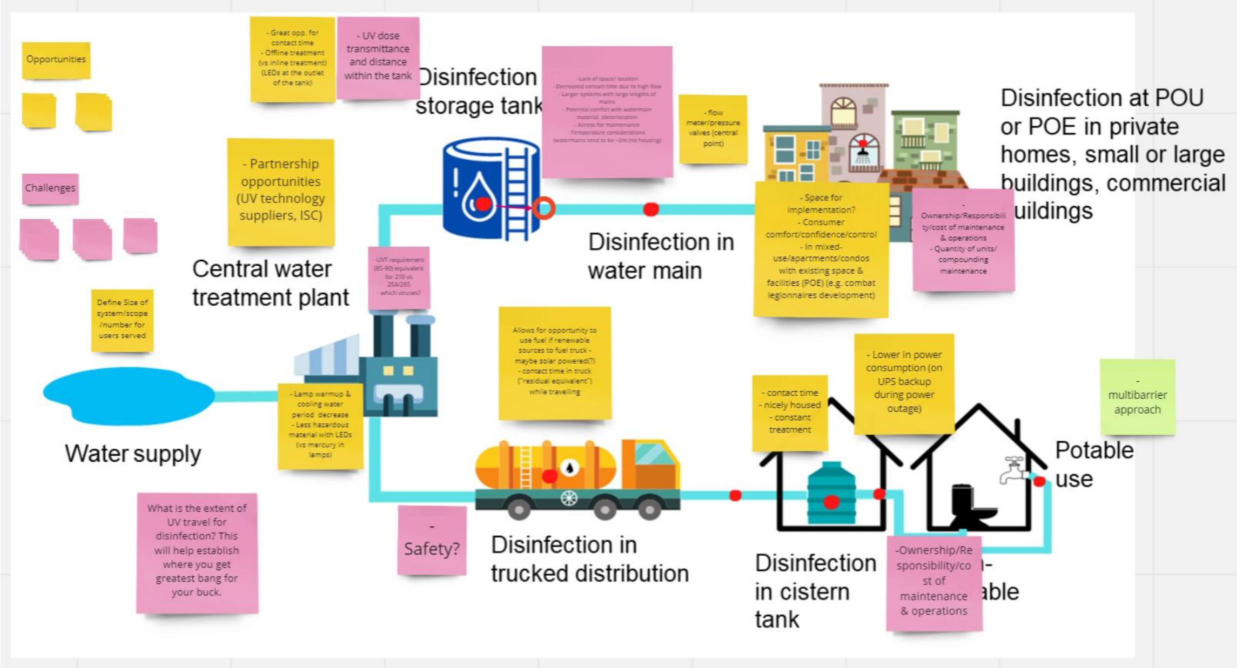

Figure 8: Brainstorm ideas from breakout room 1 – using Miro board.

The results of the focus group consist of a wide range of discussion topics, including but not limited to, the location/opportunities of UV LEDs, species/microorganisms for analysis, important considerations, challenges, and recommended resources.

The main topic of discussion for this focus group was to explore the potential opportunities and locations of implementing UV LEDs in the distribution system. One of the main draws from this discussion was to focus on implementation in point-of-entries and downstream watermains. The group discussed potentially implementation in large buildings, such as hospitals or long-term care centres, as a means to analyze the implications on water quality in these facilities. The group also discussed considering multiple scenarios, including remote communities, larger city centres, apartments, and business centres. The discussion touched on the opportunity to install UV systems at the flow meter or pressure valve at a central point. There was also discussion of the opportunity to explore using renewable or solar power for implementing UV reactors in trucked distribution systems. The group acknowledged the potential opportunity for partnerships with various organizations, including unique technology suppliers. Finally, the group emphasized the opportunity and focus on implementing UV technology at the point-of-use in the facility of buildings rather than in individual homes.

Another topic that was discussed during the meeting was the species and microorganisms that could be analyzed to provide important information about the impacts of UV disinfection. The two recommended species for analysis were total coliforms and *E. coli*. EPANET MSX consists of tools that are built on mathematical models and define the behaviour of contaminants in various forms throughout the distribution system. The following section highlights the mathematical models used to analyze various species.

During the meeting, several important considerations were discussed in relation to implementing UV systems into distribution networks. The group identified the importance of having a UV residual that can be measured; this could potentially be the ultraviolet transmittance (UVT). UVT is a parameter that measures the amount of light that is able to pass through the water and an indicator of the general water quality. They also discussed the need to identify an appropriate size and study scope of distribution system to be studied. It was also suggested that the UV system be housed in a temperature-controlled environment to ensure optimal performance. It was also emphasized that the focus should be on the UV exposure being applied, and less so on the actual design.

The meeting also brushed on a number of challenges associated with implementing UV reactors into distribution systems. The group highlighted that the effectiveness of the system would be reduced if it was installed inside water storage tanks. They also highlighted the challenges associated with accessing pipes for maintenance, which could potentially impact performance and feasibility. The group also discussed the challenges related to the distribution system, including lack of space or location for the UV reactor, and the potential challenge regarding the ownership of the infrastructure that the system is included in. It was also discussed to consider the potential burdens that can be put on water users, depending on how the system impacts them and where it is installed. Lastly, the group identified that power outages in communities as a potential issue that could affect the operation of UV systems. Overall, it was acknowledged that there are a variety of challenges associated with implementing this concept, but these challenges could be addressed through planning and design considerations.

There were also a number of recommended resources that were highlighted. Firstly, it was recommended to look into EPANET papers and projects by Louis Rossman. It was also recommended to regard literature information for efficacy of UV systems and look into a variety of ranges of efficacy application.

The following two scenarios were chosen based on the results of the stakeholder focus group: **Scenario 1:** UV LEDs installed in water distribution pipes.

Scenario 2: UV LEDs installed at the point-of-entry (POE).

These two scenarios were compared to secondary disinfection with chlorine to secondary disinfection using UV LEDs and chlorine using EPANET using the model developed in the abstraction phase of the project. The specifics and results of these simulations are described in the following chapter.

5 Chapter 5: Simulation of UV LED Scenarios (Analysis)

Design scenario 1

The first scenario for analysis consists of UVC LED reactors installed in the watermain pipes. Current commercial UV companies have developed various UVC LED reactors that are applicable for this concept; the in-pipe reactor is a pipe replacement piece which can be used at any point along the water main for disinfection. As advised, the main focus of the UV reactors will be on the downstream of pipelines immediately connected to the point-of-entry. The model will be used to analyze a variety of parameters: water age, *E. coli*, and planktonic bacteria. These parameters will be analyzed to understand the impact of UV disinfection on the distribution system and on water safety.

Design scenario 2

The second scenario for analysis consists of UVC LED reactors installed in the terminal nodes of the network to represent point-of-entry (POE) treatment. Another UVC LED reactor which is designed for POE installation. The model will be used to analyze a variety of parameters: water age, *E. coli*, and planktonic bacteria. These parameters will be analyzed to understand the impact of UV disinfection on the distribution system and on water safety.

5.1 Research questions

The analysis phase of the engineering design process requires the narrowing down of the overall objective through a series of research questions. These research questions are used as a guide for analysis of results, and to evaluate the efficacy and legitimacy of the proposed solution. The identified research questions are as follows:

1. Does adding UV LEDs to a distribution system lower the concentration of bacteria at different parts of the system? Does it lower the concentration of bacteria after a recontamination event?
2. Is it more effective to place UV LED reactors in the pipes or at the point-of-entry?

3. Does the location of the contamination event effect the level of disinfection or concentration of bacteria?
4. What is the effect of both scenarios on the concentration of planktonic bacteria? *E. coli?*
5. What is the impact of installing UV LED reactors at different points across the distribution system?
6. Does the efficacy of chlorine for disinfection change as the water age differs?

5.2 Model Results

5.2.1 Water Age

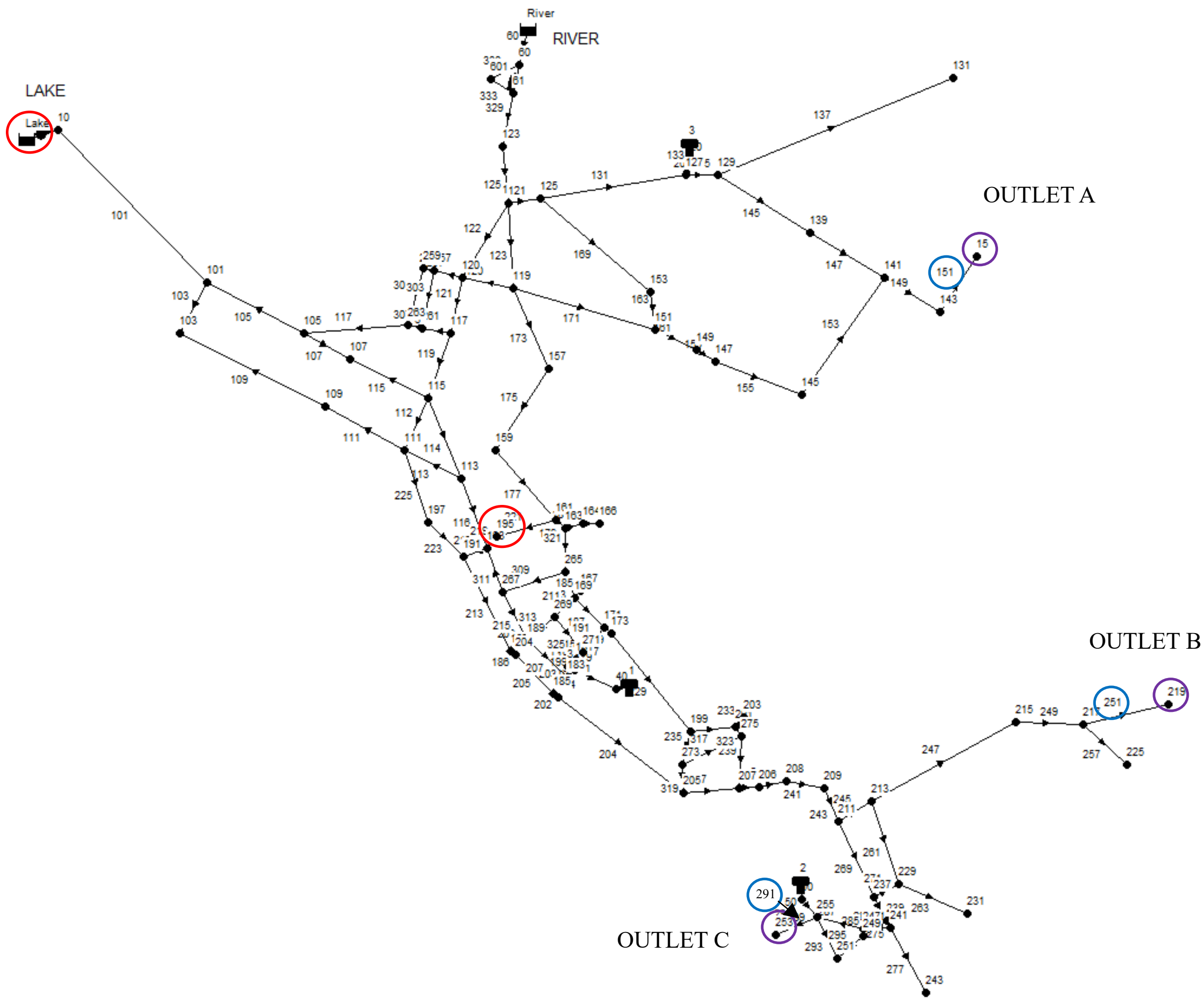

Figure 9: Location of observed points-of-use. In-node reactors indicated in purple, in-pipe reactors indicated in blue, and outbreak locations indicated in red.

Scenario 1 consists of applying in-pipe UVC LED reactors at downstream locations before the water arrives at the point-of-entry. Scenario two consists of installing batch UVC LED reactors at the point-of-entry. For the context of this project, an outlet is defined as an exit from the WDS and entry point to a building; therefore, Scenario 1 consists of UVC LED reactors that are placed in the pipe (link) that is connected to the point-of-entry, and Scenario 2 consists of batch UVC LED reactors at the point-of-entry (at the node). These particular outlets were chosen due to their proximity to the terminal points of the network, as well as the varying water ages.

For this analysis, link 151 and node 15 are **outlet A**, link 251 and node 219 are **outlet B,** and link 291 and node 253 are **outlet C.** Each of these outlets was chosen for observation for both scenarios. **Figure 9** highlights the location of the UV LEDs at each of these outlets. These various pipes and nodes were chosen due to their proximity to the point-of-use/entry and their varying water age. **Figure 10** highlights the water age over 120 hours for the selected pipes. **Figure 11** highlights the water age for the selected nodes.

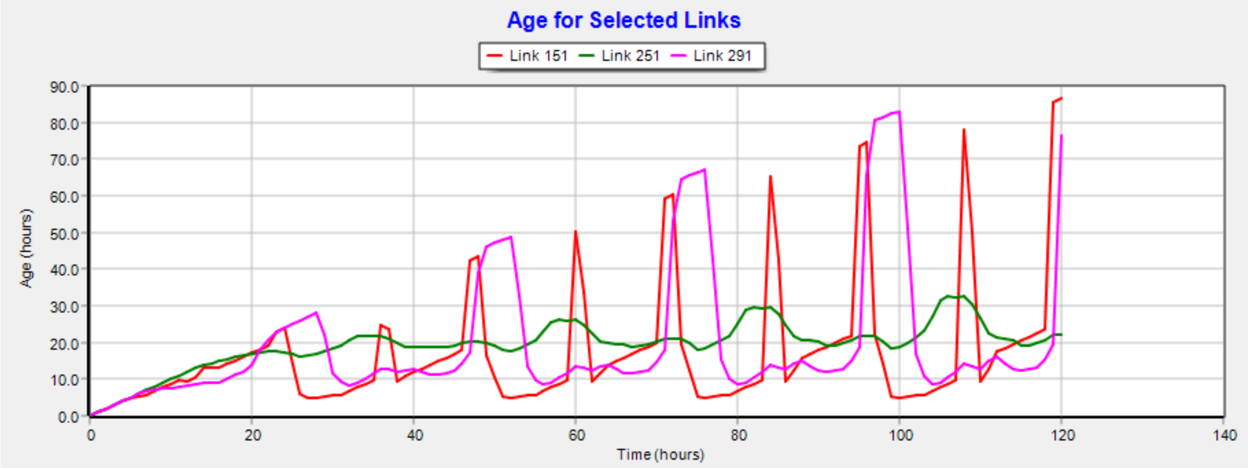

Figure 10: Scenario 1 downstream pipes water age over 120 hours

As shown in the figure, the water age fluctuates over time for each network link. Link 251 (**outlet B**) seems to remain relatively stable at 36 hours, and links 151 (**outlet A)** and 291 (**outlet C)** both surpass 70 hours. Higher water age can lead to potentially contaminated water, as the water has spent more time outside of the treatment plant after disinfection.

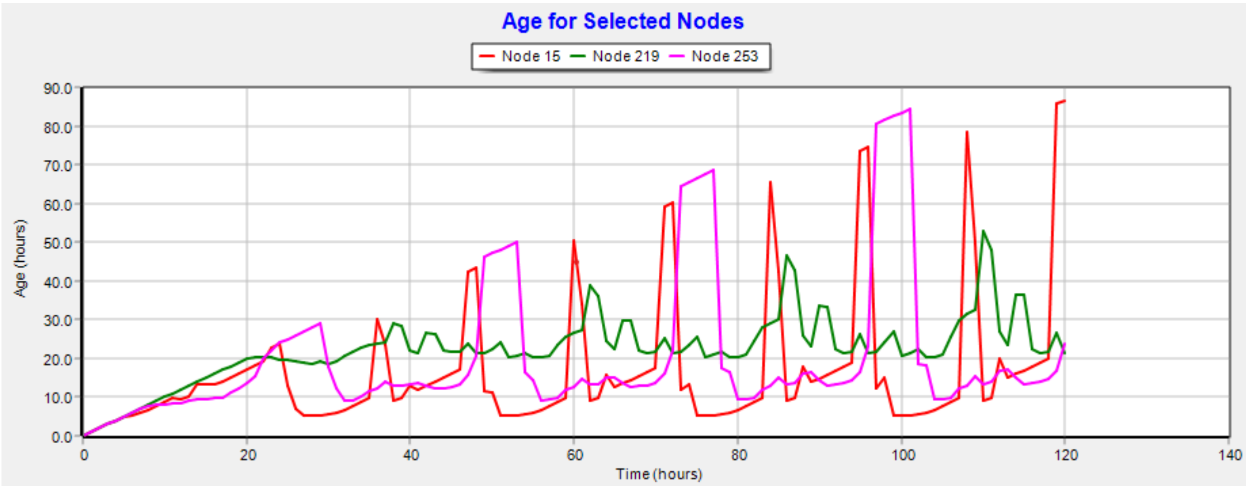

Figure 11: Scenario 2 nodes water age over 120 hours

As shown in the figure, water age fluctuates over time for each network node. Node 253 (**outlet C**) and node 15 (**outlet A)** surpass 70 hours, and node 219 (**outlet B)** has a slightly lower and slightly more stable water age, but surpasses 50 hours. Higher water age can lead to potentially contaminated water, as the water has spent more time outside of the treatment plant after disinfection, and within the distribution system.

The impacts of water age on the distribution system and water safety can be further discussed by analyzing the change in chlorine residual concentrations overtime. **Figure 12** highlights the concentration of chlorine over the 120-hour simulation time, as well as the water age.

Figure 12: Log of concentration of chlorine and water age at outlet A, B and C over 120 hours

Figure 12 illustrates the relationship between the change in chlorine concentration and water age for all outlets and shows a clear correlation between a decrease in chlorine concentration with every increase in water age.

5.2.2 Planktonic Bacteria – Chlorine and UV LED Disinfection

Scenario one consists of implementing a UVC LED reactor at the downstream pipelines. As shown in **Figure 10 and 11,** most outlets of this system contain water that has a high age; this means a longer period of time has passed since the water received treatment at the plant and is an ideal place for secondary treatment. Scenario two consists of implementing a UVC LED reactor at the terminal nodes of the system, to mimic a POE disinfection mechanism.

The current study is classified as a Class B system and is required to satisfy the necessary requirements. For Scenario two, a dose of 16 mJ/cm^2 is applied at the outlets using a 254-nm emitting UV LED device. **Figures 13 to 15** highlight the results of chlorine only and the combination of UV LED and chlorine for both scenarios at outlets A, B, and C. Extended simulation results can be found in **Appendix C.**

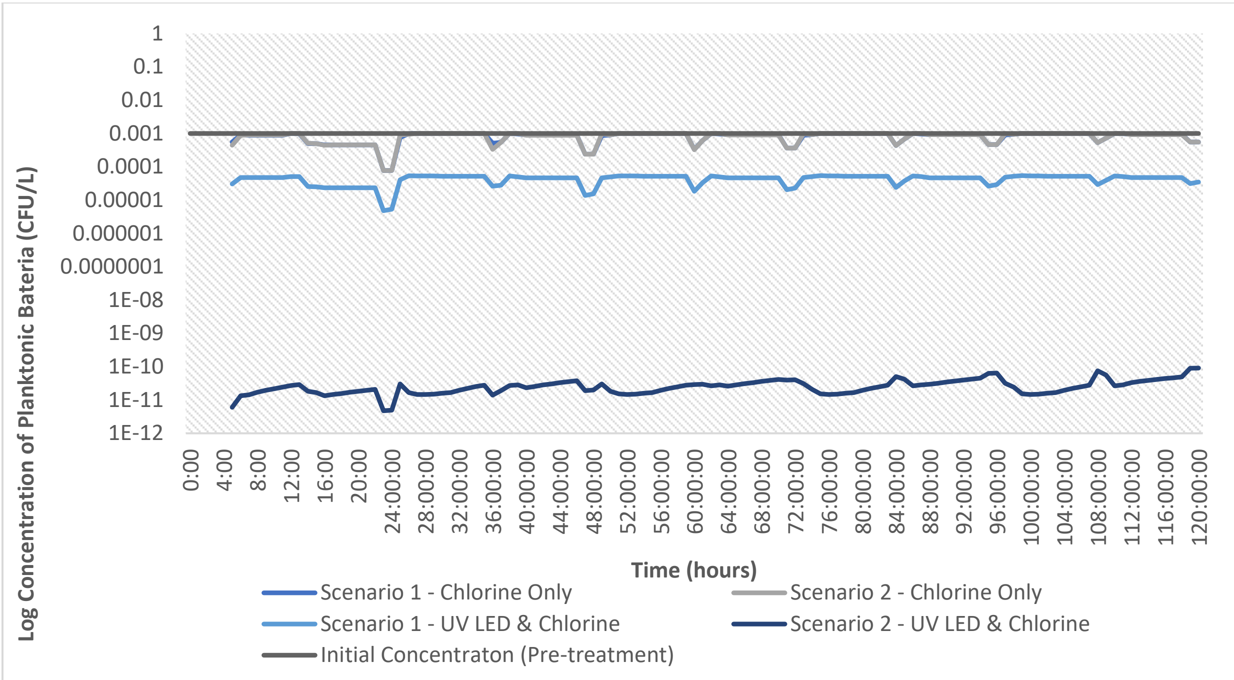

Figure 13: Log concentration of planktonic bacteria at outlet A after chlorine only disinfection and combined UV LED & chlorine disinfection over 120 hours for Scenarios 1 and 2.

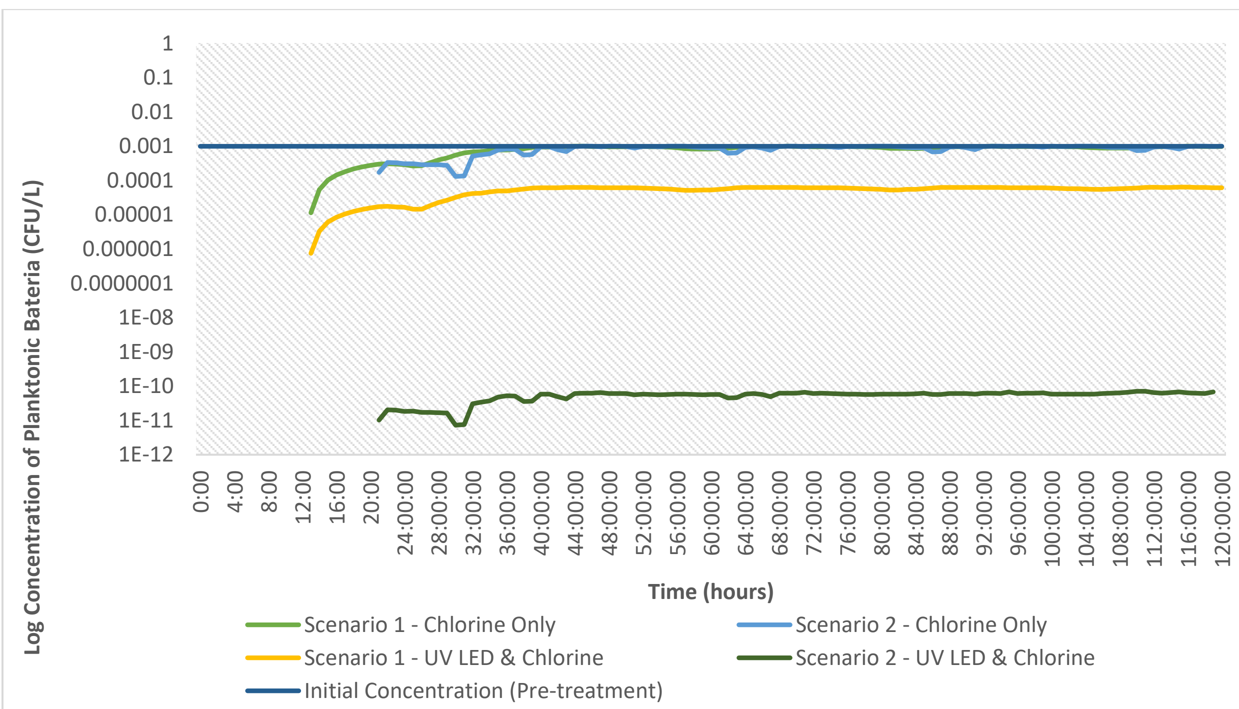

Figure 14 :Log concentration of planktonic bacteria present at outlet B after chlorine only disinfection and combined UV LED & chlorine disinfection over 120 hours for Scenarios 1 and 2.

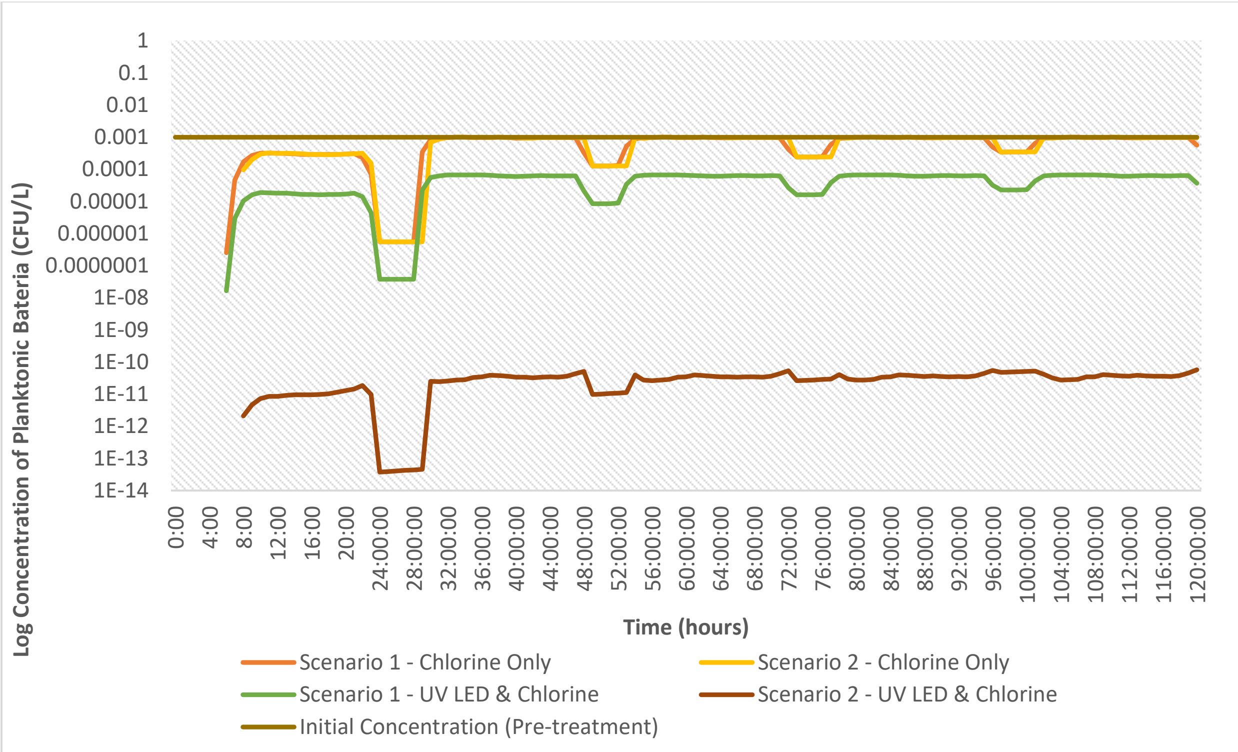

Figure 15: Log concentration of planktonic bacteria present at outlet C after chlorine only disinfection and combined UV LED & chlorine disinfection over 120 hours for Scenarios 1 and 2.

5.2.3 *E. coli* at Distribution Entry Point – Chlorine and UV LED Disinfection

The following **Figures 16 to 18** highlight the results of applying UV LED disinfection on *E. coli* at outlets A, B, and C under Scenario 1 and 2 circumstances. Extended results can be found in **Appendix C**.

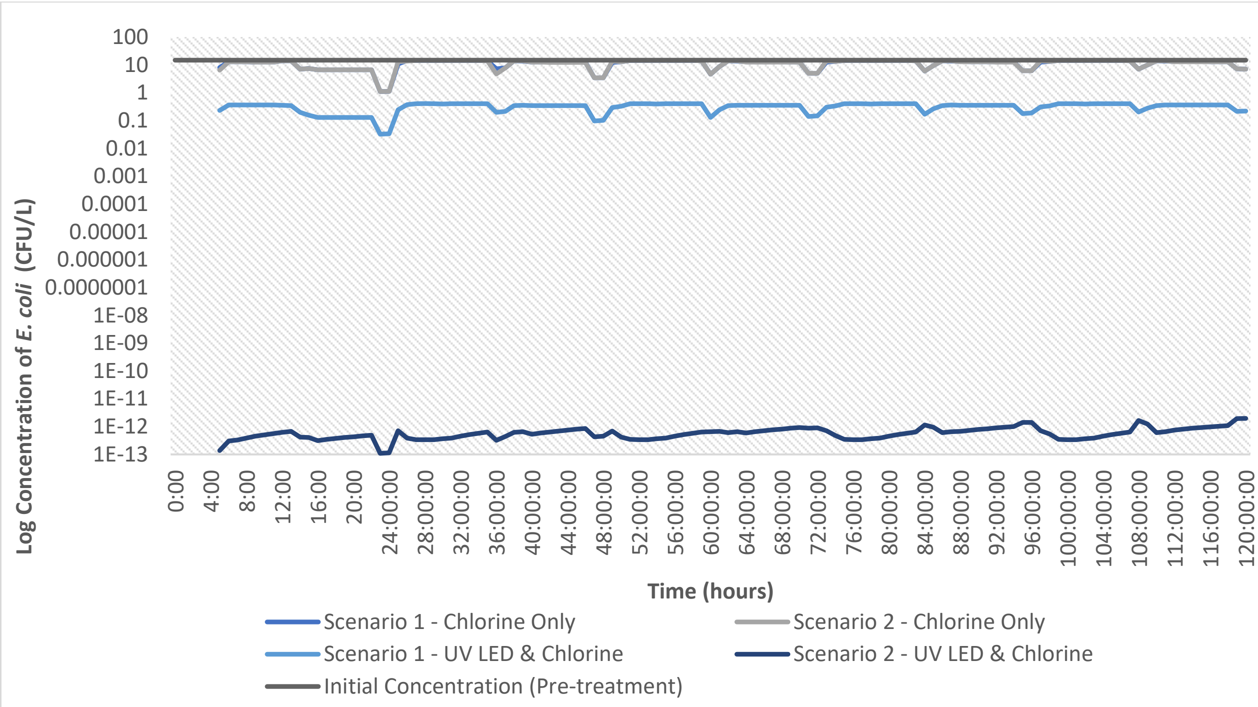

Figure 16: Log concentration of E. coli present at outlet A after chlorine only disinfection and combined UV LED & chlorine disinfection over 120 hours for Scenarios 1 and 2.

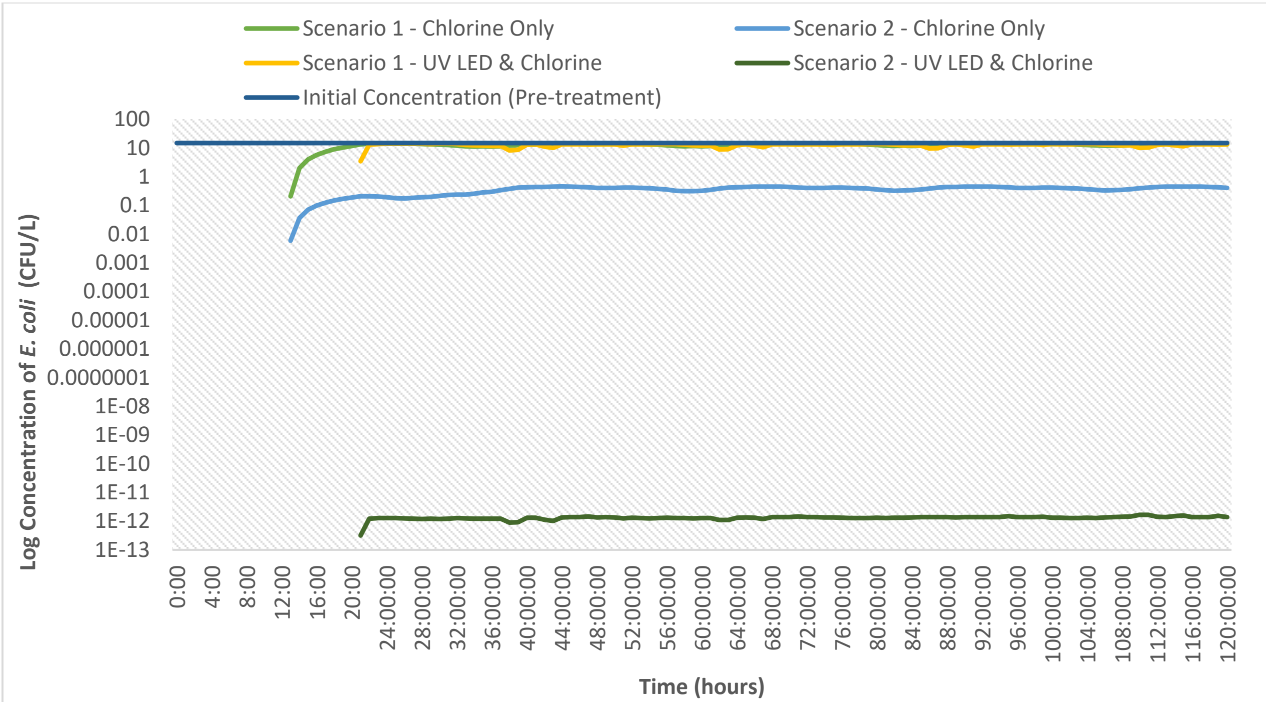

Figure 17: Log concentration of E. coli present at outlet B after chlorine only disinfection and combined UV LED & chlorine disinfection over 120 hours for Scenarios 1 and 2.

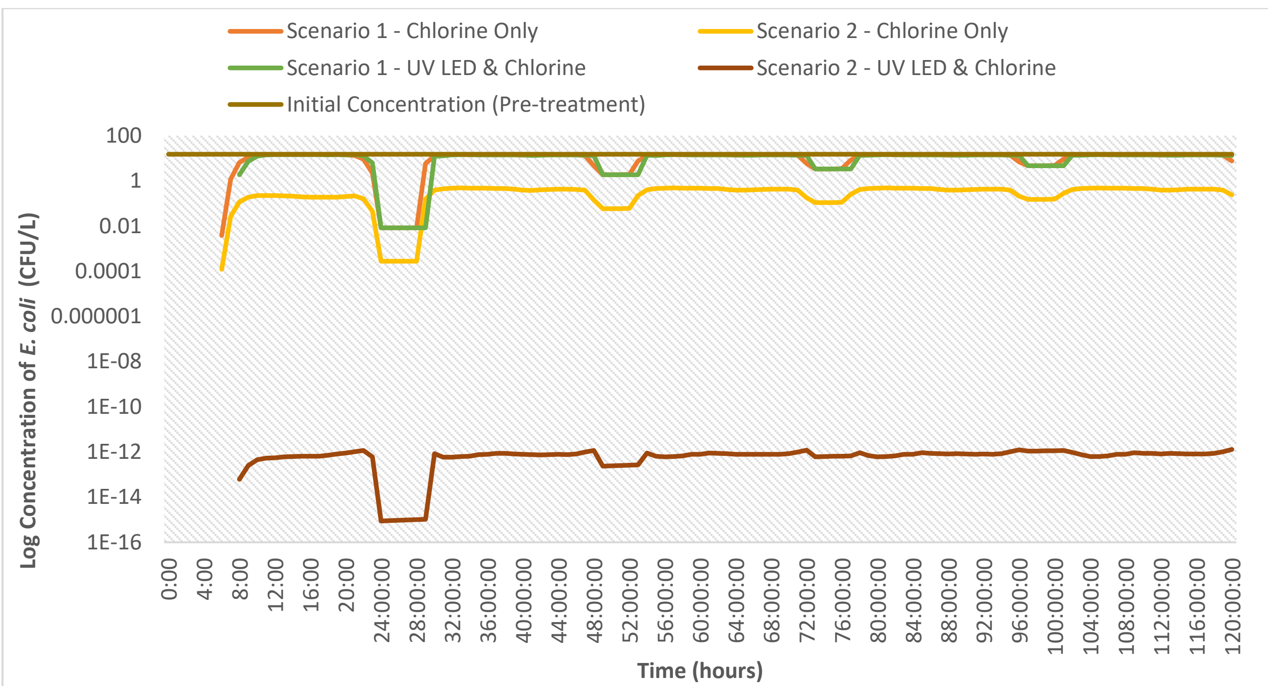

Figure 18: Log concentration of E. coli present at outlet C after chlorine only disinfection and combined UV LED & chlorine disinfection over 120 hours for Scenarios 1 and 2.

5.2.4 *E. coli* outbreak at Node 195 – Chlorine and UV LED Disinfection

Previous research highlights that a line break or pressure loss in the distribution system to be a leading cause of potential water safety issues. These breaks and losses of pressure in the system increase the likelihood of contaminants re-entering the water after it has been treated. EPANET MSX was used to model an *E. coli* outbreak event along the distribution system at node 195 (see **Figure 9**) to evaluate the impact of contamination downstream and effectiveness of using UV LEDs to reduce contamination at consumption. The following **Figures 19 to 21** highlight the results of applying UV LED disinfection on *E. coli* at outlets A, B, and C under scenarios 1 and 2 circumstances after an *E. coli* outbreak at node 195.

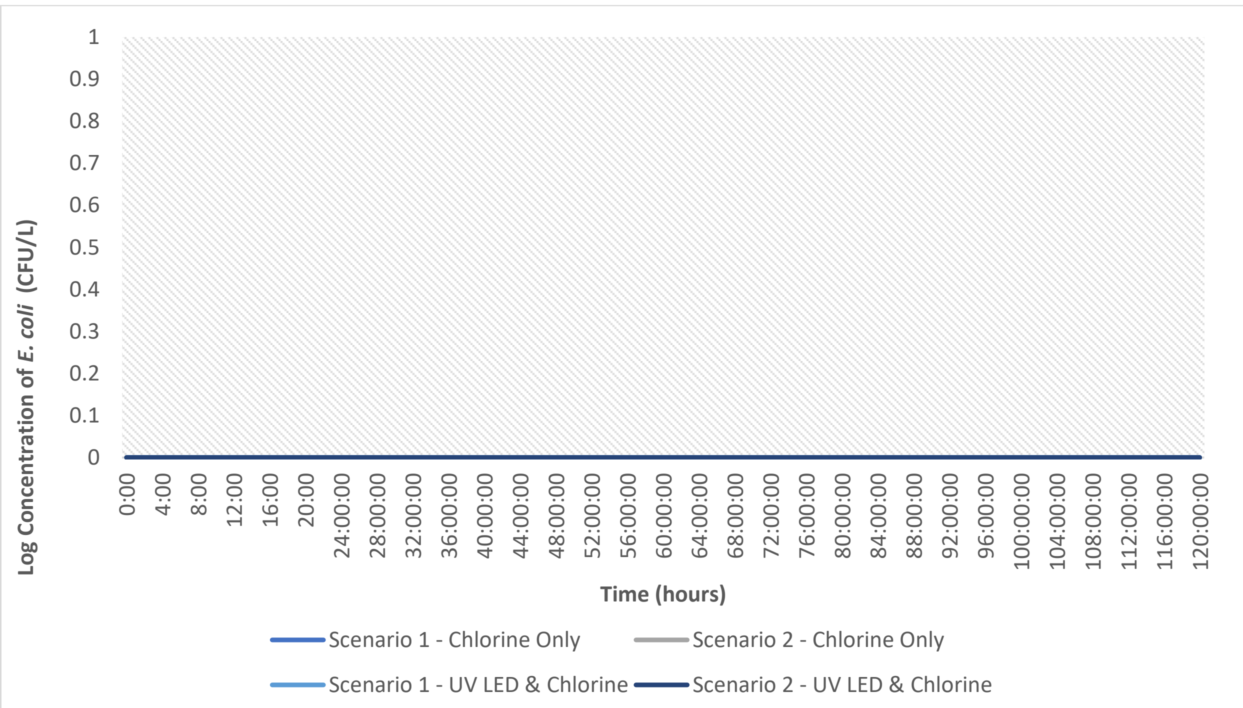

Figure 19: Log concentration of E. coli present at outlet A after chlorine only disinfection and combined UV LED & chlorine disinfection over 120 hours for Scenarios 1 and 2 after an outbreak at node 195. Inlet A does not receive water from node 195, and therefore does not present any results.

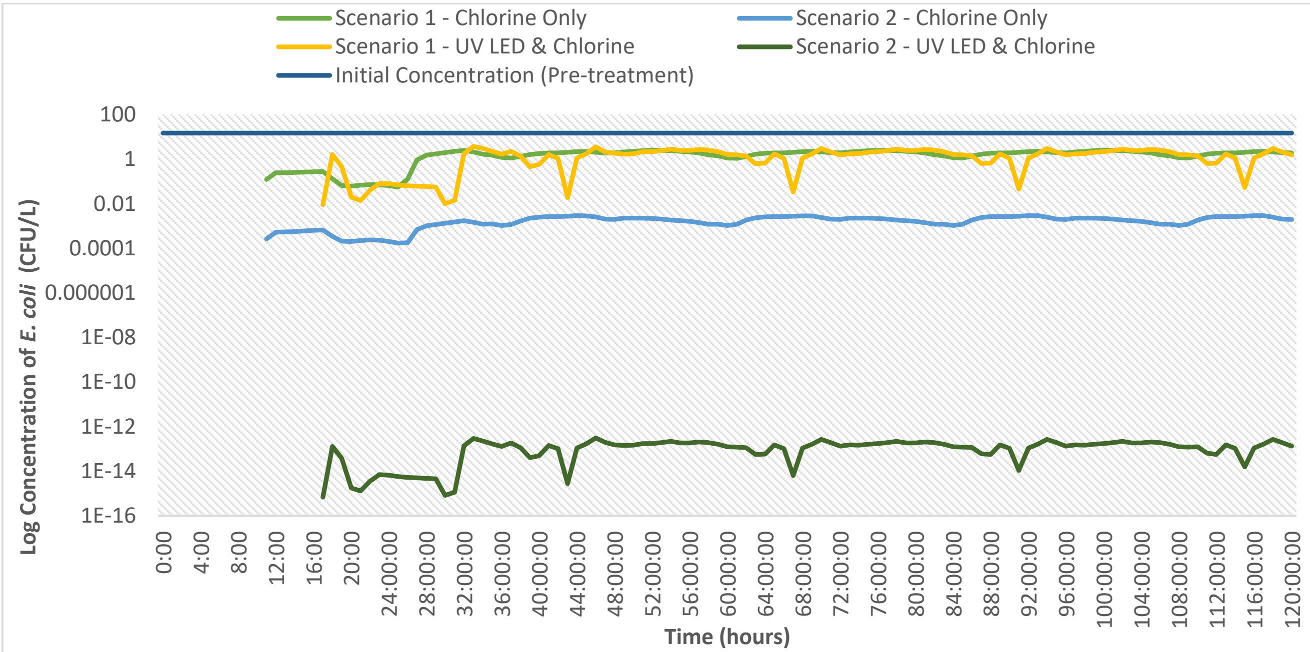

Figure 20: Log concentration of E. coli present at outlet B after chlorine only disinfection and combined UV LED & chlorine disinfection over 120 hours for Scenarios 1 and 2 after an outbreak at node 195.

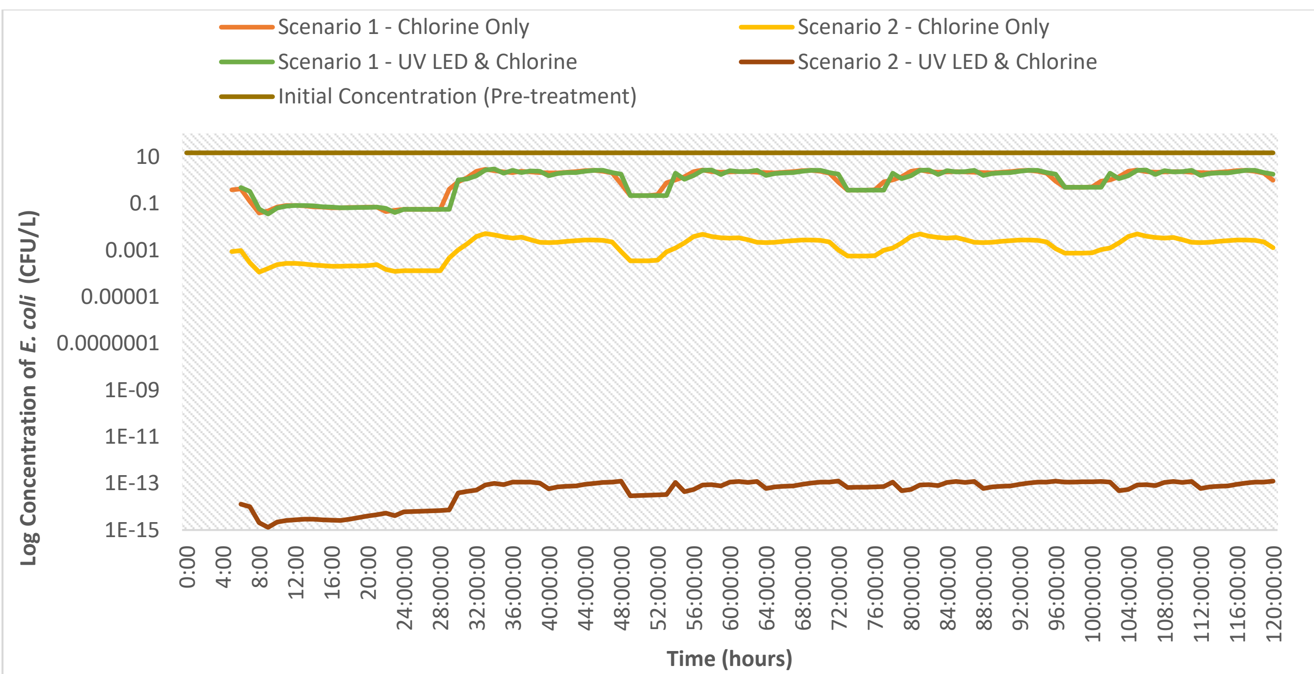

Figure 21: Log concentration of E. coli present at outlet C after chlorine only disinfection and combined UV LED & chlorine disinfection over 120 hours for Scenarios 1 and 2 after an outbreak at node 195.

6 Analysis Discussion

6.1 Water Age

Water age refers to the time it takes for water to travel from the water source to consumers. Treated water can stay in the distribution system for extended periods of time, increasing the potential of quality deterioration. The quality deterioration can be due to the interactions within the pipe walls and the water, and the reactions within the bulk water species [84]. The travel of bulk water through the distribution system can cause various chemical, physical, and aesthetic transformations, which can increase as the waters travel time increases [84]. For this reason, water age is one of the many factors for determining water quality.

It was hypothesized that downstream and terminal nodes represented optimal locations for UV LED installations, primarily due to the prolonged water age observed at the network's terminal nodes and links. Furthermore, positioning UV LEDs at terminal points allows for immediate treatment just before consumption. This hypothesis can be validated in **Figures 10 and 11**, which illustrate terminal links and nodes exhibiting a higher range of water age. This finding further supports our hypothesis that terminal modes and links often have prolonged water age, making them ideal locations for implementing UV LED treatment within the distribution system.

To further understand the impact of water age on water quality and disinfection, the relationship between chlorine residual and water age was illustrated in **Figure 12** for outlet A, B and C**.** Interestingly, the results displayed in the figure shows a clear relationship between the increase in water age and a decrease in chlorine residual. This suggests the possibility that water with higher age may be at a higher risk of contamination due to the less amount of chlorine present as secondary disinfection. This further confirms the hypothesis that increased water age is correlated with quality deterioration.

6.2 Planktonic Bacteria – Chlorine and UV disinfection

Figures 13 to 15 present the findings related to the treatment of planktonic bacteria using UV LEDs in two distinct scenarios, denoted as Scenario 1 and Scenario 2. Upon careful analysis of the results shown in the graphs, it is evident that Scenario 2 surpasses Scenario 1 in terms of disinfection efficacy when using a combination of chlorine and UV LEDs compared to the use of chlorine alone. The degree of cell inactivation is directly related to the UV dose, or fluence, which is dependent on the radiation intensity, or the irradiance, and the exposure time [79]. The minimum effective dose to successfully deactivate microorganisms can be determined rather simply using batch reactors; they are exposed for longer periods of time under a known radiation intensity [79]. In Scenario 2, a fixed dose of 16 mJ/cm^2 is applied at specified locations, regardless of exposure time considerations.

Alternatively, Scenario 1 accounts for the exposure time of water to UV LEDs by utilizing the fluid velocity within the pipeline. Flow reactors are more complicated, since the exposure time of the water or microorganism varies as the flow rate varies, the administered dose also varies [79]. This approach introduces variability in exposure and disinfection levels across different segments of the pipeline. While Scenario 2 appears more effective at first glance, its drawback lies in its failure to consider exposure time, potentially resulting in an overestimation of the achieved disinfection.

Scenario 1, on the other hand, yields results that are arguably more "realistic." However, it relies heavily on the pipeline's velocity to ensure the delivery of the required irradiance to administer a 16 mJ/cm^2 dose. Examining **Equation 12** shows that the fluence/dose equation is determined by multiplying the exposure time by irradiance. Given that exposure time varies with velocity, an irradiance of 3.5 mW/cm^2 is applied in Scenario 1 to achieve the desired 16 mJ/cm^2 dose. Consequently, Scenario 1 is not only reliant on pipeline velocity but also on the capability of the selected equipment to provide an irradiance of 3.5 mW/cm^2 throughout the flow, highlighting the significance of device selection and design in optimizing treatment efficiency.

Jarvis et al. (2019) calculated UV intensities of 4.87, 5.67, and 8.57 mW/cm^2 at drive currents of 245, 350, and 525 mA. UV intensity is determined based on the drive current or power output of the device and can vary depending on the design and manufacturer [85]. The UV fluence, however, is dependent on the UV intensity and exposure time. The following table adapted from Jarvis et al. (2019) highlights the dependence of the administered UV dose on exposure time, drive current, and irradiance. It's important to note that this table is provided for conceptualization only, as they are delivered by a bench-scale reactor and not a flow reactor.

Table 11: UV fluence delivered by a bench-scale UV-reactor at each drive current (Adapted from Jarvis et al.)

Drive Current (mA)	***I***	**Time (s)**					
	(mW/cm^2)	0	1	2	3	4	5
		UV Fluence (mJ/cm^2)					
245	4.87	0	4.87	9.75	14.62	19.50	24.37
350	5.76	0	5.76	11.52	17.28	23.04	28.80
525	8.57	0	8.57	17.13	25.70	34.27	42.83

Discussion of these scenarios also requires careful consideration of maintenance and operational responsibilities. In Scenario 1, which involves in-pipe reactors, the duty of maintaining and ensuring optimal operation is with the utility provider, placing this responsibility on the governing city or municipality. On the other hand, in Scenario 2 where the reactor is placed at the point-of-entry, the responsibility of maintenance and operational duties becomes subject on where the reactor is placed. For instance, if the reactor is placed at a node connecting the utility pipe to the service pipe, the governing city or municipality assumes this responsibility. On the other hand, if the reactor is placed at a node within the service line, whether inside a building or at a specific point-of-use, the owner becomes responsible for its upkeep. Given the various dependent variables, such as dose application, velocity, and equipment capability, the precise location and the reactor's associated responsibilities are key factors to consider when comparing the two different scenarios.

6.3 *E. coli* at Distribution Entry Point – Chlorine and UV disinfection

Compared to the findings in the analysis of planktonic bacteria, Scenario 1 exhibited a notably greater disinfection effectiveness against *E. coli* than planktonic bacteria because *E. coli* has a higher inactivation rate constant than planktonic bacteria, as detailed in **Table 7**. It's worth noting that the kinetics of a 254-nm device were consistently applied for both bacteria and *E. coli* assessments. Scenario 2 again shows a higher amount of disinfection using UV LEDs and chlorine compared to chlorine only than Scenario 1.

Many studies have evaluated the efficacy of UV LEDs for the disinfection of *E. coli* specifically. Beck et al. (2017) found that UV inactivation of *E. coli* could achieve a 3-log reduction at UV doses of 12 mJ/cm^2. The inactivation rate constants for *E. coli* were found to be 0.31 cm^2/mJ at 280 nm [62], which is slightly different than the 0.56 cm^2/mJ found by various other sources, and that used in this study. These numbers could potentially be closer to one another given the respective confidence intervals. Jarvis et al. (2019) found that UV LED reactors achieve log removals ranging from 0.5-3.9 depending on the drive current, similar to that of previously reported conventional mercury lamps [85]. It's important to note that the difference in applied wavelengths and inactivation rate constants yield different results. Since this study utilizes mathematical models, the results are heavily influenced by the parameter inputs such as inactivation rate constants. Both behaviours of results shown from Scenario 1 and Scenario 2 can be explained by various factors discussed previously; exposure time, velocity, and irradiance.

6.4 *E. coli* outbreak at Node 195 – Chlorine and UV disinfection

Figures 19 to 21 present the findings of a potential *E. coli* outbreak within the distribution network. Node 195 was selected at random to have an *E. coli* outbreak. As we can see from **Figure 19**, outlet A does not present any results; this is because these areas do not receive water from the outbreak node 195. Looking at the results for outlets B and C, both Scenarios 1 and 2 present a large reduction in *E. coli*, with Scenario 1 achieving a log reduction ranging from 2.5 to 3 and Scenario 2 achieving a log reduction over 7. This increased level of disinfection compared to planktonic bacteria is consistent with previous results and can be due to higher inactivation rate constants. Furthermore, the discrepancy of results between the two scenarios can again be explained by the various factors of exposure time, velocity, and irradiance, as discussed earlier.

6.5 Location of UV LED

Looking at the results at the different outlets, it is evident that the concentration levels both before and after disinfection are not the same among the different locations; this is because the concentration of bacteria both before and after disinfection are dependant on various parameters. As discussed earlier, the concentration of chlorine varies with water age, in-turn impacting the concentration of bacteria and *E. coli*. It has also been highlighted that the water age and concentration of bacteria vary among these outlets. Furthermore, the velocity at these locations may vary with one another, impacting the level of disinfection as discussed earlier. However, the efficacy of these reactors does not depend on its specific outlet location, but on the type of reactor and whether it is within the pipe or at the point-of-entry. This is once again evident when we compare the results between Scenario 1 and 2.

6.6 Discussion summary

A number of research questions were presented earlier in order to provide a guideline for conducting research as well as narrowing down the overall objective. **Table 13** provides a summary of the research results and discussion through providing answers to each research question and referencing the findings that present these answers.

Table 12: Answers to research questions and summary of findings

Research Question	Research Findings Summary
Does adding UV LEDs to a distribution system lower the concentration of bacteria at different parts of the system? Does it lower the concentration of bacteria after a recontamination event?	• **Yes** – Figures 13 to 15 show significant decrease in bacteria concentration after UV LED exposure for both scenarios; • **Yes** – Figures 19 to 21 show a significant decrease in *E. coli* after a contamination event exposed to UV LED
Is it more effective to place UV LED reactors in the pipes or at the point-of-entry?	• At the **point-of-entry** – as shown in results figures and annotated log removal rates (Figures 13 to 21)
Does the location of the contamination event effect the level of disinfection or concentration of bacteria?	• The location of contamination event varies the level of disinfection only if the contaminated water does NOT pass through a node or link that contains a UV LED reactor (See Figure 19 [outlet A] where contaminated water does not pass through some reactors and therefore is not treated) • Yes for in-pipe reactors, no for point-of-entry reactors – contamination may occur after the in-pipe reactor but not after the point-of-entry
What is the effect of both scenarios on the concentration of planktonic bacteria? *E. coli?*	• The contribution of UV LEDs to the overall log reduction is higher at the point-of-entry (Scenario 2) than when the UV LEDs are within the pipes (Scenario 1) • *E. coli* is more vulnerable to UV LED inactivation than planktonic bacteria – as shown in result figures (Figures 16 to 18)
What is the impact of installing UV LED reactors at different points across the distribution system?	• Figures 13 to 21 highlight the impact of installing UV LED reactors at different points across the distributions system (outlets A, B, and C). While each outlet provides different results depending on a variety of factors at these points (velocity, water age, etc.) the level of disinfection does not vary • The main impact of installing UV LEDs at different locations is whether the device is installed within the pipe (Scenario 1) or at the point-of-entry (Scenario 2)
Does the efficacy of chlorine for disinfection change as the water age differs?	• Yes – chlorine concentration decreases as water age increases (Figures 12 and 13)

7 Chapter 6: Considerations for Implementation and Future Research (Implementation)

The fifth and final stage of the engineering design process is to implement the created design into the intended product or system [2]. The implementation of UV LEDs in a real distribution system is beyond the scope of this research project. Instead, literature review, brainstorming, and logical thinking were used to identify and describe practical considerations for the implementation of UV LEDs for distributed water treatment.

Table 13: Practical considerations for Scenario 1 and 2 implementation

Practical considerations for in-pipe and Node UV LED reactors	
Scenario 1	**Scenario 2**
In-pipe velocity – the velocity of the pipe within the water impacts the exposure time, and therefore the level of disinfection achieved	Exposure time – exposure time is directly related to the level of disinfection achieved
Device drive current and capability of UV irradiance – the irradiance is dependent on the drive current of the specific device used. Different manufacturers of reactors provide various current capabilities and therefore various disinfection capabilities due to the dependence of disinfection efficacy on the device irradiance	Ability to administer 16 mJ/cm^2 - Different manufacturers of reactors provide various irradiance capabilities and therefore various disinfection capabilities due to the dependence of disinfection efficacy on the device irradiance
Device wavelength – different wavelengths have different disinfection abilities among various microorganisms	Device wavelength - different wavelengths have different disinfection abilities among various microorganisms
Inactivation kinetics dependent on wavelength – the inactivation kinetics of target microorganisms are directly linked to their level of treatment using UV LEDs	Inactivation kinetics dependent on wavelength – the inactivation kinetics of target microorganisms are directly linked to their level of treatment using UV LEDs
Length, size, and physical design of device	Placement within node for optimal disinfection
In-pipe reactor owned by utility	Can be owned by building owner or utility, dependant on exact location

7.1 Reactor Design

In the case of a UV reactor, or a UV system installed along a watermain, the water is flowing at varying velocities and can travel through the reactor using a variety of paths. Because the paths vary, the UV doses or fluences are received differently by each microorganism, resulting in a UV dose distribution [86]. Furthermore, the shapes of the UV devices also play a fundamental role in the process of calculating the inactivation of microorganisms accurately [79]. The small size of UV LEDs allows for them to be positioned to emit radiation for various angles, allowing for more options for orientation and unique reactor designs [85]. Artichowicz et al. (2020) developed a schematic that considers three ‘zones’ associated with and impacting the disinfection process: Inflow zone, radiation zone consisting of one or more UV devices, and the outflow zone. The greatest amount of radiation occurs in the radiation zone, as the water undergoes direct exposure to the UV devices [79]. Furthermore, it’s also important to consider whether the flow is turbulent or laminar [79]. Analytic formulation of these models that describe the hydraulic structure of the flow in UV reactors allow for the discussion of flow properties that may pertain to the formulation of design guidelines for flow reactors [79]. Artichowicz et al. (2020) found that if any part of the disinfected fluid receives a UV dose that is smaller than the reactors design dose, there may be insufficient UV energy that reaches some components of the microorganisms DNA, leading to bacterial regrowth. Knowledge of the internal structure and distribution of the devices intensity is crucial, as is evaluation of the reactors efficiency during validation testing [79]. Essential considerations of these studies would be location of the reactor (plant vs. in distribution), power output of device, size of device, targeted microorganisms, and extended life of LEDs compared to LP mercury lamps. An ideal UV disinfection system would be tailored to combine wavelengths within the dominant germicidal range (250 nm – 280 nm) to target bacteria and viruses [62]. A more holistic approach to the design and implementation of UV reactors and systems allows for technologies which are more ‘fit-for-purpose’, allowing for greater efficiency and results per application. Design specifications and specific disinfection needs are crucial parameters when evaluating the use of UV reactors.

7.2 Electrical Efficiency

Electrical efficiency of a UV source is an important metric of a UV LED disinfection system [87]. UVC LED's typically operate with a < 1 second power on time at 6 V and 20 Ma, making them an ideal candidate for battery or solar powered operation [87]. Due to the low output power and low wall-plug efficiency, the technology of UV LEDs for water disinfection has been confined to small-scale, point-of-use, batch applications which allow for longer exposure times to achieve the required UV dose [85]. Rapid improvements in UV LEDs, as well as extensive research and optimization, allow for this technology to expand from small-scale use to full-scale reactors in water and wastewater treatment plants [85]. UVC LEDs must reach efficiencies of 25-39% to match the electrical efficiencies of conventional LP UV sources [62], however the rapid advancements of UV LEDs may allow for this to be achieved in the near future.

7.3 Cost

Previous studies have suggested that conventional UV treatments cost 0.04-0.06 cents USD per m^3 of treated water, which is cheaper than most other emerging technologies, and could potentially decrease as the size of the treatment plan increases [85]. Furthermore, the US EPA conducted various cost analyses for using UV disinfection for both capital cost and operation and maintenance cost to reflect labor hours, replacement parts, and lamp operating information provided by the manufacturer. Specifications regarding number of lamps, sensors, and ballasts are different for different manufacturers [88]. Larger systems serving over 1 million gallons per day require processing cost considerations along with equipment costs [88]. On the other hand, smaller systems capital cost can be assumed to capture any additional process costs [88]. Indirect capital costs can include pilot tests, training, and spare parts [88], all of which are parameters essential to accurately calculate the total costs of UV technology. It's important to note that these studies were done using conventional LP mercury lamps at a higher dose, and studies done to determine that of UV LEDs overestimated the development overtime [85]. Nonetheless, more comprehensive and current studies are required to determine the cost of UV LEDs for water treatment, whether that be inside the plant or in the distribution system.

7.4 QMRA for Distribution Systems

Quantitative microbiological risk assessment (QMRA) is a tool available to regulatory agencies and drinking water authorities to quantify the health risks associated with microorganisms in water sources [89]. This risk assessment model can be used to examine entire drinking water systems, from the source water to the consumer, in order to understand the potential impacts that may be imposed on the health of consumers [89]. The four components of this assessment include hazard identification, exposure assessment, dose-response assessment, and risk characterization [89]. Health Canada has developed a QMRA (HC QMRA) model that has been used to support the development of drinking water guidelines, and to encourage facilities to conduct site-specific risk assessments [89]. However, the HC QMRA does not assess risks associated with the distribution system [89]. Application of QMRA is gaining traction within drinking water treatment uses and is already quite common within the food industry [90].

The US EPA risk assessments determined an acceptable level of risk related to drinking water to be one illness for every 10,000 people [90]. Furthermore, the World Health Organization (WHO) proposes the disability adjusted life year (DALY) as a more generalized metric of evaluation of health burden and established a drinking water threshold of 10^{-6} DALY per person per year based on the consumption of 1 litre of unboiled water per person per day [90].

The study conducted by Elliott et al. (2019) is a comprehensive analysis of using a QMRA for 10 drinking water facilities located in Canada, analyzing their associated risk levels for *Cryptosporidium*, *Giardia lablia*, Rotavirus, *Campylobacter*, and *E. coli*. This study calculated DALYs for each illness predicted by the model, based on analyses of water samples for pathogen data collection [90]. Further considerations included the process assessments on overall evaluation of each treatment plants ability, including basin volumes and flowrates, disinfection residual concentrations, temperature, and pH [90]. Various plants evaluated in this study utilized different methods of treatment, including ultrafiltration membranes, direct filtration, watershed protection plans, and UV disinfection [90]. One of the studied plants utilizing the watershed protection plan without any physical filtration was found to be at risk of exceeded WHO regulations for pathogen concentrations; this plant was equipped with a UV device during the course of the study [90]. It's interesting to note that the commissioning of the UV device at this plant resulted in a significant risk reduction. Furthermore, the plants that employed UV disinfection were found to be more effective for the reduction of protozoan risk, and as effective as free chlorine and ozone for the reduction of bacterial and viral risks [90]. Additionally, the use of UV at three different plants resulted in a significant risk reduction for all five pathogens and can be predicted to withstand complete chlorine failure without compromising the WHO target of 10^{-6} DALY per person per year [90]. This provides a very strong and promising argument for the use of UV for water treatment, especially within smaller plants that may have compromised treatment operations or chlorine use.

The insight provided by Elliot et al. (2019) into the various applications of QMRA provide strong implications for the use of the model for drinking water treatment purposes. While this model cannot be currently applied to distribution systems, future studies should focus on creating such a risk assessment for potential risks associated with drinking water distribution. This would not only provide a comprehensive analysis of UV disinfection within the distribution, but also provide a step towards improved water quality within smaller systems.

7.5 UVT using Microfluidics

Ultraviolet transmittance (UVT) is the most important water quality characteristic related to UV disinfection performance [91]. UVT is also an important parameter on the dose delivery of a UV reactor [92]. As UVT decreases, the intensity throughout the reactor also decreases. UV absorbers and UVT are impacted by things such as soluble and particulate forms of humic and fulvic acid, some metals, and natural organic matter (NOM) [92]. NOM includes a variety of chemical compounds that may result from natural processes such as decomposition of organic matter and agal metabolic reactions [93].

Chapter 4 discusses a conducted focus group of industry professionals to discuss the opportunities of implementing UV LEDs in distributions systems. During the meeting, several important considerations were discussed in relation to implementing UV systems into distribution networks. The group identified the importance of having a UV residual that can be measured; this could potentially be the UVT.

Microfluidic/nanofluidic technology makes it possible to operate controlling or sensing on microscale or nanoscale liquids [94]. Microfluidic sensors are designed for handling small quantities of liquids for chemical and biological applications; these sensors are small, inexpensive, and able to detect and characterize materials accurately [95]. Advantages of microfluidic sensing systems are minimal consumption and waste generation due to the small sample sizes used, compact and portable analytical systems due to the small size of the microfluidic manifold facilities, fast analysis times, and low-cost sensing devices by combining microfluidic systems with simple and low-cost detectors [96].

Future research concepts include using UV LEDs in distribution system while monitoring the water quality; in this case, the UVT. This research would include the fabrication of the microfluidic device that can measure and analyse UVT in drinking water sample. Zhu et al. (2005) presents the idea of combining commercial silicon photodetectors with polymer microfluidics to detect UV absorbance. Absorbance detection is one of the most prevalent methods for laboratory analysis, mainly due to its simple implementation [97].

This concept is meant to provide inexpensive and efficient drinking water treatment for remote and decentralized systems, which are most vulnerable to water related issues in Canada. Although there has been previous work done for distribution treatment, this work does not include the monitoring of water quality, specifically UVT. Furthermore, there has been very little work done in microfluidics and UV sensing; specifically, microfluidic sensors used along side UV LEDs for drinking water distribution treatment.

8 Chapter 7: Conclusions

This thesis report combines various bodies of work and projects presented using the engineering design phases. Through following the design steps, this work presented a data analysis of boil water advisories in Canada which identified the problem and need for solution that many water safety vulnerabilities can stem from issues within drinking water distribution systems. Abstraction and synthesis are crucial steps that work together to produce effective solutions. Abstraction provides the building blocks for the design solution, while synthesis involves the creative formation of these blocks into tangible and practical forms [2]. The concept of installing UV LED reactors throughout the distribution system was identified as a potential solution to providing secondary disinfection within the distribution system. This solution provides an extra layer of protection against potential contamination events occurring throughout the distribution system, which the data analysis proved to be a leading cause of boil water advisories. In the case of this project, the abstraction consists of using EPANET to model UV LED devices within WDSs. The models presented the following findings:

- UV LEDs are an effective device for the disinfection of planktonic bacteria and *E. coli;*
- UV LEDs are more effective for the treatment of bacteria such as *E. coli* which have a higher inactivation kinetic coefficient;
- Reactors placed at downstream nodes/point-of-entries provide more favourable results than in-pipe reactors;
- Various important considerations must be taken into account for successful implementation under real-life conditions;
- Chlorine residual decreases with increase in water age, illustrating the potential for unsafe drinking water conditions with older aged water.

UV LED reactors have proven to be an effective mechanism for disinfection, particularly within the drinking water industry. The concepts presented in this study should be custom-tailored to the needs and available resources of each specific community to ensure safe and successful implementation.

References

[1] United Nations, "The 17 Goals," [Online]. Available: https://sdgs.un.org/goals. [Accessed 26 November 20223].

[2] G. Voland, "Engineering by Design," Pearson Education, Inc., Upper Saddle River, NJ, 2004.

[3] S. Moghaddam-Ghadimi, A. Tam, U. T. Khan and S. L. Gora, "How might climate change impact water safety and boil water advisories in Canada?," *FACETS,* vol. 8, pp. 1-21, 2023.

[4] Health Canada, "Guidance for Issuing and Rescinding Boil Water Advisories in Canadian Drinking Water Supplies," Minister of Health, Ottawa, 2015.

[5] S. Minnes and K. Vodden, "The capacity gap: Understanding impediments to sustainable drinking water systems in rural Newfoundland and Labrador," *Water Resources Journal,* 2017.

[6] K. Lane and G. Gagnon, "Evaluating the use and intent of drinking water advisories in Atlantic Canada," *Water Policy 22,* pp. 908-924, 2020.

[7] Environment and Climate Change Canada, "Canadian Environmental Sustainability Indicators: Boil Water Advisories," Environment and Climate Change Canada, 2022.

[8] S. Howe, "GWI Program," [Online]. Available: https://www.doh.wa.gov/CommunityandEnvironment/DrinkingWater/SourceWater/GWIProgram.

[9] Nova Scotia Enviroment, "APPENDIX A - PROTOCOL FOR DETERMINING GROUNDWATER UNDER DIRECT INFLUENCE OF SURFACE WATER," Environmental Science and Program Management Divison, n.d..

[10] Y. Zhang, X. Gao, K. Smith, G. Inial, S. Liu, L. B. Conil and B. Pan, "Integrating water quality and operation into prediction of water production in drinking water treatment plants by genetic algorith enhanced artificial neural network," *Water Research,* 2019.

[11] K. M. Thomas, D. F. Charron, D. Waltner-Toews, C. Schuster, A. R. Maarouf and J. D. Holt, "A role of high impact weather events in waterborne disease outbreaks in Canada, 1975-2001," *International Journal of Environmental Health Research,* pp. 167-180, 2006.

[12] B. R. Bonsal, D. L. Peters, F. Seglenieks, A. Rivera and A. Berg, "Changes in Freshwater Availability Across Canada," in *Canada's Changing Climate Report*, Ottawa, 2019, p. Chapter 6.

[13] A. Jadas-Hécart, A. El Morer, M. Stitou, P. Bouillot and B. Legube, "The Chlorine Demand of a Treated Water," *Water Research,* pp. 1073-1084, 1992.

[14] I. Fisher, G. Kastl and A. Sathasivan, "A suitable model of combined effects of temperature and initial condition on chlorine bulk decay in water distribution systems," *Water Reseach,* pp. 3293-3303, 2012.

[15] Health Canada, "Guidance on the temperature aspects of drinking water," Water and Air Quality Bureau. Health Environments and Consumer Safety Branch, Ottawa, 2021.

[16] J. Luh, E. Christenson, A. Toregozhina, D. A. Holcomb, T. Witsil, L. Hamrick, E. Ojomo and J. Bartram, "Vulnerability assessment for loss of access to drinking water due to extreme weather events," *Springer,* pp. 665-679, 2015.

[17] E. Bush, B. D. C. Bonsal, G. Flato, J. Fyfe, N. Gillet, B. J. Greenan, T. S. James, M. Kirchmeier-Young, L. Mudryk and X. Zhang, "Canada's Changing Climate Report in Light of the Latest Global Science Assessment," Government of Canada, Ottawa, ON, 2022.

[18] E. Bush and D. S. Lemmen, "Canada's Changing Climate Report," Environment and Climate Change Canada, Gatineau, QC, 2019.

[19] J. O'Dwyer, M. Morris Downes and C. C. Adley, "The impact of meterology on the occurence of waterborne outbreaks of vero cytotoxins-producing Escherichia coli (VTEC): a logistic regression approach," *Journal of Water and Health,* pp. 39-46, 2016.

[20] E. Bertone, O. Sahin, R. Richards and A. Roiko, "Extreme events, water quality and health: A participatory Bayesian risk assessment tool for managers of reservoirs," *Cleaner Production,* pp. 657-667, 2016.

[21] K. A. Thompson and E. R. Dickenson, "Using machine learning classification to detect simulated increases of de facto reuse and urban stormwater surges in surface water," *Water Research,* 2021.

[22] I. Moffatt and S. Struck, "Water-born Disease Outbreaks in Canadian Small Drinking Water Systems," National Collaborating Centres for Public Health, 2011.

[23] Y. Zhou, M. Liu, L. Zhou, K.-S. Jang, H. Xu, K. Shi, G. Zhu, M. Liu, J. Deng, Y. Zhang, R. G. Spencer, D. N. Kothawala, E. Jeppesen and F. Wu, "Rainstorm events shift the molecular composition and export of dissolved organic matter in a large drinking water reservoir in China: High frequency buoys and field observations," *Water Research,* 2020.

[24] R. G. e. a. Taylor, "Ground water and climate change," *Nature climate change,* 2013.

[25] C. Arrighi and F. Tarani, "Flood impacts on a water distribution network," *Natural Hazards and Earth System Sciences,* pp. 2109-2123, 2017.

[26] B. J. Greenan, J. T. S., J. W. Loder, P. Pepin, K. Azetsu-Scott and D. Ianson, "Changes in Oceans Surrounding Canada," in *Canada's Changing Climate Report*, 2019, p. Chapter 7.

[27] R. P. Mulligan, "Fiona hits Atlantic Canada: Climate change means the region will see more frequent storms," 2022.

[28] X. Su, P. Belvedere, T. Tosco and V. Prigiobbe, "Studying the effect of sea level rise on nuisance flooding due to groundwater in a coastal urban area with aging infrastructure," *Urban Climate,* 2022.

[29] K. J. Pieper, C. N. Jones, W. J. Rhoads, M. Rome, D. M. Gholson, A. Katner, D. E. Boellstorff and R. E. Beighley, "Microbial Contamination of Drinking Water Supplied by Private Wells after Hurricane Harvey," *Environmental Science & Technology,* pp. 8382-8392, 2021.

[30] A. Paldor and H. Michael, "Storm Surges Cause Simulataneous Salinization and Feshening of Coastal Aquifers, Exacerbated by Climate Change," *Water Resources Research,* 2021.

[31] US EPA, "EPA's and Mississippi's Efforts to Assess and Restore Public Drinking Water Supplies after Hurricane Katrina," U.S. Environmental Protection Agency Office of Inspector General, 2006A.

[32] V. Kapoor, I. Gupta, A. Pasha Tanvir and D. Phan, "Real-Time Quantitative PCR Measurements of Fecal Indicator Bacteria and Human-Associated Source Tracking Markers in a Texas River following Hurricane Harvey," *Environmental Science & Technology Letters,* vol. 5, no. 322-328, p. 2018, 2018.

[33] B. Wols, A. Vogelaar, A. Moerman and B. Raterman, "Effects of weather conditions on drinking water distirbution pipe failures in the Netherlands," *Water Supply,* pp. 404-416, 2019.

[34] D. Swanson, D. Murphy, J. Temmer and T. Scaletta, "Advancing the Climate Resilience of Canadian Infrastructure: A review of literature to inform the way forward," International Institute for Sustainable Development, Winnipeg, 2021.

[35] D. Kolijn, Interviewee, *Climate change effects in Canada relevant to drinking water safety and infrastructure.* [Interview]. 20 July 2021.

[36] Y. Kleiner and B. Rajani, "Forecasting variations and trends in water-main breaks," *Journal of Infrastructure Systems,* pp. 122-131, 2002.

[37] A. Baracos, W. Hurst and R. Legget, "Effects of Physical Environment on Cast-Iron Pipe," *American Water Works Association,* pp. 1195-1206, 1955.

[38] A. K. Hohner, C. C. Rhoades, P. Wilkerson and F. L. Rosario-Ortiz, "Wildfires Alter Forest Watersheds and Threaten Drinking Water Quality," *Accounts of Chemical Research,* no. Water for Two Worlds: Urban and Rural Communities, pp. 1234-1244, 2019.

[39] S. J. Khan, D. Deere, F. Leush, A. Humpage, M. Jenkins and D. Cunliffe, "Extreme weather events: Should drinking water quality management," *Water Research,* pp. 124-136, 2015.

[40] M. B. Emelko, U. Silins, K. D. Bladon and M. Stone, "Implications of land disturbance on drinking water treatability in a changing climate: Demonstrating the need for "source water supply and protection" strategies," *Water Research,* pp. 461-472, 2011.

[41] K. D. Bladon, M. B. Emelko, U. Silins and M. Stone, "Wildfire and the Future of Water Supply," *Environmental Science and Technology,* pp. 8936-8943, 2014.

[42] J. R. Thienpont, K. M. Ruhland, M. F. Pisaric, S. V. Kokelj, L. E. Kimpe, J. M. Blias and J. P. Smol, "Biological responses to permafrost thaw slumping in Canadian Arctic lakes," *Freshwater Biology,* vol. 58, pp. 337-353, 2013.

[43] J. Vonk, S. Tank, W. Bowden, I. Laurion, W. Vincent and P. Alekseychik, "Reviews and syntheses: Effects of permafrost thaw on Arctic aquatic ecosystems," *Biogeosciences,* vol. 12, pp. 7129-7167, 2015.

[44] B. Abbott, J. Jones, S. Godsey, J. Larouche and W. Bowden, "Patters and persistence of hydrologic carbon and nutrient export from collapsing upland permafrost," *Biogeosciences,* vol. 12, pp. 3725-3740, 2015.

[45] K. R. Miner, J. D'Andrilli, R. Mackelprang, A. Edwards, M. J. Malaska, M. P. Waldrop and C. E. Miller, "Emergent biogeochemical risks from Arctic permafrost degradation," *Nature Climate Change,* vol. 11, pp. 809-819, 2021.

[46] J. Elliot, M. G. Clayden, K. Clouter, S. Collins, T. Tremblay and M. LeBlanc-Havard, "Community water quality data across Nunavut: an introduction to available data for community water supplies," *Summer of Activities 2021,* pp. 57-68, 2022.

[47] K. Schaefer, Y. Elshorbany, E. Jafarov, P. F. Schuster, R. G. Striegl, K. P. Wickland and E. M. Sunderland, "Potential impacts of mercury released from thawing permafrost," *Nature Communications,* 2020.

[48] J. E. Edwards, S. B. Henderson, S. Struck and T. Kosatsky, "Characteristics of small residential and commercial water systems that influence their likelihood of being on drinking water advisories in rural British Columbia, Canada: a cross-sectional study using administrative data," *Journal of Water and Health,* vol. 10, no. 4, pp. 629-649, 2012.

[49] H. Murphy, M. Thomas, P. Schmidt, D. Medeiros, S. McFadyen and K. Pintar, "Estimating the burden of acute gastrointestinal illness due to Giardia, Cryposporidium, Campylobacter, E.coli O157 and norovirus asscoiated with private wells and small water systems in Canada," *Epidemiol. Infect.,* pp. 1355-1370, 2016.

[50] A. Ercumen, J. S. Gruber and J. M. J. Colford, "Water Distribution System Deficiencies and Gastrointestinal Illnesses: A Systematic Review and Meta-Analysis," *Environmental Health Perspectives,* vol. 122, no. 7, pp. 651-660, 2014.

[51] M. F. Doria, "Bottled water versus tap water: understanding consumers' preference," *Journal of Water and Health,* pp. 271-276, 2006.

[52] H. Castleden, V. A. Crooks and I. v. Meerveld, "Examining the public health implications of drinking water-related behaviours and perceptions: A face-to-face exploratory survey of residents in eight coastal communities in British Columbia and Nova Scotia," *The Canadian Geographer,* vol. 59, no. 2, pp. 111-125, 2015.

[53] C. Goldhar, T. Bell and J. Wolf, "Vulnerability to Freshwater Changes in the Inuit Settlement Region of Nunatsiavut, Labrador: A Case Study from Rigolet," *Arctic,* pp. 71-83, March 2013.

[54] S. P.W.M.H., G. Medema and J. van Dijk, "The Dutch secret: how to provide safe drinking water without chlorine in the Netherlands," *Drinking Water Engineering and Science,* pp. 1-14, 2009.

[55] United States Environmental Protection Agency, "Drinking Water Requirements for States and Public Water Systems," 30 March 2023. [Online]. Available: https://www.epa.gov/dwreginfo/chloramines-drinking-water. [Accessed 26 November 2023].

[56] Centers for Disease Control and Prevention, "Disinfection By-products (DBPs) Factsheet," 18 July 2022. [Online]. Available: https://www.cdc.gov/biomonitoring/THM-DBP_FactSheet.html. [Accessed 26 November 2023].

[57] K. G. Linden, N. Hull and V. Speight, "Thinking Outside the Treatment Plant: UV for Water Disinfection Distribution System Disinfection," *Americal Chemical Society,* pp. 1226-1233, 2019.

[58] M. Blokker, J. Vreeburg and V. Speight, "Residual chlorine in the extremities of the drinking water distribution system: the influence of stochastic water demands," *Procedia Engineering,* vol. 70, pp. 172-180, 2014.

[59] X. Li, M. Cai, L. Wang, F. Niu, D. Yang and G. Zhang, "Evaluation survey of microbial disinfection methods in UV-LED water treament systems," *Science of the Total Environment,* pp. 1415-1427, 2018.

[60] A. Kheyrandish, M. Mohseni and F. Taghipour, "Development of a method for the characterization and operation of UV-LED for water treatment," *Water Research,* pp. 570-590, 2017.

[61] K. Song, M. Madjid and F. Taghipour, "Application of ultraviolet light-emitting diodes (UV-LEDs) for water disinfection: A review," *Water Researc,* pp. 341-349, 2016.

[62] S. Beck, H. Ryu, L. A. Boczek, J. L. Cashdollar, K. M. Jeanis, J. S. Rosenblum and O. R. Lawal, "Evaluating UV-C LED disinfection performance and investigating potential dual-wavelength synergy," *Water Research,* pp. 207-216, 2017.

[63] M. Wurtele, T. Kolbe, M. Lipsz, A. Kulberg, M. Weyers, M. Kneissl and M. Jekel, "Application of GaN-based ultraviolet-C light emitting diodes - UV LEDs- for water disinfection," *Water Research,* pp. 1481-1489, 2010.

[64] M. Khan, M. Shatalov, H. Maruska, H. Wang and K. E., "III-nitride UV devices," *Japanese Hournal of Applied Physics,* pp. 7191-7206, 2005.

[65] P. O. Nyangaresi, Y. Qin, G. Chen, B. Zhang, Y. Lu and L. Shen, "Effects of single and combined UV-LEDs on inactivation and subsequent reactivation of E.coli in water disinfection," *Water Research,* pp. 331-341, 2018.

[66] A. Hamamato, M. Mori, A. Takahashi, M. Nakano, N. Wakikawa, M. Akutagawa, T. Ikehara, Y. Nakaya and Y. Kinouchi, "New water disinfection system usin UVA light-emitting diodes," *Journal of Applied Microbiology,* 2007.

[67] Y. Aoyagi, M. Takeuchi, K. Yoshida, M. Kurouchi, N. Yasui, N. Kamiko, T. Araki and Y. Nanishi, "Inactivation of Bacterial Viruses in Water Using Deep Ultraviolet Semiconductor Light-Emitting Diodes," *Journal of Environmental Engineering,* pp. 1215-1218, 2011.

[68] K. Oguma, R. Kita, H. Sakai and M. Michio, "Application of UV light emitting diodes to batch and flow-through water disinfection systems," *Desalination,* pp. 24-30, 2013.

[69] P. Xiong and J. Hu, "Inactivation/reactivation of antibiotic-resistant bacteria by a novel UVA/LED/TiO2 system," *Water Research,* pp. 4547-4555, 2014.

[70] Brittanica, "bacteriophage," 2018.

[71] C. Bowker, A. Sain, M. Shatalov and J. Ducoste, "Microbial UV fluence-response assessment using a novel UV-LED collimated beam system," *Water Research,* 2011.

[72] S. E. Beck, R. A. Rodriguez, M. A. Hawkins, T. A. Hargy, T. C. Larason and K. G. Linden, "Comparison of UV-Induced Inactivation and RNA Damage in MS2 Phage across the Germicidal UV Spectrum," *Applied and Environmental Microbiology,* pp. 1468-1474, 2016.

[73] Centers for Disease Control and Prevention, "Natural Biomonitoring Program - Disinfecton By-products (DBPs)," CDC, 2022. [Online]. Available: https://www.cdc.gov/biomonitoring/THM-DBP_FactSheet.html#:~:text=Disinfection%20by%2Dproducts%20(DBPs)%20are%20formed%20when%20disinfectants%20like,bathing%2C%20dishwashing%2C%20and%20swimming..

[74] F. Shang, J. G. Uber and L. A. Rossma, "EPANET Multi-Species Extension User's Manual," United States Environmental Protection Agency, Cincinnati, 2011.

[75] G. R. Abhijith and A. Ostfeld, "Contaminant Fate and Transport Modeling in Distribution Systems: EPANET-C," *Water,* March 2022.

[76] L. Pemmansi and J. G. Uber, "Analysis of Fate and Transport of E. coli in Chlorinated Drinking Water Distribution System in the Presence of Natural Organic Matter," University of Cincinnati, 2012.

[77] S. Rattankul and K. Oguma, "Inactivation kinetics and efficiencies of UV-LEDs against Pseudomonas aeruginosa, Legionella pneumophila, and surrogate microorganisms," *Water Research,* pp. 31-37, 2017.

[78] J. R. Bolton and C. A. Cotton, "Ultraviolet (UV) Disinfection for Water Treatment," American Water Works Association, Denver, 2022.

[79] W. Artichowicz, A. Luczkiewicz and J. M. Sawicki, "Analysis of Radiation Dose in UV-Disinfection Flow Reactors," *Water,* 2020.

[80] British Columbia Small Water Systems Online Help Centre, "NSF Standards," [Online]. Available: https://smallwatersystemsbc.ca/operating-your-water-system/water-systems/nsf-standards.

[81] R. Andrew, "Water Matters: NSF/ANSI 55 Requirements for Ultraviolet Systems," NSF, 2010.

[82] S. T. Odonkor and T. Mahami, "Escherichia coli as a Tool for Disease Risk Assessment of Drinking Water Sources," *International Journal of Microbiology,* 2020.

[83] Wikipedia, "Pseudomonas aeurginosa," [Online]. Available: https://en.wikipedia.org/wiki/Pseudomonas_aeruginosa.

[84] United States Environmental Protection Agency, "Effects of Water Age on Distribution System Water Quality," AWWA, 2022.

[85] P. Jarvis, O. G. E. H. Autin and F. Hassard, "Application of Ultraviolet Light-Emitting Diodes (UV-LEDs) to Full-Scale Drinking Water Disinfection," *Water,* 2019.

[86] J. R. Bolton and C. A. Cotton, "Ultraviolet (UV) Disinfection for Water Treatment," American Water Works Association, Denver, 2022.

[87] T. Harris, J. Pagan and P. Batoni, "Optical and Fluidic Co-Design of a UV-LED Water Disinfection Chamber," *ECS Transactions,* pp. 11-18, 2013.

[88] US EPA, "Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule," US Environmental Protection Agency Office of Water, 2005.

[89] Health Canada, "Guidance on the Use of Quantitative Microbial Risk Assessment in Drinking Water," Government of Canada, 2019.

[90] J. G. Elliott, L. Taylor-Edmonds and R. C. Andrews, "Quantitative microbial risk assessments for drinking water facilities: evaluation of a range of treatment strategies," *Environmental Science Water Research & Technology,* pp. 1943-1955, 2019.

[91] N. M. Hull, W. H. Herold and K. G. Linden, "UV LED water disinfection: Validation and small system demonstration study," *AWWA Water Science,* 2019.

[92] M. Pirnie, K. G. Linden and J. P. Malley Jr, "Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule," United States Environmental Protection Agency: Office of Water, Washington, DC, 2006.

[93] S. Gora and M. Chaulk, "Study on Characteristics and Removal of Natural Organic Matter in Drinking Water Systems in Newfoundland and Labrador," CBCL Limited, 2011.

[94] J. Wu and M. Gu, "Microfluidic sensing: state of the art fabrication and detection techniques," *Biomedical Optics,* 2011.

[95] G. M. Rocco, M. Bozzi, D. Schreurs, L. Perregrini, S. Marconi, G. Alaimo and F. Auricchio, "3-D Printed Microfluidic Sensor in SIW Technology for Liquids' Characterization," *IEEE Transactions on Microwave Theory and Techniques,* vol. 68, 2020.

[96] J. Cleary, D. Maher and D. D., "Development and Deployment of a Microfluidic Platform for Water Quality Monitoring," in *Smart Sensors for Real-Time Water Quality Monitoring*, S. Mukhopadhyay and A. Mason, Eds., Dublin, Springer-Verlag Berlin Heidelberg, 2013, pp. 125-148.

[97] L. Zhu, C. Lee and D. DeVoe, "Integrated microfluidic UV absorbance detector with attomol-level sensitivity for BSA," *Royal Society of Chemistry,* 2005.

[98] E. Unosson, "Antibacterial Strategies for Titanium Biomaterials," Uppsala University, 2015.

Appendix A: MSX Model Inputs

Water Age:

EPANET Example Network 3 151 >>>

Time Series Table - Link 151

Time Hours	C MG/L	Age hours
0:00	0	0
1:00	0	1
2:00	0	2
3:00	0	3
4:00	0	4
5:00	0.5602	4.76
6:00	0.8922	5.24
7:00	0.891	5.76
8:00	0.891	6.76
9:00	0.891	7.76
10:00	0.891	8.76
11:00	0.891	9.76
12:00	1	9.36
13:00	0.9852	10.49
14:00	0.5027	13.26
15:00	0.5085	13.12
16:00	0.4592	13.16
17:00	0.4592	14.16
18:00	0.4592	15.16
19:00	0.4592	16.16
20:00	0.4592	17.16
21:00	0.4592	18.16
22:00	0.4592	19.16
23:00	0.0771	22.9
24:00:00	0.0771	23.9
25:00:00	0.7586	13.9
26:00:00	0.9878	5.88
27:00:00	1	5.05
28:00:00	1	4.99
29:00:00	1	5.08
30:00:00	1	5.5
31:00:00	1	5.75
32:00:00	1	6.75
33:00:00	1	7.75
34:00:00	1	8.75
35:00:00	1	9.75
36:00:00	0.5048	24.69
37:00:00	0.5453	23.61
38:00:00	1	9.26
39:00:00	0.9626	10.69
40:00:00	0.892	11.83
41:00:00	0.892	12.83
42:00:00	0.892	13.83
43:00:00	0.892	14.83
44:00:00	0.892	15.83
45:00:00	0.892	16.83
46:00:00	0.892	17.83
47:00:00	0.241	42.34
48:00:00	0.241	43.34
49:00:00	0.8571	16.47
50:00:00	0.9078	10.47
51:00:00	1	5.13
52:00:00	1	5.01
53:00:00	1	5.09
54:00:00	1	5.47
55:00:00	1	5.74
56:00:00	1	6.74
57:00:00	1	7.74
58:00:00	1	8.74
59:00:00	1	9.74
60:00:00	0.3292	50.37
61:00:00	0.6149	33.92
62:00:00	1	9.31

63:00:00	0.968	11.54
64:00:00	0.9118	13.93
65:00:00	0.9118	14.93
66:00:00	0.9118	15.93
67:00:00	0.9118	16.93
68:00:00	0.9118	17.93
69:00:00	0.9118	18.93
70:00:00	0.9118	19.93
71:00:00	0.3584	59.26
72:00:00	0.3584	60.26
73:00:00	0.8808	19.52
74:00:00	0.9224	12.52
75:00:00	1	5.13
76:00:00	1	5.01
77:00:00	1	5.09
78:00:00	1	5.47
79:00:00	1	5.74
80:00:00	1	6.74
81:00:00	1	7.74
82:00:00	1	8.74
83:00:00	1	9.74
84:00:00	0.433	65.26
85:00:00	0.6744	42.5
86:00:00	1	9.31
87:00:00	0.973	12.26
88:00:00	0.9254	15.85
89:00:00	0.9254	16.85
90:00:00	0.9254	17.85
91:00:00	0.9254	18.85
92:00:00	0.9254	19.85
93:00:00	0.9254	20.85
94:00:00	0.9254	21.85
95:00:00	0.4576	73.55
96:00:00	0.4576	74.55
97:00:00	0.8989	22.16
98:00:00	0.9344	14.22
99:00:00	1	5.13
100:00:00	1	5.01
101:00:00	1	5.09
102:00:00	1	5.47
103:00:00	1	5.74
104:00:00	1	6.74
105:00:00	1	7.74
106:00:00	1	8.74
107:00:00	1	9.74
108:00:00	0.5207	77.87
109:00:00	0.7248	49.75
110:00:00	1	9.31
111:00:00	0.9771	12.86
112:00:00	0.9367	17.44
113:00:00	0.9367	18.44
114:00:00	0.9367	19.44
115:00:00	0.9367	20.44
116:00:00	0.9367	21.44
117:00:00	0.9367	22.44
118:00:00	0.9367	23.44
119:00:00	0.5414	85.62
120:00:00	0.5414	86.62

EPANET Example Network 3
Time Series Table - Link 251

Time Hours			C MG/L	Age hours
0:00	0	0		
1:00	0	1		
2:00	0	2		
3:00	0	3		
4:00	0	4		
5:00	0	5		

6:00	0	6
7:00	0	7
8:00	0	8
9:00	0	9
10:00	0	10
11:00	0	11
12:00	0	12
13:00	0.0127	12.97
14:00	0.0905	13.75
15:00	0.1799	14.41
16:00	0.257	15.01
17:00	0.3297	15.55
18:00	0.3979	16.04
19:00	0.4567	16.56
20:00	0.5152	17.03
21:00	0.5816	17.27
22:00	0.6046	17.46
23:00	0.5992	17.46
24:00:00	0.5939	17.11
25:00:00	0.5789	16.91
26:00:00	0.5809	16.23
27:00:00	0.609	16.39
28:00:00	0.6419	16.78
29:00:00	0.6683	17.54
30:00:00	0.7126	18.38
31:00:00	0.756	19.3
32:00:00	0.7649	20.47
33:00:00	0.7478	21.64
34:00:00	0.7683	21.82
35:00:00	0.7997	21.62
36:00:00	0.7891	21.73
37:00:00	0.8164	20.96
38:00:00	0.8599	19.78
39:00:00	0.9198	18.78
40:00:00	0.9445	18.64
41:00:00	0.9481	18.76
42:00:00	0.9568	18.77
43:00:00	0.9862	18.58
44:00:00	0.9954	18.9
45:00:00	0.9962	19.26
46:00:00	0.9934	19.79
47:00:00	0.9778	20.33
48:00:00	0.9701	20.14
49:00:00	0.9664	20.05
50:00:00	0.9654	18.95
51:00:00	0.98	17.82
52:00:00	0.9785	17.7
53:00:00	0.9673	18.54
54:00:00	0.9545	19.42
55:00:00	0.9407	20.51
56:00:00	0.9043	22.76
57:00:00	0.8518	25.39
58:00:00	0.8315	26.07
59:00:00	0.8385	25.79
60:00:00	0.8276	26.11
61:00:00	0.8472	24.76
62:00:00	0.8824	22.45
63:00:00	0.9334	20.31
64:00:00	0.9555	19.69
65:00:00	0.9603	19.68
66:00:00	0.9656	19.54
67:00:00	0.9876	18.86
68:00:00	0.9948	19.11
69:00:00	0.9953	19.58
70:00:00	0.9913	20.32
71:00:00	0.9786	21.09
72:00:00	0.9733	21
73:00:00	0.9699	21
74:00:00	0.9707	19.69

75:00:00	0.9843	18.17
76:00:00	0.982	18.24
77:00:00	0.9726	19.32
78:00:00	0.962	20.49
79:00:00	0.9502	21.94
80:00:00	0.9198	25.12
81:00:00	0.8757	28.79
82:00:00	0.8584	29.71
83:00:00	0.8643	29.28
84:00:00	0.8554	29.75
85:00:00	0.8715	27.92
86:00:00	0.901	24.71
87:00:00	0.9437	21.58
88:00:00	0.9617	20.61
89:00:00	0.9659	20.5
90:00:00	0.9703	20.19
91:00:00	0.9886	19.05
92:00:00	0.9946	19.22
93:00:00	0.9954	19.73
94:00:00	0.992	20.58
95:00:00	0.9813	21.62
96:00:00	0.9773	21.62
97:00:00	0.9744	21.71
98:00:00	0.9752	20.32
99:00:00	0.9867	18.51
100:00:00	0.9849	18.71
101:00:00	0.9769	20
102:00:00	0.968	21.42
103:00:00	0.9579	23.15
104:00:00	0.9323	27.11
105:00:00	0.8953	31.64
106:00:00	0.8808	32.75
107:00:00	0.8857	32.19
108:00:00	0.8784	32.77
109:00:00	0.8921	30.54
110:00:00	0.9169	26.57
111:00:00	0.9528	22.63
112:00:00	0.9685	21.36
113:00:00	0.972	21.19
114:00:00	0.9758	20.72
115:00:00	0.9912	19.21
116:00:00	0.9962	19.31
117:00:00	0.9969	19.85
118:00:00	0.994	20.81
119:00:00	0.9848	22.06
120:00:00	0.9805	22.16

EPANET Example Network 3
Time Series Table - Link 277

Time Hours			C hours	Age
0:00	0	0		
1:00	0	1		
2:00	0	2		
3:00	0	3		
4:00	0	4		
5:00	0	5		
6:00	0.001	6		
7:00	0.0069	6.98		
8:00	0.0192	7.94		
9:00	0.0308	8.88		
10:00	0.0443	9.8		
11:00	0.0575	10.7		
12:00	0.0721	11.57		
13:00	0.0859	12.42		
14:00	0.0985	13.27		
15:00	0.11	14.12		
16:00	0.1199	14.97		

17:00	0.1293	15.82
18:00	0.1377	16.67
19:00	0.1442	17.52
20:00	0.1505	18.36
21:00	0.1589	19.15
22:00	0.1687	19.92
23:00	0.1815	20.62
24:00:00	0.193	21.49
25:00:00	0.2092	22.23
26:00:00	0.2378	22.78
27:00:00	0.258	23.44
28:00:00	0.2858	23.9
29:00:00	0.2988	24.61
30:00:00	0.3167	25.2
31:00:00	0.3337	25.79
32:00:00	0.3553	26.27
33:00:00	0.3742	26.82
34:00:00	0.3962	27.25
35:00:00	0.4179	27.67
36:00:00	0.4419	28.01
37:00:00	0.4653	28.37
38:00:00	0.486	28.79
39:00:00	0.5036	29.26
40:00:00	0.5198	29.75
41:00:00	0.5355	30.24
42:00:00	0.5501	30.76
43:00:00	0.5627	31.32
44:00:00	0.5755	31.88
45:00:00	0.5926	32.28
46:00:00	0.6119	32.59
47:00:00	0.6369	32.71
48:00:00	0.6699	32.61
49:00:00	0.6954	32.7
50:00:00	0.7311	32.38
51:00:00	0.7536	32.51
52:00:00	0.7803	32.32
53:00:00	0.7887	32.71
54:00:00	0.7963	32.89
55:00:00	0.8033	33.11
56:00:00	0.8117	33.16
57:00:00	0.8188	33.34
58:00:00	0.8272	33.35
59:00:00	0.8358	33.38
60:00:00	0.8458	33.31
61:00:00	0.8554	33.3
62:00:00	0.8632	33.43
63:00:00	0.8697	33.64
64:00:00	0.8769	33.91
65:00:00	0.8847	34.22
66:00:00	0.892	34.57
67:00:00	0.8984	34.98
68:00:00	0.9048	35.38
69:00:00	0.9127	35.57
70:00:00	0.922	35.64
71:00:00	0.9406	35.2
72:00:00	0.9516	34.64
73:00:00	0.9576	34.43
74:00:00	0.9666	33.75
75:00:00	0.9631	33.85
76:00:00	0.9636	33.62
77:00:00	0.9622	34.02
78:00:00	0.9618	34.18
79:00:00	0.9619	34.35
80:00:00	0.9623	34.34
81:00:00	0.962	34.49
82:00:00	0.9616	34.47
83:00:00	0.9616	34.45
84:00:00	0.9619	34.3
85:00:00	0.9638	34.18

86:00:00	0.9639	34.29
87:00:00	0.963	34.49
88:00:00	0.9631	34.73
89:00:00	0.9631	35.02
90:00:00	0.9629	35.35
91:00:00	0.9627	35.76
92:00:00	0.9627	36.15
93:00:00	0.9627	36.33
94:00:00	0.9627	36.4
95:00:00	0.9633	36.12
96:00:00	0.9651	35.55
97:00:00	0.9666	35.33
98:00:00	0.9721	34.53
99:00:00	0.9691	34.69
100:00:00	0.9694	34.48
101:00:00	0.9682	34.91
102:00:00	0.9678	35.07
103:00:00	0.968	35.22
104:00:00	0.9684	35.21
105:00:00	0.9682	35.37
106:00:00	0.968	35.34
107:00:00	0.968	35.32
108:00:00	0.9684	35.13
109:00:00	0.97	34.97
110:00:00	0.9701	35.1
111:00:00	0.9693	35.31
112:00:00	0.9694	35.55
113:00:00	0.9694	35.84
114:00:00	0.9692	36.18
115:00:00	0.9691	36.59
116:00:00	0.9691	36.98
117:00:00	0.9691	37.16
118:00:00	0.9691	37.23
119:00:00	0.9695	36.94
120:00:00	0.9708	36.33

EPANET Example Network 3
Time Series Table - Link 291

Time Hours			C MG/L	Age hours
0:00	0	0		
1:00	0	1		
2:00	0	2		
3:00	0	3		
4:00	0	4		
5:00	0	5		
6:00	0.0003	5.99		
7:00	0.061	6.81		
8:00	0.2877	7.17		
9:00	0.4781	7.42		
10:00	0.5827	7.56		
11:00	0.6035	7.85		
12:00	0.6073	8.19		
13:00	0.6091	8.65		
14:00	0.6038	8.82		
15:00	0.5928	8.84		
16:00	0.59	9.12		
17:00	0.5895	10.05		
18:00	0.5924	11.4		
19:00	0.5938	12.14		
20:00	0.5973	13.92		
21:00	0.5778	17.88		
22:00	0.407	20.7		
23:00	0.1058	22.69		
24:00:00	0.0006	24		
25:00:00	0.0006	25		
26:00:00	0.0006	26		
27:00:00	0.0006	27		

28:00:00	0.0006	28
29:00:00	0.37	22
30:00:00	0.8567	11.72
31:00:00	0.9445	9.26
32:00:00	0.9929	8.37
33:00:00	0.9981	9.05
34:00:00	0.995	10.26
35:00:00	0.9914	11.47
36:00:00	0.9882	12.78
37:00:00	0.9883	12.74
38:00:00	0.9951	12.02
39:00:00	0.9739	12.32
40:00:00	0.9413	12.68
41:00:00	0.9471	11.9
42:00:00	0.9686	11.26
43:00:00	0.9792	11.31
44:00:00	0.9789	11.58
45:00:00	0.9777	12.19
46:00:00	0.9798	14.12
47:00:00	0.9541	17.38
48:00:00	0.3295	39.14
49:00:00	0.1284	46.15
50:00:00	0.1284	47.15
51:00:00	0.1284	48.15
52:00:00	0.1365	48.86
53:00:00	0.5259	32.51
54:00:00	0.9043	13.37
55:00:00	0.9611	9.68
56:00:00	0.9935	8.5
57:00:00	0.9981	9.06
58:00:00	0.9946	10.44
59:00:00	0.992	11.76
60:00:00	0.9872	13.49
61:00:00	0.9867	13.11
62:00:00	0.9946	12.47
63:00:00	0.9741	13.44
64:00:00	0.9492	14.01
65:00:00	0.9564	12.72
66:00:00	0.9748	11.75
67:00:00	0.9826	11.74
68:00:00	0.9824	11.96
69:00:00	0.9816	12.53
70:00:00	0.9828	14.56
71:00:00	0.962	18.1
72:00:00	0.4152	53.43
73:00:00	0.2429	64.55
74:00:00	0.2429	65.55
75:00:00	0.2429	66.55
76:00:00	0.2496	67.11
77:00:00	0.59	42.45
78:00:00	0.9198	15.2
79:00:00	0.9659	10.28
80:00:00	0.994	8.56
81:00:00	0.9981	9.09
82:00:00	0.9958	10.51
83:00:00	0.9936	11.9
84:00:00	0.9878	13.81
85:00:00	0.9878	13.29
86:00:00	0.9953	12.66
87:00:00	0.9781	14.19
88:00:00	0.957	15.11
89:00:00	0.9627	13.49
90:00:00	0.9784	12.2
91:00:00	0.9852	12.12
92:00:00	0.985	12.31
93:00:00	0.9845	12.85
94:00:00	0.9852	14.95
95:00:00	0.9674	18.77
96:00:00	0.4928	65.73

```
 97:00:00      0.3427   80.51
 98:00:00      0.3427   81.51
 99:00:00      0.3427   82.51
 100:00:00     0.3486   82.92
 101:00:00     0.6457   51
 102:00:00     0.9321   16.7
 103:00:00     0.9693   10.76
 104:00:00     0.9929   8.61
 105:00:00     0.9977   9.12
 106:00:00     0.9948   10.57
 107:00:00     0.992    12.01
 108:00:00     0.9902   14.07
 109:00:00     0.9912   13.44
 110:00:00     0.9963   12.82
 111:00:00     0.9819   14.83
 112:00:00     0.9631   16.04
 113:00:00     0.9673   14.14
 114:00:00     0.9807   12.58
 115:00:00     0.9871   12.43
 116:00:00     0.987    12.61
 117:00:00     0.9867   13.13
 118:00:00     0.9873   15.28
 119:00:00     0.9716   19.34
 120:00:00     0.5599   76.4
```

Scenario 1 – Planktonic Bacteria:

```
[TITLE]
Scenario 1

[OPTIONS]
  AREA_UNITS FT2             ;Surface concentration is mass/m2
  RATE_UNITS DAY             ;Reaction rates are concentration/hour
  SOLVER     EUL            ;5-th order Runge-Kutta integrator
  TIMESTEP   300            ;300 sec (4 min) solution time step
  COUPLING   NONE
  COMPILER   NONE
  ATOL      0.01
  RTOL      0.001

[SPECIES]
BULK           C       MG              ;residual chlorine
BULK           C1      MG
WALL           C2      MG
BULK           S        MG             ;BDOC
BULK           H       UG              ;THMs
BULK           N       MG              ;TOC
BULK           Xb      CFU             ;planktonic microbial
BULK           Xb1     CFU
WALL           Xb2     CFU
WALL           Xa      CFU             ;biofilm microbial density
WALL           Xa1     CFU
BULK           Xa2     CFU
BULK            UVXb   CFU


[COEFFICIENTS]
CONSTANT       kcn     0.165           ;second order rate constant chlorine to TOC
CONSTANT       Yn      0.98            ;yield coefficient TOC/BDOC
CONSTANT       Yh      112.435         ;yield coefficient THM
CONSTANT       kw      3.7e-4           ;wall decay coefficient chlorine
CONSTANT       kf       0.4426         ;mass-transfer coefficient chlorine
CONSTANT       umb     1.512           ;max specific growth for planktonic
CONSTANT       kinact  0.35            ;microbial growth inactivation
CONSTANT       Topt    35              ;optimal temperature
```

```
CONSTANT        T       25              ;temperature
CONSTANT        Ti      30              ;temp dependant shape parameter
CONSTANT        uma     0.003           ;max specific growth biofilm
CONSTANT        PI      3.141592653589793238
CONSTANT        ks      0.195
CONSTANT        kcos    0.448
CONSTANT        kdet    1.9e-10
CONSTANT        kdep    0.2
CONSTANT        I       3.5


[TERMS]
P       2*PI*(D/2)
Rh      4/D
T1      -((Topt-T)/(Topt-Ti))^2
Et      36.7/((U*30.48))
F       Et*I
UV      10^(-kcos*F)


[PIPES]
RATE    C1      -kcn*N*C
RATE    C2      -((kw*kf)/((kw+kf)*Rh))*C
RATE    C       C1+C2
RATE    N       -Yn*kcn*N*C
RATE    S       -Yn*kcn*S*C
RATE    H        Yh*kcn*N*C
RATE    Xb1      umb*(S/ks+S)*EXP(-(kinact*C))*EXP((T1))*Xb
RATE    Xb2     -kdep*Xb
RATE    Xb      Xb1+Xb2
RATE    Xa1      uma*EXP(-(kinact*C))*EXP((T1))*Xa
RATE    Xa2     -kdet*Us*Xa
RATE    Xa      Xa1+Xa2
RATE    UVXb     UV*Xb


[TANKS]
RATE    C1      -kcn*N*C
RATE    C       C1+C2
RATE    N       -Yn*kcn*N*C
RATE    S       -Yn*kcn*S*C
RATE    H        Yh*kcn*N*C
RATE    Xb1      umb*(S/ks+S)*EXP(-(kinact*C))*EXP((T1))*Xb
RATE    Xb      Xb1+Xb2
RATE    Xa2     -kdet*Us*Xa
RATE    UVXb     UV*Xb


[SOURCES]
CONCEN  Lake            C       0.49
CONCEN  Lake            N       3.55
CONCEN  Lake            H       20
CONCEN  Lake            Xb      1e-4
CONCEN  Lake            S       0.05
CONCEN  River           C       1.0
CONCEN  River           N       0.56
CONCEN  River           H       20
CONCEN  River           Xb      1e-3
CONCEN  River           S       0.1


[REPORTS]
NODES   ALL
LINKS   ALL
SPECIES         C       YES             4
SPECIES         N       YES             4
SPECIES         H       YES             4
SPECIES         Xb      YES             15
SPECIES         S       YES             4
```

```
SPECIES         Xa      YES             4
SPECIES         UVXb    YES             50
```

Scenario 2 – Planktonic Bacteria:

```
[TITLE]
Scenario 2

[OPTIONS]
  AREA_UNITS FT2             ;Surface concentration is mass/m2
  RATE_UNITS DAY             ;Reaction rates are concentration/hour
  SOLVER     EUL            ;5-th order Runge-Kutta integrator
  TIMESTEP   300            ;300 sec (4 min) solution time step
  COUPLING   NONE
  COMPILER   NONE
  ATOL       0.01
  RTOL       0.001

[SPECIES]
BULK            C       MG              ;residual chlorine
BULK            C1      MG
WALL            C2      MG
BULK            S        MG             ;BDOC
BULK            H       UG              ;THMs
BULK            N       MG              ;TOC
BULK            Xb      CFU             ;planktonic microbial
BULK            Xb1     CFU
WALL            Xb2     CFU
WALL            Xa      CFU             ;biofilm microbial density
WALL            Xa1     CFU
BULK            Xa2     CFU
BULK             UVXb   CFU


[COEFFICIENTS]
CONSTANT        kcn     0.165           ;second order rate constant chlorine to TOC
CONSTANT        Yn      0.98            ;yield coefficient TOC/BDOC
CONSTANT        Yh      112.435         ;yield coefficient THM
CONSTANT        kw      3.7e-4           ;wall decay coefficient chlorine
CONSTANT        kf       0.4426         ;mass-transfer coefficient chlorine
CONSTANT        umb     1.512           ;max specific growth for planktonic
CONSTANT        kinact  0.35            ;microbial growth inactivation
CONSTANT        Topt    35              ;optimal temperature
CONSTANT        T       25              ;temperature
CONSTANT        Ti      30              ;temp dependant shape parameter
CONSTANT        uma     0.003           ;max specific growth biofilm
CONSTANT        PI      3.1415926535897932384
CONSTANT        ks      0.195
CONSTANT        kcos    0.448
CONSTANT        kdet    1.9e-10
CONSTANT        kdep    0.2
CONSTANT        F       16


[TERMS]
P       2*PI*(D/2)
Rh      4/D
T1      -((Topt-T)/(Topt-Ti))^2
UV      10^(-kcos*F)


[PIPES]
RATE    C1      -kcn*N*C
RATE    C2      -((kw*kf)/((kw+kf)*Rh))*C
RATE    C       C1+C2
RATE    N       -Yn*kcn*N*C
RATE    S       -Yn*kcn*S*C
```

```
RATE    H        Yh*kcn*N*C
RATE    Xb1      umb*(S/ks+S)*EXP(-(kinact*C))*EXP((T1))*Xb
RATE    Xb2     -kdep*Xb
RATE    Xb      Xb1+Xb2
RATE    Xa1      uma*EXP(-(kinact*C))*EXP((T1))*Xa
RATE    Xa2     -kdet*Us*Xa
RATE    Xa      Xa1+Xa2
RATE    UVXb     UV*Xb


[TANKS]
RATE    C1      -kcn*N*C
RATE    C       C1+C2
RATE    N       -Yn*kcn*N*C
RATE    S       -Yn*kcn*S*C
RATE    H        Yh*kcn*N*C
RATE    Xb1      umb*(S/ks+S)*EXP(-(kinact*C))*EXP((T1))*Xb
RATE    Xb      Xb1+Xb2
RATE    Xa2     -kdet*Us*Xa
RATE    UVXb     UV*Xb


[SOURCES]
CONCEN  Lake            C       0.49
CONCEN  Lake            N       3.55
CONCEN  Lake            H       20
CONCEN  Lake            Xb      1e-4
CONCEN  Lake            S       0.05
CONCEN  River           C       1.0
CONCEN  River           N       0.56
CONCEN  River           H       20
CONCEN  River           Xb      1e-3
CONCEN  River           S       0.1


[REPORTS]
LINKS   ALL
NODES   ALL
SPECIES         C       YES             4
SPECIES         N       YES             4
SPECIES         H       YES             4
SPECIES         Xb      YES             15
SPECIES         S       YES             4
SPECIES         Xa      YES             4
SPECIES         UVXb    YES             50
```

Scenario 1 – *E. coli*:

```
[TITLE]
Ecoli

[OPTIONS]
  AREA_UNITS FT2             ;Surface concentration is mass/m2
  RATE_UNITS DAY             ;Reaction rates are concentration/hour
  SOLVER     EUL            ;5-th order Runge-Kutta integrator
  TIMESTEP   300            ;300 sec (4 min) solution time step
  COUPLING   NONE
  COMPILER   NONE
  ATOL      0.01
  RTOL      0.001

[SPECIES]
BULK            C       MG              ;residual chlorine
BULK            C1      MG
WALL            C2      MG
BULK            S        MG             ;BDOC
BULK            H       UG              ;THMs
BULK            N       MG              ;TOC
```

```
BULK            E       CFU
BULK            UVE     CFU



[COEFFICIENTS]
CONSTANT        kcn     0.165           ;second order rate constant chlorine to TOC
CONSTANT        Yn      0.98            ;yield coefficient TOC/BDOC
CONSTANT        Yh      112.435         ;yield coefficient THM
CONSTANT        kw      3.7e-4          ;wall decay coefficient chlorine
CONSTANT        kf      0.4426          ;mass-transfer coefficient chlorine
CONSTANT        umb     1.512           ;max specific growth for planktonic
CONSTANT        kinact  0.35            ;microbial growth inactivation
CONSTANT        Topt    35              ;optimal temperature
CONSTANT        T       25              ;temperature
CONSTANT        Ti      30              ;temp dependant shape parameter
CONSTANT        uma     0.003           ;max specific growth biofilm
CONSTANT        PI      3.141592653589793238
CONSTANT        ks      0.195
CONSTANT        kcos    0.811
CONSTANT        kdet    1.9e-10
CONSTANT        kdep    0.2
CONSTANT        ke      0.10349
CONSTANT        I       3.5


[TERMS]
P       2*PI*(D/2)
Rh      4/D
T1      -((Topt-T)/(Topt-Ti))^2
Et      36.7/(U*30.48)
F       I*Et
UV      10^(-kcos*F)

[PIPES]
RATE    C1      -kcn*N*C
RATE    C2      -((kw*kf)/((kw+kf)*Rh))*C
RATE    C       C1+C2
RATE    N       -Yn*kcn*N*C
RATE    S       -Yn*kcn*S*C
RATE    H        Yh*kcn*N*C
RATE    E        -ke*C*E
RATE    UVE      UV*E

[TANKS]
RATE    C1      -kcn*N*C
RATE    C       C1+C2
RATE    N       -Yn*kcn*N*C
RATE    S       -Yn*kcn*S*C
RATE    H        Yh*kcn*N*C
RATE    E        -ke*C*E
RATE    UVE      UV*E

[SOURCES]
CONCEN  Lake            C       0.49
CONCEN  Lake            N       3.55
CONCEN  Lake            H       20
CONCEN  Lake            S       0.05
CONCEN  River           C       1.0
CONCEN  River           N       0.56
CONCEN  River           H       20
CONCEN  River           S       0.1
CONCEN   Lake           E       15
CONCEN  River           E       15

[REPORTS]
NODES   ALL
LINKS   ALL
SPECIES         C       YES             4
```

```
SPECIES         N       YES             4
SPECIES         H       YES             4
SPECIES         S       YES             4
SPECIES         E       YES             4
SPECIES         UVE     YES             30
```

Scenario 2 – *E. coli*:

```
[TITLE]
Ecoli

[OPTIONS]
 AREA_UNITS FT2         ;Surface concentration is mass/m2
 RATE_UNITS DAY         ;Reaction rates are concentration/hour
 SOLVER    EUL       ;5-th order Runge-Kutta integrator
 TIMESTEP   300        ;300 sec (4 min) solution time step
 COUPLING   NONE
 COMPILER   NONE
 ATOL          0.01
 RTOL          0.001

[SPECIES]
BULK                    C           MG                      ;residual chlorine
BULK                    C1          MG
WALL                    C2          MG
BULK                    S      MG               ;BDOC
BULK                    H           UG                      ;THMs
BULK                    N           MG                      ;TOC
BULK                    E           CFU
BULK              UVE    CFU



[COEFFICIENTS]
CONSTANT kcn            0.165                   ;second order rate constant chlorine to TOC
CONSTANT Yn             0.98                    ;yield coefficient TOC/BDOC
CONSTANT Yh             112.435                 ;yield coefficient THM
CONSTANT kw             3.7e-4          ;wall decay coefficient chlorine
CONSTANT kf      0.4426                         ;mass-transfer coefficient chlorine
CONSTANT umb            1.512                   ;max specific growth for planktonic
CONSTANT kinact         0.35                    ;microbial growth inactivation
CONSTANT Topt           35                      ;optimal temperature
CONSTANT T              25                      ;temperature
CONSTANT Ti             30                      ;temp dependant shape parameter
CONSTANT uma            0.003                   ;max specific growth biofilm
CONSTANT PI             3.141592653589793238
CONSTANT ks             0.195
CONSTANT kcos           0.811
CONSTANT kdet           1.9e-10
CONSTANT kdep           0.2
CONSTANT ke             0.10349
CONSTANT F              16


[TERMS]
P           2*PI*(D/2)
Rh          4/D
T1          -((Topt-T)/(Topt-Ti))^2
UV          10^(-kcos*F)

[PIPES]
RATE        C1          -kcn*N*C
RATE        C2          -((kw*kf)/((kw+kf)*Rh))*C
RATE        C           C1+C2
RATE        N           -Yn*kcn*N*C
```

```
RATE      S          -Yn*kcn*S*C
RATE      H           Yh*kcn*N*C
RATE      E           -ke*C*E
RATE      UVE         UV*E

[TANKS]
RATE      C1         -kcn*N*C
RATE      C          C1+C2
RATE      N          -Yn*kcn*N*C
RATE      S          -Yn*kcn*S*C
RATE      H           Yh*kcn*N*C
RATE      E           -ke*C*E
RATE      UVE         UV*E

[SOURCES]
CONCEN    Lake                 C          0.49
CONCEN    Lake                 N          3.55
CONCEN    Lake                 H          20
CONCEN    Lake                 S          0.05
CONCEN    River                C          1.0
CONCEN    River                N          0.56
CONCEN    River                H          20
CONCEN    River                S          0.1
CONCEN  Lake                   E          15
CONCEN    River                E          15

[REPORTS]
LINKS     ALL
NODES     ALL
SPECIES              C          YES                 4
SPECIES              N          YES                 4
SPECIES              H          YES                 4
SPECIES              S          YES                 4
SPECIES              E          YES                 4
SPECIES              UVE        YES                 30
```

Scenario 1 - *E. coli* outbreak at node 195:

```
[TITLE]
Ecoli

[OPTIONS]
  AREA_UNITS FT2             ;Surface concentration is mass/m2
  RATE_UNITS DAY             ;Reaction rates are concentration/hour
  SOLVER     EUL            ;5-th order Runge-Kutta integrator
  TIMESTEP   300            ;300 sec (4 min) solution time step
  COUPLING   NONE
  COMPILER   NONE
  ATOL       0.01
  RTOL       0.001

[SPECIES]
BULK            C       MG              ;residual chlorine
BULK            C1      MG
WALL            C2      MG
BULK            S        MG             ;BDOC
BULK            H       UG              ;THMs
BULK            N       MG              ;TOC
BULK            E       CFU
BULK             UVE    CFU


[COEFFICIENTS]
CONSTANT        kcn     0.165           ;second order rate constant chlorine to TOC
CONSTANT        Yn      0.98            ;yield coefficient TOC/BDOC
```

```
CONSTANT        Yh      112.435         ;yield coefficient THM
CONSTANT        kw      3.7e-4          ;wall decay coefficient chlorine
CONSTANT        kf      0.4426          ;mass-transfer coefficient chlorine
CONSTANT        umb     1.512           ;max specific growth for planktonic
CONSTANT        kinact  0.35            ;microbial growth inactivation
CONSTANT        Topt    35              ;optimal temperature
CONSTANT        T       25              ;temperature
CONSTANT        Ti      30              ;temp dependant shape parameter
CONSTANT        uma     0.003           ;max specific growth biofilm
CONSTANT        PI      3.141592653589793238
CONSTANT        ks      0.195
CONSTANT        kcos    0.811
CONSTANT        kdet    1.9e-10
CONSTANT        kdep    0.2
CONSTANT        ke      0.10349
CONSTANT        I       3.5


[TERMS]
P       2*PI*(D/2)
Rh      4/D
T1      -((Topt-T)/(Topt-Ti))^2
Et      36.7/((U*30.48))
F       Et*I
UV      10^(-kcos*F)

[PIPES]
RATE    C1      -kcn*N*C
RATE    C2      -((kw*kf)/((kw+kf)*Rh))*C
RATE    C       C1+C2
RATE    N       -Yn*kcn*N*C
RATE    S       -Yn*kcn*S*C
RATE    H        Yh*kcn*N*C
RATE    E        -ke*C*E
RATE    UVE      UV*E

[TANKS]
RATE    C1      -kcn*N*C
RATE    C       C1+C2
RATE    N       -Yn*kcn*N*C
RATE    S       -Yn*kcn*S*C
RATE    H        Yh*kcn*N*C
RATE    E        -ke*C*E
RATE    UVE      UV*E

[SOURCES]
CONCEN  Lake            C       0.49
CONCEN  Lake            N       3.55
CONCEN  Lake            H       20
CONCEN  Lake            S       0.05
CONCEN  River           C       1.0
CONCEN  River           N       0.56
CONCEN  River           H       20
CONCEN  River           S       0.1
FLOWPACED 195           E       15

[REPORTS]
LINKS           151     251     277     291
NODES           15      203     219     251     253
SPECIES         C       YES             4
SPECIES         N       YES             4
SPECIES         H       YES             4
SPECIES         S       YES             4
SPECIES         E       YES             4
SPECIES         UVE     YES             30
```

Scenario 2 – *E. coli* outbreak at node 195:

```
[TITLE]
Ecoli

[OPTIONS]
  AREA_UNITS FT2              ;Surface concentration is mass/m2
  RATE_UNITS DAY              ;Reaction rates are concentration/hour
  SOLVER     EUL             ;5-th order Runge-Kutta integrator
  TIMESTEP   300             ;300 sec (4 min) solution time step
  COUPLING   NONE
  COMPILER   NONE
  ATOL       0.01
  RTOL       0.001

[SPECIES]
BULK           C       MG              ;residual chlorine
BULK           C1      MG
WALL           C2      MG
BULK           S        MG             ;BDOC
BULK           H       UG              ;THMs
BULK           N       MG              ;TOC
BULK           E       CFU
BULK            UVE     CFU



[COEFFICIENTS]
CONSTANT       kcn     0.165           ;second order rate constant chlorine to TOC
CONSTANT       Yn      0.98            ;yield coefficient TOC/BDOC
CONSTANT       Yh      112.435         ;yield coefficient THM
CONSTANT       kw      3.7e-4           ;wall decay coefficient chlorine
CONSTANT       kf       0.4426         ;mass-transfer coefficient chlorine
CONSTANT       umb     1.512           ;max specific growth for planktonic
CONSTANT       kinact  0.35            ;microbial growth inactivation
CONSTANT       Topt    35              ;optimal temperature
CONSTANT       T       25              ;temperature
CONSTANT       Ti      30              ;temp dependant shape parameter
CONSTANT       uma     0.003           ;max specific growth biofilm
CONSTANT       PI      3.141592653589793238
CONSTANT       ks      0.195
CONSTANT       kcos    0.811
CONSTANT       kdet    1.9e-10
CONSTANT       kdep    0.2
CONSTANT       ke      0.10349
CONSTANT       F       16


[TERMS]
P       2*PI*(D/2)
Rh      4/D
T1      -((Topt-T)/(Topt-Ti))^2
UV      10^(-kcos*F)

[PIPES]
RATE    C1      -kcn*N*C
RATE    C2      -((kw*kf)/((kw+kf)*Rh))*C
RATE    C       C1+C2
RATE    N       -Yn*kcn*N*C
RATE    S       -Yn*kcn*S*C
RATE    H        Yh*kcn*N*C
RATE    E        -ke*C*E
RATE    UVE      UV*E

[TANKS]
RATE    C1      -kcn*N*C
RATE    C       C1+C2
RATE    N       -Yn*kcn*N*C
RATE    S       -Yn*kcn*S*C
```

```
RATE    H        Yh*kcn*N*C
RATE    E        -ke*C*E
RATE    UVE      UV*E

[SOURCES]
CONCEN  Lake           C       0.49
CONCEN  Lake           N       3.55
CONCEN  Lake           H       20
CONCEN  Lake           S       0.05
CONCEN  River          C       1.0
CONCEN  River          N       0.56
CONCEN  River          H       20
CONCEN  River          S       0.1
FLOWPACED 195          E       15

[REPORTS]
LINKS          151     251     277     291
NODES          15      203     219     251     253
SPECIES        C       YES             4
SPECIES        N       YES             4
SPECIES        H       YES             4
SPECIES        S       YES             4
SPECIES        E       YES             30
SPECIES        UVE     YES             30
```

Appendix B: EPANET Model Details

```
[TITLE]
EPANET Example Network 3
Example showing how the percent of Lake water in a dual-source
system changes over time.

[JUNCTIONS]
;ID                      Elev            Demand          Pattern
 10                      147             0                                       ;
 15                      32              1               3                       ;
 20                      129             0                                       ;
 35                      12.5            1               4                       ;
 40                      131.9           0                                       ;
 50                      116.5           0                                       ;
 60                      0               0                                       ;
 601                     0               0                                       ;
 61                      0               0                                       ;
 101                     42              189.95                                  ;
 103                     43              133.2                                   ;
 105                     28.5            135.37                                  ;
 107                     22              54.64                                   ;
 109                     20.3            231.4                                   ;
 111                     10              141.94                                  ;
 113                     2               20.01                                   ;
 115                     14              52.1                                    ;
 117                     13.6            117.71                                  ;
 119                     2               176.13                                  ;
 120                     0               0                                       ;
 121                     -2              41.63                                   ;
 123                     11              1               2                       ;
 125                     11              45.6                                    ;
 127                     56              17.66                                   ;
 129                     51              0                                       ;
 131                     6               42.75                                   ;
 139                     31              5.89                                    ;
 141                     4               9.85                                    ;
 143                     -4.5            6.2                                     ;
 145                     1               27.63                                   ;
 147                     18.5            8.55                                    ;
 149                     16              27.07                                   ;
 151                     33.5            144.48                                  ;
 153                     66.2            44.17                                   ;
 157                     13.1            51.79                                   ;
 159                     6               41.32                                   ;
 161                     4               15.8                                    ;
 163                     5               9.42                                    ;
 164                     5               0                                       ;
 166                     -2              2.6                                     ;
 167                     -5              14.56                                   ;
 169                     -5              0                                       ;
 171                     -4              39.34                                   ;
 173                     -4              0                                       ;
 177                     8               58.17                                   ;
 179                     8               0                                       ;
 181                     8               0                                       ;
 183                     11              0                                       ;
 184                     16              0                                       ;
 185                     16              25.65                                   ;
 187                     12.5            0                                       ;
 189                     4               107.92                                  ;
 191                     25              81.9                                    ;
 193                     18              71.31                                   ;
 195                     15.5            0                                       ;
 197                     23              17.04                                   ;
 199                     -2              119.32                                  ;
 201                     0.1             44.61                                   ;
 203                     2               1               5                       ;
 204                     21              0                                       ;
 205                     21              65.36                                   ;
 206                     1               0                                       ;
```

```
 207                  9              69.39                                   ;
 208                  16             0                                       ;
 209                  -2             0.87                                    ;
 211                  7              8.67                                    ;
 213                  7              13.94                                   ;
 215                  7              92.19                                   ;
 217                  6              24.22                                   ;
 219                  4              41.32                                   ;
 225                  8              22.8                                    ;
 229                  10.5           64.18                                   ;
 231                  5              16.48                                   ;
 237                  14             15.61                                   ;
 239                  13             44.61                                   ;
 241                  13             0                                       ;
 243                  14             4.34                                    ;
 247                  18             70.38                                   ;
 249                  18             0                                       ;
 251                  30             24.16                                   ;
 253                  36             54.52                                   ;
 255                  27             40.39                                   ;
 257                  17             0                                       ;
 259                  25             0                                       ;
 261                  0              0                                       ;
 263                  0              0                                       ;
 265                  0              0                                       ;
 267                  21             0                                       ;
 269                  0              0                                       ;
 271                  6              0                                       ;
 273                  8              0                                       ;
 275                  10             0                                       ;

[RESERVOIRS]
;ID                   Head           Pattern
 River                220.0                        ;
 Lake                 167.0                        ;

[TANKS]
;ID                   Elevation      InitLevel      MinLevel       MaxLevel       Diameter
       MinVol         VolCurve              Overflow
 1                    131.9          13.1           .1             32.1           85
       0                                    ;
 2                    116.5          23.5           6.5            40.3           50
       0                                    ;
 3                    129.0          29.0           4.0            35.5           164
       0                                    ;

[PIPES]
;ID                   Node1                 Node2                  Length         Diameter
       Roughness      MinorLoss      Status
 20                   3                     20                     99             99
       199            0              Open   ;
 40                   1                     40                     99             99
       199            0              Open   ;
 50                   2                     50                     99             99
       199            0              Open   ;
 60                   River                 60                     1231           24
       140            0              Open   ;
 101                  10                    101                    14200          18
       110            0              Open   ;
 103                  101                   103                    1350           16
       130            0              Open   ;
 105                  101                   105                    2540           12
       130            0              Open   ;
 107                  105                   107                    1470           12
       130            0              Open   ;
 109                  103                   109                    3940           16
       130            0              Open   ;
 111                  109                   111                    2000           12
       130            0              Open   ;
```

112	130	1150	Open	111;	1160	12
113	130	1110	Open	113;	1680	12
114	130	1150	Open	113;	2000	8
115	130	1070	Open	115;	1950	8
116	130	1130	Open	193;	1660	12
117	130	2630	Open	105;	2725	12
119	130	1150	Open	117;	2180	12
120	130	1190	Open	120;	730	12
121	130	1200	Open	117;	1870	12
122	130	1210	Open	120;	2050	8
123	141	1210	Open	119;	2000	30
125	141	1230	Open	121;	1500	30
129	130	1210	Open	125;	930	24
131	130	1250	Open	127;	3240	24
133	130	200	Open	127;	785	20
135	130	1270	Open	129;	900	24
137	130	1290	Open	131;	6480	16
145	130	1290	Open	139;	2750	8
147	130	1390	Open	141;	2050	8
149	130	1430	Open	141;	1400	8
151	130	150	Open	143;	1650	8
153	130	1450	Open	141;	3510	12
155	130	1470	Open	145;	2200	12
159	130	1470	Open	149;	880	12
161	130	1490	Open	151;	1020	8
163	130	1510	Open	153;	1170	12
169	130	1250	Open	153;	4560	8
171	130	1190	Open	151;	3460	12
173	141	1190	Open	157;	2080	30
175	141	1570	Open	159;	2910	30
177	141	1590	Open	161;	2000	30
179	141	1610	Open	163;	430	30
180	130	1630	Open	164;	150	14
181	130	1640	Open	166;	490	14

183		265		169	590	30
	141	0	Open	;		
185		167		169	60	8
	130	0	Open	;		
186		187		204	99.9	8
	130	0	Open	;		
187		169		171	1270	30
	141	0	Open	;		
189		171		173	50	30
	141	0	Open	;		
191		271		171	760	24
	130	0	Open	;		
193		35		181	30	24
	130	0	Open	;		
195		181		177	30	12
	130	0	Open	;		
197		177		179	30	12
	130	0	Open	;		
199		179		183	210	12
	130	0	Open	;		
201		40		179	1190	12
	130	0	Open	;		
202		185		184	99.9	8
	130	0	Open	;		
203		183		185	510	8
	130	0	Open	;		
204		184		205	4530.	12
	130	0	Open	;		
205		204		185	1325.	12
	130	0	Open	;		
207		189		183	1350	12
	130	0	Open	;		
209		189		187	500	8
	130	0	Open	;		
211		169		269	646	12
	130	0	Open	;		
213		191		187	2560	12
	130	0	Open	;		
215		267		189	1230	12
	130	0	Open	;		
217		191		193	520	12
	130	0	Open	;		
219		193		195	360	12
	130	0	Open	;		
221		161		195	2300	8
	130	0	Open	;		
223		197		191	1150	12
	130	0	Open	;		
225		111		197	2790	12
	130	0	Open	;		
229		173		199	4000	24
	141	0	Open	;		
231		199		201	630	24
	141	0	Open	;		
233		201		203	120	24
	130	0	Open	;		
235		199		273	725	12
	130	0	Open	;		
237		205		207	1200	12
	130	0	Open	;		
238		207		206	450	12
	130	0	Open	;		
239		275		207	1430	12
	130	0	Open	;		
240		206		208	510	12
	130	0	Open	;		
241		208		209	885	12
	130	0	Open	;		

243		209		211	1210	16
	130	0	Open	;		
245		211		213	990	16
	130	0	Open	;		
247		213		215	4285	16
	130	0	Open	;		
249		215		217	1660	16
	130	0	Open	;		
251		217		219	2050	14
	130	0	Open	;		
257		217		225	1560	12
	130	0	Open	;		
261		213		229	2200	8
	130	0	Open	;		
263		229		231	1960	12
	130	0	Open	;		
269		211		237	2080	12
	130	0	Open	;		
271		237		229	790	8
	130	0	Open	;		
273		237		239	510	12
	130	0	Open	;		
275		239		241	35	12
	130	0	Open	;		
277		241		243	2200	12
	130	0	Open	;		
281		241		247	445	10
	130	0	Open	;		
283		239		249	430	12
	130	0	Open	;		
285		247		249	10	12
	130	0	Open	;		
287		247		255	1390	10
	130	0	Open	;		
289		50		255	925	10
	130	0	Open	;		
291		255		253	1100	10
	130	0	Open	;		
293		255		251	1100	8
	130	0	Open	;		
295		249		251	1450	12
	130	0	Open	;		
297		120		257	645	8
	130	0	Open	;		
299		257		259	350	8
	130	0	Open	;		
301		259		263	1400	8
	130	0	Open	;		
303		257		261	1400	8
	130	0	Open	;		
305		117		261	645	12
	130	0	Open	;		
307		261		263	350	12
	130	0	Open	;		
309		265		267	1580	8
	130	0	Open	;		
311		193		267	1170	12
	130	0	Open	;		
313		269		189	646	12
	130	0	Open	;		
315		181		271	260	24
	130	0	Open	;		
317		273		275	2230	8
	130	0	Open	;		
319		273		205	645	12
	130	0	Open	;		
321		163		265	1200	30
	141	0	Open	;		

```
 323                    201             275                     300         12
       130              0               Open    ;
 325                    269             271                     1290        8
       130              0               Open    ;
 329                    61              123                     45500       30
       140              0               Open    ;
 330                    60              601                     1           30
       140              0               Closed  ;
 333                    601             61                      1           30
       140              0               Open    ;

[PUMPS]
;ID                     Node1           Node2                   Parameters
 10                     Lake            10                      HEAD 1  ;
 335                    60              61                      HEAD 2  ;

[VALVES]
;ID                     Node1           Node2                   Diameter    Type    Setting
       MinorLoss

[TAGS]

[DEMANDS]
;Junction               Demand          Pattern         Category

[STATUS]
;ID                     Status/Setting
 10                     Closed

[PATTERNS]
;ID                     Multipliers
;General Default Demand Pattern
 1                      1.34            1.94            1.46            1.44        .76
       .92
 1                      .85             1.07            .96             1.1         1.08
       1.19
 1                      1.16            1.08            .96             .83         .79
       .74
 1                      .64             .64             .85             .96         1.24
       1.67
;Demand Pattern for Node 123
 2                      0               0               0               0           0
       1219
 2                      0               0               0               1866        1836
       1818
 2                      1818            1822            1822            1817        1824
       1816
 2                      1833            1817            1830            1814        1840
       1859
;Demand Pattern for Node 15
 3                      620             620             620             620         620
       360
 3                      360             0               0               0           0
       360
 3                      360             360             360             360         0
       0
 3                      0               0               0               0           360
       360
;Demand Pattern for Node 35
 4                      1637            1706            1719            1719        1791
       1819
 4                      1777            1842            1815            1825        1856
       1801
 4                      1819            1733            1664            1620        1613
       1620
 4                      1616            1647            1627            1627        1671
       1668
;Demand Pattern for Node 203
```

```
 5                      4439            4531            4511            4582            4531
        4582
 5                      4572            4613            4643            4643            4592
        4613
 5                      4531            4521            4449            4439            4449
        4460
 5                      4439            4419            4368            4399            4470
        4480

[CURVES]
;ID                     X-Value         Y-Value
;PUMP: PUMP: Pump Curve for Pump 10 (Lake Source)
 1                      0               104.
 1                      2000.           92.
 1                      4000.           63.
;PUMP: PUMP: Pump Curve for Pump 335 (River Source)
 2                      0               200.
 2                      8000.           138.
 2                      14000.          86.

[CONTROLS]
;Lake source operates only part of the day
Link 10 OPEN AT TIME 1
Link 10 CLOSED AT TIME 15

;Pump 335 controlled by level in Tank 1
;When pump is closed, bypass pipe is opened
Link 335 OPEN IF Node 1 BELOW 17.1
Link 335 CLOSED IF Node 1 ABOVE 19.1
Link 330 CLOSED IF Node 1 BELOW 17.1
Link 330 OPEN IF Node 1 ABOVE 19.1



[RULES]


[ENERGY]
 Global Efficiency      75
 Global Price           0.0
 Demand Charge          0.0

[EMITTERS]
;Junction               Coefficient

[QUALITY]
;Node                   InitQual

[SOURCES]
;Node                   Type            Quality         Pattern

[REACTIONS]
;Type           Pipe/Tank               Coefficient


[REACTIONS]
 Order Bulk             1
 Order Tank             1
 Order Wall             1
 Global Bulk            0.0
 Global Wall            0.0
 Limiting Potential     0.0
 Roughness Correlation  0.0

[MIXING]
;Tank                   Model

[TIMES]
 Duration               120:00
```

```
 Hydraulic Timestep    1:00
 Quality Timestep      0:05
 Pattern Timestep      1:00
 Pattern Start         0:00
 Report Timestep       1:00
 Report Start          0:00
 Start ClockTime       12 am
 Statistic             NONE

[REPORT]
 Status                Yes
 Summary               No
 Page                  0

[OPTIONS]
 Units                 GPM
 Headloss              H-W
 Specific Gravity      1.0
 Viscosity             1.0
 Trials                40
 Accuracy              0.001
 CHECKFREQ             2
 MAXCHECK              10
 DAMPLIMIT             0
 Unbalanced            Continue 10
 Pattern               1
 Demand Multiplier     1.0
 Emitter Exponent      0.5
 Quality               Age mg/L
 Diffusivity           1.0
 Tolerance             0.01

[COORDINATES]
;Node                  X-Coord                 Y-Coord
10                     9.000                   27.850
15                     38.680                  23.760
20                     29.440                  26.910
35                     25.460                  10.520
40                     27.020                  9.810
50                     33.010                  3.010
60                     23.900                  29.940
601                    23.000                  29.490
61                     23.710                  29.030
101                    13.810                  22.940
103                    12.960                  21.310
105                    16.970                  21.280
107                    18.450                  20.460
109                    17.640                  18.920
111                    20.210                  17.530
113                    22.040                  16.610
115                    20.980                  19.180
117                    21.690                  21.280
119                    23.700                  22.760
120                    22.080                  23.100
121                    23.540                  25.500
123                    23.370                  27.310
125                    24.590                  25.640
127                    29.290                  26.400
129                    30.320                  26.390
131                    37.890                  29.550
139                    33.280                  24.540
141                    35.680                  23.080
143                    37.470                  21.970
145                    33.020                  19.290
147                    30.240                  20.380
149                    29.620                  20.740
151                    28.290                  21.390
153                    28.130                  22.630
157                    24.850                  20.160
```

```
159                     23.120                  17.500
161                     25.100                  15.280
163                     25.390                  14.980
164                     25.980                  15.140
166                     26.480                  15.130
167                     25.880                  12.980
169                     25.680                  12.740
171                     26.650                  11.800
173                     26.870                  11.590
177                     25.920                  10.590
179                     25.710                  10.400
181                     25.720                  10.740
183                     25.450                  10.180
184                     25.150                  9.520
185                     25.010                  9.670
187                     23.640                  11.040
189                     24.150                  11.370
191                     22.100                  14.070
193                     22.880                  14.350
195                     23.180                  14.720
197                     20.970                  15.180
199                     29.420                  8.440
201                     30.890                  8.570
203                     31.140                  8.890
204                     23.800                  10.900
205                     29.200                  6.460
206                     31.660                  6.640
207                     31.000                  6.610
208                     32.540                  6.810
209                     33.760                  6.590
211                     34.200                  5.540
213                     35.260                  6.160
215                     39.950                  8.730
217                     42.110                  8.670
219                     44.860                  9.320
225                     43.530                  7.380
229                     36.160                  3.490
231                     38.380                  2.540
237                     35.370                  3.080
239                     35.760                  2.310
241                     35.870                  2.110
243                     37.040                  0.000
247                     35.020                  2.050
249                     35.020                  1.810
251                     34.150                  1.100
253                     32.170                  1.880
255                     33.510                  2.450
257                     21.170                  23.320
259                     20.800                  23.400
261                     20.790                  21.450
263                     20.320                  21.570
265                     25.390                  13.600
267                     23.380                  12.950
269                     25.030                  12.140
271                     25.970                  11.000
273                     29.160                  7.380
275                     31.070                  8.290
River                   24.150                  31.060
Lake                    8.000                   27.530
1                       27.460                  9.840
2                       32.990                  3.450
3                       29.410                  27.270

[VERTICES]
;Link                   X-Coord                 Y-Coord

[LABELS]
;X-Coord              Y-Coord               Label & Anchor Node
8.000                   29.420                  "LAKE"
```

```
25.000                31.100                "RIVER"

[BACKDROP]
  DIMENSIONS   6.160                -1.550                46.700                32.610
 UNITS                None
 FILE
 OFFSET               0.00                  0.00

[END]
```

```
  Hydraulic Status:
  -----------------------------------------------------------------------
     0:00:00: Balanced after 5 trials
     0:00:00: Reservoir River is emptying
     0:00:00: Reservoir Lake is closed
     0:00:00: Tank 1 is filling at 13.10 ft
     0:00:00: Tank 2 is emptying at 23.50 ft
     0:00:00: Tank 3 is filling at 29.00 ft

     1:00:00: Pump 10 changed by timer control
     1:00:00: Balanced after 7 trials
     1:00:00: Reservoir Lake is emptying
     1:00:00: Pump 10 changed from closed to open

     2:00:00: Balanced after 3 trials
     2:00:00: Tank 2 is filling at 20.90 ft

     3:00:00: Balanced after 2 trials

     4:00:00: Balanced after 3 trials

     4:13:33: Pump 335 changed by Tank 1 control
     4:13:33: Pipe 330 changed by Tank 1 control
     4:13:33: Balanced after 4 trials
     4:13:33: Pipe 330 changed from closed to open
     4:13:33: Pump 335 changed from open to closed

     5:00:00: Balanced after 3 trials
     5:00:00: Tank 3 is emptying at 34.30 ft

     6:00:00: Balanced after 3 trials
     6:00:00: Tank 3 is filling at 34.12 ft

     7:00:00: Balanced after 3 trials

     8:00:00: Balanced after 2 trials

     9:00:00: Balanced after 3 trials
     9:00:00: Tank 3 is emptying at 35.15 ft

    10:00:00: Balanced after 2 trials
    10:00:00: Tank 1 is emptying at 22.20 ft

    11:00:00: Balanced after 3 trials
    11:00:00: Tank 2 is emptying at 27.70 ft

    12:00:00: Balanced after 2 trials
    12:00:00: Tank 2 is filling at 27.64 ft

    13:00:00: Balanced after 3 trials
    13:00:00: Tank 1 is filling at 21.73 ft

    14:00:00: Balanced after 3 trials

    15:00:00: Pump 10 changed by timer control
    15:00:00: Balanced after 5 trials
    15:00:00: Reservoir Lake is closed
```

```
15:00:00: Tank 1 is emptying at 21.98 ft
15:00:00: Tank 2 is emptying at 28.20 ft
15:00:00: Pump 10 changed from open to closed

16:00:00: Balanced after 3 trials

17:00:00: Balanced after 2 trials

18:00:00: Balanced after 3 trials

19:00:00: Balanced after 2 trials

20:00:00: Balanced after 3 trials

21:00:00: Balanced after 2 trials

21:19:39: Pump 335 changed by Tank 1 control
21:19:39: Pipe 330 changed by Tank 1 control
21:19:39: Balanced after 5 trials
21:19:39: Tank 1 is filling at 17.10 ft
21:19:39: Tank 3 is filling at 29.68 ft
21:19:39: Pipe 330 changed from open to closed
21:19:39: Pump 335 changed from closed to open

22:00:00: Balanced after 3 trials
22:00:00: Tank 1 is emptying at 17.30 ft

23:00:00: Balanced after 3 trials

24:00:00: Balanced after 4 trials
24:00:00: Tank 1 is filling at 15.79 ft

25:00:00: Balanced after 4 trials
25:00:00: Tank 1 is emptying at 16.16 ft

26:00:00: Balanced after 4 trials
26:00:00: Tank 1 is filling at 15.25 ft

27:00:00: Balanced after 2 trials

28:00:00: Balanced after 4 trials
28:00:00: Tank 2 is filling at 19.96 ft

29:00:00: Balanced after 3 trials

30:00:00: Balanced after 3 trials

30:07:34: Balanced after 4 trials
30:07:34: Tank 3 is closed at 35.50 ft
30:07:34: Pipe 20 changed from open to temporarily closed

30:28:55: Pump 335 changed by Tank 1 control
30:28:55: Pipe 330 changed by Tank 1 control
30:28:55: Balanced after 6 trials
30:28:55: Tank 1 is emptying at 19.10 ft
30:28:55: Tank 3 is emptying at 35.50 ft
30:28:55: Pipe 20 changed from temporarily closed to open
30:28:55: Pipe 330 changed from closed to open
30:28:55: Pump 335 changed from open to closed

31:00:00: Balanced after 3 trials

32:00:00: Balanced after 3 trials

33:00:00: Balanced after 3 trials
33:00:00: Tank 2 is emptying at 24.51 ft

33:58:44: Pump 335 changed by Tank 1 control
33:58:44: Pipe 330 changed by Tank 1 control
```

```
33:58:44: Balanced after 5 trials
33:58:44: Tank 1 is filling at 17.10 ft
33:58:44: Tank 3 is filling at 32.96 ft
33:58:44: Pipe 330 changed from open to closed
33:58:44: Pump 335 changed from closed to open

34:00:00: Balanced after 2 trials

35:00:00: Balanced after 3 trials
35:00:00: Tank 1 is emptying at 17.25 ft

36:00:00: Balanced after 3 trials
36:00:00: Tank 1 is filling at 17.14 ft

37:00:00: Balanced after 3 trials
37:00:00: Tank 2 is filling at 23.36 ft

38:00:00: Balanced after 3 trials

39:00:00: Balanced after 2 trials

39:39:42: Balanced after 5 trials
39:39:42: Tank 3 is closed at 35.50 ft
39:39:42: Pipe 20 changed from open to temporarily closed

39:43:39: Pump 335 changed by Tank 1 control
39:43:39: Pipe 330 changed by Tank 1 control
39:43:39: Balanced after 6 trials
39:43:39: Tank 1 is emptying at 19.10 ft
39:43:39: Tank 3 is emptying at 35.50 ft
39:43:39: Pipe 20 changed from temporarily closed to open
39:43:39: Pipe 330 changed from closed to open
39:43:39: Pump 335 changed from open to closed

40:00:00: Balanced after 3 trials

41:00:00: Balanced after 2 trials

42:00:00: Balanced after 2 trials

43:00:00: Balanced after 3 trials

44:00:00: Balanced after 3 trials
44:00:00: Tank 2 is emptying at 27.01 ft

45:00:00: Balanced after 3 trials

45:52:21: Pump 335 changed by Tank 1 control
45:52:21: Pipe 330 changed by Tank 1 control
45:52:21: Balanced after 5 trials
45:52:21: Tank 1 is filling at 17.10 ft
45:52:21: Tank 3 is filling at 30.66 ft
45:52:21: Pipe 330 changed from open to closed
45:52:21: Pump 335 changed from closed to open

46:00:00: Balanced after 4 trials
46:00:00: Tank 1 is emptying at 17.16 ft

47:00:00: Balanced after 3 trials

48:00:00: Balanced after 4 trials
48:00:00: Tank 1 is filling at 15.83 ft

49:00:00: Balanced after 3 trials
49:00:00: Tank 1 is emptying at 16.26 ft

50:00:00: Balanced after 4 trials
50:00:00: Tank 1 is filling at 15.39 ft
```

```
51:00:00: Balanced after 2 trials

52:00:00: Balanced after 3 trials
52:00:00: Tank 2 is filling at 20.09 ft

53:00:00: Balanced after 3 trials

53:37:11: Balanced after 5 trials
53:37:11: Tank 3 is closed at 35.50 ft
53:37:11: Pipe 20 changed from open to temporarily closed

54:00:00: Balanced after 3 trials

54:10:24: Pump 335 changed by Tank 1 control
54:10:24: Pipe 330 changed by Tank 1 control
54:10:24: Balanced after 6 trials
54:10:24: Tank 1 is emptying at 19.10 ft
54:10:24: Tank 3 is emptying at 35.50 ft
54:10:24: Pipe 20 changed from temporarily closed to open
54:10:24: Pipe 330 changed from closed to open
54:10:24: Pump 335 changed from open to closed

55:00:00: Balanced after 3 trials

56:00:00: Balanced after 3 trials

57:00:00: Balanced after 3 trials
57:00:00: Tank 2 is emptying at 24.52 ft

57:53:02: Pump 335 changed by Tank 1 control
57:53:02: Pipe 330 changed by Tank 1 control
57:53:02: Balanced after 5 trials
57:53:02: Tank 1 is filling at 17.10 ft
57:53:02: Tank 3 is filling at 32.90 ft
57:53:02: Pipe 330 changed from open to closed
57:53:02: Pump 335 changed from closed to open

58:00:00: Balanced after 2 trials

59:00:00: Balanced after 3 trials
59:00:00: Tank 1 is emptying at 17.25 ft

60:00:00: Balanced after 3 trials
60:00:00: Tank 1 is filling at 17.14 ft

61:00:00: Balanced after 3 trials
61:00:00: Tank 2 is filling at 23.37 ft

62:00:00: Balanced after 3 trials

63:00:00: Balanced after 2 trials

63:40:30: Balanced after 5 trials
63:40:30: Tank 3 is closed at 35.50 ft
63:40:30: Pipe 20 changed from open to temporarily closed

63:44:13: Pump 335 changed by Tank 1 control
63:44:13: Pipe 330 changed by Tank 1 control
63:44:13: Balanced after 6 trials
63:44:13: Tank 1 is emptying at 19.10 ft
63:44:13: Tank 3 is emptying at 35.50 ft
63:44:13: Pipe 20 changed from temporarily closed to open
63:44:13: Pipe 330 changed from closed to open
63:44:13: Pump 335 changed from open to closed

64:00:00: Balanced after 3 trials

65:00:00: Balanced after 2 trials
```

```
66:00:00: Balanced after 2 trials

67:00:00: Balanced after 3 trials

68:00:00: Balanced after 3 trials
68:00:00: Tank 2 is emptying at 27.02 ft

69:00:00: Balanced after 3 trials

69:52:53: Pump 335 changed by Tank 1 control
69:52:53: Pipe 330 changed by Tank 1 control
69:52:53: Balanced after 5 trials
69:52:53: Tank 1 is filling at 17.10 ft
69:52:53: Tank 3 is filling at 30.66 ft
69:52:53: Pipe 330 changed from open to closed
69:52:53: Pump 335 changed from closed to open

70:00:00: Balanced after 4 trials
70:00:00: Tank 1 is emptying at 17.15 ft

71:00:00: Balanced after 3 trials

72:00:00: Balanced after 4 trials
72:00:00: Tank 1 is filling at 15.83 ft

73:00:00: Balanced after 3 trials
73:00:00: Tank 1 is emptying at 16.26 ft

74:00:00: Balanced after 4 trials
74:00:00: Tank 1 is filling at 15.39 ft

75:00:00: Balanced after 2 trials

76:00:00: Balanced after 3 trials
76:00:00: Tank 2 is filling at 20.09 ft

77:00:00: Balanced after 3 trials

77:37:45: Balanced after 5 trials
77:37:45: Tank 3 is closed at 35.50 ft
77:37:45: Pipe 20 changed from open to temporarily closed

78:00:00: Balanced after 3 trials

78:10:43: Pump 335 changed by Tank 1 control
78:10:43: Pipe 330 changed by Tank 1 control
78:10:43: Balanced after 6 trials
78:10:43: Tank 1 is emptying at 19.10 ft
78:10:43: Tank 3 is emptying at 35.50 ft
78:10:43: Pipe 20 changed from temporarily closed to open
78:10:43: Pipe 330 changed from closed to open
78:10:43: Pump 335 changed from open to closed

79:00:00: Balanced after 3 trials

80:00:00: Balanced after 3 trials

81:00:00: Balanced after 3 trials
81:00:00: Tank 2 is emptying at 24.52 ft

81:53:08: Pump 335 changed by Tank 1 control
81:53:08: Pipe 330 changed by Tank 1 control
81:53:08: Balanced after 5 trials
81:53:08: Tank 1 is filling at 17.10 ft
81:53:08: Tank 3 is filling at 32.90 ft
81:53:08: Pipe 330 changed from open to closed
81:53:08: Pump 335 changed from closed to open

82:00:00: Balanced after 2 trials
```

```
 83:00:00: Balanced after 3 trials
 83:00:00: Tank 1 is emptying at 17.25 ft

 84:00:00: Balanced after 3 trials
 84:00:00: Tank 1 is filling at 17.14 ft

 85:00:00: Balanced after 3 trials
 85:00:00: Tank 2 is filling at 23.37 ft

 86:00:00: Balanced after 3 trials

 87:00:00: Balanced after 2 trials

 87:40:29: Balanced after 5 trials
 87:40:29: Tank 3 is closed at 35.50 ft
 87:40:29: Pipe 20 changed from open to temporarily closed

 87:44:12: Pump 335 changed by Tank 1 control
 87:44:12: Pipe 330 changed by Tank 1 control
 87:44:12: Balanced after 6 trials
 87:44:12: Tank 1 is emptying at 19.10 ft
 87:44:12: Tank 3 is emptying at 35.50 ft
 87:44:12: Pipe 20 changed from temporarily closed to open
 87:44:12: Pipe 330 changed from closed to open
 87:44:12: Pump 335 changed from open to closed

 88:00:00: Balanced after 3 trials

 89:00:00: Balanced after 2 trials

 90:00:00: Balanced after 2 trials

 91:00:00: Balanced after 3 trials

 92:00:00: Balanced after 3 trials
 92:00:00: Tank 2 is emptying at 27.02 ft

 93:00:00: Balanced after 3 trials

 93:52:51: Pump 335 changed by Tank 1 control
 93:52:51: Pipe 330 changed by Tank 1 control
 93:52:51: Balanced after 5 trials
 93:52:51: Tank 1 is filling at 17.10 ft
 93:52:51: Tank 3 is filling at 30.66 ft
 93:52:51: Pipe 330 changed from open to closed
 93:52:51: Pump 335 changed from closed to open

 94:00:00: Balanced after 4 trials
 94:00:00: Tank 1 is emptying at 17.15 ft

 95:00:00: Balanced after 3 trials

 96:00:00: Balanced after 4 trials
 96:00:00: Tank 1 is filling at 15.83 ft

 97:00:00: Balanced after 3 trials
 97:00:00: Tank 1 is emptying at 16.26 ft

 98:00:00: Balanced after 4 trials
 98:00:00: Tank 1 is filling at 15.39 ft

 99:00:00: Balanced after 2 trials

100:00:00: Balanced after 3 trials
100:00:00: Tank 2 is filling at 20.09 ft

101:00:00: Balanced after 3 trials
```

```
101:37:42: Balanced after 5 trials
101:37:42: Tank 3 is closed at 35.50 ft
101:37:42: Pipe 20 changed from open to temporarily closed

102:00:00: Balanced after 3 trials

102:10:41: Pump 335 changed by Tank 1 control
102:10:41: Pipe 330 changed by Tank 1 control
102:10:41: Balanced after 6 trials
102:10:41: Tank 1 is emptying at 19.10 ft
102:10:41: Tank 3 is emptying at 35.50 ft
102:10:41: Pipe 20 changed from temporarily closed to open
102:10:41: Pipe 330 changed from closed to open
102:10:41: Pump 335 changed from open to closed

103:00:00: Balanced after 3 trials

104:00:00: Balanced after 3 trials

105:00:00: Balanced after 3 trials
105:00:00: Tank 2 is emptying at 24.52 ft

105:53:06: Pump 335 changed by Tank 1 control
105:53:06: Pipe 330 changed by Tank 1 control
105:53:06: Balanced after 5 trials
105:53:06: Tank 1 is filling at 17.10 ft
105:53:06: Tank 3 is filling at 32.90 ft
105:53:06: Pipe 330 changed from open to closed
105:53:06: Pump 335 changed from closed to open

106:00:00: Balanced after 2 trials

107:00:00: Balanced after 3 trials
107:00:00: Tank 1 is emptying at 17.25 ft

108:00:00: Balanced after 3 trials
108:00:00: Tank 1 is filling at 17.14 ft

109:00:00: Balanced after 3 trials
109:00:00: Tank 2 is filling at 23.37 ft

110:00:00: Balanced after 3 trials

111:00:00: Balanced after 2 trials

111:40:26: Balanced after 5 trials
111:40:26: Tank 3 is closed at 35.50 ft
111:40:26: Pipe 20 changed from open to temporarily closed

111:44:10: Pump 335 changed by Tank 1 control
111:44:10: Pipe 330 changed by Tank 1 control
111:44:10: Balanced after 6 trials
111:44:10: Tank 1 is emptying at 19.10 ft
111:44:10: Tank 3 is emptying at 35.50 ft
111:44:10: Pipe 20 changed from temporarily closed to open
111:44:10: Pipe 330 changed from closed to open
111:44:10: Pump 335 changed from open to closed

112:00:00: Balanced after 3 trials

113:00:00: Balanced after 2 trials

114:00:00: Balanced after 2 trials

115:00:00: Balanced after 3 trials

116:00:00: Balanced after 3 trials
116:00:00: Tank 2 is emptying at 27.02 ft
```

```
 117:00:00: Balanced after 3 trials

 117:52:50: Pump 335 changed by Tank 1 control
 117:52:50: Pipe 330 changed by Tank 1 control
 117:52:50: Balanced after 5 trials
 117:52:50: Tank 1 is filling at 17.10 ft
 117:52:50: Tank 3 is filling at 30.66 ft
 117:52:50: Pipe 330 changed from open to closed
 117:52:50: Pump 335 changed from closed to open

 118:00:00: Balanced after 4 trials
 118:00:00: Tank 1 is emptying at 17.15 ft

 119:00:00: Balanced after 3 trials

 120:00:00: Balanced after 4 trials
 120:00:00: Tank 1 is filling at 15.83 ft

Water Quality Mass Balance (hrs)
================================
Initial Mass:       0.00000e+00
Mass Inflow:        0.00000e+00
Mass Outflow:       8.29749e+07
Mass Reacted:      -1.58848e+08
Final Mass:         7.58736e+07
Mass Ratio:         1.00000
================================

Analysis ended Thu Dec 14 19:50:12 2023
```

Appendix C: Model Results

Scenario 1 – Planktonic Bacteria

<<< Link 151 >>>

Time hr:min	C MG/L	S MG/L	H UG/L	N MG/L	Xb CFU/L	Xa CFU/FT2	UVXb CFU/L
0:00	0	0	0	0	0	0	0
1:00	0	0	0	0	0	0	0
2:00	0	0	0	0	0	0	0
3:00	0	0	0	0	0	0	0
4:00	0	0	0	0	0	0	0
5:00	0.5602	0.0544	12.235	0.3047	0.00056	0	3.03683E-05
6:00	0.8922	0.0863	19.7483	0.483	0.000892	0	4.79093E-05
7:00	0.891	0.0859	19.8697	0.4811	0.000891	0	4.72705E-05
8:00	0.891	0.0854	20.2002	0.4782	0.000891	0	4.72705E-05
9:00	0.891	0.0849	20.5287	0.4754	0.000892	0	4.72705E-05
10:00	0.891	0.0844	20.8552	0.4725	0.000892	0	4.72705E-05
11:00	0.891	0.0839	21.1798	0.4697	0.000892	0	4.72705E-05
12:00	1	0.0938	23.9643	0.5254	0.001001	0	5.06234E-05
13:00	0.9852	0.0919	23.983	0.5144	0.000986	0	5.11949E-05
14:00	0.5027	0.0465	12.7307	0.2798	0.000501	0	2.56429E-05
15:00	0.5085	0.0474	13.296	0.3549	0.000498	0	2.51138E-05
16:00	0.4592	0.0432	11.513	0.3169	0.00045	0	2.3641E-05
17:00	0.4592	0.0431	11.6253	0.3159	0.00045	0	2.3641E-05
18:00	0.4592	0.043	11.7373	0.3149	0.000451	0	2.3641E-05
19:00	0.4592	0.0428	11.8489	0.314	0.000451	0	2.3641E-05
20:00	0.4592	0.0427	11.9602	0.313	0.000451	0	2.3641E-05
21:00	0.4592	0.0426	12.0711	0.312	0.000451	0	2.3641E-05
22:00	0.4592	0.0424	12.1818	0.3111	0.000451	0	2.3641E-05
23:00	0.0771	0.0074	1.7099	0.0417	7.72E-05	0	4.81797E-06
24:00:00	0.0771	0.0074	1.7124	0.0417	7.72E-05	0	5.30299E-06
25:00:00	0.7586	0.0712	18.8139	0.4469	0.000753	0	4.09755E-05
26:00:00	0.9878	0.095	22.2013	0.5318	0.000988	0	5.37937E-05
27:00:00	1	0.0966	22.1843	0.541	0.001	0	5.32888E-05
28:00:00	1	0.0966	22.1563	0.5412	0.001	0	5.31945E-05
29:00:00	1	0.0966	22.1918	0.5409	0.001	0	5.29455E-05
30:00:00	1	0.0963	22.3675	0.5394	0.001	0	5.20259E-05
31:00:00	1	0.0962	22.4714	0.5385	0.001	0	5.24104E-05
32:00:00	1	0.0955	22.8863	0.5348	0.001	0	5.24104E-05
33:00:00	1	0.0949	23.2985	0.5312	0.001001	0	5.24104E-05
34:00:00	1	0.0942	23.7079	0.5277	0.001001	0	5.24104E-05
35:00:00	1	0.0936	24.1145	0.5241	0.001001	0	5.24104E-05
36:00:00	0.5048	0.0477	11.876	0.2672	0.000505	0	2.63354E-05
37:00:00	0.5453	0.0512	13.0292	0.2868	0.000546	0	2.80362E-05
38:00:00	1	0.0939	23.9457	0.5256	0.001001	0	5.27248E-05
39:00:00	0.9626	0.0903	23.0752	0.5057	0.000964	0	4.98814E-05
40:00:00	0.892	0.0845	20.8586	0.4732	0.000893	0	4.61106E-05
41:00:00	0.892	0.084	21.184	0.4704	0.000893	0	4.61106E-05
42:00:00	0.892	0.0835	21.5074	0.4675	0.000893	0	4.61106E-05
43:00:00	0.892	0.083	21.8289	0.4647	0.000893	0	4.61106E-05
44:00:00	0.892	0.0825	22.1485	0.462	0.000893	0	4.61106E-05
45:00:00	0.892	0.082	22.4662	0.4592	0.000894	0	4.61106E-05
46:00:00	0.892	0.0815	22.7819	0.4564	0.000894	0	4.61106E-05
47:00:00	0.241	0.0228	5.679	0.1275	0.000242	0	1.39012E-05
48:00:00	0.241	0.0227	5.7028	0.1273	0.000242	0	1.5421E-05
49:00:00	0.8571	0.0802	20.6986	0.449	0.000858	0	4.62428E-05
50:00:00	0.9078	0.0872	20.4882	0.4881	0.000908	0	4.99835E-05
51:00:00	1	0.0965	22.2338	0.5405	0.001	0	5.37647E-05
52:00:00	1	0.0966	22.1639	0.5411	0.001	0	5.32E-05
53:00:00	1	0.0966	22.1961	0.5409	0.001	0	5.29175E-05
54:00:00	1	0.0963	22.359	0.5394	0.001	0	5.20078E-05
55:00:00	1	0.0962	22.4655	0.5385	0.001	0	5.24864E-05
56:00:00	1	0.0955	22.8805	0.5349	0.001	0	5.24864E-05
57:00:00	1	0.0949	23.2927	0.5313	0.001001	0	5.24864E-05
58:00:00	1	0.0942	23.7021	0.5277	0.001001	0	5.24864E-05
59:00:00	1	0.0936	24.1088	0.5242	0.001001	0	5.24864E-05
60:00:00	0.3292	0.0307	8.0175	0.1719	0.000331	0	1.83264E-05

61:00:00	0.6149	0.0573	15.0025	0.3208	0.000616	0	3.36629E-05
62:00:00	1	0.0938	23.9615	0.5255	0.001001	0	5.29164E-05
63:00:00	0.968	0.0908	23.234	0.5083	0.000969	0	5.01383E-05
64:00:00	0.9118	0.0863	21.3587	0.4834	0.000913	0	4.62311E-05
65:00:00	0.9118	0.0858	21.6985	0.4804	0.000913	0	4.62311E-05
66:00:00	0.9118	0.0853	22.0362	0.4775	0.000913	0	4.62311E-05
67:00:00	0.9118	0.0847	22.3718	0.4746	0.000913	0	4.62311E-05
68:00:00	0.9118	0.0842	22.7054	0.4717	0.000913	0	4.62311E-05
69:00:00	0.9118	0.0837	23.0369	0.4688	0.000914	0	4.62311E-05
70:00:00	0.9118	0.0832	23.3664	0.4659	0.000914	0	4.62311E-05
71:00:00	0.3584	0.0327	9.1668	0.1833	0.000361	0	2.06252E-05
72:00:00	0.3584	0.0326	9.2175	0.1828	0.000361	0	2.28932E-05
73:00:00	0.8808	0.0821	21.4355	0.46	0.000882	0	4.77385E-05
74:00:00	0.9224	0.0884	20.919	0.495	0.000923	0	5.08141E-05
75:00:00	1	0.0965	22.2355	0.5405	0.001	0	5.37923E-05
76:00:00	1	0.0966	22.1642	0.5411	0.001	0	5.32172E-05
77:00:00	1	0.0966	22.1961	0.5409	0.001	0	5.29176E-05
78:00:00	1	0.0963	22.3597	0.5394	0.001	0	5.20193E-05
79:00:00	1	0.0962	22.4656	0.5385	0.001	0	5.24868E-05
80:00:00	1	0.0955	22.8806	0.5349	0.001	0	5.24868E-05
81:00:00	1	0.0949	23.2928	0.5313	0.001001	0	5.24868E-05
82:00:00	1	0.0942	23.7022	0.5277	0.001001	0	5.24868E-05
83:00:00	1	0.0936	24.1089	0.5242	0.001001	0	5.24868E-05
84:00:00	0.433	0.0389	11.4651	0.218	0.000437	0	2.40793E-05
85:00:00	0.6744	0.062	17.0023	0.3471	0.000677	0	3.70589E-05
86:00:00	1	0.0938	23.9614	0.5255	0.001001	0	5.29157E-05
87:00:00	0.973	0.0911	23.4091	0.5104	0.000974	0	5.03919E-05
88:00:00	0.9254	0.0873	21.8438	0.4892	0.000927	0	4.69704E-05
89:00:00	0.9254	0.0868	22.1928	0.4861	0.000927	0	4.69704E-05
90:00:00	0.9254	0.0863	22.5395	0.4831	0.000927	0	4.69704E-05
91:00:00	0.9254	0.0857	22.8842	0.4801	0.000927	0	4.69704E-05
92:00:00	0.9254	0.0852	23.2266	0.4771	0.000927	0	4.69704E-05
93:00:00	0.9254	0.0847	23.567	0.4741	0.000928	0	4.69704E-05
94:00:00	0.9254	0.0841	23.9052	0.4712	0.000928	0	4.69704E-05
95:00:00	0.4576	0.0401	12.7804	0.2246	0.000463	0	2.63278E-05
96:00:00	0.4576	0.04	12.8597	0.2239	0.000464	0	2.92397E-05
97:00:00	0.8989	0.0834	22.1283	0.4672	0.000901	0	4.8803E-05
98:00:00	0.9344	0.0893	21.376	0.4998	0.000936	0	5.14918E-05
99:00:00	1	0.0965	22.2354	0.5405	0.001	0	5.37908E-05
100:00:00	1	0.0966	22.1642	0.5411	0.001	0	5.32174E-05
101:00:00	1	0.0966	22.1961	0.5409	0.001	0	5.29176E-05
102:00:00	1	0.0963	22.3597	0.5394	0.001	0	5.20183E-05
103:00:00	1	0.0962	22.4656	0.5385	0.001	0	5.24867E-05
104:00:00	1	0.0955	22.8805	0.5349	0.001	0	5.24867E-05
105:00:00	1	0.0949	23.2927	0.5313	0.001001	0	5.24867E-05
106:00:00	1	0.0942	23.7022	0.5277	0.001001	0	5.24867E-05
107:00:00	1	0.0936	24.1088	0.5242	0.001001	0	5.24867E-05
108:00:00	0.5207	0.0449	15.0193	0.2514	0.000529	0	2.89567E-05
109:00:00	0.7248	0.0654	19.0523	0.3662	0.00073	0	3.88691E-05
110:00:00	1	0.0938	23.9614	0.5255	0.001001	0	5.29156E-05
111:00:00	0.9771	0.0914	23.5871	0.5119	0.000979	0	5.06122E-05
112:00:00	0.9367	0.0881	22.338	0.4931	0.000939	0	4.75977E-05
113:00:00	0.9367	0.0875	22.6941	0.49	0.000939	0	4.75977E-05
114:00:00	0.9367	0.087	23.0479	0.4869	0.000939	0	4.75977E-05
115:00:00	0.9367	0.0864	23.3994	0.4839	0.000939	0	4.75977E-05
116:00:00	0.9367	0.0859	23.7488	0.4808	0.000939	0	4.75977E-05
117:00:00	0.9367	0.0853	24.096	0.4778	0.00094	0	4.75977E-05
118:00:00	0.9367	0.0848	24.4409	0.4748	0.00094	0	4.75977E-05
119:00:00	0.5414	0.0453	16.4809	0.2539	0.000552	0	3.1173E-05
120:00:00	0.5414	0.0452	16.587	0.253	0.000553	0	3.46438E-05
				0.001001		5.24867E-05	

<<< Link 251 >>>

Time hr:min	C MG/L	S MG/L	H UG/L	N MG/L	Xb CFU/L	Xa CFU/FT2	UVXb CFU/L
0:00	0	0	0	0	0	0	0
1:00	0	0	0	0	0	0	0
2:00	0	0	0	0	0	0	0
3:00	0	0	0	0	0	0	0
4:00	0	0	0	0	0	0	0
5:00	0	0	0	0	0	0	0
6:00	0	0	0	0	0	0	0
7:00	0	0	0	0	0	0	0
8:00	0	0	0	0	0	0	0
9:00	0	0	0	0	0	0	0
10:00	0	0	0	0	0	0	0
11:00	0	0	0	0	0	0	0
12:00	0	0	0	0	0	0	0
13:00	0.0127	0.0012	0.3338	0.0168	1.15E-05	0	7.51E-07
14:00	0.0905	0.0087	4.3496	0.3398	5.45E-05	0	3.29E-06
15:00	0.1799	0.0172	9.4477	0.7076	0.000104	0	6.18E-06
16:00	0.257	0.0245	14.1703	1.0335	0.000145	0	8.55E-06
17:00	0.3297	0.0314	18.9148	1.3491	0.000183	0	1.07E-05
18:00	0.3979	0.0378	23.6238	1.6466	0.000217	0	1.26E-05
19:00	0.4567	0.0432	27.9716	1.9022	0.000247	0	1.43E-05
20:00	0.5152	0.0486	32.4807	2.156	0.000277	0	1.6E-05
21:00	0.5816	0.0547	38.0481	2.4844	0.000306	0	1.75E-05
22:00	0.6046	0.0567	40.8633	2.6205	0.000312	0	1.77E-05
23:00	0.5992	0.0562	40.9978	2.6579	0.000302	0	1.7E-05
24:00:00	0.5939	0.0558	40.4624	2.6859	0.000293	0	1.65E-05
25:00:00	0.5789	0.0546	40.2075	2.7626	0.000268	0	1.48E-05
26:00:00	0.5809	0.0549	39.3458	2.7733	0.00027	0	1.46E-05
27:00:00	0.609	0.0573	38.0553	2.5433	0.000328	0	1.83E-05
28:00:00	0.6419	0.06	36.0665	2.2308	0.000403	0	2.3E-05
29:00:00	0.6683	0.0621	34.994	1.9952	0.00046	0	2.66E-05
30:00:00	0.7126	0.0655	33.0236	1.627	0.000553	0	3.27E-05
31:00:00	0.756	0.0689	31.1731	1.2715	0.000643	0	3.87E-05
32:00:00	0.7649	0.0693	28.3287	0.9893	0.000689	0	4.2E-05
33:00:00	0.7478	0.0675	25.7013	0.797	0.000695	0	4.29E-05
34:00:00	0.7683	0.0691	23.9812	0.6286	0.000739	0	4.63E-05
35:00:00	0.7997	0.0718	23.2566	0.5296	0.000786	0	5.01E-05
36:00:00	0.7891	0.071	22.4498	0.5009	0.000778	0	5.02E-05
37:00:00	0.8164	0.0735	22.7457	0.4909	0.000808	0	5.28E-05
38:00:00	0.8599	0.0774	23.3974	0.4783	0.000856	0	5.62E-05
39:00:00	0.9198	0.0824	24.9686	0.4857	0.000919	0	6.04E-05
40:00:00	0.9445	0.0843	25.7093	0.4881	0.000945	0	6.17E-05
41:00:00	0.9481	0.0845	25.8429	0.4877	0.000949	0	6.16E-05
42:00:00	0.9568	0.0851	26.1792	0.4887	0.000958	0	6.17E-05
43:00:00	0.9862	0.0872	27.1919	0.4931	0.000989	0	6.33E-05
44:00:00	0.9954	0.0876	27.6355	0.4935	0.000999	0	6.36E-05
45:00:00	0.9962	0.0875	27.7846	0.4926	0.001	0	6.32E-05
46:00:00	0.9934	0.0871	27.8232	0.4902	0.000997	0	6.26E-05
47:00:00	0.9778	0.0857	27.3332	0.4816	0.000981	0	6.12E-05
48:00:00	0.9701	0.0853	26.9037	0.4779	0.000974	0	6.13E-05
49:00:00	0.9664	0.0852	26.6729	0.4771	0.00097	0	6.14E-05
50:00:00	0.9654	0.0858	26.23	0.4803	0.000969	0	6.1E-05
51:00:00	0.98	0.0873	26.4605	0.489	0.000983	0	6.12E-05
52:00:00	0.9785	0.0874	26.2571	0.4897	0.000981	0	6E-05
53:00:00	0.9673	0.0863	26.0319	0.4834	0.00097	0	5.87E-05
54:00:00	0.9545	0.0851	25.7442	0.4765	0.000957	0	5.74E-05
55:00:00	0.9407	0.0837	25.465	0.4688	0.000944	0	5.65E-05
56:00:00	0.9043	0.0805	24.5313	0.4554	0.000907	0	5.46E-05
57:00:00	0.8518	0.0759	23.234	0.4395	0.000853	0	5.18E-05
58:00:00	0.8315	0.0742	22.6778	0.4333	0.000832	0	5.16E-05
59:00:00	0.8385	0.0748	22.8537	0.4371	0.000839	0	5.32E-05
60:00:00	0.8276	0.0741	22.5722	0.4398	0.000827	0	5.36E-05
61:00:00	0.8472	0.076	23.0156	0.4504	0.000847	0	5.56E-05
62:00:00	0.8824	0.0791	23.8803	0.4641	0.000882	0	5.84E-05
63:00:00	0.9334	0.0834	25.2786	0.478	0.000935	0	6.18E-05

64:00:00	0.9555	0.0851	25.9852	0.4837	0.000958	0	6.29E-05
65:00:00	0.9603	0.0854	26.1876	0.4855	0.000962	0	6.27E-05
66:00:00	0.9656	0.0857	26.4274	0.4866	0.000968	0	6.25E-05
67:00:00	0.9876	0.0872	27.2004	0.49	0.000991	0	6.35E-05
68:00:00	0.9948	0.0875	27.5757	0.4902	0.000998	0	6.36E-05
69:00:00	0.9953	0.0874	27.7172	0.4893	0.000999	0	6.32E-05
70:00:00	0.9913	0.0868	27.727	0.4863	0.000995	0	6.24E-05
71:00:00	0.9786	0.0857	27.3628	0.4801	0.000982	0	6.13E-05
72:00:00	0.9733	0.0855	27.0387	0.479	0.000977	0	6.15E-05
73:00:00	0.9699	0.0854	26.8202	0.4785	0.000974	0	6.17E-05
74:00:00	0.9707	0.0861	26.4287	0.4824	0.000974	0	6.14E-05
75:00:00	0.9843	0.0876	26.6094	0.4908	0.000987	0	6.15E-05
76:00:00	0.982	0.0877	26.3842	0.4911	0.000985	0	6.02E-05
77:00:00	0.9726	0.0867	26.2273	0.4856	0.000976	0	5.9E-05
78:00:00	0.962	0.0856	26.0212	0.4796	0.000965	0	5.79E-05
79:00:00	0.9502	0.0844	25.8175	0.4728	0.000954	0	5.71E-05
80:00:00	0.9198	0.0817	25.1109	0.4609	0.000923	0	5.56E-05
81:00:00	0.8757	0.0777	24.1439	0.4464	0.000878	0	5.35E-05
82:00:00	0.8584	0.0762	23.7186	0.4406	0.00086	0	5.35E-05
83:00:00	0.8643	0.0767	23.8588	0.4439	0.000866	0	5.51E-05
84:00:00	0.8554	0.0761	23.6683	0.4458	0.000856	0	5.56E-05
85:00:00	0.8715	0.0777	23.9975	0.455	0.000872	0	5.74E-05
86:00:00	0.901	0.0805	24.6429	0.4671	0.000902	0	5.97E-05
87:00:00	0.9437	0.0841	25.7166	0.4796	0.000946	0	6.26E-05
88:00:00	0.9617	0.0855	26.2813	0.4843	0.000964	0	6.33E-05
89:00:00	0.9659	0.0857	26.4552	0.4858	0.000968	0	6.31E-05
90:00:00	0.9703	0.086	26.6634	0.4867	0.000973	0	6.29E-05
91:00:00	0.9886	0.0872	27.2789	0.4898	0.000992	0	6.36E-05
92:00:00	0.9946	0.0875	27.6036	0.4898	0.000998	0	6.36E-05
93:00:00	0.9954	0.0873	27.7451	0.4891	0.000999	0	6.32E-05
94:00:00	0.992	0.0868	27.7801	0.4863	0.000996	0	6.25E-05
95:00:00	0.9813	0.0859	27.4964	0.4809	0.000985	0	6.15E-05
96:00:00	0.9773	0.0858	27.2111	0.4805	0.000981	0	6.18E-05
97:00:00	0.9744	0.0857	27.0175	0.4801	0.000978	0	6.2E-05
98:00:00	0.9752	0.0864	26.6226	0.4841	0.000979	0	6.17E-05
99:00:00	0.9867	0.0878	26.7132	0.4917	0.00099	0	6.17E-05
100:00:00	0.9849	0.0879	26.5019	0.4922	0.000988	0	6.03E-05
101:00:00	0.9769	0.087	26.4073	0.4872	0.00098	0	5.93E-05
102:00:00	0.968	0.086	26.272	0.4818	0.000971	0	5.83E-05
103:00:00	0.9579	0.0849	26.1484	0.4755	0.000961	0	5.76E-05
104:00:00	0.9323	0.0825	25.6603	0.4645	0.000936	0	5.65E-05
105:00:00	0.8953	0.0789	25.02	0.4508	0.000898	0	5.48E-05
106:00:00	0.8808	0.0776	24.73	0.4455	0.000884	0	5.5E-05
107:00:00	0.8857	0.0781	24.839	0.4483	0.000889	0	5.66E-05
108:00:00	0.8784	0.0775	24.7357	0.4495	0.000881	0	5.72E-05
109:00:00	0.8921	0.079	24.9564	0.4577	0.000894	0	5.89E-05
110:00:00	0.9169	0.0814	25.3913	0.4689	0.000919	0	6.09E-05
111:00:00	0.9528	0.0846	26.1473	0.4808	0.000955	0	6.32E-05
112:00:00	0.9685	0.0859	26.5733	0.4856	0.000971	0	6.38E-05
113:00:00	0.972	0.0861	26.72	0.4869	0.000975	0	6.36E-05
114:00:00	0.9758	0.0863	26.8961	0.4876	0.000979	0	6.33E-05
115:00:00	0.9912	0.0874	27.3666	0.4906	0.000995	0	6.38E-05
116:00:00	0.9962	0.0876	27.6458	0.4907	0.001	0	6.37E-05
117:00:00	0.9969	0.0875	27.7835	0.4899	0.001001	0	6.33E-05
118:00:00	0.994	0.087	27.8451	0.4872	0.000998	0	6.26E-05
119:00:00	0.9848	0.0861	27.6392	0.4823	0.000989	0	6.17E-05
120:00:00	0.9805	0.086	27.3792	0.4814	0.000985	0	6.2E-05

<<< Link 291 >>>

Time hr:min	C MG/L	S MG/L	H UG/L	N MG/L	Xb CFU/L	Xa CFU/FT2	UVXb CFU/L
0:00	0	0	0	0	0	0	0
1:00	0	0	0	0	0	0	0
2:00	0	0	0	0	0	0	0
3:00	0	0	0	0	0	0	0
4:00	0	0	0	0	0	0	0
5:00	0	0	0	0	0	0	0
6:00	0.0003	0	0.0054	0.0001	2.54E-07	0	1.66E-08
7:00	0.061	0.006	1.8833	0.156	4.62E-05	0	2.98E-06
8:00	0.2877	0.0283	11.2582	1.1175	0.000171	0	1.05E-05
9:00	0.4781	0.0468	20.3603	1.9572	0.000272	0	1.63E-05
10:00	0.5827	0.0569	26.2931	2.4649	0.00032	0	1.89E-05
11:00	0.6035	0.0588	28.2974	2.6231	0.000322	0	1.88E-05
12:00	0.6073	0.0591	29.425	2.703	0.000316	0	1.82E-05
13:00	0.6091	0.0592	30.281	2.7303	0.000314	0	1.79E-05
14:00	0.6038	0.0586	30.4484	2.7528	0.000306	0	1.73E-05
15:00	0.5928	0.0576	30.1594	2.7684	0.000292	0	1.65E-05
16:00	0.59	0.0572	30.321	2.766	0.000289	0	1.64E-05
17:00	0.5895	0.057	31.4673	2.7552	0.000289	0	1.63E-05
18:00	0.5924	0.0569	33.3543	2.7428	0.000292	0	1.65E-05
19:00	0.5938	0.0569	34.386	2.7404	0.000292	0	1.65E-05
20:00	0.5973	0.0568	36.4496	2.6876	0.0003	0	1.71E-05
21:00	0.5778	0.0542	37.6245	2.4056	0.000311	0	1.82E-05
22:00	0.407	0.0384	24.2805	1.5946	0.000233	0	1.4E-05
23:00	0.1058	0.0102	4.517	0.3415	7.09E-05	0	4.48E-06
24:00:00	0.0006	0.0001	0.0122	0.0003	5.59E-07	0	3.75E-08
25:00:00	0.0006	0.0001	0.0122	0.0003	5.59E-07	0	3.75E-08
26:00:00	0.0006	0.0001	0.0122	0.0003	5.59E-07	0	3.75E-08
27:00:00	0.0006	0.0001	0.0122	0.0003	5.59E-07	0	3.75E-08
28:00:00	0.0006	0.0001	0.0122	0.0003	5.59E-07	0	3.75E-08
29:00:00	0.37	0.0348	10.9499	0.3638	0.000349	0	2.29E-05
30:00:00	0.8567	0.0809	21.6931	0.5677	0.000843	0	5.61E-05
31:00:00	0.9445	0.0892	22.373	0.514	0.000943	0	6.33E-05
32:00:00	0.9929	0.0936	23.5087	0.5259	0.000993	0	6.66E-05
33:00:00	0.9981	0.0938	23.8505	0.5255	0.000999	0	6.68E-05
34:00:00	0.995	0.0928	24.2447	0.5205	0.000996	0	6.67E-05
35:00:00	0.9914	0.0917	24.6314	0.5154	0.000992	0	6.66E-05
36:00:00	0.9882	0.0908	24.9633	0.511	0.000989	0	6.64E-05
37:00:00	0.9883	0.0906	25.1093	0.5106	0.00099	0	6.49E-05
38:00:00	0.9951	0.0918	24.937	0.5169	0.000996	0	6.33E-05
39:00:00	0.9739	0.0902	24.1171	0.5071	0.000975	0	6.13E-05
40:00:00	0.9413	0.0875	23.0903	0.49	0.000943	0	6E-05
41:00:00	0.9471	0.0881	23.186	0.4934	0.000948	0	6.15E-05
42:00:00	0.9686	0.0901	23.7387	0.5044	0.00097	0	6.33E-05
43:00:00	0.9792	0.0909	24.0633	0.5093	0.00098	0	6.35E-05
44:00:00	0.9789	0.0908	24.1199	0.5086	0.00098	0	6.27E-05
45:00:00	0.9777	0.0904	24.3007	0.5061	0.000979	0	6.22E-05
46:00:00	0.9798	0.0894	25.1111	0.5006	0.000982	0	6.33E-05
47:00:00	0.9541	0.0856	25.401	0.4792	0.000957	0	6.24E-05
48:00:00	0.3295	0.0292	9.1854	0.1776	0.000329	0	2.13E-05
49:00:00	0.1284	0.0115	3.6958	0.083	0.000127	0	8.42E-06
50:00:00	0.1284	0.0115	3.704	0.0829	0.000127	0	8.42E-06
51:00:00	0.1284	0.0115	3.7123	0.0828	0.000127	0	8.42E-06
52:00:00	0.1365	0.0122	3.9415	0.0866	0.000135	0	8.96E-06
53:00:00	0.5259	0.0485	13.4478	0.292	0.000524	0	3.47E-05
54:00:00	0.9043	0.085	21.827	0.4951	0.000903	0	6.07E-05
55:00:00	0.9611	0.0907	22.8059	0.516	0.000961	0	6.49E-05
56:00:00	0.9935	0.0936	23.551	0.5256	0.000994	0	6.69E-05
57:00:00	0.9981	0.0937	23.8847	0.5249	0.000999	0	6.71E-05
58:00:00	0.9946	0.0927	24.28	0.5198	0.000996	0	6.69E-05
59:00:00	0.992	0.0917	24.6717	0.5151	0.000993	0	6.67E-05
60:00:00	0.9872	0.0906	25.0077	0.5095	0.000989	0	6.63E-05
61:00:00	0.9867	0.0903	25.1177	0.5072	0.000988	0	6.48E-05
62:00:00	0.9946	0.0916	24.9411	0.5132	0.000996	0	6.33E-05
63:00:00	0.9741	0.0901	24.1735	0.5046	0.000976	0	6.13E-05

64:00:00	0.9492	0.0881	23.3724	0.4933	0.000951	0	6.06E-05
65:00:00	0.9564	0.0889	23.4777	0.4976	0.000958	0	6.23E-05
66:00:00	0.9748	0.0906	23.9207	0.5073	0.000976	0	6.38E-05
67:00:00	0.9826	0.0912	24.1713	0.5108	0.000984	0	6.38E-05
68:00:00	0.9824	0.0911	24.2428	0.5101	0.000984	0	6.3E-05
69:00:00	0.9816	0.0907	24.4553	0.5077	0.000983	0	6.25E-05
70:00:00	0.9828	0.0896	25.2337	0.5018	0.000985	0	6.36E-05
71:00:00	0.962	0.0862	25.6837	0.4826	0.000965	0	6.3E-05
72:00:00	0.4152	0.0365	11.757	0.2176	0.000416	0	2.71E-05
73:00:00	0.2429	0.0213	7.1023	0.1365	0.000243	0	1.62E-05
74:00:00	0.2429	0.0213	7.1279	0.1363	0.000243	0	1.62E-05
75:00:00	0.2429	0.0212	7.1534	0.1361	0.000243	0	1.62E-05
76:00:00	0.2496	0.0218	7.3603	0.1391	0.00025	0	1.66E-05
77:00:00	0.59	0.0538	15.4836	0.3185	0.00059	0	3.91E-05
78:00:00	0.9198	0.0862	22.418	0.4978	0.000919	0	6.19E-05
79:00:00	0.9659	0.091	23.0225	0.5166	0.000966	0	6.54E-05
80:00:00	0.994	0.0937	23.587	0.5255	0.000995	0	6.7E-05
81:00:00	0.9981	0.0937	23.8955	0.5249	0.000999	0	6.72E-05
82:00:00	0.9958	0.0928	24.307	0.5202	0.000997	0	6.7E-05
83:00:00	0.9936	0.0919	24.7105	0.5156	0.000995	0	6.69E-05
84:00:00	0.9878	0.0906	25.0796	0.5094	0.000989	0	6.65E-05
85:00:00	0.9878	0.0904	25.2023	0.5071	0.00099	0	6.5E-05
86:00:00	0.9953	0.0916	24.9732	0.5134	0.000997	0	6.33E-05
87:00:00	0.9781	0.0904	24.3201	0.5063	0.00098	0	6.15E-05
88:00:00	0.957	0.0887	23.6612	0.4965	0.000959	0	6.11E-05
89:00:00	0.9627	0.0893	23.7247	0.5001	0.000964	0	6.27E-05
90:00:00	0.9784	0.0908	24.0623	0.5088	0.00098	0	6.4E-05
91:00:00	0.9852	0.0914	24.2721	0.5119	0.000987	0	6.4E-05
92:00:00	0.985	0.0913	24.3472	0.5111	0.000986	0	6.32E-05
93:00:00	0.9845	0.0909	24.5687	0.5088	0.000986	0	6.27E-05
94:00:00	0.9852	0.0898	25.3398	0.5026	0.000987	0	6.38E-05
95:00:00	0.9674	0.0865	25.9197	0.4845	0.00097	0	6.33E-05
96:00:00	0.4928	0.0426	14.4204	0.2505	0.000496	0	3.23E-05
97:00:00	0.3427	0.0292	10.5316	0.1789	0.000346	0	2.29E-05
98:00:00	0.3427	0.0291	10.5789	0.1785	0.000346	0	2.29E-05
99:00:00	0.3427	0.029	10.6261	0.1781	0.000346	0	2.29E-05
100:00:00	0.3486	0.0295	10.8246	0.1805	0.000352	0	2.33E-05
101:00:00	0.6457	0.058	17.5206	0.3395	0.000648	0	4.29E-05
102:00:00	0.9321	0.087	22.9843	0.4991	0.000932	0	6.28E-05
103:00:00	0.9693	0.0912	23.2538	0.5162	0.00097	0	6.57E-05
104:00:00	0.9929	0.0935	23.6224	0.5248	0.000994	0	6.7E-05
105:00:00	0.9977	0.0936	23.9065	0.5247	0.000999	0	6.72E-05
106:00:00	0.9948	0.0926	24.3373	0.5195	0.000996	0	6.7E-05
107:00:00	0.992	0.0916	24.7569	0.5144	0.000993	0	6.69E-05
108:00:00	0.9902	0.0908	25.1585	0.5099	0.000992	0	6.66E-05
109:00:00	0.9912	0.0907	25.2801	0.5087	0.000993	0	6.52E-05
110:00:00	0.9963	0.0917	25.008	0.5139	0.000998	0	6.34E-05
111:00:00	0.9819	0.0907	24.4691	0.5077	0.000984	0	6.18E-05
112:00:00	0.9631	0.089	23.9498	0.4985	0.000965	0	6.15E-05
113:00:00	0.9673	0.0895	23.9709	0.5014	0.000969	0	6.3E-05
114:00:00	0.9807	0.0909	24.2022	0.5092	0.000982	0	6.41E-05
115:00:00	0.9871	0.0915	24.371	0.5125	0.000989	0	6.41E-05
116:00:00	0.987	0.0914	24.4467	0.5117	0.000989	0	6.33E-05
117:00:00	0.9867	0.091	24.6707	0.5095	0.000988	0	6.28E-05
118:00:00	0.9873	0.0899	25.4424	0.5032	0.00099	0	6.39E-05
119:00:00	0.9716	0.0867	26.1487	0.4855	0.000975	0	6.36E-05
120:00:00	0.5599	0.0473	17.1284	0.2754	0.000567	0	3.69E-05

Scenario 2 – Planktonic Bacteria

<<< Node 15 >>>

Time hr:min	C MG/L	S MG/L	H UG/L	N MG/L	Xb CFU/L	U VXb CFU/L
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	0	0	0	0	0	0
5:00	0.4472	0.0434	9.7816	0.2431	0.000447	2.48E-05
6:00	0.8918	0.0862	19.7645	0.4826	0.000892	4.89E-05
7:00	0.8925	0.086	19.913	0.4818	0.000893	4.81E-05
8:00	0.8919	0.0855	20.2281	0.4787	0.000892	4.79E-05
9:00	0.8919	0.085	20.5572	0.4758	0.000892	4.79E-05
10:00	0.8919	0.0845	20.8843	0.4729	0.000893	4.79E-05
11:00	0.8919	0.0839	21.2095	0.4701	0.000893	4.79E-05
12:00	1	0.0938	24.0054	0.5251	0.001001	5.13E-05
13:00	1	0.0933	24.3344	0.5222	0.001001	5.25E-05
14:00	0.505	0.0467	12.6524	0.268	0.000505	2.65E-05
15:00	0.507	0.0472	13.4759	0.3623	0.000495	2.54E-05
16:00	0.4586	0.0432	11.5636	0.3199	0.000449	2.39E-05
17:00	0.4587	0.043	11.659	0.3186	0.00045	2.39E-05
18:00	0.4587	0.0429	11.7718	0.3176	0.00045	2.39E-05
19:00	0.4587	0.0428	11.8843	0.3166	0.00045	2.39E-05
20:00	0.4587	0.0426	11.9964	0.3157	0.00045	2.39E-05
21:00	0.4587	0.0425	12.1081	0.3147	0.00045	2.39E-05
22:00	0.4587	0.0424	12.2196	0.3137	0.00045	2.39E-05
23:00	0.0771	0.0074	1.7099	0.0417	7.72E-05	4.82E-06
24:00:00	0.0771	0.0074	1.7124	0.0417	7.72E-05	5.3E-06
25:00:00	0.9062	0.084	23.4093	0.5445	0.000898	4.97E-05
26:00:00	0.9467	0.0909	21.3361	0.5092	0.000947	5.29E-05
27:00:00	1	0.0965	22.2217	0.5406	0.001	5.46E-05
28:00:00	1	0.0966	22.1975	0.5408	0.001	5.44E-05
29:00:00	1	0.0965	22.2276	0.5406	0.001	5.42E-05
30:00:00	1	0.0963	22.398	0.5391	0.001	5.3E-05
31:00:00	1	0.0961	22.5168	0.5381	0.001	5.32E-05
32:00:00	1	0.0955	22.9184	0.5346	0.001	5.3E-05
33:00:00	1	0.0948	23.3304	0.531	0.001001	5.3E-05
34:00:00	1	0.0942	23.7395	0.5274	0.001001	5.3E-05
35:00:00	1	0.0935	24.146	0.5239	0.001001	5.3E-05
36:00:00	0.3296	0.0314	7.5909	0.1758	0.00033	1.76E-05
37:00:00	0.5453	0.0513	12.9977	0.2871	0.000546	2.86E-05
38:00:00	1	0.0938	23.9845	0.5253	0.001001	5.34E-05
39:00:00	1	0.0934	24.2186	0.5232	0.001001	5.28E-05
40:00:00	0.8781	0.083	20.6771	0.4646	0.000879	4.59E-05
41:00:00	0.8784	0.0825	20.9842	0.4622	0.000879	4.57E-05
42:00:00	0.8784	0.082	21.2972	0.4594	0.00088	4.57E-05
43:00:00	0.8784	0.0816	21.6083	0.4567	0.00088	4.57E-05
44:00:00	0.8784	0.0811	21.9176	0.454	0.00088	4.57E-05
45:00:00	0.8784	0.0806	22.225	0.4513	0.00088	4.57E-05
46:00:00	0.8784	0.0801	22.5307	0.4487	0.00088	4.57E-05
47:00:00	0.241	0.0228	5.679	0.1275	0.000242	1.39E-05
48:00:00	0.241	0.0227	5.7028	0.1273	0.000242	1.54E-05
49:00:00	0.9792	0.0911	23.9671	0.5101	0.000981	5.32E-05
50:00:00	0.9044	0.0867	20.5095	0.4853	0.000905	5.08E-05
51:00:00	1	0.0964	22.286	0.5401	0.001	5.53E-05
52:00:00	1	0.0966	22.2102	0.5407	0.001	5.45E-05
53:00:00	1	0.0965	22.232	0.5405	0.001	5.42E-05
54:00:00	1	0.0963	22.3991	0.5391	0.001	5.31E-05
55:00:00	1	0.0961	22.5115	0.5381	0.001	5.33E-05
56:00:00	1	0.0955	22.9106	0.5346	0.001	5.31E-05
57:00:00	1	0.0948	23.3226	0.531	0.001001	5.31E-05
58:00:00	1	0.0942	23.7318	0.5275	0.001001	5.31E-05
59:00:00	1	0.0936	24.1383	0.5239	0.001001	5.31E-05
60:00:00	0.3259	0.0304	7.9402	0.1701	0.000327	1.87E-05
61:00:00	0.6149	0.0573	15.0025	0.3208	0.000616	3.37E-05

62:00:00	1	0.0939	23.9149	0.5259	0.001001	5.36E-05
63:00:00	1	0.0935	24.2021	0.5234	0.001001	5.28E-05
64:00:00	0.8963	0.0845	21.1998	0.4734	0.000897	4.68E-05
65:00:00	0.8963	0.084	21.5089	0.4707	0.000897	4.66E-05
66:00:00	0.8963	0.0835	21.834	0.4678	0.000898	4.66E-05
67:00:00	0.8963	0.083	22.1573	0.465	0.000898	4.66E-05
68:00:00	0.8963	0.0825	22.4785	0.4622	0.000898	4.66E-05
69:00:00	0.8963	0.082	22.7979	0.4594	0.000898	4.66E-05
70:00:00	0.8963	0.0815	23.1153	0.4567	0.000899	4.66E-05
71:00:00	0.3584	0.0327	9.1668	0.1833	0.000361	2.06E-05
72:00:00	0.3584	0.0326	9.2175	0.1828	0.000361	2.29E-05
73:00:00	0.9819	0.0913	24.0752	0.5112	0.000983	5.37E-05
74:00:00	0.9192	0.0879	20.9717	0.4922	0.00092	5.17E-05
75:00:00	1	0.0964	22.2876	0.5401	0.001	5.53E-05
76:00:00	1	0.0966	22.2106	0.5407	0.001	5.45E-05
77:00:00	1	0.0965	22.232	0.5405	0.001	5.42E-05
78:00:00	1	0.0963	22.4016	0.5391	0.001	5.31E-05
79:00:00	1	0.0961	22.5114	0.5381	0.001	5.33E-05
80:00:00	1	0.0955	22.9107	0.5346	0.001	5.31E-05
81:00:00	1	0.0948	23.3227	0.531	0.001001	5.31E-05
82:00:00	1	0.0942	23.732	0.5275	0.001001	5.31E-05
83:00:00	1	0.0936	24.1384	0.5239	0.001001	5.31E-05
84:00:00	0.4301	0.0386	11.4025	0.2164	0.000434	2.47E-05
85:00:00	0.6744	0.062	17.0023	0.3471	0.000677	3.71E-05
86:00:00	1	0.0939	23.9151	0.5259	0.001001	5.36E-05
87:00:00	1	0.0935	24.2018	0.5234	0.001001	5.28E-05
88:00:00	0.9123	0.0857	21.7718	0.4802	0.000914	4.77E-05
89:00:00	0.9123	0.0852	22.0913	0.4774	0.000914	4.74E-05
90:00:00	0.9123	0.0847	22.427	0.4744	0.000914	4.74E-05
91:00:00	0.9123	0.0842	22.7606	0.4715	0.000914	4.74E-05
92:00:00	0.9123	0.0837	23.0922	0.4686	0.000915	4.74E-05
93:00:00	0.9123	0.0832	23.4218	0.4658	0.000915	4.74E-05
94:00:00	0.9123	0.0827	23.7493	0.4629	0.000915	4.74E-05
95:00:00	0.4576	0.0401	12.7804	0.2246	0.000463	2.63E-05
96:00:00	0.4576	0.04	12.8597	0.2239	0.000464	2.92E-05
97:00:00	0.9848	0.0915	24.1813	0.5124	0.000986	5.4E-05
98:00:00	0.9318	0.0888	21.4471	0.4973	0.000933	5.24E-05
99:00:00	1	0.0964	22.2875	0.5401	0.001	5.53E-05
100:00:00	1	0.0966	22.2105	0.5407	0.001	5.45E-05
101:00:00	1	0.0965	22.232	0.5405	0.001	5.42E-05
102:00:00	1	0.0963	22.4014	0.5391	0.001	5.31E-05
103:00:00	1	0.0961	22.5114	0.5381	0.001	5.33E-05
104:00:00	1	0.0955	22.9107	0.5346	0.001	5.31E-05
105:00:00	1	0.0948	23.3226	0.531	0.001001	5.31E-05
106:00:00	1	0.0942	23.7319	0.5275	0.001001	5.31E-05
107:00:00	1	0.0936	24.1383	0.5239	0.001001	5.31E-05
108:00:00	0.5182	0.0446	14.9743	0.25	0.000526	2.98E-05
109:00:00	0.7248	0.0654	19.0523	0.3662	0.00073	3.89E-05
110:00:00	1	0.0939	23.915	0.5259	0.001001	5.36E-05
111:00:00	1	0.0935	24.2018	0.5234	0.001001	5.28E-05
112:00:00	0.9259	0.0866	22.353	0.485	0.000928	4.84E-05
113:00:00	0.9259	0.0861	22.6807	0.4822	0.000928	4.82E-05
114:00:00	0.9259	0.0856	23.0248	0.4792	0.000928	4.82E-05
115:00:00	0.9259	0.085	23.3668	0.4762	0.000929	4.82E-05
116:00:00	0.9259	0.0845	23.7066	0.4732	0.000929	4.82E-05
117:00:00	0.9259	0.084	24.0444	0.4703	0.000929	4.82E-05
118:00:00	0.9259	0.0835	24.38	0.4674	0.000929	4.82E-05
119:00:00	0.5414	0.0453	16.4809	0.2539	0.000552	3.12E-05
120:00:00	0.5414	0.0452	16.587	0.253	0.000553	3.46E-05

<<< Node 219 >>>

Time	C	S	H	N	Xb	U VXb
hr:min	MG/L	MG/L	UG/L	MG/L	CFU/L	CFU/L
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	0	0	0	0	0	0
5:00	0	0	0	0	0	0
6:00	0	0	0	0	0	0
7:00	0	0	0	0	0	0
8:00	0	0	0	0	0	0
9:00	0	0	0	0	0	0
10:00	0	0	0	0	0	0
11:00	0	0	0	0	0	0
12:00	0	0	0	0	0	0
13:00	0	0	0	0	0	0
14:00	0	0	0	0	0	0
15:00	0	0	0	0	0	0
16:00	0	0	0	0	0	0
17:00	0	0	0	0	0	0
18:00	0	0	0	0	0	0
19:00	0	0	0	0	0	0
20:00	0	0	0	0	0	0
21:00	0.2024	0.0194	6.1735	0.3365	0.000175	1.14E-05
22:00	0.5964	0.0553	40.2767	2.3026	0.000341	2.02E-05
23:00	0.6136	0.0568	43.6977	2.5047	0.000333	1.92E-05
24:00:00	0.6095	0.0566	44.5154	2.6311	0.000312	1.77E-05
25:00:00	0.6077	0.0564	44.3504	2.6402	0.00031	1.75E-05
26:00:00	0.5937	0.0553	43.2609	2.6787	0.000291	1.63E-05
27:00:00	0.5915	0.0551	42.596	2.6607	0.000291	1.65E-05
28:00:00	0.5914	0.0552	42.3859	2.6861	0.000289	1.62E-05
29:00:00	0.5807	0.0542	42.1811	2.6777	0.000278	1.54E-05
30:00:00	0.5061	0.0483	43.8151	3.2239	0.000132	5.09E-06
31:00:00	0.5109	0.0487	44.5149	3.2138	0.000137	5.25E-06
32:00:00	0.7173	0.0651	40.5517	1.9086	0.000518	3.06E-05
33:00:00	0.7155	0.0646	36.2206	1.5529	0.000562	3.34E-05
34:00:00	0.7322	0.0659	33.8534	1.328	0.000609	3.61E-05
35:00:00	0.8127	0.0719	27.8358	0.7316	0.000772	4.67E-05
36:00:00	0.8403	0.0738	24.8331	0.4958	0.000833	5.11E-05
37:00:00	0.8292	0.073	26.3928	0.5984	0.000807	5.04E-05
38:00:00	0.5711	0.0515	17.1985	0.4416	0.000553	3.53E-05
39:00:00	0.5942	0.0536	17.5694	0.4338	0.000579	3.79E-05
40:00:00	0.956	0.083	27.5202	0.4792	0.000958	6.32E-05
41:00:00	0.972	0.0845	27.8332	0.4819	0.000975	6.43E-05
42:00:00	0.7974	0.0705	22.7423	0.4446	0.000794	5.22E-05
43:00:00	0.7087	0.0636	20.0444	0.4279	0.000702	4.58E-05
44:00:00	0.9829	0.085	28.2985	0.4791	0.000987	6.47E-05
45:00:00	0.998	0.0861	28.786	0.482	0.001003	6.56E-05
46:00:00	1	0.0863	28.7723	0.4835	0.001005	6.62E-05
47:00:00	0.9702	0.0832	29.0372	0.4939	0.000971	6.17E-05
48:00:00	1	0.0864	28.7225	0.484	0.001005	6.24E-05
49:00:00	1	0.0864	28.7504	0.4837	0.001005	6.18E-05
50:00:00	0.9771	0.0846	27.9463	0.4739	0.000982	6.12E-05
51:00:00	0.8887	0.0777	24.9768	0.4349	0.000893	5.65E-05
52:00:00	0.9913	0.0862	28.1266	0.4828	0.000996	6.49E-05
53:00:00	0.9871	0.0861	27.8358	0.4822	0.000991	6.35E-05
54:00:00	0.972	0.085	27.2446	0.4763	0.000976	6.1E-05
55:00:00	0.9945	0.0867	28.0575	0.4857	0.000999	6.14E-05
56:00:00	0.9994	0.087	28.288	0.4873	0.001004	6.03E-05
57:00:00	0.9987	0.087	28.246	0.4872	0.001003	6.01E-05
58:00:00	0.9466	0.0827	26.6387	0.4629	0.000951	5.58E-05
59:00:00	0.9018	0.0791	25.1839	0.4427	0.000906	5.35E-05
60:00:00	0.8895	0.0778	24.9715	0.4356	0.000894	5.32E-05
61:00:00	0.8777	0.0765	24.7706	0.4286	0.000882	5.48E-05
62:00:00	0.6339	0.0566	18.2499	0.3842	0.000628	4.02E-05

63:00:00	0.6535	0.0583	18.8139	0.3935	0.000648	4.27E-05
64:00:00	0.9213	0.0802	26.0827	0.4495	0.000926	6.13E-05
65:00:00	0.9713	0.0841	27.7751	0.4711	0.000976	6.48E-05
66:00:00	0.8914	0.0778	25.5922	0.4567	0.000893	5.98E-05
67:00:00	0.7633	0.0678	21.9692	0.4357	0.000759	5.03E-05
68:00:00	0.9846	0.085	28.3458	0.4774	0.000989	6.51E-05
69:00:00	0.9972	0.086	28.7476	0.4817	0.001002	6.58E-05
70:00:00	1	0.0864	28.7674	0.4836	0.001005	6.66E-05
71:00:00	0.968	0.0829	28.2913	0.4642	0.000973	6.14E-05
72:00:00	1	0.0864	28.7391	0.4838	0.001005	6.23E-05
73:00:00	1	0.0863	28.7894	0.4834	0.001005	6.18E-05
74:00:00	0.9719	0.0841	27.8604	0.4708	0.000977	6.08E-05
75:00:00	0.924	0.0803	26.2688	0.4495	0.000929	5.9E-05
76:00:00	0.9939	0.0865	28.1625	0.4843	0.000998	6.52E-05
77:00:00	0.9884	0.0862	27.8909	0.4827	0.000993	6.36E-05
78:00:00	0.9766	0.0854	27.4315	0.4781	0.000981	6.13E-05
79:00:00	0.996	0.0868	28.1177	0.4863	0.001	6.15E-05
80:00:00	0.9995	0.087	28.2952	0.4873	0.001004	6.03E-05
81:00:00	0.9992	0.087	28.2633	0.4874	0.001003	6.01E-05
82:00:00	0.9555	0.0833	26.9883	0.4664	0.00096	5.64E-05
83:00:00	0.9175	0.0801	25.8038	0.4488	0.000922	5.44E-05
84:00:00	0.9069	0.079	25.6776	0.4422	0.000911	5.46E-05
85:00:00	0.8967	0.0778	25.5329	0.4359	0.000901	5.61E-05
86:00:00	0.6938	0.061	20.6381	0.3943	0.000691	4.45E-05
87:00:00	0.7086	0.0623	21.0746	0.4014	0.000706	4.68E-05
88:00:00	0.9326	0.0809	26.5678	0.4535	0.000937	6.22E-05
89:00:00	0.9771	0.0846	27.9624	0.4738	0.000982	6.53E-05
90:00:00	0.9063	0.0788	26.2809	0.4582	0.000908	6.1E-05
91:00:00	0.8024	0.0705	23.6398	0.4388	0.0008	5.32E-05
92:00:00	0.9869	0.0852	28.4445	0.478	0.000992	6.53E-05
93:00:00	0.9976	0.086	28.767	0.4818	0.001002	6.58E-05
94:00:00	1	0.0864	28.7621	0.4836	0.001005	6.67E-05
95:00:00	0.9726	0.0831	28.5225	0.4656	0.000978	6.17E-05
96:00:00	1	0.0864	28.7391	0.4838	0.001005	6.23E-05
97:00:00	1	0.0863	28.7838	0.4834	0.001005	6.17E-05
98:00:00	0.9759	0.0843	28.0364	0.4723	0.000981	6.11E-05
99:00:00	0.9351	0.0809	26.7697	0.4533	0.00094	5.98E-05
100:00:00	0.996	0.0867	28.2075	0.4855	0.001	6.52E-05
101:00:00	0.9902	0.0863	27.9739	0.4833	0.000994	6.37E-05
102:00:00	0.98	0.0856	27.5927	0.4791	0.000984	6.15E-05
103:00:00	0.9966	0.0869	28.1443	0.4865	0.001001	6.15E-05
104:00:00	0.9996	0.087	28.2991	0.4874	0.001004	6.03E-05
105:00:00	0.9993	0.087	28.2691	0.4874	0.001003	6.01E-05
106:00:00	0.9624	0.0837	27.3019	0.4687	0.000967	5.69E-05
107:00:00	0.9303	0.0809	26.385	0.4531	0.000935	5.52E-05
108:00:00	0.9212	0.0798	26.3361	0.4469	0.000926	5.56E-05
109:00:00	0.9124	0.0788	26.2722	0.441	0.000918	5.72E-05
110:00:00	0.7431	0.064	22.9553	0.3997	0.000744	4.8E-05
111:00:00	0.7547	0.0651	23.296	0.4053	0.000755	5.01E-05
112:00:00	0.9432	0.0816	27.069	0.4569	0.000948	6.29E-05
113:00:00	0.9813	0.0849	28.1398	0.4753	0.000986	6.56E-05
114:00:00	0.9214	0.0796	27.0307	0.4592	0.000925	6.21E-05
115:00:00	0.834	0.0723	25.2329	0.4392	0.000835	5.55E-05
116:00:00	0.9862	0.085	28.506	0.4768	0.000991	6.53E-05
117:00:00	0.998	0.0861	28.7864	0.4819	0.001003	6.59E-05
118:00:00	1	0.0864	28.7622	0.4836	0.001005	6.67E-05
119:00:00	0.9772	0.0834	28.7543	0.4669	0.000983	6.21E-05
120:00:00	1	0.0864	28.7391	0.4838	0.001005	6.23E-05

<<< Node 253 >>>

Time hr:min	C MG/L	S MG/L	H UG/L	N MG/L	Xb CFU/L	UVXb CFU/L
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	0	0	0	0	0	0
5:00	0	0	0	0	0	0
6:00	0	0	0	0	0	0
7:00	0	0	0	0	0	0
8:00	0.1099	0.0107	2.8273	0.1608	9.78E-05	6.51E-06
9:00	0.3298	0.0324	13.1143	1.2389	0.000201	1.24E-05
10:00	0.5344	0.0522	24.0702	2.2415	0.000296	1.76E-05
11:00	0.5959	0.058	28.1225	2.5372	0.000324	1.91E-05
12:00	0.6021	0.0586	29.4297	2.6671	0.000315	1.81E-05
13:00	0.6095	0.0591	30.6465	2.7022	0.000318	1.82E-05
14:00	0.6081	0.0589	31.3432	2.7316	0.000312	1.78E-05
15:00	0.6044	0.0585	31.4903	2.7477	0.000306	1.73E-05
16:00	0.5964	0.0577	31.4605	2.769	0.000295	1.66E-05
17:00	0.5944	0.0574	31.5219	2.7562	0.000294	1.67E-05
18:00	0.5845	0.0563	32.5508	2.7424	0.000284	1.6E-05
19:00	0.5944	0.0569	34.4663	2.7368	0.000293	1.66E-05
20:00	0.5959	0.0567	36.4926	2.7088	0.000296	1.67E-05
21:00	0.6033	0.057	38.7796	2.6873	0.000305	1.73E-05
22:00	0.5707	0.0532	38.008	2.2756	0.000318	1.88E-05
23:00	0.2735	0.0262	14.4127	1.0851	0.000157	9.5E-06
24:00:00	0.0006	0.0001	0.0122	0.0003	5.59E-07	3.75E-08
25:00:00	0.0006	0.0001	0.0122	0.0003	5.59E-07	3.75E-08
26:00:00	0.0006	0.0001	0.0122	0.0003	5.59E-07	3.75E-08
27:00:00	0.0006	0.0001	0.0122	0.0003	5.59E-07	3.75E-08
28:00:00	0.0006	0.0001	0.0122	0.0003	5.59E-07	3.75E-08
29:00:00	0.0006	0.0001	0.0122	0.0003	5.59E-07	3.75E-08
30:00:00	0.7654	0.0714	25.914	0.8972	0.000701	4.63E-05
31:00:00	0.8876	0.0834	21.471	0.4965	0.000885	5.9E-05
32:00:00	0.9825	0.0924	23.4568	0.5214	0.000983	6.63E-05
33:00:00	0.9951	0.0932	23.9538	0.523	0.000996	6.68E-05
34:00:00	0.999	0.0934	24.1803	0.523	0.001	6.7E-05
35:00:00	0.9894	0.0914	24.6547	0.5143	0.000991	6.63E-05
36:00:00	0.9956	0.0917	24.9533	0.5147	0.000997	6.68E-05
37:00:00	0.9874	0.0901	25.3561	0.5072	0.000989	6.64E-05
38:00:00	0.9941	0.0909	25.3664	0.5104	0.000996	6.46E-05
39:00:00	0.9915	0.091	25.2013	0.5175	0.000992	6.26E-05
40:00:00	0.9786	0.0902	24.4613	0.5054	0.00098	6.14E-05
41:00:00	0.9386	0.0866	23.4386	0.485	0.00094	5.97E-05
42:00:00	0.944	0.0873	23.4274	0.489	0.000945	6.15E-05
43:00:00	0.9727	0.0898	24.2679	0.5028	0.000974	6.37E-05
44:00:00	0.9769	0.09	24.4872	0.5039	0.000978	6.36E-05
45:00:00	0.9769	0.0902	24.3332	0.5053	0.000978	6.23E-05
46:00:00	0.9758	0.0896	24.6287	0.5019	0.000978	6.21E-05
47:00:00	0.9779	0.0882	25.7117	0.494	0.00098	6.39E-05
48:00:00	0.9368	0.0828	25.7283	0.4637	0.00094	6.05E-05
49:00:00	0.1284	0.0115	3.6958	0.083	0.000127	8.42E-06
50:00:00	0.1284	0.0115	3.704	0.0829	0.000127	8.42E-06
51:00:00	0.1284	0.0115	3.7123	0.0828	0.000127	8.42E-06
52:00:00	0.1284	0.0115	3.7205	0.0828	0.000127	8.42E-06
53:00:00	0.1284	0.0115	3.7287	0.0827	0.000127	8.42E-06
54:00:00	0.9722	0.0885	25.0701	0.4959	0.000974	6.44E-05
55:00:00	0.9095	0.0852	22.1115	0.4949	0.000908	6.13E-05
56:00:00	0.9833	0.0924	23.5378	0.5203	0.000984	6.63E-05
57:00:00	0.9967	0.0934	23.9798	0.5233	0.000998	6.71E-05
58:00:00	0.999	0.0933	24.2124	0.5226	0.001	6.71E-05
59:00:00	0.9894	0.0913	24.7207	0.5134	0.000991	6.67E-05
60:00:00	0.9954	0.0917	24.9634	0.5142	0.000997	6.65E-05
61:00:00	0.9827	0.0895	25.3569	0.5042	0.000984	6.63E-05
62:00:00	0.9942	0.0908	25.4565	0.5094	0.000996	6.48E-05
63:00:00	0.991	0.0909	25.0942	0.509	0.000993	6.27E-05

64:00:00	0.9799	0.0902	24.5691	0.5054	0.000981	6.14E-05
65:00:00	0.9492	0.0875	23.7545	0.49	0.000951	6.06E-05
66:00:00	0.9554	0.0883	23.7858	0.4943	0.000957	6.24E-05
67:00:00	0.9782	0.0902	24.4309	0.5054	0.00098	6.41E-05
68:00:00	0.9828	0.0905	24.6231	0.507	0.000984	6.41E-05
69:00:00	0.9815	0.0906	24.5001	0.5072	0.000983	6.26E-05
70:00:00	0.9802	0.0899	24.797	0.5037	0.000982	6.25E-05
71:00:00	0.9815	0.0885	25.8367	0.4955	0.000984	6.42E-05
72:00:00	0.9473	0.0836	26.1194	0.468	0.000951	6.12E-05
73:00:00	0.2429	0.0213	7.1023	0.1365	0.000243	1.62E-05
74:00:00	0.2429	0.0213	7.1279	0.1363	0.000243	1.62E-05
75:00:00	0.2429	0.0212	7.1534	0.1361	0.000243	1.62E-05
76:00:00	0.2429	0.0212	7.179	0.1359	0.000243	1.62E-05
77:00:00	0.2429	0.0212	7.2045	0.1357	0.000243	1.62E-05
78:00:00	0.977	0.0888	25.2675	0.4974	0.000979	6.48E-05
79:00:00	0.9337	0.0873	22.8298	0.5007	0.000933	6.3E-05
80:00:00	0.9822	0.0921	23.6265	0.5192	0.000983	6.66E-05
81:00:00	0.9967	0.0934	23.9957	0.5232	0.000998	6.71E-05
82:00:00	0.9991	0.0933	24.2141	0.5227	0.001	6.71E-05
83:00:00	0.9919	0.0916	24.7757	0.5142	0.000993	6.68E-05
84:00:00	0.9958	0.0917	24.9816	0.5143	0.000997	6.68E-05
85:00:00	0.9864	0.0898	25.4773	0.5053	0.000988	6.66E-05
86:00:00	0.9949	0.0908	25.4956	0.5094	0.000997	6.5E-05
87:00:00	0.9914	0.0909	25.1497	0.5088	0.000993	6.26E-05
88:00:00	0.9828	0.0905	24.6856	0.5066	0.000984	6.16E-05
89:00:00	0.9566	0.088	24.0458	0.4928	0.000958	6.1E-05
90:00:00	0.9617	0.0887	24.0444	0.4966	0.000963	6.28E-05
91:00:00	0.9819	0.0905	24.5562	0.507	0.000984	6.44E-05
92:00:00	0.986	0.0908	24.7232	0.5085	0.000988	6.42E-05
93:00:00	0.9842	0.0907	24.6135	0.5082	0.000986	6.28E-05
94:00:00	0.9833	0.0901	24.92	0.5048	0.000985	6.26E-05
95:00:00	0.9843	0.0887	25.9555	0.4965	0.000987	6.44E-05
96:00:00	0.9552	0.0841	26.4582	0.4708	0.000959	6.17E-05
97:00:00	0.3427	0.0292	10.5316	0.1789	0.000346	2.29E-05
98:00:00	0.3427	0.0291	10.5789	0.1785	0.000346	2.29E-05
99:00:00	0.3427	0.029	10.6261	0.1781	0.000346	2.29E-05
100:00:00	0.3427	0.029	10.6733	0.1777	0.000347	2.29E-05
101:00:00	0.3427	0.0289	10.7203	0.1773	0.000347	2.29E-05
102:00:00	0.9811	0.0891	25.418	0.4991	0.000984	6.5E-05
103:00:00	0.9438	0.0879	23.3035	0.5017	0.000944	6.37E-05
104:00:00	0.9855	0.0924	23.7185	0.52	0.000986	6.66E-05
105:00:00	0.9957	0.0932	24.0173	0.5227	0.000997	6.71E-05
106:00:00	0.9992	0.0933	24.2194	0.5227	0.001	6.71E-05
107:00:00	0.9894	0.0912	24.8278	0.5125	0.000991	6.69E-05
108:00:00	0.9959	0.0917	25.0103	0.5141	0.000997	6.68E-05
109:00:00	0.9888	0.09	25.5691	0.5056	0.000991	6.66E-05
110:00:00	0.9954	0.0908	25.5273	0.5094	0.000997	6.5E-05
111:00:00	0.9937	0.091	25.222	0.5098	0.000996	6.28E-05
112:00:00	0.9854	0.0906	24.8012	0.5074	0.000987	6.18E-05
113:00:00	0.9626	0.0883	24.3365	0.4948	0.000965	6.15E-05
114:00:00	0.968	0.0891	24.3056	0.499	0.00097	6.32E-05
115:00:00	0.9839	0.0906	24.6825	0.5073	0.000986	6.46E-05
116:00:00	0.9873	0.0908	24.8088	0.5087	0.000989	6.43E-05
117:00:00	0.9868	0.0909	24.7273	0.5091	0.000989	6.29E-05
118:00:00	0.986	0.0903	25.0437	0.5058	0.000988	6.28E-05
119:00:00	0.9866	0.0888	26.0701	0.4973	0.000989	6.45E-05
120:00:00	0.9615	0.0844	26.7851	0.4726	0.000966	6.22E-05

Scenario 1 – *E. coli*

<<< Link 151 >>>

Time hr:min	C MG/L	S MG/L	H UG/L	N MG/L	E CFU/L	UVE CFU/L
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	0	0	0	0	0	0
5:00	0.5602	0.0544	12.235	0.3047	8.2474	0.233744
6:00	0.8924	0.0863	19.7435	0.4832	13.1003	0.366846
7:00	0.8911	0.0859	19.8695	0.4812	13.0589	0.365372
8:00	0.8911	0.0854	20.2001	0.4783	13.0088	0.365372
9:00	0.8911	0.0849	20.5286	0.4754	12.9589	0.365372
10:00	0.8911	0.0844	20.8552	0.4726	12.9092	0.365372
11:00	0.8911	0.0839	21.1798	0.4698	12.8596	0.365372
12:00	1	0.0938	23.9643	0.5254	14.4009	0.357362
13:00	0.9852	0.0919	23.983	0.5144	14.1312	0.351834
14:00	0.5028	0.0465	12.7302	0.2794	7.2179	0.201491
15:00	0.5085	0.0474	13.296	0.3549	7.5044	0.157576
16:00	0.4592	0.0432	11.513	0.3169	6.8032	0.132235
17:00	0.4592	0.0431	11.6253	0.3159	6.7897	0.132235
18:00	0.4592	0.043	11.7373	0.3149	6.7763	0.132235
19:00	0.4592	0.0428	11.8489	0.314	6.7629	0.132235
20:00	0.4592	0.0427	11.9602	0.313	6.7495	0.132235
21:00	0.4592	0.0426	12.0711	0.312	6.7362	0.132235
22:00	0.4592	0.0424	12.1818	0.3111	6.7228	0.132235
23:00	0.0771	0.0074	1.7099	0.0417	1.1304	0.032747
24:00:00	0.0771	0.0074	1.7124	0.0417	1.13	0.03428
25:00:00	0.7587	0.0712	18.8152	0.4471	11.0396	0.248428
26:00:00	0.9878	0.095	22.2013	0.5318	14.4488	0.379427
27:00:00	1	0.0966	22.1843	0.541	14.6716	0.409539
28:00:00	1	0.0966	22.1563	0.5412	14.6758	0.413007
29:00:00	1	0.0966	22.1918	0.5409	14.6705	0.410963
30:00:00	1	0.0963	22.3675	0.5394	14.6439	0.402552
31:00:00	1	0.0962	22.4714	0.5385	14.6281	0.403926
32:00:00	1	0.0955	22.8863	0.5348	14.5652	0.403926
33:00:00	1	0.0949	23.2985	0.5312	14.5025	0.403926
34:00:00	1	0.0942	23.7079	0.5277	14.4401	0.403926
35:00:00	1	0.0936	24.1145	0.5241	14.3779	0.403926
36:00:00	0.5048	0.0477	11.876	0.2672	7.3041	0.199651
37:00:00	0.5453	0.0512	13.0292	0.2868	7.8577	0.214419
38:00:00	1	0.0939	23.9457	0.5256	14.4033	0.346724
39:00:00	0.9626	0.0903	23.0752	0.5057	13.8603	0.356657
40:00:00	0.8939	0.0847	20.8621	0.4745	12.9572	0.352935
41:00:00	0.8939	0.0842	21.1891	0.4717	12.9074	0.352935
42:00:00	0.8939	0.0837	21.5141	0.4689	12.8577	0.352935
43:00:00	0.8939	0.0832	21.8372	0.466	12.8082	0.352935
44:00:00	0.8939	0.0827	22.1584	0.4632	12.759	0.352935
45:00:00	0.8939	0.0822	22.4776	0.4605	12.7099	0.352935
46:00:00	0.8939	0.0817	22.7949	0.4577	12.661	0.352935
47:00:00	0.241	0.0228	5.679	0.1275	3.4861	0.09713
48:00:00	0.241	0.0227	5.7028	0.1273	3.4825	0.101857
49:00:00	0.8571	0.0802	20.6985	0.4489	12.3169	0.298744
50:00:00	0.9089	0.0873	20.4882	0.4888	13.285	0.332967
51:00:00	1	0.0965	22.2338	0.5405	14.6641	0.405455
52:00:00	1	0.0966	22.1639	0.5411	14.6747	0.412638
53:00:00	1	0.0966	22.1961	0.5409	14.6698	0.410743
54:00:00	1	0.0963	22.359	0.5394	14.6452	0.401852
55:00:00	1	0.0962	22.4655	0.5385	14.629	0.404004
56:00:00	1	0.0955	22.8805	0.5349	14.5661	0.404004
57:00:00	1	0.0949	23.2927	0.5313	14.5034	0.404004
58:00:00	1	0.0942	23.7021	0.5277	14.441	0.404004
59:00:00	1	0.0936	24.1088	0.5242	14.3788	0.404003
60:00:00	0.3292	0.0307	8.0175	0.1719	4.7211	0.129733
61:00:00	0.6149	0.0573	15.0025	0.3208	8.8143	0.24675

62:00:00	1	0.0938	23.9615	0.5255	14.4009	0.349821
63:00:00	0.968	0.0908	23.234	0.5083	13.9339	0.361425
64:00:00	0.9118	0.0863	21.3587	0.4834	13.2055	0.357383
65:00:00	0.9118	0.0858	21.6985	0.4804	13.1536	0.357383
66:00:00	0.9118	0.0853	22.0362	0.4775	13.102	0.357383
67:00:00	0.9118	0.0847	22.3718	0.4746	13.0506	0.357383
68:00:00	0.9118	0.0842	22.7054	0.4717	12.9994	0.357383
69:00:00	0.9118	0.0837	23.0369	0.4688	12.9483	0.357383
70:00:00	0.9118	0.0832	23.3664	0.4659	12.8975	0.357383
71:00:00	0.3584	0.0327	9.1668	0.1833	5.072	0.143179
72:00:00	0.3584	0.0326	9.2175	0.1828	5.0642	0.150054
73:00:00	0.8811	0.0822	21.4359	0.4602	12.6377	0.308117
74:00:00	0.9224	0.0884	20.919	0.495	13.4631	0.337889
75:00:00	1	0.0965	22.2355	0.5405	14.6638	0.405406
76:00:00	1	0.0966	22.1642	0.5411	14.6746	0.412785
77:00:00	1	0.0966	22.1961	0.5409	14.6698	0.410745
78:00:00	1	0.0963	22.3597	0.5394	14.6451	0.401902
79:00:00	1	0.0962	22.4656	0.5385	14.629	0.404006
80:00:00	1	0.0955	22.8806	0.5349	14.566	0.404006
81:00:00	1	0.0949	23.2928	0.5313	14.5034	0.404006
82:00:00	1	0.0942	23.7022	0.5277	14.4409	0.404006
83:00:00	1	0.0936	24.1089	0.5242	14.3788	0.404006
84:00:00	0.433	0.0389	11.4651	0.218	6.0669	0.169423
85:00:00	0.6744	0.062	17.0023	0.3471	9.5828	0.269519
86:00:00	1	0.0938	23.9614	0.5255	14.4009	0.349765
87:00:00	0.973	0.0911	23.4091	0.5104	13.9964	0.363186
88:00:00	0.9254	0.0873	21.8438	0.4892	13.3765	0.362626
89:00:00	0.9254	0.0868	22.1928	0.4861	13.3232	0.362626
90:00:00	0.9254	0.0863	22.5395	0.4831	13.2701	0.362626
91:00:00	0.9254	0.0857	22.8842	0.4801	13.2173	0.362626
92:00:00	0.9254	0.0852	23.2266	0.4771	13.1646	0.362626
93:00:00	0.9254	0.0847	23.567	0.4741	13.1122	0.362626
94:00:00	0.9254	0.0841	23.9052	0.4712	13.06	0.362626
95:00:00	0.4576	0.0401	12.7804	0.2246	6.3073	0.18185
96:00:00	0.4576	0.04	12.8597	0.2239	6.2948	0.190398
97:00:00	0.8993	0.0835	22.1285	0.4675	12.8601	0.317768
98:00:00	0.9344	0.0893	21.376	0.4998	13.6099	0.342564
99:00:00	1	0.0965	22.2354	0.5405	14.6638	0.405413
100:00:00	1	0.0966	22.1642	0.5411	14.6746	0.41279
101:00:00	1	0.0966	22.1961	0.5409	14.6698	0.410745
102:00:00	1	0.0963	22.3597	0.5394	14.6451	0.401898
103:00:00	1	0.0962	22.4656	0.5385	14.629	0.404006
104:00:00	1	0.0955	22.8805	0.5349	14.5661	0.404006
105:00:00	1	0.0949	23.2927	0.5313	14.5034	0.404006
106:00:00	1	0.0942	23.7022	0.5277	14.4409	0.404006
107:00:00	1	0.0936	24.1088	0.5242	14.3788	0.404006
108:00:00	0.5207	0.0449	15.0193	0.2514	7.1001	0.20278
109:00:00	0.7248	0.0654	19.0523	0.3662	10.1744	0.285628
110:00:00	1	0.0938	23.9614	0.5255	14.4009	0.349781
111:00:00	0.9771	0.0914	23.5871	0.5119	14.0444	0.364759
112:00:00	0.937	0.0881	22.3384	0.4934	13.5093	0.366945
113:00:00	0.937	0.0875	22.6947	0.4903	13.4548	0.366945
114:00:00	0.937	0.087	23.0488	0.4872	13.4006	0.366945
115:00:00	0.937	0.0864	23.4007	0.4841	13.3465	0.366945
116:00:00	0.937	0.0859	23.7503	0.4811	13.2927	0.366945
117:00:00	0.937	0.0854	24.0978	0.478	13.2391	0.366945
118:00:00	0.937	0.0848	24.443	0.475	13.1857	0.366945
119:00:00	0.5414	0.0453	16.4809	0.2539	7.246	0.214311
120:00:00	0.5414	0.0452	16.587	0.253	7.2291	0.224129

<<< Link 251 >>>

Time hr:min	C MG/L	S MG/L	H UG/L	N MG/L	E CFU/L	UVE CFU/L
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	0	0	0	0	0	0
5:00	0	0	0	0	0	0
6:00	0	0	0	0	0	0
7:00	0	0	0	0	0	0
8:00	0	0	0	0	0	0
9:00	0	0	0	0	0	0
10:00	0	0	0	0	0	0
11:00	0	0	0	0	0	0
12:00	0	0	0	0	0	0
13:00	0.0127	0.0012	0.3338	0.0168	0.2093	0.005954
14:00	0.0905	0.0087	4.3501	0.3398	2.0087	0.036195
15:00	0.1799	0.0172	9.4485	0.7078	4.0612	0.070477
16:00	0.2571	0.0245	14.1723	1.0339	5.8512	0.099145
17:00	0.3298	0.0314	18.9172	1.3497	7.5562	0.125343
18:00	0.3979	0.0378	23.6266	1.6471	9.1552	0.14921
19:00	0.4567	0.0432	27.9747	1.9028	10.5297	0.169307
20:00	0.5153	0.0486	32.4842	2.1566	11.8943	0.188984
21:00	0.5817	0.0547	38.0519	2.485	13.5366	0.209212
22:00	0.6047	0.0567	40.8687	2.6211	14.153	0.211986
23:00	0.5994	0.0562	41.0048	2.6582	14.1724	0.202179
24:00:00	0.5941	0.0558	40.4671	2.6858	14.1711	0.192089
25:00:00	0.5792	0.0546	40.2136	2.7625	14.1661	0.181889
26:00:00	0.5811	0.0549	39.35	2.7732	14.2245	0.176619
27:00:00	0.6091	0.0573	38.058	2.5433	14.0327	0.184008
28:00:00	0.6421	0.0601	36.0697	2.2308	13.7029	0.193543
29:00:00	0.6684	0.0621	34.9971	1.9953	13.4605	0.202083
30:00:00	0.7129	0.0656	33.0281	1.6275	13.1229	0.217793
31:00:00	0.7564	0.0689	31.1791	1.2721	12.7954	0.23411
32:00:00	0.7653	0.0693	28.336	0.99	12.2102	0.240461
33:00:00	0.7482	0.0676	25.7088	0.7977	11.5155	0.239374
34:00:00	0.7687	0.0692	23.9888	0.6294	11.357	0.256595
35:00:00	0.8002	0.0718	23.264	0.5303	11.5085	0.285836
36:00:00	0.7895	0.0711	22.4564	0.5014	11.3183	0.303565
37:00:00	0.8168	0.0736	22.7485	0.4911	11.6488	0.338482
38:00:00	0.8601	0.0774	23.3994	0.4784	12.1667	0.377297
39:00:00	0.9197	0.0824	24.9697	0.4858	12.9136	0.41517
40:00:00	0.9445	0.0843	25.71	0.4882	13.2096	0.432974
41:00:00	0.9482	0.0845	25.8433	0.4878	13.2467	0.440092
42:00:00	0.9568	0.0851	26.179	0.4887	13.34	0.445835
43:00:00	0.9861	0.0872	27.1915	0.4932	13.6797	0.458116
44:00:00	0.9954	0.0876	27.635	0.4935	13.767	0.460569
45:00:00	0.9961	0.0875	27.7837	0.4926	13.7571	0.457143
46:00:00	0.9933	0.0871	27.8223	0.4902	13.6997	0.44787
47:00:00	0.9779	0.0858	27.3336	0.4816	13.4888	0.428214
48:00:00	0.9703	0.0854	26.9054	0.478	13.4084	0.412306
49:00:00	0.9666	0.0852	26.6748	0.4773	13.3762	0.40734
50:00:00	0.9657	0.0858	26.2328	0.4805	13.4288	0.406431
51:00:00	0.9803	0.0874	26.463	0.4892	13.6576	0.417992
52:00:00	0.9787	0.0875	26.2581	0.4898	13.6612	0.420617
53:00:00	0.9675	0.0863	26.0329	0.4835	13.4926	0.410764
54:00:00	0.9546	0.0851	25.7457	0.4766	13.3043	0.396314
55:00:00	0.9408	0.0837	25.4658	0.4689	13.0967	0.382704
56:00:00	0.9044	0.0805	24.5317	0.4555	12.6032	0.357289
57:00:00	0.8519	0.0759	23.2343	0.4396	11.9018	0.328402
58:00:00	0.8316	0.0742	22.6786	0.4334	11.6377	0.313456
59:00:00	0.8388	0.0749	22.8555	0.4373	11.7428	0.31856
60:00:00	0.8279	0.0741	22.5738	0.44	11.6267	0.32718
61:00:00	0.8478	0.076	23.02	0.4508	11.9201	0.352441

62:00:00	0.883	0.0792	23.885	0.4645	12.4047	0.384231
63:00:00	0.9336	0.0834	25.2804	0.4781	13.0551	0.416326
64:00:00	0.9558	0.0851	25.9882	0.4839	13.3281	0.43379
65:00:00	0.9605	0.0854	26.1893	0.4856	13.3832	0.443196
66:00:00	0.9657	0.0857	26.4282	0.4867	13.4366	0.448982
67:00:00	0.9878	0.0872	27.2011	0.49	13.6876	0.457833
68:00:00	0.9948	0.0875	27.5755	0.4902	13.7484	0.45905
69:00:00	0.9952	0.0874	27.714	0.4892	13.733	0.454898
70:00:00	0.9912	0.0868	27.7239	0.4862	13.6587	0.443663
71:00:00	0.9788	0.0858	27.3654	0.4802	13.4905	0.424822
72:00:00	0.9735	0.0856	27.0405	0.4792	13.4454	0.409835
73:00:00	0.9702	0.0855	26.8224	0.4786	13.4185	0.405527
74:00:00	0.9712	0.0862	26.4326	0.4828	13.4974	0.40743
75:00:00	0.9848	0.0877	26.613	0.4912	13.7156	0.420262
76:00:00	0.9823	0.0877	26.386	0.4913	13.7067	0.42254
77:00:00	0.9729	0.0868	26.2294	0.4858	13.5606	0.413227
78:00:00	0.9622	0.0857	26.023	0.4798	13.3992	0.399754
79:00:00	0.9502	0.0844	25.8166	0.4728	13.2138	0.386819
80:00:00	0.9198	0.0817	25.11	0.4609	12.7929	0.364007
81:00:00	0.8759	0.0777	24.1447	0.4465	12.1933	0.339142
82:00:00	0.8587	0.0762	23.7206	0.4407	11.9642	0.325613
83:00:00	0.8646	0.0768	23.8615	0.4441	12.0518	0.330106
84:00:00	0.8557	0.0761	23.6712	0.446	11.9567	0.33989
85:00:00	0.8724	0.0778	24.0041	0.4555	12.2107	0.363821
86:00:00	0.9019	0.0806	24.65	0.4676	12.6254	0.393034
87:00:00	0.9442	0.0842	25.7212	0.48	13.1779	0.421269
88:00:00	0.963	0.0856	26.2878	0.4851	13.4104	0.437181
89:00:00	0.967	0.0859	26.4614	0.4866	13.4569	0.446337
90:00:00	0.9714	0.0861	26.6703	0.4874	13.5021	0.451836
91:00:00	0.9898	0.0874	27.2869	0.4905	13.7102	0.458889
92:00:00	0.9957	0.0876	27.6122	0.4905	13.7583	0.459555
93:00:00	0.996	0.0874	27.7487	0.4895	13.7425	0.455402
94:00:00	0.9926	0.0869	27.7848	0.4867	13.6758	0.444426
95:00:00	0.9822	0.086	27.5051	0.4815	13.5299	0.426311
96:00:00	0.9776	0.0858	27.2139	0.4807	13.4929	0.411548
97:00:00	0.9748	0.0858	27.0208	0.4803	13.4716	0.407427
98:00:00	0.9756	0.0865	26.6264	0.4843	13.5478	0.40921
99:00:00	0.9871	0.0879	26.7162	0.492	13.7418	0.421197
100:00:00	0.985	0.0879	26.5025	0.4923	13.7379	0.423554
101:00:00	0.9771	0.087	26.4081	0.4873	13.6084	0.41476
102:00:00	0.9681	0.086	26.2727	0.4819	13.4658	0.401884
103:00:00	0.9579	0.0849	26.1487	0.4755	13.3012	0.38971
104:00:00	0.9323	0.0825	25.6606	0.4646	12.9337	0.36906
105:00:00	0.8955	0.0789	25.0213	0.451	12.4113	0.34751
106:00:00	0.881	0.0776	24.7317	0.4456	12.211	0.335296
107:00:00	0.886	0.0781	24.8415	0.4485	12.2868	0.339532
108:00:00	0.8787	0.0776	24.738	0.4497	12.2061	0.350372
109:00:00	0.8929	0.0791	24.9608	0.4582	12.4301	0.373271
110:00:00	0.9177	0.0815	25.3961	0.4694	12.7931	0.400412
111:00:00	0.9532	0.0847	26.1505	0.481	13.2719	0.425461
112:00:00	0.9689	0.086	26.5767	0.4858	13.4721	0.439945
113:00:00	0.9723	0.0862	26.7224	0.487	13.5116	0.448836
114:00:00	0.9761	0.0864	26.8987	0.4878	13.5492	0.454017
115:00:00	0.9914	0.0875	27.3689	0.4907	13.7267	0.459637
116:00:00	0.9964	0.0876	27.6468	0.4907	13.7652	0.459846
117:00:00	0.9966	0.0874	27.7813	0.4897	13.7488	0.455692
118:00:00	0.9938	0.087	27.8428	0.4871	13.6875	0.444921
119:00:00	0.9849	0.0861	27.6399	0.4824	13.5586	0.427476
120:00:00	0.9811	0.086	27.3837	0.4818	13.5288	0.413032

<<< Link 291 >>>

Time hr:min	C MG/L	S MG/L	H UG/L	N MG/L	E CFU/L	UVE CFU/L
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	0	0	0	0	0	0
5:00	0	0	0	0	0	0
6:00	0.0003	0	0.0054	0.0001	0.0038	0.000122
7:00	0.061	0.006	1.8833	0.156	1.1888	0.02673
8:00	0.2877	0.0283	11.2589	1.1178	6.5019	0.115126
9:00	0.4782	0.0468	20.3615	1.9576	11.0272	0.186946
10:00	0.5827	0.0569	26.2941	2.4652	13.6136	0.222439
11:00	0.6036	0.0588	28.2992	2.6239	14.2607	0.224724
12:00	0.6074	0.0591	29.4267	2.7042	14.4964	0.219846
13:00	0.6092	0.0592	30.2819	2.7307	14.5742	0.215493
14:00	0.6038	0.0586	30.4488	2.7529	14.5507	0.206377
15:00	0.5932	0.0576	30.1615	2.7684	14.4459	0.194532
16:00	0.5902	0.0573	30.3222	2.7657	14.396	0.18928
17:00	0.5897	0.057	31.469	2.7549	14.3538	0.189021
18:00	0.5929	0.057	33.3616	2.7429	14.3526	0.192297
19:00	0.5944	0.057	34.397	2.7407	14.3592	0.192029
20:00	0.5976	0.0568	36.4554	2.6879	14.2566	0.20035
21:00	0.5779	0.0542	37.6287	2.406	13.295	0.214994
22:00	0.407	0.0384	24.284	1.5949	9.1411	0.159797
23:00	0.1058	0.0102	4.5171	0.3415	2.218	0.044317
24:00:00	0.0006	0.0001	0.0122	0.0003	0.0083	0.000273
25:00:00	0.0006	0.0001	0.0122	0.0003	0.0083	0.000273
26:00:00	0.0006	0.0001	0.0122	0.0003	0.0083	0.000273
27:00:00	0.0006	0.0001	0.0122	0.0003	0.0083	0.000273
28:00:00	0.0006	0.0001	0.0122	0.0003	0.0083	0.000273
29:00:00	0.3701	0.0348	10.9507	0.3639	5.742	0.15411
30:00:00	0.8569	0.0809	21.6941	0.5678	12.6629	0.387107
31:00:00	0.9453	0.0893	22.3744	0.5145	13.7103	0.446357
32:00:00	0.9938	0.0938	23.5084	0.5264	14.3641	0.476255
33:00:00	0.9985	0.0938	23.8505	0.5256	14.3919	0.480544
34:00:00	0.9952	0.0928	24.2451	0.5207	14.2758	0.478614
35:00:00	0.9922	0.0918	24.635	0.5159	14.1656	0.476086
36:00:00	0.9885	0.0908	24.965	0.5115	14.0521	0.470926
37:00:00	0.9892	0.0907	25.1126	0.5117	14.0473	0.462818
38:00:00	0.9949	0.0918	24.9371	0.5171	14.1777	0.454721
39:00:00	0.9741	0.0903	24.1181	0.5072	13.9192	0.422081
40:00:00	0.9416	0.0875	23.0913	0.4902	13.4794	0.38499
41:00:00	0.948	0.0882	23.1891	0.494	13.5791	0.379789
42:00:00	0.97	0.0902	23.7428	0.5054	13.893	0.401192
43:00:00	0.9802	0.0911	24.066	0.51	14.0272	0.417785
44:00:00	0.9795	0.0909	24.1215	0.509	14.0057	0.424011
45:00:00	0.9779	0.0904	24.3018	0.5062	13.9488	0.425011
46:00:00	0.98	0.0894	25.1162	0.5007	13.8623	0.419802
47:00:00	0.9548	0.0857	25.4095	0.4797	13.3603	0.385368
48:00:00	0.3295	0.0292	9.186	0.1776	4.6116	0.139359
49:00:00	0.1284	0.0115	3.6961	0.083	1.8407	0.05757
50:00:00	0.1284	0.0115	3.7044	0.0829	1.8397	0.05757
51:00:00	0.1284	0.0115	3.7126	0.0829	1.8387	0.05757
52:00:00	0.1366	0.0122	3.9419	0.0867	1.9506	0.061089
53:00:00	0.5261	0.0485	13.4489	0.2922	7.5391	0.223477
54:00:00	0.9054	0.0851	21.8293	0.4959	13.1016	0.407198
55:00:00	0.9627	0.0909	22.8096	0.517	13.9388	0.452637
56:00:00	0.9942	0.0937	23.553	0.526	14.3644	0.475038
57:00:00	0.9983	0.0937	23.8844	0.525	14.383	0.480543
58:00:00	0.9945	0.0926	24.2795	0.5198	14.2579	0.477034
59:00:00	0.9922	0.0917	24.6723	0.5152	14.1578	0.473587
60:00:00	0.9873	0.0906	25.0094	0.5094	14.0208	0.466154
61:00:00	0.9875	0.0904	25.1225	0.5077	14.0031	0.459778
62:00:00	0.9945	0.0916	24.9388	0.5132	14.1537	0.453035
63:00:00	0.9744	0.0901	24.174	0.5048	13.9062	0.418025

64:00:00	0.9497	0.0882	23.3744	0.4937	13.5823	0.383975
65:00:00	0.9575	0.089	23.481	0.4985	13.7067	0.382058
66:00:00	0.976	0.0907	23.9233	0.5082	13.9733	0.40351
67:00:00	0.9835	0.0913	24.1738	0.5115	14.0694	0.419275
68:00:00	0.983	0.0912	24.2452	0.5105	14.0505	0.425762
69:00:00	0.9822	0.0907	24.4589	0.5081	14.003	0.427143
70:00:00	0.9834	0.0897	25.2375	0.5022	13.9049	0.421358
71:00:00	0.9631	0.0863	25.6942	0.4833	13.4661	0.387508
72:00:00	0.4154	0.0366	11.7591	0.2177	5.7729	0.176343
73:00:00	0.243	0.0213	7.1044	0.1367	3.3942	0.108408
74:00:00	0.243	0.0213	7.13	0.1364	3.3907	0.108408
75:00:00	0.243	0.0213	7.1556	0.1362	3.3871	0.108408
76:00:00	0.2498	0.0218	7.3626	0.1392	3.4778	0.111363
77:00:00	0.5903	0.0538	15.4861	0.3188	8.3887	0.251517
78:00:00	0.9204	0.0863	22.4189	0.4982	13.2821	0.413389
79:00:00	0.9676	0.0913	23.0251	0.5175	13.9954	0.454822
80:00:00	0.995	0.0938	23.5891	0.5261	14.3732	0.475399
81:00:00	0.9985	0.0937	23.8972	0.5251	14.3853	0.48096
82:00:00	0.9953	0.0927	24.3121	0.52	14.2684	0.477758
83:00:00	0.9933	0.0918	24.7193	0.5154	14.1719	0.474615
84:00:00	0.9892	0.0907	25.0899	0.5098	14.0429	0.467139
85:00:00	0.9896	0.0906	25.2059	0.5083	14.0293	0.461032
86:00:00	0.9955	0.0917	24.9741	0.5135	14.1647	0.453639
87:00:00	0.9785	0.0905	24.3217	0.5065	13.9572	0.419749
88:00:00	0.9575	0.0887	23.6624	0.4969	13.6789	0.387135
89:00:00	0.964	0.0895	23.7271	0.5011	13.787	0.38468
90:00:00	0.9797	0.091	24.0648	0.5097	14.018	0.404972
91:00:00	0.986	0.0915	24.2738	0.5125	14.0998	0.420366
92:00:00	0.9856	0.0913	24.3499	0.5115	14.0815	0.426827
93:00:00	0.985	0.0909	24.5709	0.5091	14.0355	0.428133
94:00:00	0.986	0.0898	25.3429	0.5031	13.9346	0.422428
95:00:00	0.9688	0.0867	25.9309	0.4854	13.5321	0.389804
96:00:00	0.4931	0.0427	14.4245	0.2507	6.7709	0.210635
97:00:00	0.343	0.0292	10.5354	0.1791	4.6787	0.152661
98:00:00	0.343	0.0291	10.5829	0.1786	4.6718	0.152661
99:00:00	0.343	0.0291	10.6302	0.1782	4.6649	0.152661
100:00:00	0.3489	0.0295	10.8287	0.1807	4.7409	0.155258
101:00:00	0.646	0.0581	17.5235	0.3396	9.0848	0.276392
102:00:00	0.9333	0.0872	22.9866	0.4998	13.427	0.419414
103:00:00	0.9728	0.0916	23.2599	0.5181	14.0541	0.45728
104:00:00	0.9958	0.0938	23.6249	0.5262	14.3821	0.475747
105:00:00	0.9988	0.0938	23.9076	0.5252	14.3879	0.481047
106:00:00	0.9961	0.0928	24.347	0.5201	14.2759	0.478083
107:00:00	0.9944	0.0919	24.7687	0.5155	14.1829	0.47506
108:00:00	0.9909	0.0908	25.1714	0.51	14.0615	0.467923
109:00:00	0.9913	0.0907	25.2827	0.5086	14.0469	0.461769
110:00:00	0.9962	0.0917	25.0081	0.5137	14.1726	0.453963
111:00:00	0.9818	0.0907	24.4684	0.5077	13.9947	0.421176
112:00:00	0.9641	0.0891	23.9525	0.4992	13.7527	0.389972
113:00:00	0.9696	0.0898	23.976	0.503	13.849	0.387099
114:00:00	0.9828	0.0912	24.2075	0.5107	14.0526	0.406316
115:00:00	0.9882	0.0916	24.3737	0.5132	14.1233	0.421264
116:00:00	0.9877	0.0915	24.4494	0.5122	14.1033	0.427621
117:00:00	0.987	0.091	24.673	0.5097	14.0566	0.428871
118:00:00	0.9881	0.09	25.4474	0.5038	13.9575	0.423324
119:00:00	0.9736	0.0869	26.1653	0.4869	13.5828	0.391872
120:00:00	0.5605	0.0474	17.1361	0.2756	7.5738	0.240479

Scenario 2 – *E. coli*

<<< Node 15 >>>

Time hr:min	C MG/L	S MG/L	H UG/L	N MG/L	E CFU/L	UVE CFU/L
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	0	0	0	0	0	0
5:00	0.4472	0.0434	9.7816	0.2431	6.5822	1.38E-13
6:00	0.8923	0.0862	19.7599	0.483	13.0963	3.08E-13
7:00	0.8927	0.0861	19.9124	0.482	13.0805	3.33E-13
8:00	0.8921	0.0855	20.2277	0.4788	13.0227	3.9E-13
9:00	0.8921	0.085	20.557	0.4759	12.9727	4.47E-13
10:00	0.8921	0.0845	20.8843	0.4731	12.9229	5.04E-13
11:00	0.8921	0.084	21.2096	0.4702	12.8733	5.61E-13
12:00	1	0.0938	24.0054	0.5251	14.3946	6.18E-13
13:00	1	0.0933	24.3344	0.5222	14.3442	6.7E-13
14:00	0.5055	0.0467	12.6503	0.2661	7.2177	4.15E-13
15:00	0.507	0.0472	13.4759	0.3623	7.4929	4.04E-13
16:00	0.4586	0.0432	11.5636	0.3199	6.7997	3.17E-13
17:00	0.4587	0.043	11.659	0.3186	6.7879	3.44E-13
18:00	0.4587	0.0429	11.7718	0.3176	6.7745	3.74E-13
19:00	0.4587	0.0428	11.8843	0.3166	6.7611	4.04E-13
20:00	0.4587	0.0426	11.9964	0.3157	6.7478	4.34E-13
21:00	0.4587	0.0425	12.1081	0.3147	6.7344	4.63E-13
22:00	0.4587	0.0424	12.2196	0.3137	6.7211	4.93E-13
23:00	0.0771	0.0074	1.7099	0.0417	1.1304	1.09E-13
24:00:00	0.0771	0.0074	1.7124	0.0417	1.13	1.14E-13
25:00:00	0.9063	0.0841	23.4106	0.5446	13.1288	7.12E-13
26:00:00	0.9467	0.0909	21.3361	0.5092	13.8394	3.82E-13
27:00:00	1	0.0965	22.2217	0.5406	14.6659	3.41E-13
28:00:00	1	0.0966	22.1975	0.5408	14.6696	3.37E-13
29:00:00	1	0.0965	22.2276	0.5406	14.6651	3.42E-13
30:00:00	1	0.0963	22.398	0.5391	14.6393	3.68E-13
31:00:00	1	0.0961	22.5168	0.5381	14.6213	3.87E-13
32:00:00	1	0.0955	22.9184	0.5346	14.5603	4.49E-13
33:00:00	1	0.0948	23.3304	0.531	14.4976	5.13E-13
34:00:00	1	0.0942	23.7395	0.5274	14.4353	5.77E-13
35:00:00	1	0.0935	24.146	0.5239	14.3731	6.4E-13
36:00:00	0.3296	0.0314	7.5909	0.1758	4.7928	3.23E-13
37:00:00	0.5453	0.0513	12.9977	0.2871	7.8626	4.39E-13
38:00:00	1	0.0938	23.9845	0.5253	14.3974	6.15E-13
39:00:00	1	0.0934	24.2186	0.5232	14.3609	6.52E-13
1900-01-01 16:00	0.8781	0.083	20.6771	0.4646	12.7002	5.33E-13
41:00:00	0.8784	0.0825	20.9842	0.4622	12.6601	5.86E-13
42:00:00	0.8784	0.082	21.2972	0.4594	12.6123	6.42E-13
43:00:00	0.8784	0.0816	21.6083	0.4567	12.5646	6.97E-13
44:00:00	0.8784	0.0811	21.9176	0.454	12.5171	7.52E-13
45:00:00	0.8784	0.0806	22.225	0.4513	12.4697	8.07E-13
46:00:00	0.8784	0.0801	22.5307	0.4487	12.4226	8.62E-13
47:00:00	0.241	0.0228	5.679	0.1275	3.4861	4.35E-13
48:00:00	0.241	0.0227	5.7028	0.1273	3.4825	4.5E-13
49:00:00	0.9792	0.0911	23.9671	0.5101	14.023	6.9E-13
50:00:00	0.9046	0.0867	20.5094	0.4855	13.2058	4.22E-13
51:00:00	1	0.0964	22.286	0.5401	14.6562	3.51E-13
52:00:00	1	0.0966	22.2102	0.5407	14.6677	3.39E-13
53:00:00	1	0.0965	22.232	0.5405	14.6644	3.43E-13
54:00:00	1	0.0963	22.3991	0.5391	14.6391	3.69E-13
55:00:00	1	0.0961	22.5115	0.5381	14.6221	3.86E-13
56:00:00	1	0.0955	22.9106	0.5346	14.5615	4.48E-13
57:00:00	1	0.0948	23.3226	0.531	14.4988	5.12E-13
58:00:00	1	0.0942	23.7318	0.5275	14.4364	5.76E-13
59:00:00	1	0.0936	24.1383	0.5239	14.3743	6.39E-13
60:00:00	0.3259	0.0304	7.9402	0.1701	4.6722	6.57E-13
61:00:00	0.6149	0.0573	15.0025	0.3208	8.8143	6.8E-13
62:00:00	1	0.0939	23.9149	0.5259	14.4081	6.04E-13

63:00:00	1	0.0935	24.2021	0.5234	14.3635	6.5E-13
64:00:00	0.8963	0.0845	21.1998	0.4734	12.949	5.94E-13
65:00:00	0.8963	0.084	21.5089	0.4707	12.9018	6.48E-13
66:00:00	0.8963	0.0835	21.834	0.4678	12.852	7.04E-13
67:00:00	0.8963	0.083	22.1573	0.465	12.8024	7.61E-13
68:00:00	0.8963	0.0825	22.4785	0.4622	12.753	8.17E-13
69:00:00	0.8963	0.082	22.7979	0.4594	12.7038	8.73E-13
70:00:00	0.8963	0.0815	23.1153	0.4567	12.6548	9.29E-13
71:00:00	0.3584	0.0327	9.1668	0.1833	5.072	8.83E-13
72:00:00	0.3584	0.0326	9.2175	0.1828	5.0642	9.05E-13
73:00:00	0.9824	0.0913	24.0762	0.5115	14.0644	7.04E-13
74:00:00	0.9193	0.0879	20.972	0.4923	13.3996	4.81E-13
75:00:00	1	0.0964	22.2876	0.5401	14.6559	3.51E-13
76:00:00	1	0.0966	22.2106	0.5407	14.6676	3.39E-13
77:00:00	1	0.0965	22.232	0.5405	14.6644	3.43E-13
78:00:00	1	0.0963	22.4016	0.5391	14.6387	3.69E-13
79:00:00	1	0.0961	22.5114	0.5381	14.6221	3.86E-13
80:00:00	1	0.0955	22.9107	0.5346	14.5615	4.48E-13
81:00:00	1	0.0948	23.3227	0.531	14.4988	5.12E-13
82:00:00	1	0.0942	23.732	0.5275	14.4364	5.76E-13
83:00:00	1	0.0936	24.1384	0.5239	14.3743	6.39E-13
84:00:00	0.4301	0.0386	11.4025	0.2164	6.0238	1.13E-12
85:00:00	0.6744	0.062	17.0023	0.3471	9.5828	9.55E-13
86:00:00	1	0.0939	23.9151	0.5259	14.4081	6.04E-13
87:00:00	1	0.0935	24.2018	0.5234	14.3635	6.5E-13
88:00:00	0.9123	0.0857	21.7718	0.4802	13.1508	6.71E-13
89:00:00	0.9123	0.0852	22.0913	0.4774	13.1019	7.26E-13
90:00:00	0.9123	0.0847	22.427	0.4744	13.0505	7.83E-13
91:00:00	0.9123	0.0842	22.7606	0.4715	12.9992	8.41E-13
92:00:00	0.9123	0.0837	23.0922	0.4686	12.9482	8.98E-13
93:00:00	0.9123	0.0832	23.4218	0.4658	12.8973	9.55E-13
94:00:00	0.9123	0.0827	23.7493	0.4629	12.8467	1.01E-12
95:00:00	0.4576	0.0401	12.7804	0.2246	6.3073	1.4E-12
96:00:00	0.4576	0.04	12.8597	0.2239	6.2948	1.43E-12
97:00:00	0.9848	0.0915	24.1813	0.5124	14.0924	7.19E-13
98:00:00	0.9318	0.0888	21.4471	0.4973	13.5518	5.48E-13
99:00:00	1	0.0964	22.2875	0.5401	14.6559	3.51E-13
100:00:00	1	0.0966	22.2105	0.5407	14.6676	3.39E-13
101:00:00	1	0.0965	22.232	0.5405	14.6644	3.43E-13
102:00:00	1	0.0963	22.4014	0.5391	14.6387	3.69E-13
103:00:00	1	0.0961	22.5114	0.5381	14.6221	3.86E-13
104:00:00	1	0.0955	22.9107	0.5346	14.5615	4.48E-13
105:00:00	1	0.0948	23.3226	0.531	14.4988	5.12E-13
106:00:00	1	0.0942	23.7319	0.5275	14.4364	5.76E-13
107:00:00	1	0.0936	24.1383	0.5239	14.3743	6.39E-13
108:00:00	0.5182	0.0446	14.9743	0.25	7.0623	1.65E-12
109:00:00	0.7248	0.0654	19.0523	0.3662	10.1744	1.25E-12
110:00:00	1	0.0939	23.915	0.5259	14.4081	6.04E-13
111:00:00	1	0.0935	24.2018	0.5234	14.3636	6.5E-13
112:00:00	0.9259	0.0866	22.353	0.485	13.3055	7.53E-13
113:00:00	0.9259	0.0861	22.6807	0.4822	13.2553	8.09E-13
114:00:00	0.9259	0.0856	23.0248	0.4792	13.2024	8.67E-13
115:00:00	0.9259	0.085	23.3668	0.4762	13.1498	9.25E-13
116:00:00	0.9259	0.0845	23.7066	0.4732	13.0974	9.83E-13
117:00:00	0.9259	0.084	24.0444	0.4703	13.0452	1.04E-12
118:00:00	0.9259	0.0835	24.38	0.4674	12.9932	1.1E-12
119:00:00	0.5414	0.0453	16.4809	0.2539	7.246	1.94E-12
120:00:00	0.5414	0.0452	16.587	0.253	7.2291	1.97E-12

<<< Node 219 >>>

Time hr:min	C MG/L	S MG/L	H UG/L	N MG/L	E CFU/L	UVE CFU/L
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	0	0	0	0	0	0
5:00	0	0	0	0	0	0
6:00	0	0	0	0	0	0
7:00	0	0	0	0	0	0
8:00	0	0	0	0	0	0
9:00	0	0	0	0	0	0
10:00	0	0	0	0	0	0
11:00	0	0	0	0	0	0
12:00	0	0	0	0	0	0
13:00	0	0	0	0	0	0
14:00	0	0	0	0	0	0
15:00	0	0	0	0	0	0
16:00	0	0	0	0	0	0
17:00	0	0	0	0	0	0
18:00	0	0	0	0	0	0
19:00	0	0	0	0	0	0
20:00	0	0	0	0	0	0
21:00	0.2024	0.0194	6.1735	0.3365	3.4872	3.17E-13
22:00	0.5964	0.0553	40.2779	2.3027	13.2567	1.23E-12
23:00	0.6136	0.0568	43.6979	2.5047	13.9593	1.28E-12
24:00:00	0.6095	0.0566	44.5193	2.6314	14.2152	1.28E-12
25:00:00	0.6077	0.0564	44.3505	2.6402	14.2083	1.28E-12
26:00:00	0.5938	0.0553	43.2631	2.6788	14.1283	1.24E-12
27:00:00	0.5919	0.0552	42.6066	2.6604	14.0589	1.22E-12
28:00:00	0.5914	0.0552	42.3859	2.6861	14.1176	1.2E-12
29:00:00	0.5816	0.0543	42.205	2.6769	13.9688	1.21E-12
30:00:00	0.5061	0.0483	43.8152	3.2239	14.3472	1.2E-12
31:00:00	0.5109	0.0487	44.5149	3.2138	14.3844	1.22E-12
32:00:00	0.7173	0.0651	40.5517	1.9086	13.7916	1.28E-12
33:00:00	0.7157	0.0646	36.2337	1.5537	12.9036	1.24E-12
34:00:00	0.7324	0.0659	33.857	1.3281	12.5583	1.22E-12
35:00:00	0.813	0.0719	27.8413	0.7319	12.0672	1.21E-12
36:00:00	0.8416	0.074	24.8633	0.4987	11.8302	1.21E-12
37:00:00	0.8293	0.073	26.3972	0.5988	11.9261	1.23E-12
38:00:00	0.5711	0.0515	17.2053	0.4423	8.3868	8.96E-13
39:00:00	0.5953	0.0537	17.5735	0.4341	8.6815	9.08E-13
40:00:00	0.956	0.083	27.5218	0.4793	13.1372	1.32E-12
41:00:00	0.9731	0.0846	27.8401	0.482	13.3632	1.32E-12
42:00:00	0.7974	0.0705	22.7428	0.4446	11.1759	1.14E-12
43:00:00	0.7088	0.0636	20.0448	0.4279	10.0885	1.01E-12
44:00:00	0.9829	0.085	28.2996	0.4791	13.4388	1.36E-12
45:00:00	0.998	0.0861	28.7865	0.482	13.6172	1.39E-12
46:00:00	1	0.0863	28.7723	0.4835	13.6548	1.37E-12
47:00:00	0.9692	0.0832	29.0404	0.4949	13.2533	1.45E-12
48:00:00	1	0.0864	28.7225	0.484	13.6628	1.37E-12
49:00:00	1	0.0864	28.7504	0.4837	13.6583	1.37E-12
50:00:00	0.9771	0.0846	27.9463	0.4739	13.368	1.34E-12
51:00:00	0.8887	0.0777	24.9778	0.4349	12.2286	1.26E-12
52:00:00	0.9926	0.0864	28.1415	0.4836	13.6195	1.31E-12
53:00:00	0.9871	0.0861	27.8357	0.4822	13.5677	1.28E-12
54:00:00	0.9723	0.0851	27.2493	0.4765	13.3903	1.26E-12
55:00:00	0.9948	0.0868	28.0607	0.4859	13.6722	1.28E-12
56:00:00	0.9994	0.087	28.288	0.4873	13.7192	1.3E-12
57:00:00	0.9988	0.087	28.2468	0.4872	13.7156	1.29E-12
58:00:00	0.9467	0.0827	26.6389	0.463	13.0217	1.27E-12
59:00:00	0.9019	0.0791	25.1844	0.4428	12.4349	1.24E-12
60:00:00	0.8888	0.0777	24.9754	0.4349	12.2294	1.27E-12
61:00:00	0.8775	0.0765	24.7691	0.4285	12.0578	1.29E-12
62:00:00	0.6339	0.0566	18.2502	0.3842	9.0021	1.09E-12
63:00:00	0.6536	0.0583	18.8148	0.3935	9.276	1.11E-12

64:00:00	0.9213	0.0802	26.0834	0.4495	12.6489	1.31E-12
65:00:00	0.9739	0.0844	27.7954	0.4729	13.3335	1.34E-12
66:00:00	0.8914	0.0778	25.5924	0.4567	12.3077	1.3E-12
67:00:00	0.7633	0.0678	21.9693	0.4357	10.7474	1.19E-12
68:00:00	0.986	0.0852	28.3681	0.4783	13.4718	1.37E-12
69:00:00	0.9972	0.086	28.7476	0.4817	13.608	1.38E-12
70:00:00	1	0.0864	28.7674	0.4836	13.6557	1.37E-12
71:00:00	0.9672	0.0828	28.2804	0.4638	13.1357	1.47E-12
72:00:00	1	0.0864	28.7391	0.4838	13.6601	1.37E-12
73:00:00	1	0.0863	28.7894	0.4834	13.6522	1.38E-12
74:00:00	0.9723	0.0841	27.8655	0.4711	13.2937	1.36E-12
75:00:00	0.924	0.0803	26.2693	0.4496	12.6674	1.34E-12
76:00:00	0.9952	0.0867	28.1745	0.4853	13.6623	1.3E-12
77:00:00	0.9884	0.0862	27.8909	0.4827	13.5829	1.29E-12
78:00:00	0.9769	0.0854	27.4352	0.4783	13.4457	1.28E-12
79:00:00	0.9961	0.0869	28.1187	0.4864	13.6873	1.29E-12
80:00:00	0.9995	0.087	28.2952	0.4873	13.7208	1.3E-12
81:00:00	0.9992	0.087	28.2633	0.4874	13.7202	1.3E-12
82:00:00	0.9555	0.0833	26.9883	0.4664	13.1264	1.31E-12
83:00:00	0.9175	0.0802	25.8042	0.4489	12.6221	1.31E-12
84:00:00	0.906	0.0789	25.6656	0.4416	12.435	1.35E-12
85:00:00	0.8964	0.0778	25.531	0.4357	12.2812	1.38E-12
86:00:00	0.6938	0.061	20.6385	0.3944	9.7091	1.37E-12
87:00:00	0.7094	0.0624	21.084	0.4019	9.9275	1.37E-12
88:00:00	0.9328	0.081	26.5704	0.4536	12.7799	1.37E-12
89:00:00	0.9779	0.0847	27.9722	0.4743	13.3785	1.36E-12
90:00:00	0.9063	0.0788	26.2819	0.4582	12.4693	1.39E-12
91:00:00	0.8024	0.0705	23.64	0.4388	11.1854	1.38E-12
92:00:00	0.9881	0.0853	28.4638	0.4787	13.4945	1.38E-12
93:00:00	0.9976	0.086	28.7672	0.4818	13.6119	1.39E-12
94:00:00	1	0.0864	28.7621	0.4836	13.6565	1.37E-12
95:00:00	0.9723	0.0831	28.5179	0.4654	13.1901	1.49E-12
96:00:00	1	0.0864	28.7391	0.4838	13.6602	1.37E-12
97:00:00	1	0.0863	28.7838	0.4834	13.6531	1.38E-12
98:00:00	0.9766	0.0844	28.0547	0.4726	13.3426	1.39E-12
99:00:00	0.9355	0.081	26.7767	0.4536	12.7958	1.4E-12
100:00:00	0.996	0.0867	28.2076	0.4855	13.67	1.31E-12
101:00:00	0.9903	0.0863	27.9743	0.4833	13.6028	1.3E-12
102:00:00	0.9805	0.0856	27.5998	0.4794	13.4844	1.3E-12
103:00:00	0.9967	0.0869	28.1461	0.4866	13.6932	1.29E-12
104:00:00	0.9996	0.087	28.2991	0.4874	13.7215	1.3E-12
105:00:00	0.9993	0.087	28.2691	0.4874	13.7214	1.3E-12
106:00:00	0.9624	0.0837	27.3019	0.4687	13.2015	1.35E-12
107:00:00	0.9303	0.0809	26.3852	0.4531	12.7618	1.38E-12
108:00:00	0.9206	0.0797	26.333	0.4465	12.5935	1.43E-12
109:00:00	0.9125	0.0788	26.2734	0.441	12.4555	1.47E-12
110:00:00	0.7431	0.064	22.9556	0.3998	10.2359	1.66E-12
111:00:00	0.7563	0.0653	23.3099	0.4063	10.424	1.65E-12
112:00:00	0.9432	0.0816	27.0691	0.4569	12.8902	1.43E-12
113:00:00	0.9813	0.0849	28.1403	0.4753	13.414	1.38E-12
114:00:00	0.9215	0.0796	27.0324	0.4592	12.6217	1.48E-12
115:00:00	0.8346	0.0724	25.2387	0.4394	11.5104	1.57E-12
116:00:00	0.99	0.0854	28.5591	0.4791	13.5133	1.4E-12
117:00:00	0.998	0.0861	28.7864	0.4819	13.6157	1.39E-12
118:00:00	1	0.0864	28.7622	0.4836	13.6565	1.37E-12
119:00:00	0.9766	0.0833	28.7487	0.4666	13.232	1.52E-12
120:00:00	1	0.0864	28.7391	0.4838	13.6601	1.37E-12

<<< Node 253 >>>

Time hr:min	C MG/L	S MG/L	H UG/L	N MG/L	E CFU/L	UVE CFU/L
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	0	0	0	0	0	0
5:00	0	0	0	0	0	0
6:00	0	0	0	0	0	0
7:00	0	0	0	0	0	0
8:00	0.1099	0.0107	2.8273	0.1608	1.8561	6.14E-14
9:00	0.3298	0.0324	13.1168	1.2397	7.3513	2.51E-13
10:00	0.5345	0.0522	24.0724	2.242	12.4429	4.45E-13
11:00	0.596	0.058	28.1238	2.5374	13.9512	5.27E-13
12:00	0.6021	0.0586	29.4301	2.6672	14.3359	5.55E-13
13:00	0.6095	0.0591	30.6474	2.7024	14.5088	5.99E-13
14:00	0.6081	0.0589	31.3432	2.7316	14.5525	6.28E-13
15:00	0.6044	0.0585	31.4904	2.7477	14.5373	6.37E-13
16:00	0.5964	0.0577	31.4607	2.7691	14.4792	6.41E-13
17:00	0.5945	0.0574	31.5237	2.7563	14.4189	6.52E-13
18:00	0.5851	0.0564	32.5542	2.7417	14.252	7.13E-13
19:00	0.5947	0.057	34.4712	2.7368	14.3521	7.96E-13
20:00	0.5961	0.0567	36.4969	2.7089	14.2892	8.97E-13
21:00	0.6034	0.057	38.7817	2.6875	14.315	1E-12
22:00	0.5708	0.0532	38.0102	2.2758	12.8734	1.15E-12
23:00	0.2735	0.0262	14.414	1.0852	6.1986	6.03E-13
24:00:00	0.0006	0.0001	0.0122	0.0003	0.0083	8.69E-16
25:00:00	0.0006	0.0001	0.0122	0.0003	0.0083	9.06E-16
26:00:00	0.0006	0.0001	0.0122	0.0003	0.0083	9.42E-16
27:00:00	0.0006	0.0001	0.0122	0.0003	0.0083	9.79E-16
28:00:00	0.0006	0.0001	0.0122	0.0003	0.0083	1.02E-15
29:00:00	0.0006	0.0001	0.0122	0.0003	0.0083	1.05E-15
30:00:00	0.7661	0.0715	25.9172	0.8974	12.1776	8.34E-13
31:00:00	0.8877	0.0834	21.4714	0.4966	12.8674	5.82E-13
32:00:00	0.9852	0.0927	23.4624	0.5229	14.2242	5.82E-13
33:00:00	0.9972	0.0935	23.9534	0.5241	14.3536	6.2E-13
34:00:00	0.999	0.0934	24.1802	0.523	14.3507	6.49E-13
35:00:00	0.9895	0.0914	24.6553	0.5144	14.116	7.56E-13
36:00:00	0.9963	0.0918	24.9562	0.515	14.1855	7.8E-13
37:00:00	0.9866	0.09	25.3512	0.5073	13.9611	8.76E-13
38:00:00	0.9943	0.0909	25.3676	0.5105	14.0878	8.52E-13
39:00:00	0.9907	0.091	25.2013	0.5183	14.0921	8.21E-13
40:00:00	0.9786	0.0903	24.4614	0.5054	13.9385	7.71E-13
41:00:00	0.939	0.0866	23.4406	0.4852	13.3781	7.61E-13
42:00:00	0.9446	0.0874	23.4309	0.4895	13.4819	7.41E-13
43:00:00	0.9746	0.09	24.2771	0.5041	13.8945	7.6E-13
44:00:00	0.9805	0.0904	24.5012	0.5064	13.9656	7.74E-13
45:00:00	0.9772	0.0903	24.3351	0.5055	13.9316	7.62E-13
46:00:00	0.9759	0.0896	24.6292	0.502	13.8631	8.15E-13
47:00:00	0.9784	0.0883	25.7159	0.4943	13.7404	9.77E-13
48:00:00	0.9371	0.0828	25.7321	0.4639	12.9896	1.16E-12
49:00:00	0.1284	0.0115	3.6961	0.083	1.8407	2.32E-13
50:00:00	0.1284	0.0115	3.7044	0.0829	1.8397	2.4E-13
51:00:00	0.1284	0.0115	3.7126	0.0829	1.8387	2.48E-13
52:00:00	0.1284	0.0115	3.7208	0.0828	1.8377	2.56E-13
53:00:00	0.1284	0.0115	3.729	0.0827	1.8366	2.64E-13
54:00:00	0.9731	0.0886	25.074	0.4965	13.7436	9.01E-13
55:00:00	0.9122	0.0856	22.1186	0.497	13.1767	6.35E-13
56:00:00	0.9849	0.0926	23.5447	0.5211	14.2046	6.01E-13
57:00:00	0.997	0.0934	23.9806	0.5235	14.3458	6.26E-13
58:00:00	0.9991	0.0933	24.2131	0.5227	14.3462	6.55E-13
59:00:00	0.9895	0.0913	24.7234	0.5135	14.1042	7.7E-13
60:00:00	0.9957	0.0917	24.9652	0.5144	14.1729	7.85E-13
61:00:00	0.9839	0.0896	25.3738	0.5044	13.9071	8.96E-13
62:00:00	0.9944	0.0908	25.4585	0.5095	14.0753	8.68E-13
63:00:00	0.9898	0.0908	25.0845	0.5082	14.0442	8.35E-13

64:00:00	0.9799	0.0903	24.5699	0.5054	13.945	7.91E-13
65:00:00	0.9498	0.0876	23.7573	0.4904	13.5254	7.9E-13
66:00:00	0.956	0.0883	23.7886	0.4947	13.6326	7.71E-13
67:00:00	0.9792	0.0904	24.4334	0.5061	13.9519	7.75E-13
68:00:00	0.9843	0.0907	24.6272	0.5081	14.0152	7.85E-13
69:00:00	0.9817	0.0906	24.5009	0.5073	13.9878	7.77E-13
70:00:00	0.9805	0.09	24.7986	0.5039	13.9207	8.3E-13
71:00:00	0.982	0.0885	25.8417	0.4958	13.7854	9.9E-13
72:00:00	0.9479	0.0836	26.1258	0.4684	13.1235	1.19E-12
73:00:00	0.243	0.0213	7.1044	0.1367	3.3942	6.04E-13
74:00:00	0.243	0.0213	7.13	0.1364	3.3907	6.19E-13
75:00:00	0.243	0.0213	7.1556	0.1362	3.3871	6.34E-13
76:00:00	0.243	0.0212	7.1812	0.136	3.3836	6.49E-13
77:00:00	0.243	0.0212	7.2067	0.1358	3.38	6.64E-13
78:00:00	0.9779	0.0889	25.2721	0.498	13.7995	9.22E-13
79:00:00	0.9338	0.0873	22.8301	0.5008	13.445	6.97E-13
80:00:00	0.987	0.0927	23.6327	0.5215	14.2302	6.12E-13
81:00:00	0.9974	0.0934	23.9981	0.5236	14.3504	6.28E-13
82:00:00	0.9993	0.0933	24.2149	0.5228	14.3493	6.54E-13
83:00:00	0.991	0.0914	24.7852	0.5138	14.1235	7.77E-13
84:00:00	0.9963	0.0918	24.988	0.5145	14.1807	7.88E-13
85:00:00	0.9864	0.0898	25.4804	0.5048	13.9356	9.09E-13
86:00:00	0.9954	0.0909	25.4975	0.5096	14.0867	8.72E-13
87:00:00	0.9914	0.0909	25.1494	0.5088	14.0627	8.42E-13
88:00:00	0.9831	0.0905	24.686	0.5068	13.9852	8.05E-13
89:00:00	0.9576	0.0881	24.0479	0.4935	13.6203	8.27E-13
90:00:00	0.9628	0.0888	24.0464	0.4974	13.7149	8.04E-13
91:00:00	0.9823	0.0906	24.5585	0.5073	13.99	7.91E-13
92:00:00	0.9867	0.0909	24.7238	0.5091	14.0439	7.97E-13
93:00:00	0.9845	0.0908	24.6153	0.5084	14.0212	7.91E-13
94:00:00	0.9835	0.0902	24.922	0.505	13.9559	8.46E-13
95:00:00	0.9848	0.0887	25.9588	0.4969	13.8177	1E-12
96:00:00	0.956	0.0842	26.4642	0.4713	13.2167	1.24E-12
97:00:00	0.343	0.0292	10.5354	0.1791	4.6787	1.07E-12
98:00:00	0.343	0.0291	10.5829	0.1786	4.6718	1.09E-12
99:00:00	0.343	0.0291	10.6302	0.1782	4.6649	1.11E-12
100:00:00	0.343	0.029	10.6774	0.1778	4.658	1.13E-12
101:00:00	0.343	0.0289	10.7245	0.1774	4.6511	1.15E-12
102:00:00	0.9813	0.0891	25.42	0.4992	13.838	9.41E-13
103:00:00	0.9444	0.088	23.3058	0.5022	13.5642	7.57E-13
104:00:00	0.9891	0.0929	23.7266	0.5218	14.2533	6.24E-13
105:00:00	0.9978	0.0935	24.0164	0.5237	14.3552	6.31E-13
106:00:00	0.9994	0.0934	24.2204	0.5228	14.3505	6.55E-13
107:00:00	0.9926	0.0915	24.852	0.514	14.1408	7.85E-13
108:00:00	0.9969	0.0918	25.0156	0.5146	14.1871	7.91E-13
109:00:00	0.9886	0.0899	25.5834	0.5051	13.9588	9.21E-13
110:00:00	0.9961	0.0909	25.5325	0.5097	14.0947	8.77E-13
111:00:00	0.9928	0.0909	25.2163	0.5093	14.0786	8.5E-13
112:00:00	0.9857	0.0907	24.802	0.5077	14.0143	8.21E-13
113:00:00	0.9641	0.0885	24.3421	0.4958	13.6932	8.68E-13
114:00:00	0.9686	0.0892	24.308	0.4994	13.7787	8.4E-13
115:00:00	0.9851	0.0908	24.6843	0.5082	14.0197	8.09E-13
116:00:00	0.9888	0.091	24.82	0.5097	14.066	8.1E-13
117:00:00	0.9869	0.0909	24.7286	0.5092	14.0468	8.07E-13
118:00:00	0.9861	0.0903	25.0441	0.5058	13.9829	8.62E-13
119:00:00	0.9871	0.0889	26.0738	0.4976	13.8424	1.02E-12
120:00:00	0.9628	0.0845	26.7985	0.4734	13.2875	1.28E-12

Scenario 1 – *E. coli* outbreak at node 195

<<< Link 151 >>>

Time	C	S	H	N	E	UVE
hr:min	MG/L	MG/L	UG/L	MG/L	CFU/L	CFU/L
-------	----------	----------	----------	----------	----------	----------
0:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
1:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
2:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
3:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
4:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
5:00	0.5602	0.0544	12.2350	0.3047	0.0000	0.000000000000000000000000000000
6:00	0.8922	0.0863	19.7483	0.4830	0.0000	0.000000000000000000000000000000
7:00	0.8910	0.0859	19.8697	0.4811	0.0000	0.000000000000000000000000000000
8:00	0.8910	0.0854	20.2002	0.4782	0.0000	0.000000000000000000000000000000
9:00	0.8910	0.0849	20.5287	0.4754	0.0000	0.000000000000000000000000000000
10:00	0.8910	0.0844	20.8552	0.4725	0.0000	0.000000000000000000000000000000
11:00	0.8910	0.0839	21.1798	0.4697	0.0000	0.000000000000000000000000000000
12:00	1.0000	0.0938	23.9643	0.5254	0.0000	0.000000000000000000000000000000
13:00	0.9852	0.0919	23.9830	0.5144	0.0000	0.000000000000000000000000000000
14:00	0.5027	0.0465	12.7307	0.2798	0.0000	0.000000000000000000000000000000
15:00	0.5085	0.0474	13.2960	0.3549	0.0000	0.000000000000000000000000000000
16:00	0.4592	0.0432	11.5130	0.3169	0.0000	0.000000000000000000000000000000
17:00	0.4592	0.0431	11.6253	0.3159	0.0000	0.000000000000000000000000000000
18:00	0.4592	0.0430	11.7373	0.3149	0.0000	0.000000000000000000000000000000
19:00	0.4592	0.0428	11.8489	0.3140	0.0000	0.000000000000000000000000000000
20:00	0.4592	0.0427	11.9602	0.3130	0.0000	0.000000000000000000000000000000
21:00	0.4592	0.0426	12.0711	0.3120	0.0000	0.000000000000000000000000000000
22:00	0.4592	0.0424	12.1818	0.3111	0.0000	0.000000000000000000000000000000
23:00	0.0771	0.0074	1.7099	0.0417	0.0000	0.000000000000000000000000000000
24:00	0.0771	0.0074	1.7124	0.0417	0.0000	0.000000000000000000000000000000
25:00	0.7586	0.0712	18.8139	0.4469	0.0000	0.000000000000000000000000000000
26:00	0.9878	0.0950	22.2013	0.5318	0.0000	0.000000000000000000000000000000
27:00	1.0000	0.0966	22.1843	0.5410	0.0000	0.000000000000000000000000000000
28:00	1.0000	0.0966	22.1563	0.5412	0.0000	0.000000000000000000000000000000
29:00	1.0000	0.0966	22.1918	0.5409	0.0000	0.000000000000000000000000000000

30:00	1.0000	0.0963	22.3675	0.5394	0.0000	0.000000000000000000000000000000
31:00	1.0000	0.0962	22.4714	0.5385	0.0000	0.000000000000000000000000000000
32:00	1.0000	0.0955	22.8863	0.5348	0.0000	0.000000000000000000000000000000
33:00	1.0000	0.0949	23.2985	0.5312	0.0000	0.000000000000000000000000000000
34:00	1.0000	0.0942	23.7079	0.5277	0.0000	0.000000000000000000000000000000
35:00	1.0000	0.0936	24.1145	0.5241	0.0000	0.000000000000000000000000000000
36:00	0.5048	0.0477	11.8760	0.2672	0.0000	0.000000000000000000000000000000
37:00	0.5453	0.0512	13.0292	0.2868	0.0000	0.000000000000000000000000000000
38:00	1.0000	0.0939	23.9457	0.5256	0.0000	0.000000000000000000000000000000
39:00	0.9626	0.0903	23.0752	0.5057	0.0000	0.000000000000000000000000000000
40:00	0.8920	0.0845	20.8586	0.4732	0.0000	0.000000000000000000000000000000
41:00	0.8920	0.0840	21.1840	0.4704	0.0000	0.000000000000000000000000000000
42:00	0.8920	0.0835	21.5074	0.4675	0.0000	0.000000000000000000000000000000
43:00	0.8920	0.0830	21.8289	0.4647	0.0000	0.000000000000000000000000000000
44:00	0.8920	0.0825	22.1485	0.4620	0.0000	0.000000000000000000000000000000
45:00	0.8920	0.0820	22.4662	0.4592	0.0000	0.000000000000000000000000000000
46:00	0.8920	0.0815	22.7819	0.4564	0.0000	0.000000000000000000000000000000
47:00	0.2410	0.0228	5.6790	0.1275	0.0000	0.000000000000000000000000000000
48:00	0.2410	0.0227	5.7028	0.1273	0.0000	0.000000000000000000000000000000
49:00	0.8571	0.0802	20.6986	0.4490	0.0000	0.000000000000000000000000000000
50:00	0.9078	0.0872	20.4882	0.4881	0.0000	0.000000000000000000000000000000
51:00	1.0000	0.0965	22.2338	0.5405	0.0000	0.000000000000000000000000000000
52:00	1.0000	0.0966	22.1639	0.5411	0.0000	0.000000000000000000000000000000
53:00	1.0000	0.0966	22.1961	0.5409	0.0000	0.000000000000000000000000000000
54:00	1.0000	0.0963	22.3590	0.5394	0.0000	0.000000000000000000000000000000
55:00	1.0000	0.0962	22.4655	0.5385	0.0000	0.000000000000000000000000000000
56:00	1.0000	0.0955	22.8805	0.5349	0.0000	0.000000000000000000000000000000
57:00	1.0000	0.0949	23.2927	0.5313	0.0000	0.000000000000000000000000000000
58:00	1.0000	0.0942	23.7021	0.5277	0.0000	0.000000000000000000000000000000
59:00	1.0000	0.0936	24.1088	0.5242	0.0000	0.000000000000000000000000000000
60:00	0.3292	0.0307	8.0175	0.1719	0.0000	0.000000000000000000000000000000
61:00	0.6149	0.0573	15.0025	0.3208	0.0000	0.000000000000000000000000000000
62:00	1.0000	0.0938	23.9615	0.5255	0.0000	0.000000000000000000000000000000
63:00	0.9680	0.0908	23.2340	0.5083	0.0000	0.000000000000000000000000000000
64:00	0.9118	0.0863	21.3587	0.4834	0.0000	0.000000000000000000000000000000

65:00	0.9118	0.0858	21.6985	0.4804	0.0000	0.000000000000000000000000000000
66:00	0.9118	0.0853	22.0362	0.4775	0.0000	0.000000000000000000000000000000
67:00	0.9118	0.0847	22.3718	0.4746	0.0000	0.000000000000000000000000000000
68:00	0.9118	0.0842	22.7054	0.4717	0.0000	0.000000000000000000000000000000
69:00	0.9118	0.0837	23.0369	0.4688	0.0000	0.000000000000000000000000000000
70:00	0.9118	0.0832	23.3664	0.4659	0.0000	0.000000000000000000000000000000
71:00	0.3584	0.0327	9.1668	0.1833	0.0000	0.000000000000000000000000000000
72:00	0.3584	0.0326	9.2175	0.1828	0.0000	0.000000000000000000000000000000
73:00	0.8808	0.0821	21.4355	0.4600	0.0000	0.000000000000000000000000000000
74:00	0.9224	0.0884	20.9190	0.4950	0.0000	0.000000000000000000000000000000
75:00	1.0000	0.0965	22.2355	0.5405	0.0000	0.000000000000000000000000000000
76:00	1.0000	0.0966	22.1642	0.5411	0.0000	0.000000000000000000000000000000
77:00	1.0000	0.0966	22.1961	0.5409	0.0000	0.000000000000000000000000000000
78:00	1.0000	0.0963	22.3597	0.5394	0.0000	0.000000000000000000000000000000
79:00	1.0000	0.0962	22.4656	0.5385	0.0000	0.000000000000000000000000000000
80:00	1.0000	0.0955	22.8806	0.5349	0.0000	0.000000000000000000000000000000
81:00	1.0000	0.0949	23.2928	0.5313	0.0000	0.000000000000000000000000000000
82:00	1.0000	0.0942	23.7022	0.5277	0.0000	0.000000000000000000000000000000
83:00	1.0000	0.0936	24.1089	0.5242	0.0000	0.000000000000000000000000000000
84:00	0.4330	0.0389	11.4651	0.2180	0.0000	0.000000000000000000000000000000
85:00	0.6744	0.0620	17.0023	0.3471	0.0000	0.000000000000000000000000000000
86:00	1.0000	0.0938	23.9614	0.5255	0.0000	0.000000000000000000000000000000
87:00	0.9730	0.0911	23.4091	0.5104	0.0000	0.000000000000000000000000000000
88:00	0.9254	0.0873	21.8438	0.4892	0.0000	0.000000000000000000000000000000
89:00	0.9254	0.0868	22.1928	0.4861	0.0000	0.000000000000000000000000000000
90:00	0.9254	0.0863	22.5395	0.4831	0.0000	0.000000000000000000000000000000
91:00	0.9254	0.0857	22.8842	0.4801	0.0000	0.000000000000000000000000000000
92:00	0.9254	0.0852	23.2266	0.4771	0.0000	0.000000000000000000000000000000
93:00	0.9254	0.0847	23.5670	0.4741	0.0000	0.000000000000000000000000000000
94:00	0.9254	0.0841	23.9052	0.4712	0.0000	0.000000000000000000000000000000
95:00	0.4576	0.0401	12.7804	0.2246	0.0000	0.000000000000000000000000000000
96:00	0.4576	0.0400	12.8597	0.2239	0.0000	0.000000000000000000000000000000
97:00	0.8989	0.0834	22.1283	0.4672	0.0000	0.000000000000000000000000000000
98:00	0.9344	0.0893	21.3760	0.4998	0.0000	0.000000000000000000000000000000
99:00	1.0000	0.0965	22.2354	0.5405	0.0000	0.000000000000000000000000000000

100:00	1.0000	0.0966	22.1642	0.5411	0.0000	0.000000000000000000000000000000
101:00	1.0000	0.0966	22.1961	0.5409	0.0000	0.000000000000000000000000000000
102:00	1.0000	0.0963	22.3597	0.5394	0.0000	0.000000000000000000000000000000
103:00	1.0000	0.0962	22.4656	0.5385	0.0000	0.000000000000000000000000000000
104:00	1.0000	0.0955	22.8805	0.5349	0.0000	0.000000000000000000000000000000
105:00	1.0000	0.0949	23.2927	0.5313	0.0000	0.000000000000000000000000000000
106:00	1.0000	0.0942	23.7022	0.5277	0.0000	0.000000000000000000000000000000
107:00	1.0000	0.0936	24.1088	0.5242	0.0000	0.000000000000000000000000000000
108:00	0.5207	0.0449	15.0193	0.2514	0.0000	0.000000000000000000000000000000
109:00	0.7248	0.0654	19.0523	0.3662	0.0000	0.000000000000000000000000000000
110:00	1.0000	0.0938	23.9614	0.5255	0.0000	0.000000000000000000000000000000
111:00	0.9771	0.0914	23.5871	0.5119	0.0000	0.000000000000000000000000000000
112:00	0.9367	0.0881	22.3380	0.4931	0.0000	0.000000000000000000000000000000
113:00	0.9367	0.0875	22.6941	0.4900	0.0000	0.000000000000000000000000000000
114:00	0.9367	0.0870	23.0479	0.4869	0.0000	0.000000000000000000000000000000
115:00	0.9367	0.0864	23.3994	0.4839	0.0000	0.000000000000000000000000000000
116:00	0.9367	0.0859	23.7488	0.4808	0.0000	0.000000000000000000000000000000
117:00	0.9367	0.0853	24.0960	0.4778	0.0000	0.000000000000000000000000000000
118:00	0.9367	0.0848	24.4409	0.4748	0.0000	0.000000000000000000000000000000
119:00	0.5414	0.0453	16.4809	0.2539	0.0000	0.000000000000000000000000000000
120:00	0.5414	0.0452	16.5870	0.2530	0.0000	0.000000000000000000000000000000

<<< Link 251 >>>

Time	C	S	H	N	E	UVE
hr:min	MG/L	MG/L	UG/L	MG/L	CFU/L	CFU/L
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0:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
1:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
2:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
3:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
4:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
5:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
6:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
7:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000

8:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
9:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
10:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000
11:00	0.0000	0.0000	0.0000	0.0000	0.1252	0.000267238676315173510000000000
12:00	0.0000	0.0000	0.0000	0.0000	0.2460	0.000536674109753221270000000000
13:00	0.0127	0.0012	0.3338	0.0168	0.2492	0.000544417998753488060000000000
14:00	0.0905	0.0087	4.3501	0.3398	0.2558	0.000566446688026189800000000000
15:00	0.1799	0.0172	9.4486	0.7077	0.2669	0.000604770088102668520000000000
16:00	0.2570	0.0245	14.1712	1.0336	0.2777	0.000640432932414114480000000000
17:00	0.3297	0.0314	18.9158	1.3492	0.2874	0.000672302267048507930000000000
18:00	0.3979	0.0378	23.6248	1.6467	0.1310	0.000345793843735009430000000000
19:00	0.4567	0.0432	27.9727	1.9023	0.0670	0.000209718404221348460000000000
20:00	0.5152	0.0486	32.4819	2.1561	0.0628	0.000205733813345432280000000000
21:00	0.5816	0.0547	38.0493	2.4845	0.0693	0.000228128541493788360000000000
22:00	0.6046	0.0567	40.8639	2.6206	0.0733	0.000240134468185715380000000000
23:00	0.5992	0.0562	40.9978	2.6580	0.0719	0.000230636942433193330000000000
24:00	0.5939	0.0558	40.4624	2.6859	0.0662	0.000206502852961421010000000000
25:00	0.5789	0.0546	40.2075	2.7626	0.0564	0.000172948712133802470000000000
26:00	0.5809	0.0549	39.3458	2.7733	0.1288	0.000180020899279043080000000000
27:00	0.6090	0.0573	38.0559	2.5433	0.9189	0.000682753685396164660000000000
28:00	0.6420	0.0600	36.0672	2.2308	1.5200	0.001033513690344989300000000000
29:00	0.6683	0.0621	34.9948	1.9952	1.7623	0.001174140954390168200000000000
30:00	0.7128	0.0656	33.0256	1.6274	2.0061	0.001327986828982830000000000000
31:00	0.7562	0.0689	31.1768	1.2722	2.2920	0.001545652979984879500000000000
32:00	0.7651	0.0693	28.3331	0.9900	2.5558	0.001767226727679371800000000000
33:00	0.7480	0.0676	25.7055	0.7977	2.1347	0.001495010801590979100000000000
34:00	0.7686	0.0692	23.9858	0.6294	1.7011	0.001236387644894421100000000000
35:00	0.8001	0.0718	23.2622	0.5303	1.5305	0.001239147852174937700000000000
36:00	0.7894	0.0711	22.4555	0.5016	1.2305	0.001081350143067538700000000000
37:00	0.8167	0.0736	22.7473	0.4911	1.1438	0.001177782542072236500000000000
38:00	0.8601	0.0774	23.3983	0.4784	1.3216	0.001708796247839927700000000000
39:00	0.9197	0.0824	24.9689	0.4858	1.6322	0.002291883574798703200000000000
40:00	0.9445	0.0843	25.7090	0.4882	1.8190	0.002554804086685180700000000000
41:00	0.9481	0.0845	25.8421	0.4878	1.9394	0.002713073045015335100000000000
42:00	0.9567	0.0851	26.1777	0.4887	1.9296	0.002696537878364324600000000000

43:00	0.9861	0.0872	27.1897	0.4931	2.0328	0.00279565108940005300000000000
44:00	0.9953	0.0876	27.6327	0.4935	2.1811	0.00293318298645317550000000000
45:00	0.9961	0.0875	27.7809	0.4926	2.2512	0.00292056612670421600000000000
46:00	0.9933	0.0871	27.8198	0.4902	2.0909	0.00256390660069882870000000000
47:00	0.9779	0.0858	27.3314	0.4816	1.9582	0.00207981979474425320000000000
48:00	0.9703	0.0854	26.9035	0.4780	1.9202	0.00199019769206643100000000000
49:00	0.9666	0.0852	26.6736	0.4773	2.1560	0.00227847206406295300000000000
50:00	0.9657	0.0858	26.2328	0.4805	2.2597	0.00230540940538048740000000000
51:00	0.9802	0.0874	26.4629	0.4892	2.4048	0.00228069559670984750000000000
52:00	0.9787	0.0875	26.2580	0.4898	2.5609	0.00223143794573843480000000000
53:00	0.9674	0.0863	26.0326	0.4835	2.5308	0.00208844337612390520000000000
54:00	0.9546	0.0851	25.7452	0.4766	2.4044	0.00186112185474485160000000000
55:00	0.9407	0.0837	25.4649	0.4688	2.3014	0.00172776775434613230000000000
56:00	0.9043	0.0805	24.5305	0.4554	2.1616	0.00161473813932389020000000000
57:00	0.8519	0.0759	23.2332	0.4396	1.9041	0.00142822857014834880000000000
58:00	0.8316	0.0742	22.6773	0.4334	1.5603	0.00120004266500473020000000000
59:00	0.8388	0.0749	22.8545	0.4373	1.4355	0.00122329476289451120000000000
60:00	0.8279	0.0741	22.5731	0.4400	1.1552	0.00106341252103447910000000000
61:00	0.8478	0.0760	23.0196	0.4508	1.1163	0.00120562897063791750000000000
62:00	0.8830	0.0792	23.8842	0.4645	1.3630	0.00184467865619808440000000000
63:00	0.9336	0.0834	25.2792	0.4781	1.7113	0.00236949347890913490000000000
64:00	0.9558	0.0851	25.9866	0.4839	1.8883	0.00261013489216566090000000000
65:00	0.9605	0.0854	26.1878	0.4856	1.9533	0.00268482556566596030000000000
66:00	0.9656	0.0857	26.4266	0.4866	1.9406	0.00265546073205769060000000000
67:00	0.9877	0.0872	27.1991	0.4900	2.0712	0.00277725141495466230000000000
68:00	0.9948	0.0875	27.5728	0.4902	2.2217	0.00291514978744089600000000000
69:00	0.9951	0.0874	27.7114	0.4892	2.2891	0.00288958102464675900000000000
70:00	0.9912	0.0868	27.7217	0.4862	2.1405	0.00245797587558627130000000000
71:00	0.9788	0.0858	27.3634	0.4802	1.9652	0.00204101740382611750000000000
72:00	0.9735	0.0856	27.0389	0.4792	1.9623	0.00202289526350796220000000000
73:00	0.9702	0.0855	26.8215	0.4786	2.1654	0.00228524277918040750000000000
74:00	0.9712	0.0862	26.4322	0.4828	2.2639	0.00231660646386444570000000000
75:00	0.9848	0.0877	26.6128	0.4912	2.4036	0.00228889612480998040000000000
76:00	0.9823	0.0877	26.3860	0.4913	2.5616	0.00224188272841274740000000000
77:00	0.9729	0.0868	26.2294	0.4858	2.5307	0.00209833332337439060000000000

78:00	0.9622	0.0857	26.0226	0.4798	2.4035	0.00186901679262518880000000000
79:00	0.9502	0.0844	25.8159	0.4728	2.3015	0.00172994448803365230000000000
80:00	0.9198	0.0816	25.1089	0.4608	2.1623	0.00161799532361328600000000000
81:00	0.8758	0.0777	24.1435	0.4464	1.9067	0.00143525982275605200000000000
82:00	0.8586	0.0762	23.7187	0.4407	1.5635	0.00120834587141871450000000000
83:00	0.8645	0.0768	23.8599	0.4440	1.4387	0.00123234081547707320000000000
84:00	0.8556	0.0761	23.6701	0.4460	1.1599	0.00107523624319583180000000000
85:00	0.8724	0.0778	24.0031	0.4555	1.1206	0.00121664779726415870000000000
86:00	0.9018	0.0806	24.6486	0.4676	1.3697	0.00186924322042614220000000000
87:00	0.9442	0.0841	25.7198	0.4799	1.7128	0.00240222620777785780000000000
88:00	0.9629	0.0856	26.2866	0.4851	1.8913	0.00265218433924019340000000000
89:00	0.9670	0.0859	26.4604	0.4866	1.9567	0.00272785057313740250000000000
90:00	0.9714	0.0861	26.6690	0.4874	1.9434	0.00269701401703059670000000000
91:00	0.9897	0.0874	27.2850	0.4904	2.0724	0.00281631923280656340000000000
92:00	0.9956	0.0876	27.6098	0.4905	2.2227	0.00295357266440987590000000000
93:00	0.9960	0.0874	27.7466	0.4895	2.2901	0.00292778271250426770000000000
94:00	0.9926	0.0869	27.7831	0.4867	2.1383	0.00248122867196798320000000000
95:00	0.9822	0.0860	27.5034	0.4815	1.9665	0.00205239071510732170000000000
96:00	0.9776	0.0858	27.2124	0.4807	1.9607	0.00202195858582854270000000000
97:00	0.9748	0.0858	27.0201	0.4803	2.1647	0.00228519574739038940000000000
98:00	0.9756	0.0865	26.6258	0.4843	2.2632	0.00231658713892102240000000000
99:00	0.9871	0.0879	26.7156	0.4920	2.4033	0.00228893244639039040000000000
100:00	0.9850	0.0879	26.5024	0.4923	2.5612	0.00224188668653368950000000000
101:00	0.9770	0.0870	26.4077	0.4873	2.5302	0.00209835893474519250000000000
102:00	0.9680	0.0860	26.2715	0.4818	2.4029	0.00186906079761683940000000000
103:00	0.9579	0.0849	26.1471	0.4755	2.3005	0.00172903703060001130000000000
104:00	0.9322	0.0824	25.6588	0.4645	2.1615	0.00161804421804845330000000000
105:00	0.8954	0.0789	25.0195	0.4509	1.9068	0.00143785541877150540000000000
106:00	0.8809	0.0776	24.7295	0.4455	1.5640	0.00121191609650850300000000000
107:00	0.8860	0.0781	24.8392	0.4484	1.4393	0.00123521534260362390000000000
108:00	0.8786	0.0776	24.7365	0.4497	1.1617	0.00108003430068492890000000000
109:00	0.8928	0.0791	24.9598	0.4582	1.1229	0.00122296588961035010000000000
110:00	0.9176	0.0815	25.3949	0.4694	1.3720	0.00187675340566784140000000000
111:00	0.9531	0.0847	26.1489	0.4810	1.7144	0.00240742741152644160000000000
112:00	0.9688	0.0859	26.5748	0.4858	1.8926	0.00265643396414816380000000000

113:00	0.9722	0.0862	26.7204	0.4870	1.9580	0.00273209903389215470000000000
114:00	0.9759	0.0864	26.8966	0.4877	1.9447	0.00270193186588585380000000000
115:00	0.9913	0.0875	27.3668	0.4907	2.0730	0.00281980610452592370000000000
116:00	0.9963	0.0876	27.6442	0.4907	2.2231	0.00295645557343959810000000000
117:00	0.9966	0.0874	27.7789	0.4897	2.2905	0.00293020997196435930000000000
118:00	0.9938	0.0870	27.8409	0.4871	2.1387	0.00248333346098661420000000000
119:00	0.9850	0.0861	27.6384	0.4824	1.9663	0.00205312855541706090000000000
120:00	0.9811	0.0860	27.3824	0.4818	1.9604	0.00202253879979252820000000000

<<< Link 291 >>>

Time	C	S	H	N	E	UVE
hr:min	MG/L	MG/L	UG/L	MG/L	CFU/L	CFU/L
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0:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000
1:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000
2:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000
3:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000
4:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000
5:00	0.0000	0.0000	0.0000	0.0000	0.3840	0.00088533590314909816000000000
6:00	0.0003	0.0000	0.0057	0.0001	0.4237	0.00097852095495909452000000000
7:00	0.0610	0.0060	1.8837	0.1560	0.1250	0.00029279987211339176000000000
8:00	0.2877	0.0283	11.2591	1.1178	0.0394	0.00011488717427710071000000000
9:00	0.4782	0.0468	20.3616	1.9576	0.0489	0.00016393567784689367000000000
10:00	0.5827	0.0569	26.2939	2.4651	0.0709	0.00023660493025090545000000000
11:00	0.6035	0.0588	28.2978	2.6231	0.0817	0.00026832573348656297000000000
12:00	0.6073	0.0591	29.4252	2.7031	0.0826	0.00026841906947083771000000000
13:00	0.6092	0.0592	30.2811	2.7303	0.0799	0.00025409288355149329000000000
14:00	0.6038	0.0586	30.4484	2.7528	0.0738	0.00023395236348733306000000000
15:00	0.5928	0.0576	30.1594	2.7684	0.0695	0.00021598518651444465000000000
16:00	0.5900	0.0572	30.3210	2.7660	0.0662	0.00020360350026749074000000000
17:00	0.5895	0.0570	31.4673	2.7552	0.0665	0.00020454880723264068000000000
18:00	0.5924	0.0569	33.3544	2.7428	0.0682	0.00021197432943154126000000000
19:00	0.5938	0.0569	34.3860	2.7404	0.0674	0.00020859806681983173000000000
20:00	0.5973	0.0568	36.4498	2.6876	0.0700	0.00022130136494524777000000000

21:00	0.5778	0.0542	37.6265	2.4058	0.0703	0.000237436310271732510000000000
22:00	0.4070	0.0384	24.2841	1.5949	0.0452	0.000151333792018704120000000000
23:00	0.1058	0.0102	4.5173	0.3415	0.0514	0.000125373524497263130000000000
24:00	0.0006	0.0001	0.0122	0.0003	0.0563	0.000132542918436229230000000000
25:00	0.0006	0.0001	0.0122	0.0003	0.0563	0.000132542918436229230000000000
26:00	0.0006	0.0001	0.0122	0.0003	0.0563	0.000132542947540059690000000000
27:00	0.0006	0.0001	0.0122	0.0003	0.0563	0.000132542947540059690000000000
28:00	0.0006	0.0001	0.0122	0.0003	0.0563	0.000132542947540059690000000000
29:00	0.3701	0.0348	10.9502	0.3639	0.4197	0.000460954528534784910000000000
30:00	0.8569	0.0809	21.6936	0.5678	0.8608	0.001011578366160392800000000000
31:00	0.9453	0.0893	22.3739	0.5144	1.3095	0.001847700099460780600000000000
32:00	0.9939	0.0938	23.5062	0.5264	2.4323	0.003889394691213965400000000000
33:00	0.9985	0.0938	23.8478	0.5257	2.9536	0.005159067455679178200000000000
34:00	0.9953	0.0928	24.2427	0.5207	2.5878	0.004503311123698949800000000000
35:00	0.9922	0.0918	24.6328	0.5159	2.2495	0.003712679957970976800000000000
36:00	0.9886	0.0908	24.9667	0.5115	2.1693	0.003325874218717217400000000000
37:00	0.9892	0.0907	25.1116	0.5117	2.4108	0.003575065871700644500000000000
38:00	0.9950	0.0918	24.9339	0.5171	2.2551	0.002829882781952619600000000000
39:00	0.9741	0.0903	24.1156	0.5073	2.1358	0.002158924704417586300000000000
40:00	0.9416	0.0875	23.0898	0.4902	2.0966	0.002138721756637096400000000000
41:00	0.9477	0.0882	23.1878	0.4938	2.0410	0.002200666582211852100000000000
42:00	0.9698	0.0902	23.7417	0.5052	2.1892	0.002432635519653558700000000000
43:00	0.9802	0.0911	24.0660	0.5100	2.3606	0.002601850777864456200000000000
44:00	0.9795	0.0909	24.1215	0.5090	2.5669	0.002705327700823545500000000000
45:00	0.9779	0.0904	24.3019	0.5063	2.6430	0.002696740208193659800000000000
46:00	0.9800	0.0894	25.1161	0.5007	2.4080	0.002649415517225861500000000000
47:00	0.9547	0.0856	25.4059	0.4796	2.0382	0.002288705902174115200000000000
48:00	0.3295	0.0292	9.1853	0.1776	0.7067	0.000867493276018649340000000000
49:00	0.1284	0.0115	3.6960	0.0830	0.2188	0.000355285475961863990000000000
50:00	0.1284	0.0115	3.7042	0.0829	0.2187	0.000355285592377185820000000000
51:00	0.1284	0.0115	3.7124	0.0829	0.2186	0.000355285592377185820000000000
52:00	0.1366	0.0122	3.9417	0.0867	0.2391	0.000378195196390151980000000000
53:00	0.5261	0.0485	13.4486	0.2922	0.7719	0.000858581275679171090000000000
54:00	0.9054	0.0851	21.8291	0.4959	1.0241	0.001232639071531593800000000000
55:00	0.9626	0.0909	22.8091	0.5170	1.4131	0.002050859155133366600000000000

56:00	0.9943	0.0937	23.5504	0.5260	2.3734	0.003874735441058874100000000000
57:00	0.9983	0.0937	23.8821	0.5251	2.7579	0.004872007295489311200000000000
58:00	0.9945	0.0926	24.2785	0.5198	2.3229	0.003903160104528069500000000000
59:00	0.9922	0.0917	24.6714	0.5152	2.1761	0.003405822440981864900000000000
60:00	0.9869	0.0906	25.0052	0.5093	2.2997	0.003278520656749606100000000000
61:00	0.9873	0.0904	25.1184	0.5076	2.3572	0.003430667798966169400000000000
62:00	0.9945	0.0916	24.9359	0.5132	2.3147	0.002801303984597325300000000000
63:00	0.9744	0.0902	24.1716	0.5049	2.1746	0.002186058089137077300000000000
64:00	0.9497	0.0882	23.3728	0.4937	2.1123	0.002144308062270283700000000000
65:00	0.9575	0.0890	23.4800	0.4984	2.0397	0.002194746164605021500000000000
66:00	0.9759	0.0907	23.9230	0.5081	2.1839	0.002425953978672623600000000000
67:00	0.9833	0.0913	24.1730	0.5113	2.3501	0.002599584637209773100000000000
68:00	0.9829	0.0912	24.2438	0.5104	2.5671	0.002740307245403528200000000000
69:00	0.9822	0.0907	24.4578	0.5080	2.6486	0.002753605367615819000000000000
70:00	0.9833	0.0897	25.2363	0.5021	2.3963	0.002645608503371477100000000000
71:00	0.9630	0.0863	25.6931	0.4832	2.0332	0.002281054854393005400000000000
72:00	0.4154	0.0366	11.7583	0.2177	0.8263	0.001026325509883463400000000000
73:00	0.2430	0.0213	7.1039	0.1366	0.3742	0.000564001442398875950000000000
74:00	0.2430	0.0213	7.1295	0.1364	0.3738	0.000564001617021858690000000000
75:00	0.2430	0.0213	7.1551	0.1362	0.3734	0.000564001617021858690000000000
76:00	0.2498	0.0218	7.3621	0.1392	0.3916	0.000589224626310169700000000000
77:00	0.5903	0.0538	15.4857	0.3188	0.8651	0.000985988814389705700000000000
78:00	0.9204	0.0863	22.4185	0.4982	1.0267	0.001235313131473958500000000000
79:00	0.9675	0.0912	23.0242	0.5175	1.4069	0.002053857548162341100000000000
80:00	0.9951	0.0938	23.5846	0.5261	2.3935	0.003923643380403518700000000000
81:00	0.9985	0.0937	23.8920	0.5251	2.7837	0.004998213611543178600000000000
82:00	0.9953	0.0927	24.3098	0.5200	2.3390	0.003973326645791530600000000000
83:00	0.9933	0.0918	24.7176	0.5154	2.1803	0.003487454261630773500000000000
84:00	0.9890	0.0907	25.0879	0.5097	2.2886	0.003279401222243905100000000000
85:00	0.9895	0.0906	25.2029	0.5082	2.3642	0.003482004627585411100000000000
86:00	0.9954	0.0917	24.9712	0.5135	2.3125	0.002815418411046266600000000000
87:00	0.9784	0.0904	24.3195	0.5065	2.1749	0.002192393178120255500000000000
88:00	0.9575	0.0887	23.6613	0.4969	2.1114	0.002143938560038805000000000000
89:00	0.9639	0.0895	23.7263	0.5010	2.0395	0.002194886794313788400000000000
90:00	0.9796	0.0910	24.0640	0.5096	2.1835	0.002425770740956068000000000000

91:00	0.9859	0.0915	24.2739	0.5124	2.3493	0.0025990894064307213000000000000
92:00	0.9855	0.0913	24.3488	0.5114	2.5667	0.0027404625434428453000000000000
93:00	0.9848	0.0909	24.5681	0.5090	2.6481	0.0027541138697415590000000000000
94:00	0.9858	0.0898	25.3428	0.5030	2.3957	0.0026452462188899517000000000000
95:00	0.9687	0.0867	25.9297	0.4853	2.0336	0.0022825440391898155000000000000
96:00	0.4930	0.0427	14.4236	0.2507	0.9228	0.0011613874230533838000000000000
97:00	0.3429	0.0292	10.5347	0.1790	0.5015	0.00074257253436371684000000000000
98:00	0.3429	0.0291	10.5821	0.1786	0.5007	0.00074257276719436049000000000000
99:00	0.3429	0.0291	10.6294	0.1782	0.5000	0.00074257276719436049000000000000
100:00	0.3488	0.0295	10.8279	0.1807	0.5167	0.00076923030428588390000000000000
101:00	0.6460	0.0581	17.5229	0.3396	0.9252	0.0010746994521468878000000000000
102:00	0.9331	0.0871	22.9860	0.4997	1.0291	0.0012406465830281377000000000000
103:00	0.9721	0.0915	23.2581	0.5178	1.4083	0.0020710211247205734000000000000
104:00	0.9950	0.0938	23.6168	0.5259	2.3937	0.0039231730625033379000000000000
105:00	0.9980	0.0937	23.9009	0.5249	2.7849	0.0050084092654287815000000000000
106:00	0.9958	0.0927	24.3435	0.5200	2.3393	0.0039777662605047226000000000000
107:00	0.9941	0.0919	24.7663	0.5154	2.1815	0.0034917418379336596000000000000
108:00	0.9901	0.0907	25.1657	0.5097	2.2903	0.0033069560304284096000000000000
109:00	0.9911	0.0907	25.2800	0.5086	2.3636	0.0034889800008386374000000000000
110:00	0.9961	0.0917	25.0050	0.5137	2.3127	0.0028175779152661562000000000000
111:00	0.9818	0.0907	24.4663	0.5077	2.1748	0.0021916599944233894000000000000
112:00	0.9641	0.0891	23.9515	0.4992	2.1112	0.0021439455449581146000000000000
113:00	0.9694	0.0898	23.9762	0.5028	2.0389	0.0021952828392386436000000000000
114:00	0.9825	0.0912	24.2077	0.5104	2.1824	0.0024254682939499617000000000000
115:00	0.9880	0.0916	24.3743	0.5131	2.3488	0.0025995213072746992000000000000
116:00	0.9876	0.0915	24.4500	0.5121	2.5674	0.0027281662914901972000000000000
117:00	0.9870	0.0910	24.6723	0.5097	2.6493	0.0027277360204607248000000000000
118:00	0.9881	0.0900	25.4478	0.5038	2.3952	0.0026459612417966127000000000000
119:00	0.9738	0.0870	26.1630	0.4870	2.0321	0.0022823368199169636000000000000
120:00	0.5604	0.0474	17.1350	0.2756	0.9991	0.0012767728185281157000000000000

Scenario 2 – *E. coli* outbreak at node 195

<<< Node 15 >>>

Time	C	S	H	N	E	UVE
hr:min	MG/L	MG/L	UG/L	MG/L	CFU/L	CFU/L
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0:00	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000	0.00000000000000000000000000000
1:00	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000	0.00000000000000000000000000000
2:00	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000	0.00000000000000000000000000000
3:00	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000	0.00000000000000000000000000000
4:00	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000	0.00000000000000000000000000000
5:00	0.4472	0.0434	9.7816	0.2431	0.00000000000000000000000000000	0.00000000000000000000000000000
6:00	0.8918	0.0862	19.7645	0.4826	0.00000000000000000000000000000	0.00000000000000000000000000000
7:00	0.8925	0.0860	19.9130	0.4818	0.00000000000000000000000000000	0.00000000000000000000000000000
8:00	0.8919	0.0855	20.2281	0.4787	0.00000000000000000000000000000	0.00000000000000000000000000000
9:00	0.8919	0.0850	20.5572	0.4758	0.00000000000000000000000000000	0.00000000000000000000000000000
10:00	0.8919	0.0845	20.8843	0.4729	0.00000000000000000000000000000	0.00000000000000000000000000000
11:00	0.8919	0.0839	21.2095	0.4701	0.00000000000000000000000000000	0.00000000000000000000000000000
12:00	1.0000	0.0938	24.0054	0.5251	0.00000000000000000000000000000	0.00000000000000000000000000000
13:00	1.0000	0.0933	24.3344	0.5222	0.00000000000000000000000000000	0.00000000000000000000000000000
14:00	0.5050	0.0467	12.6524	0.2680	0.00000000000000000000000000000	0.00000000000000000000000000000
15:00	0.5070	0.0472	13.4759	0.3623	0.00000000000000000000000000000	0.00000000000000000000000000000
16:00	0.4586	0.0432	11.5636	0.3199	0.00000000000000000000000000000	0.00000000000000000000000000000
17:00	0.4587	0.0430	11.6590	0.3186	0.00000000000000000000000000000	0.00000000000000000000000000000
18:00	0.4587	0.0429	11.7718	0.3176	0.00000000000000000000000000000	0.00000000000000000000000000000
19:00	0.4587	0.0428	11.8843	0.3166	0.00000000000000000000000000000	0.00000000000000000000000000000
20:00	0.4587	0.0426	11.9964	0.3157	0.00000000000000000000000000000	0.00000000000000000000000000000
21:00	0.4587	0.0425	12.1081	0.3147	0.00000000000000000000000000000	0.00000000000000000000000000000
22:00	0.4587	0.0424	12.2196	0.3137	0.00000000000000000000000000000	0.00000000000000000000000000000
23:00	0.0771	0.0074	1.7099	0.0417	0.00000000000000000000000000000	0.00000000000000000000000000000
24:00	0.0771	0.0074	1.7124	0.0417	0.00000000000000000000000000000	0.00000000000000000000000000000
25:00	0.9062	0.0840	23.4093	0.5445	0.00000000000000000000000000000	0.00000000000000000000000000000
26:00	0.9467	0.0909	21.3361	0.5092	0.00000000000000000000000000000	0.00000000000000000000000000000
27:00	1.0000	0.0965	22.2217	0.5406	0.00000000000000000000000000000	0.00000000000000000000000000000
28:00	1.0000	0.0966	22.1975	0.5408	0.00000000000000000000000000000	0.00000000000000000000000000000

29:00	1.0000	0.0965	22.2276	0.5406	0.000000000000000000000000000000	0.000000000000000000000000000000
30:00	1.0000	0.0963	22.3980	0.5391	0.000000000000000000000000000000	0.000000000000000000000000000000
31:00	1.0000	0.0961	22.5168	0.5381	0.000000000000000000000000000000	0.000000000000000000000000000000
32:00	1.0000	0.0955	22.9184	0.5346	0.000000000000000000000000000000	0.000000000000000000000000000000
33:00	1.0000	0.0948	23.3304	0.5310	0.000000000000000000000000000000	0.000000000000000000000000000000
34:00	1.0000	0.0942	23.7395	0.5274	0.000000000000000000000000000000	0.000000000000000000000000000000
35:00	1.0000	0.0935	24.1460	0.5239	0.000000000000000000000000000000	0.000000000000000000000000000000
36:00	0.3296	0.0314	7.5909	0.1758	0.000000000000000000000000000000	0.000000000000000000000000000000
37:00	0.5453	0.0513	12.9977	0.2871	0.000000000000000000000000000000	0.000000000000000000000000000000
38:00	1.0000	0.0938	23.9845	0.5253	0.000000000000000000000000000000	0.000000000000000000000000000000
39:00	1.0000	0.0934	24.2186	0.5232	0.000000000000000000000000000000	0.000000000000000000000000000000
40:00	0.8781	0.0830	20.6771	0.4646	0.000000000000000000000000000000	0.000000000000000000000000000000
41:00	0.8784	0.0825	20.9842	0.4622	0.000000000000000000000000000000	0.000000000000000000000000000000
42:00	0.8784	0.0820	21.2972	0.4594	0.000000000000000000000000000000	0.000000000000000000000000000000
43:00	0.8784	0.0816	21.6083	0.4567	0.000000000000000000000000000000	0.000000000000000000000000000000
44:00	0.8784	0.0811	21.9176	0.4540	0.000000000000000000000000000000	0.000000000000000000000000000000
45:00	0.8784	0.0806	22.2250	0.4513	0.000000000000000000000000000000	0.000000000000000000000000000000
46:00	0.8784	0.0801	22.5307	0.4487	0.000000000000000000000000000000	0.000000000000000000000000000000
47:00	0.2410	0.0228	5.6790	0.1275	0.000000000000000000000000000000	0.000000000000000000000000000000
48:00	0.2410	0.0227	5.7028	0.1273	0.000000000000000000000000000000	0.000000000000000000000000000000
49:00	0.9792	0.0911	23.9671	0.5101	0.000000000000000000000000000000	0.000000000000000000000000000000
50:00	0.9044	0.0867	20.5095	0.4853	0.000000000000000000000000000000	0.000000000000000000000000000000
51:00	1.0000	0.0964	22.2860	0.5401	0.000000000000000000000000000000	0.000000000000000000000000000000
52:00	1.0000	0.0966	22.2102	0.5407	0.000000000000000000000000000000	0.000000000000000000000000000000
53:00	1.0000	0.0965	22.2320	0.5405	0.000000000000000000000000000000	0.000000000000000000000000000000
54:00	1.0000	0.0963	22.3991	0.5391	0.000000000000000000000000000000	0.000000000000000000000000000000
55:00	1.0000	0.0961	22.5115	0.5381	0.000000000000000000000000000000	0.000000000000000000000000000000
56:00	1.0000	0.0955	22.9106	0.5346	0.000000000000000000000000000000	0.000000000000000000000000000000
57:00	1.0000	0.0948	23.3226	0.5310	0.000000000000000000000000000000	0.000000000000000000000000000000
58:00	1.0000	0.0942	23.7318	0.5275	0.000000000000000000000000000000	0.000000000000000000000000000000
59:00	1.0000	0.0936	24.1383	0.5239	0.000000000000000000000000000000	0.000000000000000000000000000000
60:00	0.3259	0.0304	7.9402	0.1701	0.000000000000000000000000000000	0.000000000000000000000000000000
61:00	0.6149	0.0573	15.0025	0.3208	0.000000000000000000000000000000	0.000000000000000000000000000000
62:00	1.0000	0.0939	23.9149	0.5259	0.000000000000000000000000000000	0.000000000000000000000000000000
63:00	1.0000	0.0935	24.2021	0.5234	0.000000000000000000000000000000	0.000000000000000000000000000000

64:00	0.8963	0.0845	21.1998	0.4734	0.000000000000000000000000000000	0.000000000000000000000000000000
65:00	0.8963	0.0840	21.5089	0.4707	0.000000000000000000000000000000	0.000000000000000000000000000000
66:00	0.8963	0.0835	21.8340	0.4678	0.000000000000000000000000000000	0.000000000000000000000000000000
67:00	0.8963	0.0830	22.1573	0.4650	0.000000000000000000000000000000	0.000000000000000000000000000000
68:00	0.8963	0.0825	22.4785	0.4622	0.000000000000000000000000000000	0.000000000000000000000000000000
69:00	0.8963	0.0820	22.7979	0.4594	0.000000000000000000000000000000	0.000000000000000000000000000000
70:00	0.8963	0.0815	23.1153	0.4567	0.000000000000000000000000000000	0.000000000000000000000000000000
71:00	0.3584	0.0327	9.1668	0.1833	0.000000000000000000000000000000	0.000000000000000000000000000000
72:00	0.3584	0.0326	9.2175	0.1828	0.000000000000000000000000000000	0.000000000000000000000000000000
73:00	0.9819	0.0913	24.0752	0.5112	0.000000000000000000000000000000	0.000000000000000000000000000000
74:00	0.9192	0.0879	20.9717	0.4922	0.000000000000000000000000000000	0.000000000000000000000000000000
75:00	1.0000	0.0964	22.2876	0.5401	0.000000000000000000000000000000	0.000000000000000000000000000000
76:00	1.0000	0.0966	22.2106	0.5407	0.000000000000000000000000000000	0.000000000000000000000000000000
77:00	1.0000	0.0965	22.2320	0.5405	0.000000000000000000000000000000	0.000000000000000000000000000000
78:00	1.0000	0.0963	22.4016	0.5391	0.000000000000000000000000000000	0.000000000000000000000000000000
79:00	1.0000	0.0961	22.5114	0.5381	0.000000000000000000000000000000	0.000000000000000000000000000000
80:00	1.0000	0.0955	22.9107	0.5346	0.000000000000000000000000000000	0.000000000000000000000000000000
81:00	1.0000	0.0948	23.3227	0.5310	0.000000000000000000000000000000	0.000000000000000000000000000000
82:00	1.0000	0.0942	23.7320	0.5275	0.000000000000000000000000000000	0.000000000000000000000000000000
83:00	1.0000	0.0936	24.1384	0.5239	0.000000000000000000000000000000	0.000000000000000000000000000000
84:00	0.4301	0.0386	11.4025	0.2164	0.000000000000000000000000000000	0.000000000000000000000000000000
85:00	0.6744	0.0620	17.0023	0.3471	0.000000000000000000000000000000	0.000000000000000000000000000000
86:00	1.0000	0.0939	23.9151	0.5259	0.000000000000000000000000000000	0.000000000000000000000000000000
87:00	1.0000	0.0935	24.2018	0.5234	0.000000000000000000000000000000	0.000000000000000000000000000000
88:00	0.9123	0.0857	21.7718	0.4802	0.000000000000000000000000000000	0.000000000000000000000000000000
89:00	0.9123	0.0852	22.0913	0.4774	0.000000000000000000000000000000	0.000000000000000000000000000000
90:00	0.9123	0.0847	22.4270	0.4744	0.000000000000000000000000000000	0.000000000000000000000000000000
91:00	0.9123	0.0842	22.7606	0.4715	0.000000000000000000000000000000	0.000000000000000000000000000000
92:00	0.9123	0.0837	23.0922	0.4686	0.000000000000000000000000000000	0.000000000000000000000000000000
93:00	0.9123	0.0832	23.4218	0.4658	0.000000000000000000000000000000	0.000000000000000000000000000000
94:00	0.9123	0.0827	23.7493	0.4629	0.000000000000000000000000000000	0.000000000000000000000000000000
95:00	0.4576	0.0401	12.7804	0.2246	0.000000000000000000000000000000	0.000000000000000000000000000000
96:00	0.4576	0.0400	12.8597	0.2239	0.000000000000000000000000000000	0.000000000000000000000000000000
97:00	0.9848	0.0915	24.1813	0.5124	0.000000000000000000000000000000	0.000000000000000000000000000000
98:00	0.9318	0.0888	21.4471	0.4973	0.000000000000000000000000000000	0.000000000000000000000000000000

99:00	1.0000	0.0964	22.2875	0.5401	0.000000000000000000000000000000	0.000000000000000000000000000000
100:00	1.0000	0.0966	22.2105	0.5407	0.000000000000000000000000000000	0.000000000000000000000000000000
101:00	1.0000	0.0965	22.2320	0.5405	0.000000000000000000000000000000	0.000000000000000000000000000000
102:00	1.0000	0.0963	22.4014	0.5391	0.000000000000000000000000000000	0.000000000000000000000000000000
103:00	1.0000	0.0961	22.5114	0.5381	0.000000000000000000000000000000	0.000000000000000000000000000000
104:00	1.0000	0.0955	22.9107	0.5346	0.000000000000000000000000000000	0.000000000000000000000000000000
105:00	1.0000	0.0948	23.3226	0.5310	0.000000000000000000000000000000	0.000000000000000000000000000000
106:00	1.0000	0.0942	23.7319	0.5275	0.000000000000000000000000000000	0.000000000000000000000000000000
107:00	1.0000	0.0936	24.1383	0.5239	0.000000000000000000000000000000	0.000000000000000000000000000000
108:00	0.5182	0.0446	14.9743	0.2500	0.000000000000000000000000000000	0.000000000000000000000000000000
109:00	0.7248	0.0654	19.0523	0.3662	0.000000000000000000000000000000	0.000000000000000000000000000000
110:00	1.0000	0.0939	23.9150	0.5259	0.000000000000000000000000000000	0.000000000000000000000000000000
111:00	1.0000	0.0935	24.2018	0.5234	0.000000000000000000000000000000	0.000000000000000000000000000000
112:00	0.9259	0.0866	22.3530	0.4850	0.000000000000000000000000000000	0.000000000000000000000000000000
113:00	0.9259	0.0861	22.6807	0.4822	0.000000000000000000000000000000	0.000000000000000000000000000000
114:00	0.9259	0.0856	23.0248	0.4792	0.000000000000000000000000000000	0.000000000000000000000000000000
115:00	0.9259	0.0850	23.3668	0.4762	0.000000000000000000000000000000	0.000000000000000000000000000000
116:00	0.9259	0.0845	23.7066	0.4732	0.000000000000000000000000000000	0.000000000000000000000000000000
117:00	0.9259	0.0840	24.0444	0.4703	0.000000000000000000000000000000	0.000000000000000000000000000000
118:00	0.9259	0.0835	24.3800	0.4674	0.000000000000000000000000000000	0.000000000000000000000000000000
119:00	0.5414	0.0453	16.4809	0.2539	0.000000000000000000000000000000	0.000000000000000000000000000000
120:00	0.5414	0.0452	16.5870	0.2530	0.000000000000000000000000000000	0.000000000000000000000000000000

<<< Node 219 >>>

Time	C	S	H	N	E	UVE
hr:min	MG/L	MG/L	UG/L	MG/L	CFU/L	CFU/L
0:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
1:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
2:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
3:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
4:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
5:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
6:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000

7:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
8:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
9:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
10:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
11:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
12:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
13:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
14:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
15:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
16:00	0.0000	0.0000	0.0000	0.0000	0.000000000000000000000000000000	0.000000000000000000000000000000
17:00	0.0000	0.0000	0.0000	0.0000	0.009193668141961097700000000000	0.000000000000000684845143156856
18:00	0.0000	0.0000	0.0000	0.0000	1.649788379669189500000000000000	0.000000000000130158999355443890
19:00	0.0000	0.0000	0.0000	0.0000	0.459160089492797850000000000000	0.000000000000038247013791747192
20:00	0.0000	0.0000	0.0000	0.0000	0.020073207095265380000000000000	0.000000000000001760443949057539
21:00	0.2025	0.0194	6.1735	0.3365	0.013988255523145199000000000000	0.000000000000001298702043191105
22:00	0.5964	0.0553	40.2779	2.3027	0.039893988519906998000000000000	0.000000000000003516131384599772
23:00	0.6136	0.0568	43.6982	2.5049	0.081586152315139771000000000000	0.000000000000007157967964286239
24:00	0.6095	0.0566	44.5154	2.6311	0.079877868294715881000000000000	0.000000000000006667600685846464
25:00	0.6077	0.0564	44.3504	2.6402	0.070177718997001648000000000000	0.000000000000005844822950553264
26:00	0.5937	0.0553	43.2609	2.6787	0.064773857593536377000000000000	0.000000000000005240381086425543
27:00	0.5915	0.0551	42.5960	2.6607	0.062939226627349854000000000000	0.000000000000005049306123634497
28:00	0.5914	0.0552	42.3859	2.6861	0.059497378766536713000000000000	0.000000000000004677804672748812
29:00	0.5807	0.0542	42.1811	2.6777	0.056707955896854401000000000000	0.000000000000004588443967362904
30:00	0.5061	0.0483	43.8151	3.2239	0.009987324476242065400000000000	0.000000000000000834561498836724
31:00	0.5109	0.0487	44.5149	3.2138	0.014706552959978580000000000000	0.000000000000001148980817071790
32:00	0.7173	0.0651	40.5517	1.9086	1.800387501716613800000000000000	0.000000000000138183003451156080
33:00	0.7157	0.0646	36.2326	1.5536	3.805062770843505900000000000000	0.000000000000299563759215137890
34:00	0.7322	0.0659	33.8539	1.3280	3.018371343612670900000000000000	0.000000000000224556660701098750
35:00	0.8127	0.0719	27.8364	0.7318	2.298258066177368200000000000000	0.000000000000170846870721844120
36:00	0.8413	0.0740	24.8527	0.4979	1.671056270599365200000000000000	0.000000000000128093973687619380
37:00	0.8287	0.0730	26.4105	0.6008	2.312035322189331100000000000000	0.000000000000183800037364435790
38:00	0.5711	0.0515	17.1986	0.4416	1.400668501853942900000000000000	0.000000000000111251306290135330
39:00	0.5955	0.0538	17.5738	0.4341	0.469581663608551030000000000000	0.000000000000040233001121197515
40:00	0.9560	0.0830	27.5202	0.4792	0.578859567642211910000000000000	0.000000000000050122808735540009
41:00	0.9731	0.0846	27.8401	0.4820	1.651556730270385700000000000000	0.000000000000144422112615359700

42:00	0.7974	0.0705	22.7424	0.4446	1.1080799102783203000000000000000	0.000000000000101256032909464310
43:00	0.7088	0.0636	20.0447	0.4279	0.0190608669072389600000000000000	0.000000000000002748391520878551
44:00	0.9829	0.0850	28.2989	0.4791	1.1538941860198975000000000000000	0.000000000000109983054022606830
45:00	0.9980	0.0861	28.7860	0.4820	1.7690526247024536000000000000000	0.000000000000167417200437093570
46:00	1.0000	0.0863	28.7725	0.4835	3.5938026905059814000000000000000	0.000000000000310513821686481120
47:00	0.9691	0.0832	29.0390	0.4949	2.1618561744689941000000000000000	0.000000000000195530305271626740
48:00	1.0000	0.0864	28.7197	0.4840	1.8418027162551880000000000000000	0.000000000000153008356852668560
49:00	1.0000	0.0864	28.7405	0.4838	1.6671708822250366000000000000000	0.000000000000141244722623619370
50:00	0.9771	0.0846	27.9460	0.4739	1.7683391571044922000000000000000	0.000000000000145535344301013500
51:00	0.8887	0.0777	24.9764	0.4349	2.1862061023712158000000000000000	0.000000000000176075828721943000
52:00	0.9926	0.0864	28.1415	0.4836	2.2188436985015869000000000000000	0.000000000000171388782072706690
53:00	0.9871	0.0861	27.8358	0.4822	2.4412572383880615000000000000000	0.000000000000191812047473614860
54:00	0.9723	0.0851	27.2494	0.4765	2.8601329326629639000000000000000	0.000000000000218480900146707240
55:00	0.9948	0.0868	28.0604	0.4859	2.5091843605041504000000000000000	0.000000000000188025769541806660
56:00	0.9994	0.0870	28.2879	0.4873	2.4942517280578613000000000000000	0.000000000000185318598032273300
57:00	0.9986	0.0870	28.2382	0.4872	2.7484920024871826000000000000000	0.000000000000204787372498106690
58:00	0.9467	0.0827	26.6384	0.4630	2.6252396106719971000000000000000	0.000000000000194554048977939320
59:00	0.9018	0.0791	25.1839	0.4427	2.1837553977966309000000000000000	0.000000000000161591334930932810
60:00	0.8888	0.0777	24.9761	0.4349	1.6280767917633057000000000000000	0.000000000000124427201940273400
61:00	0.8775	0.0765	24.7641	0.4285	1.5615303516387939000000000000000	0.000000000000120412306427869490
62:00	0.6340	0.0566	18.2482	0.3843	1.4071613550186157000000000000000	0.000000000000113696798829075740
63:00	0.6537	0.0583	18.8191	0.3936	0.6289586424827575700000000000000	0.000000000000055575092054380160
64:00	0.9213	0.0802	26.0831	0.4495	0.6753625273704528800000000000000	0.000000000000057580649233043846
65:00	0.9738	0.0844	27.7941	0.4728	1.7483794689178467000000000000000	0.000000000000152956111860481910
66:00	0.8914	0.0778	25.5923	0.4567	1.1127291917800903000000000000000	0.000000000000102894092985500450
67:00	0.7633	0.0678	21.9693	0.4357	0.0344894267618656160000000000000	0.000000000000006374501028075111
68:00	0.9860	0.0852	28.3676	0.4782	1.1522324085235596000000000000000	0.000000000000109098670310510400
69:00	0.9972	0.0860	28.7476	0.4817	1.7346153259277344000000000000000	0.000000000000163258078930694770
70:00	1.0000	0.0864	28.7645	0.4836	3.1074655055999756000000000000000	0.000000000000269605762411376240
71:00	0.9672	0.0828	28.2803	0.4638	2.1454534530639648000000000000000	0.000000000000192709197666292300
72:00	1.0000	0.0864	28.7391	0.4838	1.5687962770462036000000000000000	0.000000000000131356649732752850
73:00	1.0000	0.0863	28.7750	0.4835	1.7675676345825195000000000000000	0.000000000000149930835433541300
74:00	0.9725	0.0841	27.8657	0.4712	1.8010298013687134000000000000000	0.000000000000148561881112979630
75:00	0.9240	0.0803	26.2687	0.4496	2.0406885147094727000000000000000	0.000000000000164321911654864710
76:00	0.9952	0.0867	28.1745	0.4853	2.2187998294830322000000000000000	0.000000000000171406413910536740

77:00	0.9884	0.0862	27.8907	0.4827	2.4533047676086426000000000000000	0.0000000000001924221686936539 20
78:00	0.9768	0.0854	27.4330	0.4782	2.8592195510864258000000000000000	0.000000000000218574507451774200
79:00	0.9964	0.0869	28.1217	0.4866	2.5112016201019287000000000000000	0.000000000000188130557681777390
80:00	0.9995	0.0870	28.2936	0.4874	2.4879810810089111000000000000000	0.000000000000185053984939551050
81:00	0.9991	0.0870	28.2527	0.4874	2.7473430633544922000000000000000	0.000000000000204601743533650020
82:00	0.9555	0.0833	26.9877	0.4664	2.6279675960540771000000000000000	0.000000000000194907254940680790
83:00	0.9175	0.0801	25.8038	0.4488	2.1862058639526367000000000000000	0.000000000000161915348750180100
84:00	0.9060	0.0788	25.6658	0.4416	1.6260439157485962000000000000000	0.000000000000124555029376409440
85:00	0.8964	0.0778	25.5258	0.4358	1.5651496648788452000000000000000	0.000000000000120973218421804860
86:00	0.6938	0.0610	20.6391	0.3944	1.4135054349899292000000000000000	0.000000000000118294100643484560
87:00	0.7094	0.0624	21.0846	0.4018	0.6390877366065979000000000000000	0.000000000000060349776120471182
88:00	0.9326	0.0809	26.5682	0.4535	0.6728686690330505400000000000000	0.000000000000057380044726079715
89:00	0.9778	0.0847	27.9696	0.4742	1.7500659227371216000000000000000	0.000000000000153191031366205210
90:00	0.9064	0.0788	26.2829	0.4583	1.1184597015380859000000000000000	0.000000000000104871874259757770
91:00	0.8024	0.0705	23.6398	0.4388	0.0459139309823513030000000000000	0.000000000000010832301174752354
92:00	0.9877	0.0853	28.4573	0.4785	1.1522033214569092000000000000000	0.000000000000109366095552617530
93:00	0.9976	0.0860	28.7670	0.4818	1.7371984720230103000000000000000	0.000000000000163529752890065330
94:00	1.0000	0.0864	28.7608	0.4836	3.1033606529235840000000000000000	0.000000000000269003894680375220
95:00	0.9723	0.0831	28.5183	0.4654	2.1500513553619385000000000000000	0.000000000000193202211499175770
96:00	1.0000	0.0864	28.7390	0.4838	1.5686945915222168000000000000000	0.000000000000131330046121945490
97:00	1.0000	0.0863	28.7739	0.4835	1.7669751644134521000000000000000	0.000000000000149885448020095620
98:00	0.9767	0.0844	28.0539	0.4727	1.8005596399307251000000000000000	0.000000000000148549792258756420
99:00	0.9355	0.0810	26.7764	0.4536	2.0416302680969238000000000000000	0.000000000000164452896829828110
100:00	0.9960	0.0867	28.2076	0.4855	2.2185955047607422000000000000000	0.000000000000171393850717863060
101:00	0.9902	0.0863	27.9737	0.4833	2.4526622295379639000000000000000	0.000000000000192391174064047990
102:00	0.9803	0.0856	27.5967	0.4793	2.8584301471710205000000000000000	0.000000000000218561713866138870
103:00	0.9968	0.0869	28.1448	0.4866	2.5111284255981445000000000000000	0.000000000000188127860728873330
104:00	0.9996	0.0870	28.2975	0.4874	2.4881875514984131000000000000000	0.000000000000185070207314556870
105:00	0.9992	0.0870	28.2592	0.4874	2.7473075389862061000000000000000	0.000000000000204611108329914860
106:00	0.9623	0.0837	27.3016	0.4687	2.6265883445739746000000000000000	0.000000000000194849250124452810
107:00	0.9303	0.0809	26.3850	0.4531	2.1840996742248535000000000000000	0.000000000000161770296052028690
108:00	0.9204	0.0797	26.3309	0.4464	1.6245321035385132000000000000000	0.000000000000124324229838941590
109:00	0.9123	0.0788	26.2662	0.4410	1.5627307891845703000000000000000	0.000000000000120889694196942010
110:00	0.7431	0.0640	22.9558	0.3998	1.4180306196212769000000000000000	0.000000000000123212434721166330
111:00	0.7565	0.0653	23.3116	0.4064	0.6464356184005737300000000000000	0.000000000000065408934507831668

112:00	0.9432	0.0816	27.0694	0.4569	0.67235010862350464000000000000000	0.0000000000000057388345648962807
113:00	0.9813	0.0849	28.1397	0.4753	1.74904310703277590000000000000000	0.0000000000000153124298722488730
114:00	0.9215	0.0796	27.0319	0.4592	1.12011337280273440000000000000000	0.0000000000000106550666456161490
115:00	0.8340	0.0723	25.2330	0.4392	0.05389229580760002100000000000000	0.0000000000000015426079332100592
116:00	0.9892	0.0853	28.5471	0.4786	1.15088057518005370000000000000000	0.0000000000000109540448814480360
117:00	0.9980	0.0861	28.7862	0.4819	1.73689377307891850000000000000000	0.0000000000000163502552968063100
118:00	1.0000	0.0864	28.7643	0.4836	3.10721755027771000000000000000000	0.0000000000000269537078203749280
119:00	0.9765	0.0833	28.7440	0.4666	2.14890718460083010000000000000000	0.0000000000000193132714139919450
120:00	1.0000	0.0864	28.7391	0.4838	1.56872534751892090000000000000000	0.0000000000000131334789506450110

<<< Node 253 >>>

Time	C	S	H	N	E	UVE
hr:min	MG/L	MG/L	UG/L	MG/L	CFU/L	CFU/L
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0:00	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000000	0.0000000000000000000000000000000
1:00	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000000	0.0000000000000000000000000000000
2:00	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000000	0.0000000000000000000000000000000
3:00	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000000	0.0000000000000000000000000000000
4:00	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000000	0.0000000000000000000000000000000
5:00	0.0000	0.0000	0.0000	0.0000	0.00000000000000000000000000000000	0.0000000000000000000000000000000
6:00	0.0000	0.0000	0.0000	0.0000	0.48736500740051270000000000000000	0.0000000000000012697557510098732
7:00	0.0000	0.0000	0.0000	0.0000	0.32872855663299561000000000000000	0.0000000000000010012050562257287
8:00	0.1099	0.0107	2.8273	0.1608	0.05828452855348587000000000000000	0.0000000000000002033182946480148
9:00	0.3298	0.0324	13.1168	1.2397	0.03588538616895675700000000000000	0.0000000000000001302546090463982
10:00	0.5345	0.0522	24.0724	2.2420	0.06428622454404830900000000000000	0.0000000000000002166821875667301
11:00	0.5959	0.0580	28.1232	2.5373	0.07755737751722335800000000000000	0.0000000000000002538159849194165
12:00	0.6021	0.0586	29.4299	2.6672	0.08150294423103332500000000000000	0.0000000000000002724766289671971
13:00	0.6095	0.0591	30.6466	2.7022	0.08210705220699310300000000000000	0.0000000000000002896591369945479
14:00	0.6081	0.0589	31.3432	2.7316	0.07927924394607543900000000000000	0.0000000000000002939295806530726
15:00	0.6044	0.0585	31.4903	2.7477	0.07233552634716033900000000000000	0.0000000000000002726772275449306
16:00	0.5964	0.0577	31.4606	2.7690	0.06954327225685119600000000000000	0.0000000000000002659427438670196
17:00	0.5944	0.0574	31.5219	2.7562	0.06569142639636993400000000000000	0.0000000000000002557296652813245
18:00	0.5845	0.0563	32.5508	2.7424	0.06614784151315689100000000000000	0.0000000000000002912824332863134
19:00	0.5944	0.0569	34.4664	2.7368	0.06772310286760330200000000000000	0.0000000000000003362706824555943

20:00	0.5959	0.0567	36.4927	2.7088	0.0694396272301673890000000000000	0.00000000000003952162134747894
21:00	0.6033	0.0570	38.7796	2.6873	0.0703380852937698360000000000000	0.00000000000004514894402486919
22:00	0.5708	0.0532	38.0103	2.2758	0.0624356865882873540000000000000	0.00000000000005330260175975170
23:00	0.2735	0.0262	14.4142	1.0852	0.0417914874851703640000000000000	0.00000000000004180151216896756
24:00	0.0006	0.0001	0.0122	0.0003	0.0562881492078304290000000000000	0.00000000000005928182427507875
25:00	0.0006	0.0001	0.0122	0.0003	0.0562880150973796840000000000000	0.00000000000006176041632049902
26:00	0.0006	0.0001	0.0122	0.0003	0.0562878772616386410000000000000	0.00000000000006423900413075456
27:00	0.0006	0.0001	0.0122	0.0003	0.0562877431511878970000000000000	0.00000000000006671758347068062
28:00	0.0006	0.0001	0.0122	0.0003	0.0562876053154468540000000000000	0.00000000000006919615857544194
29:00	0.0006	0.0001	0.0122	0.0003	0.0562874712049961090000000000000	0.00000000000007167472520987379
30:00	0.7661	0.0715	25.9169	0.8974	1.0414292812347412000000000000000	0.000000000000039037061750442012
31:00	0.8877	0.0834	21.4713	0.4966	1.1535645723342896000000000000000	0.000000000000045034014359420990
32:00	0.9851	0.0927	23.4623	0.5228	1.5597610473632812000000000000000	0.000000000000051284067189303131
33:00	0.9973	0.0935	23.9506	0.5242	2.7361586093902588000000000000000	0.000000000000085596562119077263
34:00	0.9993	0.0934	24.1717	0.5233	3.0513463020324707000000000000000	0.000000000000098954617286720059
35:00	0.9896	0.0914	24.6549	0.5144	2.0231659412384033000000000000000	0.000000000000087540319773909275
36:00	0.9961	0.0918	24.9454	0.5150	2.6693375110626221000000000000000	0.000000000000115186302878690640
37:00	0.9870	0.0900	25.3574	0.5074	2.1202991008758545000000000000000	0.000000000000112018711364084140
38:00	0.9943	0.0909	25.3665	0.5105	2.4857809543609619000000000000000	0.000000000000113619325807588070
39:00	0.9907	0.0910	25.1993	0.5183	2.4479489326477051000000000000000	0.000000000000104901459426539470
40:00	0.9788	0.0903	24.4579	0.5056	1.5686713457107544000000000000000	0.000000000000057830937304562124
41:00	0.9390	0.0866	23.4399	0.4852	1.9180240631103516000000000000000	0.000000000000070216761279082857
42:00	0.9446	0.0874	23.4305	0.4895	2.1363165378570557000000000000000	0.000000000000075538364354820614
43:00	0.9728	0.0898	24.2683	0.5029	2.1068189144134521000000000000000	0.000000000000076681506467907862
44:00	0.9805	0.0904	24.5012	0.5064	2.4000604152679443000000000000000	0.000000000000091928214714966094
45:00	0.9772	0.0903	24.3350	0.5055	2.7080669403076172000000000000000	0.000000000000101428360068517300
46:00	0.9759	0.0896	24.6292	0.5020	2.6862287521362305000000000000000	0.000000000000111194351794761950
47:00	0.9784	0.0883	25.7159	0.4943	2.1188745498657227000000000000000	0.000000000000112823053850796830
48:00	0.9372	0.0828	25.7309	0.4639	1.8050787448883057000000000000000	0.000000000000123166003763129640
49:00	0.1284	0.0115	3.6960	0.0830	0.2188442647457122800000000000000	0.000000000000028769206391080979
50:00	0.1284	0.0115	3.7042	0.0829	0.2187231332063674900000000000000	0.000000000000029732621665288020
51:00	0.1284	0.0115	3.7124	0.0829	0.2186020761728286700000000000000	0.000000000000030695505002804185
52:00	0.1284	0.0115	3.7206	0.0828	0.2184810936450958300000000000000	0.000000000000031657856403629475
53:00	0.1284	0.0115	3.7289	0.0827	0.2183601707220077500000000000000	0.000000000000032619672479632100
54:00	0.9730	0.0886	25.0734	0.4965	1.9816533327102661000000000000000	0.000000000000111339567123239220

55:00	0.9122	0.0856	22.1183	0.4969	1.11834633350372310000000000000	0.00000000000043922696968227981
56:00	0.9850	0.0926	23.5422	0.5212	1.58548867702484130000000000000	0.00000000000054345481429905404
57:00	0.9971	0.0934	23.9746	0.5236	2.64952540397644040000000000000	0.00000000000084628234053776147
58:00	0.9992	0.0933	24.2114	0.5228	2.73824691772460940000000000000	0.00000000000089442789654760324
59:00	0.9895	0.0913	24.7220	0.5135	1.76528728008270260000000000000	0.00000000000078618101612137892
60:00	0.9957	0.0917	24.9647	0.5144	2.61899566650390620000000000000	0.00000000000112915841227970850
61:00	0.9820	0.0894	25.3515	0.5037	2.31288504600524900000000000000	0.00000000000122160528220893740
62:00	0.9944	0.0908	25.4556	0.5096	2.32140445709228520000000000000	0.00000000000109718366390985230
63:00	0.9898	0.0908	25.0812	0.5082	2.64561104774475100000000000000	0.00000000000120444181971740560
64:00	0.9800	0.0903	24.5685	0.5055	1.62826919555664060000000000000	0.00000000000061221827032855586
65:00	0.9498	0.0876	23.7565	0.4904	1.93698930740356450000000000000	0.00000000000071437708450573095
66:00	0.9560	0.0883	23.7871	0.4947	2.10103034973144530000000000000	0.00000000000074744660601925444
67:00	0.9791	0.0904	24.4327	0.5060	2.10542774200439450000000000000	0.00000000000076648336657693383
68:00	0.9843	0.0907	24.6269	0.5081	2.38744783401489260000000000000	0.00000000000091816142091648983
69:00	0.9816	0.0906	24.5001	0.5073	2.70097041130065920000000000000	0.00000000000101870999157961660
70:00	0.9804	0.0900	24.7973	0.5038	2.69390773773193360000000000000	0.00000000000112045436947635910
71:00	0.9819	0.0885	25.8410	0.4958	2.10733079910278320000000000000	0.00000000000112513209198691210
72:00	0.9479	0.0836	26.1247	0.4684	1.83951151371002200000000000000	0.00000000000126216908018922380
73:00	0.2430	0.0213	7.1039	0.1366	0.37416866421699524000000000000	0.00000000000066292078163693313
74:00	0.2430	0.0213	7.1295	0.1364	0.37377676367759705000000000000	0.00000000000067938899948535858
75:00	0.2430	0.0213	7.1551	0.1362	0.37338528037071228000000000000	0.00000000000069584000562429582
76:00	0.2430	0.0212	7.1807	0.1360	0.37299421429634094000000000000	0.00000000000071227380005374485
77:00	0.2430	0.0212	7.2062	0.1357	0.37260356545448303000000000000	0.00000000000072869038277370568
78:00	0.9779	0.0889	25.2710	0.4980	1.99561667442321780000000000000	0.00000000000112307888412276760
79:00	0.9338	0.0873	22.8300	0.5008	1.18728792667388920000000000000	0.00000000000047894065151538392
80:00	0.9870	0.0927	23.6321	0.5215	1.57269537448883060000000000000	0.00000000000054070771704451889
81:00	0.9974	0.0935	23.9931	0.5236	2.66237902641296390000000000000	0.00000000000085077629078007810
82:00	0.9993	0.0933	24.2134	0.5228	2.73269057273864750000000000000	0.00000000000089107764407198725
83:00	0.9911	0.0915	24.7847	0.5138	1.78801333904266360000000000000	0.00000000000079495329589895913
84:00	0.9963	0.0918	24.9882	0.5145	2.60279035568237300000000000000	0.00000000000111583485506994150
85:00	0.9855	0.0897	25.4724	0.5044	2.30493974685668950000000000000	0.00000000000121735236366209140
86:00	0.9953	0.0909	25.4940	0.5096	2.33204078674316410000000000000	0.00000000000110301267360231330
87:00	0.9914	0.0909	25.1469	0.5088	2.63296675682067870000000000000	0.00000000000119461474675126860
88:00	0.9831	0.0905	24.6858	0.5068	1.62585663795471190000000000000	0.00000000000061111794064875463
89:00	0.9576	0.0881	24.0477	0.4935	1.93692946434021000000000000000	0.00000000000071428221681563847

90:00	0.9628	0.0888	24.0461	0.4974	2.1009500026702881000000000000000	0.0000000000000747457583566250 86
91:00	0.9822	0.0906	24.5577	0.5072	2.1050262451171875000000000000000	0.0000000000000767209917557770 68
92:00	0.9867	0.0909	24.7234	0.5090	2.3868868350982666000000000000000	0.0000000000000918187577293901 05
93:00	0.9844	0.0908	24.6144	0.5084	2.7005364894866943000000000000000	0.0000000000001018700301522700 00
94:00	0.9833	0.0902	24.9203	0.5049	2.6934332847595215000000000000000	0.0000000000001120638209507231 20
95:00	0.9847	0.0887	25.9583	0.4969	2.1066572666168213000000000000000	0.0000000000001124890518190355 10
96:00	0.9560	0.0842	26.4639	0.4713	1.8384822607040405000000000000000	0.0000000000001261657743339625 30
97:00	0.3429	0.0292	10.5347	0.1790	0.5014693140983581500000000000000	0.0000000000001124242504104387 70
98:00	0.3429	0.0291	10.5821	0.1786	0.5007283091545105000000000000000	0.0000000000001146309338683620 90
99:00	0.3429	0.0291	10.6294	0.1782	0.4999883472919464100000000000000	0.0000000000001168343443909772 30
100:00	0.3429	0.0290	10.6766	0.1778	0.4992495179176330600000000000000	0.0000000000001190345023070749 10
101:00	0.3429	0.0289	10.7237	0.1774	0.4985117614269256600000000000000	0.0000000000001212314076166551 30
102:00	0.9813	0.0891	25.4198	0.4992	1.9952305555343628000000000000000	0.0000000000001123015390533041 40
103:00	0.9444	0.0880	23.3055	0.5021	1.1888558864593506000000000000000	0.0000000000000488804960049882 28
104:00	0.9888	0.0928	23.7258	0.5217	1.5735334157943726000000000000000	0.0000000000000543738773624291 57
105:00	0.9962	0.0933	24.0055	0.5231	2.6638820171356201000000000000000	0.0000000000000855195160021950 12
106:00	0.9994	0.0933	24.2209	0.5228	2.7355501651763916000000000000000	0.0000000000000893565007143576 34
107:00	0.9925	0.0915	24.8507	0.5139	1.7876232862472534000000000000000	0.0000000000000796594100361744 38
108:00	0.9967	0.0918	25.0156	0.5145	2.6039414405822754000000000000000	0.0000000000001117259700012494 80
109:00	0.9866	0.0897	25.5704	0.5043	2.3047010898590088000000000000000	0.0000000000001220186603666240 10
110:00	0.9960	0.0909	25.5288	0.5097	2.3308238983154297000000000000000	0.0000000000001103241643548615 00
111:00	0.9927	0.0909	25.2109	0.5092	2.6332633495330811000000000000000	0.0000000000001194810851819216 90
112:00	0.9859	0.0907	24.8030	0.5077	1.6259214878082275000000000000000	0.0000000000000611171608656292 66
113:00	0.9641	0.0885	24.3419	0.4958	1.9363700151443481000000000000000	0.0000000000000714307763329327 66
114:00	0.9685	0.0892	24.3074	0.4993	2.1000273227691650000000000000000	0.0000000000000749398847556086 16
115:00	0.9847	0.0907	24.6850	0.5079	2.1034052371978760000000000000000	0.0000000000000767651594417786 96
116:00	0.9888	0.0910	24.8197	0.5097	2.3865611553192139000000000000000	0.0000000000000918184595737926 71
117:00	0.9869	0.0909	24.7283	0.5092	2.7001547813415527000000000000000	0.0000000000001018343734533223 90
118:00	0.9861	0.0903	25.0439	0.5058	2.6934437751770020000000000000000	0.0000000000001119960854199970 90
119:00	0.9871	0.0889	26.0732	0.4976	2.1059181690216064000000000000000	0.0000000000001125571668205219 10
120:00	0.9628	0.0845	26.7985	0.4734	1.8376888036727905000000000000000	0.0000000000001261469498737427 50

Appendix D: Model Validation

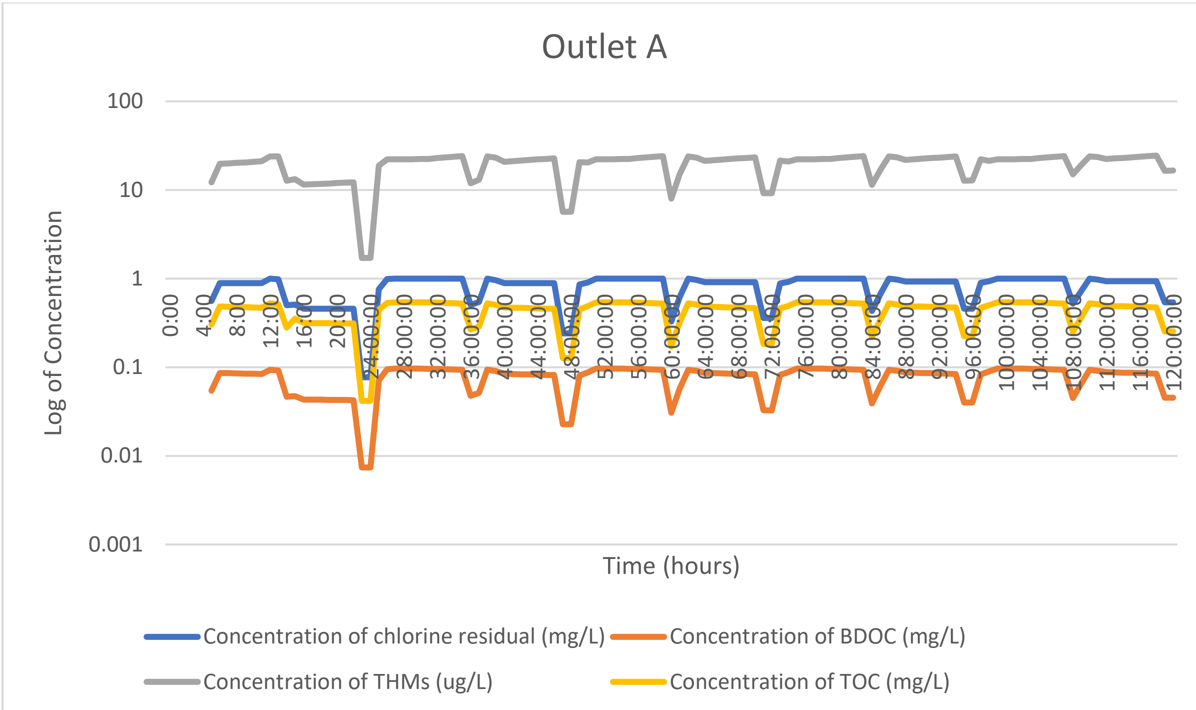

Figure D 1: Log concentrations of chlorine, BDOC, THMs, and TOC to validate the model and their relationship with one another.

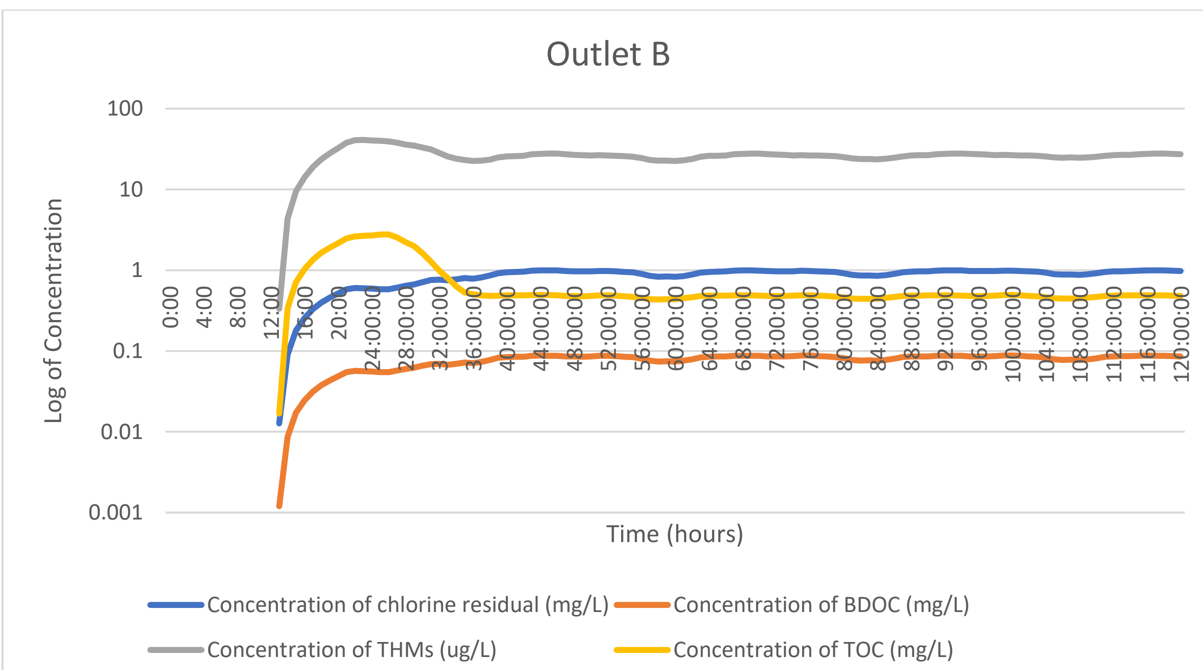

Figure D 2: Log concentrations of chlorine, BDOC, THMs, and TOC to validate the model and their relationship with one another.

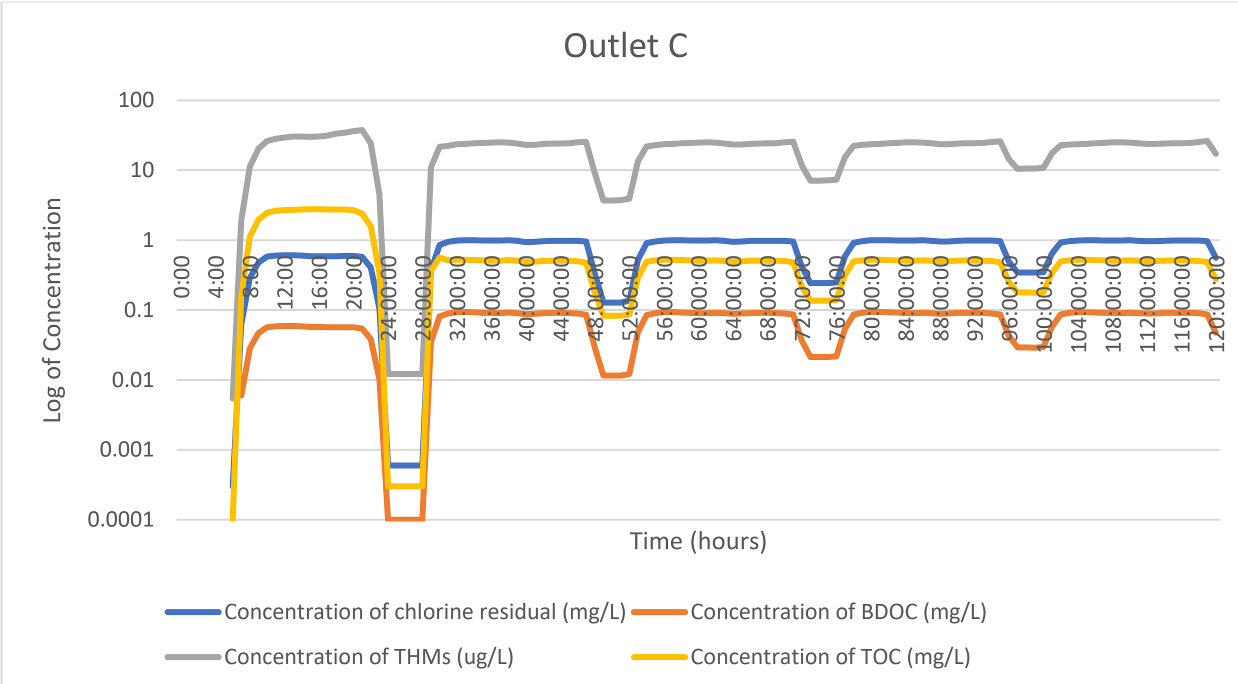

Figure D 3: Log concentrations of chlorine, BDOC, THMs, and TOC to validate the model and their relationship with one another.

Figure D 3: Log of concentration of chlorine and water age at outlet A, B and C to verify the accuracy of interaction between EPANET model and MSX extension