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# The Development of a Sustainable Operation Model for Small Non-Community Drinking Water Systems in Ontario, Canada

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**Abstract**

The provision of safe drinking water in Ontario's small non-community drinking water systems (SDWSs) poses a challenge for many system owners. Our study aims at developing a sustainable operation model for SDWSs by recognizing the importance of source water protection. Although the current literature on Ontario's SDWSs is limited, the review of the existing water management strategies in Canada and across the world provided fruitful results to create a unique model for Ontario's SDWSs using the Multiple-Barrier Approach framework. Our sustainable operation model consists of five main components: 1. Commitment to providing safe drinking water; 2. Assessment of the system and source water; 3. System operation and operator training; 4. Management of incidents and emergencies; 5. Communication and raising awareness. Our model addresses the areas that need more attention for today, and in the future, such as protecting source water, financial stability enhanced communication and increased awareness. A sustainable operation model for SDSWs based on the Multiple-Barrier Approach framework addresses the shortcomings of the current water management framework for SDWSs and offers a viable strategy to establish a sustainable operation model with an integrated approach.

**Keywords:** small water systems, water safety, sustainable operation

## 1. Introduction

Public awareness surrounding access to safe drinking water has increased considerably since the Walkerton tragedy in 2000, yet strategies to establish a sustainable operation model for Ontario's small non-community drinking water systems (SDWSs) have not been fully developed. The provision of safe drinking water in SDWSs and the sustainability of these systems pose a challenge for many system owners. Furthermore, a key initiative to safeguard drinking water sources in Ontario, the planning for source water protection, does not include SDWSs.

There is no universal or Canada-wide definition of an SDWS due to significant differences in the assessment of system parameters (NCCPH, 2015). For example, Health Canada (2013) defines small drinking water systems as systems that serve between 501 to 5000 people, while the United States Environmental Protection Agency considers a system serving 10,000 or fewer people to be a small drinking water system (EPA, 2017). In Ontario, SDWSs are defined as systems that make drinking water available to the public and are not connected to a community drinking water system (MOHLTC, 2015). In Ontario, there are over 9000 SDWSs providing drinking water to the public with no connection to a community drinking water system; most are located in rural areas (MOHLTC, 2015; Pons et al., 2014). Examples of SDWSs include municipally-owned airports, industrial parks, recreational facilities, community centres, libraries, motels, resorts, restaurants, churches, gas stations, and private cottages on communal water systems (MOHLTC, 2015). As a significant portion of the users is transient populations, it is difficult to get accurate and precise estimates of the percentage of the public using SDWSs. Although community water systems and SDWSs face similar challenges to provide safe drinking water, SDWSs typically have fewer resources to overcome these challenges (Murphy et al., 2016b).

The current regulatory regime for SDWSs was established only a decade ago when the Ministry of Health and Long-Term Care (MOHLTC) took over the regulatory role from the Ministry of the Environment and designated Ontario's 35 local public health units as SDWS program administrators. Since the local public health units

assumed this responsibility, there has not been an evaluation of the SDWS program.

Sustainability of a water system largely depends on its operational capacity with adequate financial and technical support in addition to the social and environmental dimensions (National Research Council, 1997). The current policy and regulatory arrangements for SDWSs leave room for improvement to better protect public health. Our study focuses on developing an effective and efficient approach to drinking water safety in SDWSs and argues that the development of a sustainable operation model requires the inclusion of SDWS in source water planning.

### *1.1 Drinking Water Safety*

Waterborne illnesses and diseases are ongoing concerns in many rural parts of Canada where most SDWSs are located (Maier et al., 2014; Moffatt & Struck, 2011; Murphy et al., 2016a; Murphy et al., 2016b). The Public Health Agency of Canada estimates 20.5 million cases of Acute Gastrointestinal Illness annually in Canada; there are studies that conclude that small water systems may cause an increased risk of acquiring Acute Gastrointestinal Illness (Murphy, 2016a; Murphy et al., 2016b). According to Schuster et al. (2005), water treatment failure and extreme weather events that affect water sources were the most common reasons for waterborne outbreaks in Canada between 1974 and 2001. As a result of climate change effects and source water contamination, there may be an increased risk for waterborne disease outbreaks from drinking water systems today and in the future.

Pons (2015) reports that groundwater is the primary source for 82% of SDWSs in Ontario. There is a common misconception about groundwater being a safe source. Groundwater has several potential contamination sources such as agricultural activities nearby and surface runoff after heavy rain. According to a comprehensive study (Wallender et al., 2014), untreated groundwater continues to be a significant public health issue as it has been the cause of over 30% of waterborne outbreaks in the United States between 1971 and 2008. Protecting drinking water sources is the first step (Dore, 2015) and the most reliable and effective way to ensure the safety of drinking water.

#### 1.1.1 Source Water Protection

Source water protection is defined by the development and utilization of institutional arrangements, such as municipalities assessing drinking water safety risks and working with relevant stakeholders to minimize or prevent potential pollutants from contaminating water sources that can be used for drinking purposes (Ivey et al., 2006). Protecting drinking water sources constitutes the most effective and efficient means to ensure water safety and requires integration of both water and land use management practices (O'Connor, 2002b; Simms at al., 2010). Several case studies conclude that the cost of treating contaminated water is 30 to 40 times higher than protecting its source from contamination (Simpson, & de Loë, 2014). In addition to being an integral step to protect public health, source water protection is a proactive approach to prevent contamination of source water, which results in financial savings in water system operations (Minnes, 2017).

In recent decades, ensuring the safety of drinking water sources has been a widely accepted goal across the world, and source water protection strategies are being considered a vital activity. In Canada, institutional arrangements for source water protection vary because there is no federal legislation, and the provincial and territorial governments determine source water protection strategies. Patrick et al. (2013) note that source water protection planning is required in only three provinces, namely, Ontario, Manitoba and Prince Edward Island, where other provinces have either discretionary measures or no plans.

The result of inadequately protecting our drinking water sources can be devastating, as demonstrated by several contaminated water incidents in Canada and elsewhere. The Walkerton tragedy, an outbreak of gastroenteritis, caused seven deaths and affected over 2300 people as a result of contaminated water consumption from a community drinking water system in the town of Walkerton in 2000 (O'Connor, 2002b). Though not specially linked to an SDWS, this tragedy has been a significant turning point in revamping Canada's drinking water safety net, whereby municipal water systems are generally considered safer than SDWSs. Most recently, chemical and microbiological contamination of source water in the Flint, Michigan affected 99,000 people between April 2014 and October 2015 (Kennedy et al., 2016; State of Michigan, 2016).

### *1.2 Drinking Water System Management Programs*

Drinking water system management strategies vary significantly in Canada and internationally. Developing and maintaining a sustainable operation in water systems is a crucial consideration for the provision of safe drinking water for both today and in the future. A drinking water system management framework provides water systems with the necessary resources to achieve and maintain compliance with regulatory requirements (EPA, 2003).

Besides, it is essential to note the necessity of the social dimension in water management. As such, public

awareness should be considered a fundamental piece of any water management strategy (Kot et al., 2015). In the Canadian context, Driedger et al. (2014) argue that the public's trust in public water systems has not been fully restored in Ontario since the Walkerton tragedy. According to Jones et al. (2007), the public's distrust in public water systems, as well as consideration of aesthetic aspects of water, causes the increased use of bottled water. Another Canadian study (McLeod et al., 2014) also confirmed the finding that people who believe the municipal water is not safe to drink, use bottled water as their drinking water source. The CCME's guide brings a distinct and holistic approach to the application of the Multiple-Barrier Approach and water system management with the recognition of social aspects such as public involvement and awareness. Although the CCME offers a viable alternative to establishing a collaborative water management strategy based on the Multiple-Barrier Approach framework, Ontario has adopted the limited application of the Multiple-Barrier Approach with risk assessment focus as introduced in the Walkerton Inquiry Report.

Ontario's community drinking water systems are mandated to comply with the Drinking Water Quality Standard (MOECC, 2017). The owners of community drinking water systems report their systems' operational process, management, and delegated responsibilities to the Ministry of the Environment and Climate Change for approval to start and maintain their operation. Ontario's Quality Management Standard ensures compliance in various aspects of the water system operation by focusing on the technical components and delegated responsibilities for regular operation (MOECC, 2015), yet it lacks social dimensions such as community capacity and safe drinking water awareness. Source water protection plans, complementing the water management framework of Ontario's community water systems, have been successfully implemented.

#### 1.2.1 Management of Small Drinking Water Systems

In recent years, there has been increased attention to the management strategies for small drinking water systems across the world. The World Health Organization (2012) promotes a comprehensive guide for small drinking water supplies and encourages the application of water safety plans for the provision of safe drinking water. The use of water safety plans is considered a proactive approach to identifying and managing the potential risks and taking precautions as necessary (WHO, 2012). The World Health Organization defines the following six tasks to develop and maintain a water safety plan (WHO, 2012, p.9):

- Engage the community and assemble a team
- Describe the community water supply
- Identify and assess hazards, hazardous events, risks, and existing control measures
- Develop and implement an incremental improvement plan
- Monitor control measures and verify the effectiveness of the water safety plan
- Document, review and improve all aspects of water safety plan implementation

Alberta is the only Canadian jurisdiction to follow the World Health Organization recommendations for developing water safety plans. Alberta's model mainly focuses on source water, treatment, storage, and distribution aspects of the water supply system (Government of Alberta, 2015). By requiring the development of water safety plans, Alberta is ahead of most of the other provinces with stricter criteria for water system operation. Alberta's model does not address the community engagement and awareness aspects of water management as well as an operator training component. Table 1 gives an overview of the different approaches around the world to manage small drinking water systems.

Table 1. International management strategies for small drinking water systems

| | New Zealand | European Union | The United States | Australia | World Health Organization |
|---|---|---|---|---|---|
| Source water | Detailed information on water sources and protection strategies | Limited guidance on source water protection | Focus on source water management strategies | Comprehensive assessment of the source water | Recognition of source water and potential contamination sources |
| Operational guidance | Guidance on the treatment process and distribution system | Limited information on the treatment and distribution system | Offers operational guidance for the system owners and operators | Detailed operational guidance | Comprehensive guidance on operational processes |
| Training | No training requirement | No training requirement | No training requirement | Training requirement for the owner/ operator | Limited discussion regarding training needs |
| Financial planning | No discussion on financial aspects of the system operation | No discussion on financial aspects of the system operation | Consideration of financial planning | No discussion on financial aspects of the system operation | Recognition of financial security to operate safely |

New Zealand has developed a model similar to the World Health Organization's approach to managing small drinking water systems. As such, water safety plans form the foundation of the water management framework, where their approval is required to operate a water system (MOH, 2017). The significant shortfall of New Zealand's structure is the exclusive focus on the technical and environmental parameters where community engagement processes, training opportunities, and financial planning are not sufficiently taken into consideration. The use of water safety plan has similar approach to the Walkerton Inquiry Report's Multiple-Barrier Approach framework where risk assessment is the central theme.

The European Union, with 65 million residents using small drinking water systems, also recognizes the World Health Organization's approach to the provision of safe drinking water in small drinking water systems, yet utilizes a different model called 'Framework for Action for the management of small drinking water supplies' (European Commission, 2014). The Framework is composed of four segments (European Commission, 2014):

- Duty to keep and maintain a register of water supplies
- Duty to record certain information in the register
- Duty to risk assess
- Reporting

The European Union acknowledges the challenges of small drinking water system operation and therefore establishes a system to ensure these systems are kept under the registry and public health officials are available for risk assessment when needed (European Commission, 2014). The European Union framework is quite similar to Ontario's current water management strategy for SDWSs. The European Union strategy lacks several critical components, such as training requirements, source water protection, financial planning, and community awareness. Since 2011, Iceland transitioned to a new national water management model with the use of water safety plans as introduced by the World Health Organization and accomplished a 14% reduction of diarrheal illnesses in regions where the water safety plans were in place (Gunnarsdottir et al., 2015).

In the United States, the Environmental Protection Agency promotes the utilization of 'Simple Tools for Effective Performance' mainly for small drinking water systems (EPA, 2003). The Simple Tools for Effective Performance framework highlights the importance of developing a strategic plan for the water systems and consists of seven steps. The Simple Tools for Effective Performance framework uses the foundational pillars of the Multiple-Barrier Approach except for the training requirement and community engagement. Although the Environmental Protection Agency's framework briefly discusses the source water protection concept, there is not

enough emphasis on the importance of source protection plans and being proactive to protect the water source.

In addition to the Environmental Protection Agency's approach, each State has the option to develop its water management program. For example, the State of Washington requires the development and utilization of Small Water System Management Programs by the owners of non-community public water systems (Washington State, 2017). The program is comprised of the following five sections: Information and records, water quality, system operations, financial planning, and next steps (Washington State, 2017). Under the water quality section, there is a focus on developing a source water protection plan for the water system (Washington State, 2017).

Australia's strategy for managing small drinking water systems seems to be more participatory and holistic compared to other international approaches discussed earlier. The Australian Drinking Water Guidelines aims to provide a framework for drinking water systems considering scientific, economic, social, and cultural aspects (NHMRC, & NRMMC, 2011). The Australian Drinking Water Guidelines, branded as 'the Framework,' provides a structured and systematic approach from source to tap to ensure the provision of safe drinking water (NHMRC, & NRMMC, 2011). There are 12 elements that constitute the skeleton of the Framework (NHMRC, & NRMMC, 2011). The Framework concepts are similar to the Canadian Council of Ministers of the Environment's Multiple-Barrier Approach principles by including societal factors such as community involvement and awareness. According to Sinclair and Rizak (2004), "the Framework integrates quality and risk management principles and provides a comprehensive, flexible, and proactive means of optimizing, drinking-water quality and protecting public health" (p. 1567). One shortcoming of the Framework is that there is no mention of the importance of adequate financial resources for system operation.

The recognition of the social components of water management, such as community engagement and user awareness, contributes to ensuring the provision of safe drinking water, as documented in several cases, including the Walkerton tragedy. Although the World Health Organization proposes the use of water safety plans in water systems similar to Ontario's SDWSs, the incremental improvement plan in the World Health Organization's approach conflicts with the operation model for SDWSs. The *Small Drinking Water Systems Regulation* (Government of Ontario, 2013), mandating the SDWS operation, requires approval from the regulator that the system meets all of the legislative clauses before commencing the operation and at any given time when in service (Government of Ontario, 2013), therefore incremental improvement plans might result in process without full compliance with the regulations.

Drinking water management strategies across the world demonstrate different approaches to the provision of safe drinking water and prove that the one-size-fits-all approach is not suitable for developing water management models.

Ontario has shown a considerable effort to modernize water management practices since the Walkerton tragedy. Given the success of establishing a regulatory framework for Ontario's SDWSs over a decade ago, the current SDWS policy and legal framework needs revision with the light of successful water management strategies applied in other jurisdictions. The application of the Multiple-Barrier Approach, as introduced by the CCME, offers a viable tool to examine the current gaps and make recommendations to enhance the SDWS program.

### *1.3 Drinking Water Management in Ontario*

Canada's water management is decentralized and fragmented, where different levels of governments take responsibilities and create governance gaps (Bereskie et al., 2017), all of which come into focus concerning small drinking water systems. The Federal Government guides drinking water quality parameters (Health Canada, 2017) but does not mandate the management of water systems. Furthermore, the water quality standards developed by the Federal Government is not enforceable where provinces and territories which regulate the public water systems have the option to adopt them or not (Bereskie et al., 2017).

The Ministry of the Environment was the only regulatory agency for Ontario's water systems until 2008 when the MOHLTC took over the regulatory role of SDWSs which has the following vital implications: Better coordination of the program as the majority of SDWSs such as restaurants, golf courses, and some churches have already been inspected by public health unit staff under the *Health Protection and Promotion Act* regulations; public health units have many more local offices across the province compared to Ministry of the Environment regional offices which eased access to these systems by public health units.

Today, the Ministry of the Environment and Conservation and Parks (MOECP) and the MOHLTC are responsible for overseeing public drinking water systems in the province. Ontario's 35 public health units regulate SDWSs by representing the MOHLTC on the local level. The Ministry of the Environment and Climate Change regulates community water systems where local municipalities are often designated as water system

owners with the legal responsibility to supply safe drinking water to their residents. The quality and safety of drinking water in Ontario's municipal water systems is overseen by the Ministry of the Environment and Climate Change through the *Safe Drinking Water Act, Ontario Regulation 169* (Water Quality Standards), and Ontario Regulation 170 (Drinking Water Systems) (DWO, 2015). *The Drinking Water Quality Standard* (Standard) is the operational guidance document for municipal water system owners created under the authority of the *Safe Drinking Water Act* (MOECC, 2017). The Standard requires each water system operator to develop a Quality Management System (MOECC, 2017). All of the policy and regulatory arrangements in Ontario's water management have been designed based on the Walkerton Inquiry Report's Multiple-Barrier Approach principles (MOECC, 2017).

Table 2 shows a comparison between municipal water systems and SDWSs. As summarized in the table, the management approach to ensure the provision of safe drinking water for municipal water systems is considerably more stringent than the one for SDWSs. Municipal water systems benefit from source water protection, which is considered the first and foremost important step in ensuring safe drinking water. On the other hand, SDWS water sources may be prone to any contamination source, including agricultural or industrial activities in the neighbourhood. Operator training for municipal water systems is a structured model based on the system type where recertification is required based on the system classification. The regulation for the SDWSs offers neither a detailed description of the training nor recertification. Municipal water systems are being tested more frequently than SDWSs for bacteriological contaminants such as total coliforms and *Escherichia coli (E. coli)* (DWO, 2015; Government of Ontario, 2013). Furthermore, chemical testing requirements are not spelled out clearly in SDWSs. Lastly, municipal water systems report their adverse water quality incidents to two agencies to receive guidance, MOECP, and MOHLTC, where SDWSs are only required to report to the MOHLTC.

Table 2. Comparison between municipal water systems and SDWSs

| | Municipal Water Systems | SDWSs |
|---|---|---|
| Regulatory oversight | MOECP | MOHLTC |
| Legal framework | SDWA, Reg. 170 | HPPA, Reg. 319 |
| Source Protection | In effect | No protection |
| Operator training definition | Defined, structured based on the system size | No clear definition |
| Reporting AWQIs | Central MOECC reporting line, public health | Public health |
| Source Protection | In effect | No protection |
| Operator training | Defined, structured based on the system size | No clear definition |
| Sampling | Regular bacteriological ad chemical testing | Regular chemical testing |

MOECP: Ministry of the Environment and Conservation and Parks; MOHLTC: Ministry of Health and Long-Term Care

Approximately 80% of Ontario's population uses community drinking water systems to access safe drinking water, while 20% rely on non-community drinking water systems (Bereksie et al., 2017; Pons et al., 2014). The MOHLTC's local service delivery agencies, public health units, regulate SDWSs, and also offer guidance for private household well owners (Pons et al., 2014). Our study focuses on small non-community drinking water systems that fit the definition of an SDWS under *Ontario Regulation 319*, also known as 'Small Drinking Water Systems*.'*

## 2. Methods

Our study utilizes the Multiple-Barrier Approach as the foundation to construct a sustainable operation model for SDWSs. The Multiple-Barrier Approach is a combination of procedures, processes, and tools to prevent or reduce the contamination of drinking water from source to the end-user (CCME, 2004) and would add value to health risk reduction if applied to SDWS management. The Multiple-Barrier Approach is far more inclusive than older approaches focusing on treatment at source.

The Canadian Council of Ministers of the Environment's (CCME, 2004) document, '*From Source to Tap: Guidance on the Multi-Barrier Approach to Safe Drinking Water,'* explains the application of the Multiple-Barrier Approach for all stakeholders in the water management sector in Canada. Figure 1 shows a

summary of the Multiple-Barrier Approach components where the water system is examined in three main sections: protection of the water source, water treatment processes, and the distribution system. Also, the Multiple-Barrier Approach uses tools and procedures to complement the management and monitoring of the water system, such as public involvement and awareness, legislative and policy frameworks, guidelines, standards and objectives, and research, science and technology (CCME, 2004). The application of Multiple-Barrier Approach concept in a holistic way requires considerable preparation and commitment from all stakeholders in the provision of safe drinking water. Components of the model should work in harmony to complement each other. As the model demonstrates, water safety issues are often multi-dimensional and require interventions from different stakeholders. Research, science, and technology, along with public involvement, form the foundation of policy and legislative framework development process. The systems' water source, treatment, and distribution processes are regulated with the overarching policies and legal arrangements. The Multiple-Barrier Approach recognizes the system as a whole and establishes criteria to ensure sufficient protective mechanisms are in place.

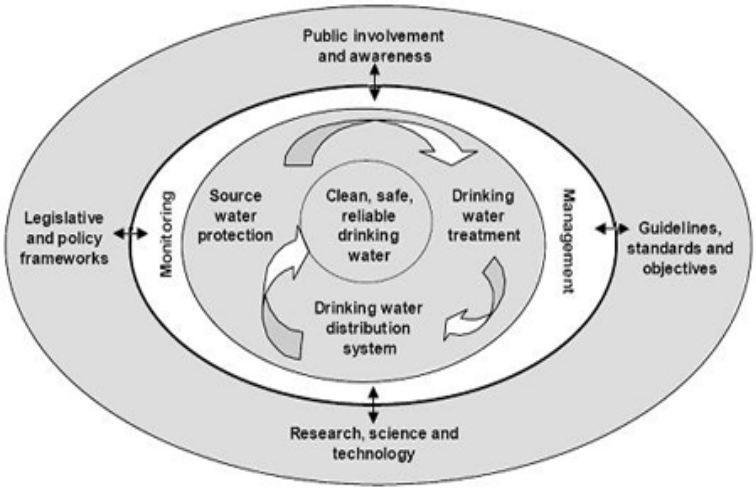


Figure 1. Components of the Canadian Council of Ministers of the Environment's Multiple-Barrier Approach (CCME, 20014, p.16)

CCME's definition of the Multiple-Barrier Approach offers a viable solution to water systems in all sizes. It is an inclusive model that goes well beyond just engineering solutions to design, operate water systems, going further to combine with social aspects such as public involvement and awareness. The earlier approaches to ensuring water safety were focused on the treatment process; however, recent outbreaks in Canada and elsewhere have proven the necessity to consider several other factors in the provision of safe drinking water (Cool et al., 2010; Murphy et al., 2016b). This study focuses on the development of a sustainable operation model for SDWSs underpinned by CCME's Multiple-Barrier Approach.

## 3. Results

There are considerably different strategies for managing water systems in Canada and across the world, with a need to establish a collaborative framework based on the Multiple-Barrier Approach principles. SDWSs are mostly located in rural areas with limited financial and operational capacity, and therefore, they require special consideration to ensure the provision of safe drinking water.

As the regulatory agency, the Ministry of the Environment and Climate Change until 2008, and later the MOHLTC has not developed a 'drinking water system management' framework for SDWSs. The current legislation, the *Small Drinking Water Systems Regulation*, mainly offers operational guidance with sections on treatment, operational checks and testing, and corrective actions (Government of Ontario, 2013). The policy documents guide risk assessment procedures and testing but are mostly limited to the interpretation of the Regulation (MOHLTC, 2015).

Our study utilizes the concepts presented in CCME's Guide to developing a water management model to improve the current policy and legal framework for SDWSs. Our model (Table 3) consists of five components with action items under each component and is built on the pillars of the CCME's Multiple-Barrier Approach

framework.

Table 3. Sustainable SDWS operation model

| Components | Content |
|---|---|
| Component A: Commitment to providing safe drinking water | • Enacting regulations and policies for sustainable SDWS operation<br>• Securing adequate funds for the operation<br>• Developing Quality Improvement Plans |
| Component B: Assessment of the system and source water | • Conducting source water risk assessment<br>• Assessing the water quality<br>• Identifying potential hazards |
| Component C: System operation and operator training | • Ensuring the SDWS operation is compliant with the Regulation<br>• Utilizing certified and suitable equipment with regular maintenance<br>• Training SDWS owner/operator for best operational practices |
| Component D: Management of incidents and emergencies | • Establishing corrective action procedures<br>• Preparing Emergency Response Plan |
| Component E: Communication and raising awareness | • Connecting with stakeholders<br>• Networking with other SDWS owners & operators<br>• Increasing community/user awareness |

Component A: Commitment to providing safe drinking water

To create an efficient and effective model, water system owners and operators, regulators, and other stakeholders need to be committed to the provision of safe drinking water. Developing policies and legislative documents that meet the SDWS users' expectations and reflecting best practices in water management ensures the protection of public health (CCME, 2004). The most integral step to show commitment to providing safe drinking water is enacting regulations and policies to accomplish a sustainable operation based on the Multiple-Barrier Approach.

Several SDWSs have been achieving the highest possible levels of compliance while keeping the costs and financial burden as low as possible. More affordable operator training opportunities and reduced water testing costs have the potential to increase compliance with the regulatory requirements (Sekercioglu et al., 2018b).

Quality Improvement Plans should be in place for the sustainability of the system and can include the following areas: Capital works, training, enhanced operational procedures, corrective action process, communication and reporting (NHMRC, & NRMMC, 2011). Developing Quality Improvement Plans for SDWSs will maintain the level of commitment to the overall goal, protecting public health.

Component B: Assessment of the system and source water

SDWS assessment is a fundamental step to developing effective strategies for the prevention and control of potential hazards (NHMRC & NRMMC, 2011). Water quality may be affected in three areas: 1) the source water; 2) the water system where the treatment process takes place, and 3) the distribution system where the water goes through to the end-user. Each critical control point that might affect drinking water safety should be marked on a flow diagram and assessed periodically (NHMRC & NRMMC, 2011). Ontario has a comprehensive source water protection planning process, and SDWSs can benefit from this already existing structure. Identifying potential hazards and understanding the water quality under normal operation conditions complements the efforts to keep drinking water safe.

Component C: System operation and operator training

The effectiveness of barriers to prevent potential hazards depends on the success of day-to-day operations in an SDWS. The owners should have the legal liability to use high-quality water system equipment and ensure all adjustments and operational checks of the equipment are performed regularly by trained operators. Record keeping and documentation are the responsibility of the operator as well (NHMRC & NRMMC, 2011).

The SDWS owner and operator training is a pivotal activity to accomplish the provision of safe drinking water. Only a trained owner and operator can ensure compliance with the regulatory requirements. Subsidies for operator training and water testing would help relieve some of that financial stress that most SDWS owners experience, especially the systems that are owned and operated by not-for-profit organizations

The utilization of Emergency Response Plans by trained owners and operators would support public health officials in addressing issues during adverse water quality incidents, since each SDWS has a unique setup and can continue to operate based on individual risk assessment to respond to possible adverse water quality incidents.

Component D: Management of incidents and emergencies

*The Small Drinking Water Systems Regulation* gives directions to address the management of incidents. Overall, the process to rectify adverse water quality incidents is well-defined except for a source water contamination scenario (Government of Ontario, 2013). The gap in the current regulatory framework regarding the absence of Emergency Response Plans may increase the risk of unsafe drinking water for SDWS users. There are several types of incidents, such as power outage, source water contamination, mechanical failures, where Emergency Response Plans can be utilized promptly (CCME, 2004). Besides, reaching out to the public and raising awareness on drinking water safety enables effective advocacy for the current challenges in the provision of safe drinking water in SDWSs.

Component E: Communication and raising awareness

The communication among SDWS owners as well as between SDWS owners and the regulatory agency is neither consistent nor sufficient (Sekercioglu et al., 2018b). Our framework highlights the importance of enhancing dialogue between stakeholders by organizing regular meetings to share updates and introducing local SDWS owners and operators to each other. To increase user awareness, the SDWS owners may develop standardized procedures for the notification of adverse water quality incidents that are available for use when necessary (CCME, 2004).

## 4. Discussion

Access to safe drinking water is considered a human right (United Nations, 2010). From a global perspective, safe water needs to be pathogen-free, aesthetically acceptable, physically accessible, and affordable (Scanlon et al., 2004). Different water management models in Canada and around the world aim at addressing not only today's issues but also the future emerging problems as well. Ontario's SDWSs experience unique challenges to ensure the provision of safe drinking water for its users. Without addressing the current policy and regulatory gaps, these systems might pose a considerable risk to public health.

The current SDWS policy and legal framework were established in 2008, and since then, Ontario's public health units have been working with SDWS owners and operators to ensure the provision of safe drinking water. The current policy and legal framework for SDWSs have many strengths. The *Ontario Regulation 319*, recognizes the necessity for a customized approach, which requires a site-specific risk assessment for each SDWS (Government of Ontario, 2013). The Regulation also provides detailed guidance on operational checks, sampling, and corrective action steps during adverse water quality incidents (Government of Ontario, 2013). As public health units cover the entire province with many regional offices, designating them as the regulator offers easy access to the regulatory agency for SDWS owners and operators. The Regulation spells out the role and responsibilities of SDWS owners and operators for operations and treatment to corrective action steps (Government of Ontario, 2013).

On the other hand, the recent analysis of SDWS data obtained from Wellington-Dufferin-Guelph Public Health and interviews with SDWS owners in the Wellington-Dufferin-Guelph region raised several critical issues in the current institutional arrangements that might put the provision of safe drinking water from SDWSs at risk, including lack of training opportunities for the owners and operators (Sekercioglu et al., 2018a; Sekercioglu et al., 2018b). The current policy and legal measures do not provide solutions to the drawbacks of the current SDWS program. The shortcomings of the current SDWS program policy and legal framework can be summarized in four main areas: Source water, operations, communication, adverse water quality incidents.

Source water: SDWSs do not benefit from Ontario's source water protection planning. When the province made significant improvements to source water protection pursuing the Walkerton Inquiry Report recommendations, SDWSs were not included in the plan of source protection areas. Furthermore, *Small Drinking Water Systems Regulation* does not have a section to provide direction on source water management.

Operations: Lack of training and funding opportunities create inconsistency and pose challenges for the operation of SDWSs. There is no official operator training offered by the regulatory agency, and the training requirements are not specified in the Regulation (Government of Ontario, 2013). The Walkerton Clean Water Centre recently developed a course for SDWS operators (WCWC, 2018); however, accessibility and cost for this opportunity continue to be a challenge for system owners and operators (Sekercioglu et al., 2018b). The need for financial support to maintain the operation of some SDWSs such as the water testing costs, treatment equipment, and the hiring of trained operators has been a concern for several SDWS owners (Sekercioglu et al., 2018b). The current SDWS policy and legal framework do not provide any guidance to reduce or remove financial barriers.

Communication: The dialogue between SDWS owners themselves as well as between the SDWS owners and the regulatory agency is neither consistent nor sufficient (Sekercioglu et al., 2018b). The current policy and legal framework lacks the social dimension of water management and does not facilitate networking between the owners and operators of SDWSs. Sections relevant to increased communication and creating a sense of community among SDWS owners and operators in respective public health unit jurisdictions should be included in the new model.

Adverse Water Quality Incidents: As defined by Justice O'Connor (2002a), response to adverse water quality incidents is an integral step of the Multiple-Barrier Approach, yet SDWSs are not required to have an Emergency Response Plan. Although there is a corrective action process in place for the SDWS owners and operators to follow during adverse conditions, it is often limited to seeking guidance from public health officials (Sekercioglu et al., 2018b). The Emergency Response Plan processes enable the identification of water system vulnerabilities and make enhancements to establish emergency procedures (INAC, 2014). The utilization of an Emergency Response Plan and the creation of networking opportunities where common challenges are discussed may result in improving relationships and support between water system owners (INAC, 2014).

With new and emerging threats to safe drinking water access, such as extreme weather events, effective and efficient interventions to enhance the current water management regime for SDWSs are required. There is an evident need to revamp the SDWS program with collaborative water management strategies. Our proposed sustainable operation model addresses the shortcomings of the current policy and legal framework with five main components: 1. Commitment to providing safe drinking water; 2. Assessment of the system and source water; 3. System operation and operator training; 4. Management of incidents and emergencies; 5. Communication and raising awareness.

Our model is designed to be accessible by SDWS stakeholders such as operators, suppliers, and regulators, and also be flexible enough to accommodate system-specific characteristics. With the recognition of considerable differences among SDWSs, our adaptive model is built on five fundamental pillars to support both policymakers and SDWS owners.

Although the current SDWS program has strengths, namely, the requirement of a site-specific risk assessment and detailed operational guidance regarding sampling and corrective action processes, there are significant gaps that need to be addressed to run a more efficient and effective program. Our model addresses the areas that need more attention for today and in the future, such as protecting source water, financial stability enhanced communication and increased awareness. Future research could be done to investigate the potential to increase collaboration between the MOECP and the MOHLTC, as the two regulatory bodies responsible for ensuring safe drinking water to Ontario residents.

## 5. Conclusion

SDWSs are an integral part of public water systems annually impacting thousands of people, but at least two key challenges remain. Now that a decade has passed since the transfer of the SDWSs' regulator role from the Ministry of the Environment and Climate Change to the Ministry of Health and Long-Term Care, it is an opportune time to review the SDWS program and propose some changes to enhance the current policy and regulatory regime. Ontario's 35 public health units are reasonable choice to administer the SDWS program at the local level since they cover the entire province, and each health unit is individually responsible for serving the population within its geographic border. Although the SDWS program had some successes, such as the completion of site assessments for over 9000 SDWSs in a considerably short period and strong local representation of the program by public health units, it has presented unique challenges related to water safety

and communicating with owners and operators. The current policy and regulatory arrangements are not adequate to rectify these issues.

A sustainable operation model for SDSWs based on the Multiple-Barrier Approach framework addresses the shortcomings of the current water management framework for SDWSs and offers a viable strategy to establish an operation with a collaborative approach. After the Walkerton tragedy, Ontario has come a long way in improving the water regime. With emerging challenges, including climate change effects, there is a significant need to revamp the SDWS program to maintain the commitment to provide safe drinking water.

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