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## Article

# Exploring the Use of a Sanitation Safety Plan Framework to Identify Key Hazards in First Nations Wastewater Systems

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**Abstract:** First Nations communities in Canada have a documented history of sub-standard water quality. While efforts have been made to address drinking water quality, little has been done to address longstanding challenges in wastewater systems. This study developed a hazard identification checklist using a sanitation safety plan (SSP) framework to characterize potential hazards in 29 First Nations wastewater systems in Atlantic Canada. System types included in this study included centralized, decentralized, and municipal transfer agreements (MTAs). Using past system assessment reports, potential hazardous events were evaluated along the sanitation chain to assess risk within systems. Overall, 69% of hazardous events had an unknown level of risk while 7% were high-risk. This research found that decentralized systems and MTAs have poorly characterized risk due to a lack of documentation and communication. The presence of significant knowledge deficits and high-risk hazards in centralized systems cause risk propagation and accumulation along the sanitation chain, resulting in potential effluent quality concerns. This desktop study demonstrates that an SSP approach offers an alternative assessment process to the regulatory approach currently being used by proposing an enhanced systemic understanding of risk that can inform management practices and integrate the plurality of stakeholders involved in these systems.

**Keywords:** sanitation safety planning; hazard; wastewater management; sanitation management; operational risk



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## 1. Introduction

### 1.1. First Nations Wastewater Systems

It is widely acknowledged that Indigenous communities experience water insecurity, both in quantity and quality, at a higher rate of incidence than non-indigenous communities across Canada [1–5]. Studies have found that insufficient regulatory frameworks [1,6], decreased community capacity [7], infrastructure and resource gaps [8], federal government-centric authority [6,7], and lack of robust consultation [1,9,10] are all components of this persistent problem.

A national assessment of First Nations water and wastewater infrastructure was conducted through Indigenous and Northern Affairs Canada (INAC) in 2011 to assess and characterize risks related to operations and water quality treatment performance. This assessment evaluated 532 wastewater systems, serving 418 First Nations communities [8]. Of these systems, 54% employed piped wastewater collection (centralized), 36% relied on individual septic systems (decentralized), 8% used truck haul, and 2% had no wastewater services at all [8]. The INAC risk assessment guidelines used in the national study considered effluent quality, design capacity, operations, reporting, and operator risk components. This analysis found there were 72 (14%) high-risk wastewater treatment systems, 272 (51%) moderate-risk systems and 188 (35%) low-risk systems. However, the 2011 report acknowledged concerns with data quality and availability. For example, the report found

that 50% of wastewater treatment systems in Atlantic Canada had unknown treatment capacities and only 4% of the systems had maintenance management plans. Further, the risk assessment guidelines used to conduct the analysis did not accurately identify concerns in decentralized wastewater systems or communities that relied on municipal transfer agreements (MTAs), where a partnership is established with an adjacent municipality to provide services to a First Nations community, resulting in numerous systems with poorly characterized risk [8].

It is known that small and remote wastewater treatment systems are more likely to experience degraded effluent water quality than larger urban facilities [11], and this is likely further exacerbated in First Nations communities. Research by Islam and Yuan (2018) found that the major challenges in First Nations wastewater systems included remoteness, lack of resources (availability of equipment and supplies, availability of capital for improvements), high operator turnover rates, age of the system, and ineffective barriers to prevent harmful effluent discharge to receiving watersheds [12]. These challenges present obstacles to ensuring safe effluent water quality and indicate that there is systemic risk that is not currently addressed in Canada by the federal Wastewater System Effluent Regulations (WSER) requirements. The current state of wastewater management in First Nations communities is marked by a paucity of information and data regarding operation, maintenance, and efficacy of wastewater systems [8]. This is particularly true for decentralized systems and communities that rely on MTAs. The national assessment of First Nations water and wastewater infrastructure only assessed 5% of individual septic systems and found 47% of this representative sample to have significant operational concerns [8]. Further, 20% of these systems were found to discharge directly to ground surface. The knowledge gaps and known risks in both centralized and decentralized systems, coupled with the lack of a comprehensive water management strategy in First Nations communities, suggest the need for an alternative approach to sanitation risk management beyond the traditional end-of-pipe regulatory framework provided by regulations.

The objective of this research is to identify key hazards in centralized, decentralized, and MTA systems in First Nations communities using a sanitation safety planning (SSP) framework. Previous studies have emphasized an inventory of infrastructure deficiencies and regulatory barriers for both water and sanitation systems [8,12], but have not integrated these findings into a practical management strategy to improve wastewater systems in First Nations communities. This research investigates how the SSP process can be used to operationalize system management through proactive risk assessment, shifting the focus from aggregated summary reports to actionable improvements for communities.

### *1.2. Sanitation Safety Planning*

SSP is a collaborative management methodology promoted by the World Health Organization (WHO) for the assessment and reduction of risk in sanitation systems [13]. Similar to the well-known and widely studied drinking water counterpart, water safety planning (WSP) [14–16], SSPs focus on hazard identification and proactive risk management. SSPs aggregate information about risk along the entire sanitation chain by engaging relevant stakeholders, defining the boundaries and components of the sanitation system, identifying hazards, and assigning risk, and then prioritize recommendations for risk mitigation and system improvement to maintain safe effluent water quality to protect human and environmental health [13]. The full SSP cycle is presented in the Supplementary Materials in Figure S1 for reference.

While SSPs are similar to WSP in several ways, there are key differences that make it important not to simply replicate the drinking water approach in sanitation systems. In drinking water systems, exposure groups are largely limited to consumers of water. However, in a sanitation system, there are multiple endpoint groups that may be exposed to effluent, as wastewater effluent may be utilized for other activities such as agricultural irrigation [13,16]. In addition, while drinking water guidelines have been revised for decades to best protect human health and avoid exposure to contaminants, the regulatory

environment for sanitation systems is less well-defined, with roles and responsibilities shared across different sectors due to the multi-stakeholder nature of these systems [17]. Because roles and responsibilities are plural, a single agency to implement an SSP is often inadequate. This is particularly true for systems in First Nations communities that fall under multiple federal agencies for oversight and guidance [18]. The plurality of stakeholders involved in a sanitation system represents a key consideration for SSP implementation [13,17].

SSP provides an alternative approach to First Nations wastewater management in Canada because it prioritizes and relies on local knowledge to identify, address, and monitor context-specific hazards along the entire sanitation chain within a community and promotes the development of community-appropriate multibarrier risk reduction [19]. The SSP methodology brings together actors and stakeholders from multiple sectors and has the potential to improve communication and facilitate joint problem-solving [17,20]. Because SSPs should be developed collaboratively between communities and key agencies, the process allows the inclusion of First Nations perspectives of water and water protection by including community stakeholders [13,21–23]. At its core, SSP management aims to maximize health benefits and minimize health risks of treated wastewater to protect receiving bodies and ensure sustainable environmental and human health [13].

The purpose of this study was to examine the potential benefits of an SSP approach to provide risk-based proactive management framework for wastewater systems in First Nations communities. The objective was achieved by completing the following tasks: (i) identify key stakeholders in First Nations wastewater systems critical to successful SSP adoption, (ii) characterize wastewater systems in 29 First Nations communities, and (iii) use an SSP checklist to examine risks present in these communities. The results of this analysis revealed key hazards common among centralized, decentralized, and MTA systems that can direct future SSP development efforts and inform practical management decisions in First Nations communities. We focused our study on First Nations communities located within Atlantic Canada; an abundance of information was available from these communities through previously established research relationships. Information collected and shared by the Atlantic Policy Congress of First Nations Chief Secretariat (APC) provided an in-depth, low-impact, and non-invasive opportunity to complete a desktop study of wastewater concerns in these First Nations communities.

### *1.3. Positionality/Reflexivity Statement*

The authors of this study represent students and researchers from the Centre for Water Resource Studies (CWRS) at Dalhousie University in Halifax, Nova Scotia. The CWRS, through its Director Dr. Graham Gagnon, has maintained a close working relationship with the APC. This research was conducted with the support of the APC, which advocates a strong Indigenous voice supported by research and analysis, aimed at changing policies impacting First Nations. The authors have used this connection to explore wastewater systems in the First Nations systems connected to the APC. Dr. Stoddart facilitated the acquisition of the reports requested from the APC for this study and guided the investigation of how an SSP framework could benefit First Nations communities. Dr. Lane provided insight to the SSP and risk analysis process through experience with past work on water safety planning in several of the same First Nations communities. The authors acknowledge that we bring a post-positivist and pragmatist worldview to the evaluation of risk in these water systems from our training as engineers and risk specialists. We attempt to understand wastewater concerns in these systems in the context of the sociopolitical realities present in First Nations communities in Canada. Due to funding and time constraints, direct inclusion of First Nations stakeholders was not possible at the time this study was being conducted. The authors have attempted to provide a critical analysis specifically of the SSP framework with current data available for these systems with the knowledge that successful adoption of the SSP method would require further studies that engage and include First Nations stakeholders as full participants and collaborators.

## 2. Materials and Methods

### 2.1. First Nations Community Characteristics

This research focused on 29 Mi'kmaq, Maliseet, and Innu First Nations on-reserve communities located within Atlantic Canada. The participating communities are associated with the Atlantic Policy Congress of First Nations Chiefs (APC). In 2013 and 2018, the APC partnered with the CWRs and CBCL Limited Consulting Engineers to complete water and wastewater infrastructure asset condition assessments for the participating communities. The APC made these asset condition assessment reports available to researchers at the CWRs for the purpose of this study. Names of First Nations and community systems have not been shared in accordance with the non-disclosure policy of the APC, which is aligned with the First Nations data ownership, control, access, and possession (OCAP) guidelines [24].

The 2013 and 2018 assessment reports were used to identify system characteristics such as approximate populations served, age of infrastructure, wastewater treatment process, and the presence of any MTAs with neighboring municipalities. Systems were categorized as centralized, representing piped wastewater collection and treatment systems, decentralized, representing individual on-site septic systems, or a combination of both treatment approaches. The reports were also used to ascertain treatment system functionality, operational practices, and effluent treatment and monitoring details. These data were evaluated using an SSP hazard checklist developed for this study to identify knowledge gaps in hazard identification and risk mitigation in First Nations sanitation systems. The results presented in this study use the most up-to-date information available for each of the 29 systems; 28 communities were included in the 2013 report and 22 communities in the 2018 report. The first three steps of the SSP methodology were investigated in this work: the identification of key stakeholders, description of the sanitation system, and identification of hazardous events and assessment of risks (Figure S1). The remaining steps of the SSP methodology (develop and implement incremental improvement plan, monitor control measures and performance, and develop supporting programs and review plans) were beyond the scope of this initial exploratory investigation.

### 2.2. Stakeholder Identification

The initial step in the SSP process is to assemble a team with members that reflect all interested stakeholders along the sanitation chain. There are several government and Indigenous stakeholders responsible for sanitation operations and performance in First Nations systems that need to be considered for successful hazardous event identification and risk management [13]. For this component of the study, authors conducted an analysis to identify appropriate stakeholders necessary to implement a successful SSP process in the context of Atlantic Region First Nations communities. The WHO SSP manual provides a tool to guide users through a stakeholder analysis process [13] which was used in conjunction with a literature review of wastewater system operations, government reports, and other relevant documentation related to wastewater systems to identify the relevant stakeholders for First Nations sanitation systems.

### 2.3. Evaluation of Hazardous Events Using an SSP Hazard Checklist

The SSP hazard identification checklist developed for this study was adapted from the WHO SSP methodology and informed by available First Nations wastewater evaluations, provincial and federal guidelines, and other protocols and reports [8,12,13,25,26]. The developed checklist contained 52 potential hazardous events grouped into six hazard categories (collection issues, effluent management, operators, reporting and regulations, treatment design, and treatment operations). These hazard categories and hazardous events are presented in Supplemental Table S1. The hazardous events presented in Table S1 focus on operational components of the sanitation chain, emphasizing events that can be addressed readily by operators in the wastewater systems. Table S1 does not include hazardous events related to public health and potential exposure to hazardous materials



from a wastewater system. While an important component of risk assessment in the SSP framework, insufficient data specific to each system was available from the assessment reports to provide an accurate characterization of hazardous materials (such as methane gas production, management of sludge residuals, etc.). The wastewater systems of the 29 First Nations communities were evaluated for level of risk for each of the potential hazards using information extracted from the system assessment reports provided by the APC.

In this study, a “hazardous event” was considered an incident or occurrence within a sanitation system that has the potential to interrupt treatment and management along the sanitation chain.

The “risk” of the hazardous event is defined by both the probability and impact of the event to the sanitation system should the event occur. Probability and impact are combined to generate a qualitative risk level (low, moderate, high, etc.). Because this work was dependent solely on the content of the 2013 and 2018 assessment reports, it was often not possible to assess the frequency and/or impact of hazardous events, particularly in the case of decentralized or MTA-based treatment. Risk levels were assigned in this study following work by [27,28] which apply a risk level without explicit consideration of probability and impact explicitly. In rural settings or systems with little available information, the WHO recommends a “simple team decision” to rank risk prioritization [28], p. 18. The designations of risk levels used in this study are defined in Table 1.

**Table 1.** Criteria used to categorize risk levels for hazardous events included on SSP checklist.

| Risk Level            | Criteria  |
|-----------------------|---|
| <b>Low</b>            | Hazard was clearly not an identified concern.   |
| <b>Moderate</b>       | Evidence exists suggesting risk mitigation efforts are needed to address this hazard. |
| <b>High</b>           | Hazard was identified as a clear and serious concern.                                 |
| <b>Unknown</b>        | Insufficient information available to assign a risk level.                            |
| <b>Not Applicable</b> | Hazard is not present in the overall system and is therefore not evaluated.           |

For hazardous events where risk level could not be ascertained from the information in the system assessment reports, a risk level of “unknown” was assigned to indicate a knowledge gap. If a hazardous event was not possible within an individual system, the risk level was determined to be “not applicable”. For example, if disinfection is not a component of the wastewater system, the disinfection-related hazards found in Table S1 were excluded from risk characterization and marked as “not applicable”. The results from the risk assessment of hazardous events were used to understand the distribution of risk in a First Nations sanitation treatment system and to categorize risk types common amongst First Nations communities.

### 3. Results and Discussion

#### 3.1. Stakeholders in First Nations Wastewater Systems

Building an SSP team with appropriate expertise and representation from each step of the sanitation process, including waste generation, collection and transport, treatment, and use or disposal of final effluent and waste materials, ensures the whole system can be monitored and improved over time [13]. Following the WHO stakeholder analysis process, this work identified groups or organizations that either have some regulatory or oversight responsibility for First Nations wastewater systems or have influence over practices that affect wastewater quality. Review of literature surrounding First Nations wastewater system management revealed six subsets of key stakeholders involved in a sanitation system [7,18,29–31]. Key actors along the sanitation chain in First Nations communities are shown in Table 2.

**Table 2.** Stakeholders in First Nations wastewater systems range from members in a community to government agencies, showcasing the plurality of actors involved in these wastewater systems.

| Stakeholder  | Role and Responsibilities  |
|--|--|
| Owners and Operators                                 | <ul style="list-style-type: none"> <li>• Daily provision of safe water and wastewater systems in communities.</li> <li>• Sample collection in wastewater systems within communities.</li> </ul>  |
| Communities, Chief, and Council                      | <ul style="list-style-type: none"> <li>• Design, construction, and operations and maintenance of wastewater systems.</li> <li>• Sample collection completed within communities.</li> <li>• Report sample collection values to corresponding government authority.</li> <li>• Safe disposal of effluent.</li> <li>• Employment of operators.</li> <li>• Purchasing of system supplies.</li> </ul> |
| Municipalities providing services via MTA agreements | <ul style="list-style-type: none"> <li>• Provide wastewater services to the First Nations community as stipulated by the MTA agreement.</li> </ul>   |
| Indigenous Services Canada (ISC), formerly AANDC     | <ul style="list-style-type: none"> <li>• Develop guidelines for treatment system construction and operation protocols.</li> <li>• Funding for operational and maintenance activities.</li> <li>• Review of system designs.</li> <li>• Staff and operator training (Circuit Rider Training Program).</li> </ul>   |
| Health Canada  | <ul style="list-style-type: none"> <li>• Focuses on drinking water quality guidelines.</li> <li>• May assist in water quality sampling upon request but does not have any formal role in decentralized systems.</li> </ul>   |
| Environment Canada                                   | <ul style="list-style-type: none"> <li>• Regulates effluent quality of waters being discharged to receiving bodies.</li> <li>• Provides advice and technical expertise on source water protection and sustainable water use.</li> </ul>  |
| Indigenous and Northern Affairs Canada (INAC)        | <ul style="list-style-type: none"> <li>• Supports wastewater operations in the Northern territories (Yukon, Northwest Territories, and Nunavut).</li> </ul>  |
| Downstream water users and other interest groups     | <ul style="list-style-type: none"> <li>• Engage with broader water quality and sustainability issues specific to their interests and water needs.</li> </ul>   |

There are two First Nations stakeholders and four federal government agencies involved in both the wastewater management and monitoring components of the system. Currently, the oversight of wastewater systems in First Nations communities falls under the jurisdiction of multiple federal agencies, and the roles, responsibilities, and the organizational names of many stakeholders have changed over time [8,12,18,22]. In the case of MTAs, municipalities providing wastewater services to First Nations communities represent an additional stakeholder. Other potential stakeholders in the SSP process include groups who have a broad interest in water quality (i.e., NGOs or cultural groups) and downstream customers and users of water [13]. These stakeholders can include recreational users of water, agricultural operations, aquaculture facilities, and drinking water treatment facilities, and will vary depending on the type, location, and size of the receiving body. These stakeholders may come into contact with hazardous materials from an upstream wastewater facility, and future sanitation studies in First Nations need to include an assessment of potential exposure; due to insufficient data, exposure to hazardous materials was not considered here.

The stakeholder analysis demonstrates the division of oversight of wastewater treatment provision across multiple federal agencies and First Nations representatives. The relationship of the stakeholders to processes along the sanitation chain, from treatment design to effluent regulation, are illustrated in Figure S2. The prioritization of team building and stakeholder engagement as step one in the SSP process highlights the need for an intentionally collaborative approach to wastewater management. There has been a history of limited responsiveness of both Health Canada (HC) and INAC with regard to drinking water services in First Nations communities [31], and while concerns specific to wastewater are less documented, similar intra- and interagency coordination challenges could impact the implementation of SSP in First Nations communities. If successful SSP adoption is to occur in a First Nations context, federal and community commitment and

communication would be necessary to formalize and improve wastewater management. Given the longstanding recommendation for improved First Nations consultation and capacity building [1,7,22], the SSP framework could provide a structure to facilitate meaningful collaboration between federal agencies and First Nations communities, as well as municipalities in the case of MTAs.

### 3.2. Sanitation System Characteristics

The second step of the SSP process is to describe the sanitation system through mapping, waste characterization, evaluation of compliance and contextual information, and identification of discharge locations [13]. Information from the system assessment reports for the 29 First Nations communities was used to describe each wastewater system. Table 3 shows a summary of key system characteristics including operator (First Nations or MTA), population, number of connections, system type, infrastructure age, drinking water source, and effluent discharge location. The system types present in First Nations communities were characterized as either centralized, decentralized, or combined. The system descriptor “number of connections”, when applied to decentralized systems, indicates the number of septic systems estimated to be present in the community as determined by the number of residences and other buildings. Greater levels of system description are not included here to protect community anonymity in accordance with OCAP principles [24].

In general, there is little available data on decentralized systems located in First Nations communities in Atlantic Canada. The assessment reports made available by the APC did not include an investigation of decentralized systems present in First Nations communities. Likewise, there is little detail available regarding the details of MTA agreements. Many of the MTAs for Atlantic First Nations communities exist between ISC and the municipality, limiting the involvement and agency of the First Nations community in managing its water services. Because municipal systems were not evaluated, the assessment reports offered limited information about the wastewater treatment processes in these instances. In total, there were 21 First Nations-owned and -operated systems and eight MTA systems included in this study. The First Nations-operated systems comprised five centralized systems, ten combined systems, and six decentralized systems. The reliance on both centralized wastewater treatment and decentralized treatment, with half of the communities employing a combination of these two systems, indicated that a robust SSP approach would have to consider both centralized and decentralized sanitation chains, stakeholders, and downstream effects. It should be noted that “decentralized” systems discussed in this work refer to the use of individual on-site septic systems.

Evaluation of the 29 communities show that most wastewater systems serve small populations (Table 3). All sanitation systems serve less than 4000 people with no more than 1100 connections to sanitation services, with the exception of Community ZC where these numbers are not available. The majority of centralized systems were also found to be more than ten years old, with several having unknown ages. The 2011 national assessment report and other scholars have noted that, despite significant federal spending, insufficient long-term funding of water and wastewater systems have led to key infrastructure neglect, gaps in upgrades, and delayed system repairs [5,7,8]. The combination of unknown system conditions and persistent funding gaps present significant high-risk determinants that underlie system performance and treatment effectiveness.

The SSP process prioritizes mapping system boundaries and identifying discharge locations to allow for effective monitoring of effluent impacts on receiving bodies and potential downstream water uses [13]. Table 3 details the type of receiving body, if known, for each community. Most First Nations centralized systems discharge to freshwater sources, including flowing watercourses and lakes, with fewer systems discharging into saltwater sources. Current Canadian regulations do not establish water quality standards based on receiving body type [25]. An SSP approach to effluent management could consider the sensitivity of the receiving body, similar to the environmental risk assessment process required by the CCME strategy. The AFN recognizes the value of site-specific risk-based



assessment, but First Nations communities may not have the capacity or support to develop environmental discharge objectives [32]. The semi-qualitative SSP approach may provide a tool for First Nations communities to consider receiving body vulnerability.

**Table 3.** Characteristics of 29 First Nations sanitations systems in Atlantic Canada based on the 2013 and 2018 system assessment reports.

| System | Operator     | Population | Connections | Centralized, Decentralized or Combined System | System Age (years) | Drinking Water Source Type | Discharge Location    |
|--------|--------------|------------|-------------|---|--------------------|----------------------------|-----------------------|
| A      | MTA          | <300       | 42          | Centralized                                   | U *                | SW **                      | Unknown               |
| B      | First Nation | <300       | 52          | Decentralized                                 | U                  | GW ***                     | On-Site               |
| C      | First Nation | <300       | 32          | Decentralized                                 | U                  | GW                         | On-Site               |
| D      | First Nation | 1000+      | 260         | Combined                                      | 34                 | GW                         | Harbour/Bay           |
| E      | First Nation | 600–1000   | 165         | Combined                                      | 34                 | SW                         | Flowing Water (Brook) |
| F      | First Nation | 300–599    | 66          | Decentralized                                 | U                  | GW                         | On-Site               |
| G      | First Nation | 1000+      | 700         | Combined                                      | >20                | SW                         | Flowing Water (River) |
| H      | First Nation | 300–599    | 131         | Combined                                      | 19                 | GW                         | Flowing Water (River) |
| I      | First Nation | 300–599    | 152         | Centralized                                   | 6                  | GW                         | Harbour/Bay           |
| J      | MTA          | <300       | 206         | Combined                                      | U                  | SW                         | Harbour/Bay           |
| K      | MTA          | <300       | 27          | Centralized                                   | U                  | U                          | Wetlands              |
| L      | First Nation | <300       | 24          | Decentralized                                 | U                  | SW                         | On-site               |
| M      | MTA          | 1000+      | 318         | Centralized                                   | U                  | GW                         | Harbour/Bay           |
| N      | MTA          | 600–1000   | 347         | Combined                                      | U                  | SW                         | Unknown               |
| O      | MTA          | 300–599    | 75          | Centralized                                   | U                  | SW                         | Unknown               |
| P      | MTA          | 600–1000   | 284         | Centralized                                   | U                  | GW                         | Flowing Water (River) |
| Q      | First Nation | 600–1000   | 300         | Combined                                      | >30                | SW                         | Harbour/Bay           |
| R      | First Nation | 1000+      | 1100        | Combined                                      | >30                | GW                         | Lake                  |
| S      | First Nation | 600–1000   | 200         | Centralized                                   | 12                 | GW                         | Flowing Water (River) |
| T      | First Nation | 300–599    | U           | Centralized                                   | 11                 | GW                         | Harbour/Bay           |
| U      | First Nation | <300       | 70          | Decentralized                                 | U                  | GW                         | On-Site               |
| V      | First Nation | 300–599    | 138         | Centralized                                   | 19                 | GW                         | Flowing Water (River) |
| W      | First Nation | 600–1000   | 150         | Centralized                                   | >20                | GW                         | Land                  |
| X      | First Nation | 1000+      | 300         | Combined                                      | U                  | GW                         | Lake                  |
| Y      | First Nation | 1000+      | 353         | Combined                                      | 18                 | GW                         | Flowing Water (Brook) |
| Z      | First Nation | 1000+      | 400         | Combined                                      | >20                | GW                         | Flowing Water (River) |
| ZA     | First Nation | 300–599    | 120         | Combined                                      | >20                | GW                         | Lake                  |
| ZB     | MTA          | 600–1000   | 260         | Combined                                      | U                  | GW                         | Unknown               |
| ZC     | First Nation | U          | U           | Decentralized                                 | U                  | U                          | On-Site               |

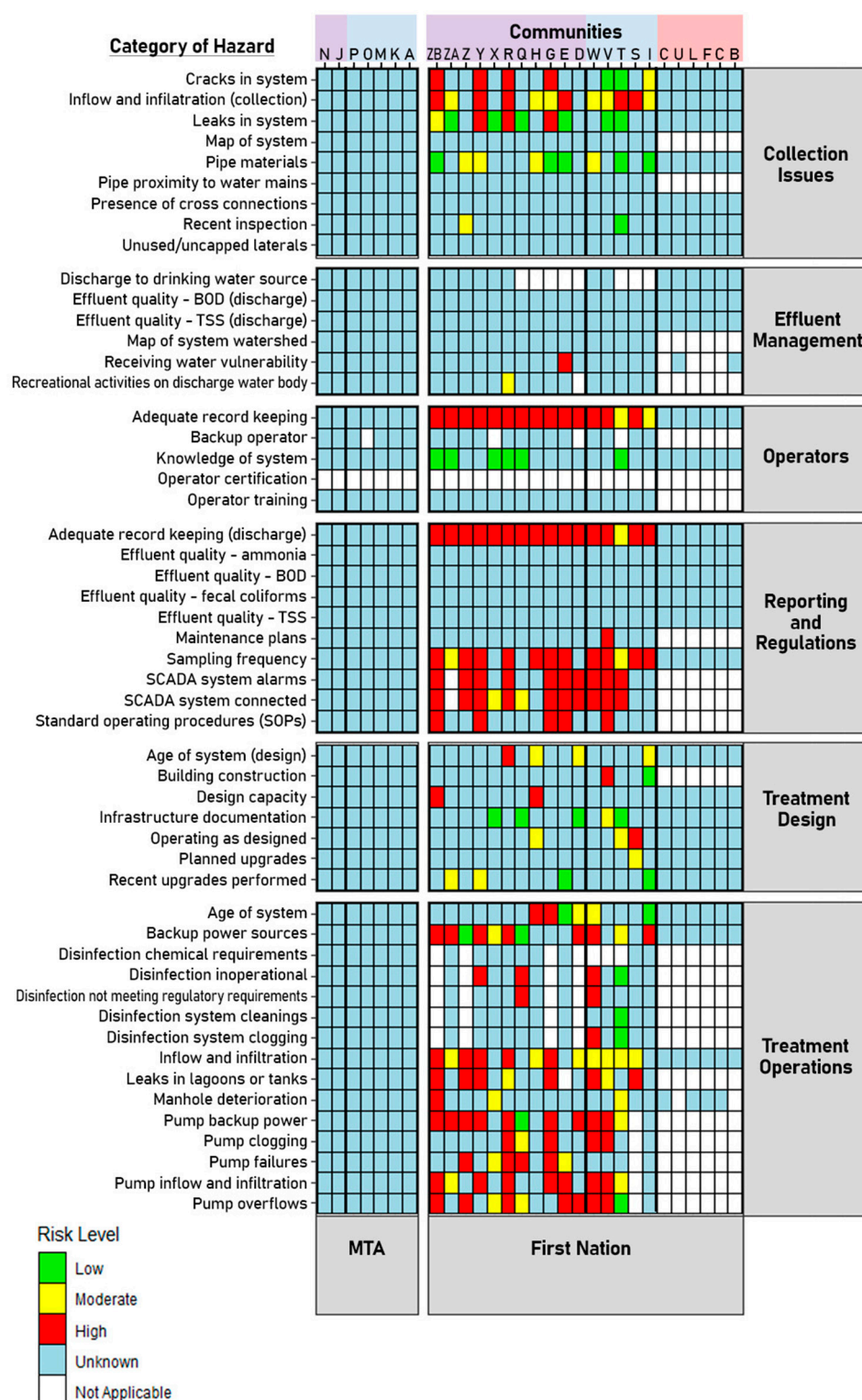
\* U = Unknown age, \*\* SW = Surface water, \*\*\* GW = Groundwater.

### 3.3. Evaluating Knowledge Using an SSP Checklist

The SSP hazard identification checklist developed for this study included six categories of hazards: collection issues, effluent management, operators, reporting and regulations, treatment design, and treatment operations. The full list of the evaluated hazardous events is presented in a checklist in Table S1. This evaluation exercise was meant to demonstrate the applicability of an SSP approach in a First Nations context. The process of identifying, selecting, and prioritizing relevant hazards would be implemented in practice on a community-by-community basis by the identified stakeholders. Figure S3 shows the number of hazardous events categorized by risk level. Of the 1508 potential hazardous events evaluated (52 hazardous events in 29 sanitation systems), 69% of hazardous events had an unknown level of risk and 7% of hazardous events were identified as high risk. The remainder of the hazards across systems were found to be 4% moderate and 3% low risk. These findings indicate the risk level for the majority of hazards evaluated in this research are unknown, and if known, are high risk. This result, in part, reflects the use of system assessment reports for risk evaluation, rather than interviews with various stakeholders and other knowledge exchange practices. The assessment reports, produced by an engineering consulting firm, did include community visits but focused predominantly on centralized infrastructure and operations. System assessments were conducted to learn about the wastewater treatment systems using operator interviews, site visits, review of logbooks, examination of water quality data records, system maps, and all other available documentation. Given this rigorous process, the assessment reports are thought to reflect a best estimate of system knowledge and legitimate documentation gaps.

#### 3.3.1. Hazards and Risks in MTA Systems

When the hazardous events and associated risk levels are disaggregated by owner/operator affiliation (First Nations vs. MTA), patterns of risk can be identified across similar system cohorts. Figure 1 presents the results from the hazard identification checklist, separating sanitation systems by operator status. MTA systems are characterized by a significant lack of data across all hazard categories included in the SSP checklist. While individual MTA agreements were not available as primary sources for consideration in this study, some were reviewed by the engineering firm to inform the 2013 and 2018 system assessment reports. The system assessment reports highlighted differences in agreement arrangements, unclear responsibility for maintenance and repair, and lack of clarity regarding communication and data sharing. For communities that rely on MTA services, there is less need for capacity and expertise for wastewater management within the community. However, depending on the nature of the MTA, communities are often responsible for wastewater collection infrastructure on First Nations land and would benefit from knowledge of the infrastructure, collection processes, and environmental impact of effluent discharge. The results of this research conclude that communities that rely on MTAs may be at a knowledge disadvantage and could benefit from improved clarity and communication with the municipal facilities and federal agencies responsible for the provision of wastewater services. Further, specific SSP hazard checklists can and should be developed to better serve First Nations communities that rely on MTAs. These checklists should focus on knowledge exchange practices, communication and documentation practices, standard operating procedures for waste collection processes, and emergency preparedness and response.



**Figure 1.** The risk levels associated with each hazardous event on the SSP checklist, as determined from the system assessment reports from 2013 and 2018. Communities are highlighted in colours that correspond to system type (centralized = red, combined = purple, decentralized = blue).

### 3.3.2. Hazards and Risks in Decentralized Systems

When the hazardous events and associated risk levels are disaggregated by system type, it is clear that little knowledge was provided in the system assessment reports regarding decentralized systems. The system assessment reports that informed this study provided limited evaluation of decentralized systems (on-site septic systems) because

individual property owners were not consulted during the system assessments. The difficulties of accessing and evaluating decentralized wastewater treatment systems are a product of provincial and federal policy and regulation which devolve on-site septic system installation, monitoring, maintenance, and reporting of malfunctions to individual property owners [30,33]. Currently, the only regulations for wastewater effluent treated on federal lands in Canada (including First Nations communities) apply to centralized systems that collect and treat more than 100 m<sup>3</sup>/d of wastewater [26].

For decentralized systems, many hazardous events unique to on-site wastewater management systems differ depending on the system type, environmental conditions, stakeholders managing the system, and the guidelines available for these types of systems. This underscores the importance of system-specific assessments and risk management. In general, there is a lack of knowledge about groundwater under the influence of surface water in First Nations communities, so little can be said about the potential risk of decentralized septic drainage fields impacting subsurface water supplies. The knowledge gaps in decentralized sanitation systems indicate key areas of wastewater treatment management that need to be addressed. The insufficient oversight of decentralized systems is a well-known issue in wastewater management in Indigenous communities [8]. Recent work has been done by the WHO and Asian Development Bank (ADB) to develop SSP approaches to managing decentralized systems to address stakeholders, system boundaries, hazard identification, and risk assessment in individual and communal septic systems [17,34]. Given the lack of governance and risk mitigation frameworks for decentralized systems in First Nations communities, an SSP approach may be a useful mechanism for managing and improving the safety of these systems.

### 3.3.3. Hazards and Risks in First Nations-Owned Centralized Systems

Centralized and partially centralized systems owned and operated by First Nations communities had the greatest number of measurable risks (low, moderate, and high) because of the increased data available for assessment (shown in Figure 1). In these systems, the risk category for treatment operations had the greatest number of hazardous events with known risk levels while the categories for reporting and regulations and effluent management were characterized by a significant number of unknown risk levels for hazardous events. Effluent management hazardous events were frequently attributed “unknown” risk levels due to the lack of current effluent data presented in the system assessment reports, which was a result of inadequate record-keeping practices. The abundance of unknown risk levels for the hazards included in this study showed the possible value of assessing the sanitation chain through an SSP lens. An SSP could provide a framework for considering wastewater management beyond the end-of-pipe regulatory requirements and provide a process that engages a range of stakeholders to develop First Nations-led management initiatives. The value of the safety planning approach is the ability of stakeholders to assess risk and prioritize incremental improvement. Ideally, communities that engaged in the SSP process would be able to identify record-keeping practices as a high-risk concern and implement procedures to better support these important operational components in a wastewater treatment system.

### 3.4. SSPs Reveal How Risk Accumulates in a Sanitation System

The critical evaluation of sanitation systems in 29 First Nations systems demonstrates the clear importance of analyzing how risk (both known and unknown) accumulates through the sanitation chain. Whereas endpoint monitoring only identifies concerns with effluent quality, an SSP critically evaluates risk throughout the entire sanitation system. The systematic evaluation of risk in this study revealed not only which risk was present but how risk can propagate. The SSP checklist developed for this study considers hazards in a sanitation system in the order that they are encountered in the system, from collection to discharge. For example, a lack of maintenance plans can lead to increased risk of a pump

failure in the treatment facility, a relationship that is not captured when evaluating whether effluent parameters are in violation of regulations.

Two theoretical examples of the complex relationships between hazards along the sanitation chain are modeled in Figure 2. The model in Figure 2A examines hazards related to the management of a wastewater system, focusing on human/personnel capacity in a system, and visualizing how a lack of access to resources for operator training and certification impacts the sanitation system. Figure 2B examines a series of technical hazards related to the daily operations of the sanitation system, focusing on how operational concerns are compounded. Both models show how knowledge and/or risk from one hazard has the potential to impact other hazards in a theoretical sanitation system resulting in the propagation and/or accumulation of risk. It is important to recognize that not all of these relationships exist in all First Nations sanitation systems; the authors present these figures as examples only. Validation of these relationships by consulting directly with sanitation system stakeholders will be critical to future SSP studies.

For example, in Figure 2A, operator training directly influences an operator's knowledge of the sanitation system. Knowledge of the sanitation system, including how to properly operate treatment processes and collect samples, impacts record-keeping practices. Adequate record keeping is directly impacted by how well an operator is trained [2,35,36]; thus, we begin to understand how the presence of a trained operator greatly impacts the risk of several hazards in a sanitation system. Considering these hazards as singularities erroneously indicates that each hazard has no impact on another hazard. As shown in Figure 2, increases in risk in a sanitation system are a direct result of the interactions between hazards. Furthermore, management of effluent and proper treatment operation are not the only critical methods for reducing risk in a system. Proper personnel training and adequate record keeping play a large role in lowering risk to a sanitation system, and previous studies have demonstrated that this is particularly true in small systems [2,21,35,36].

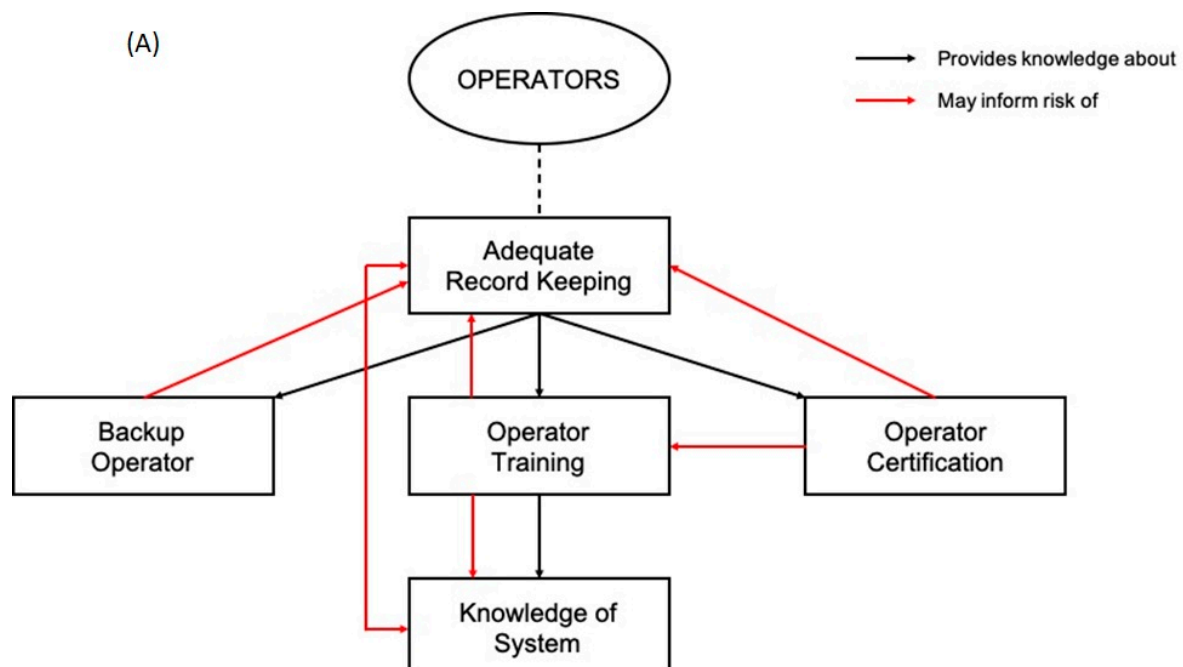
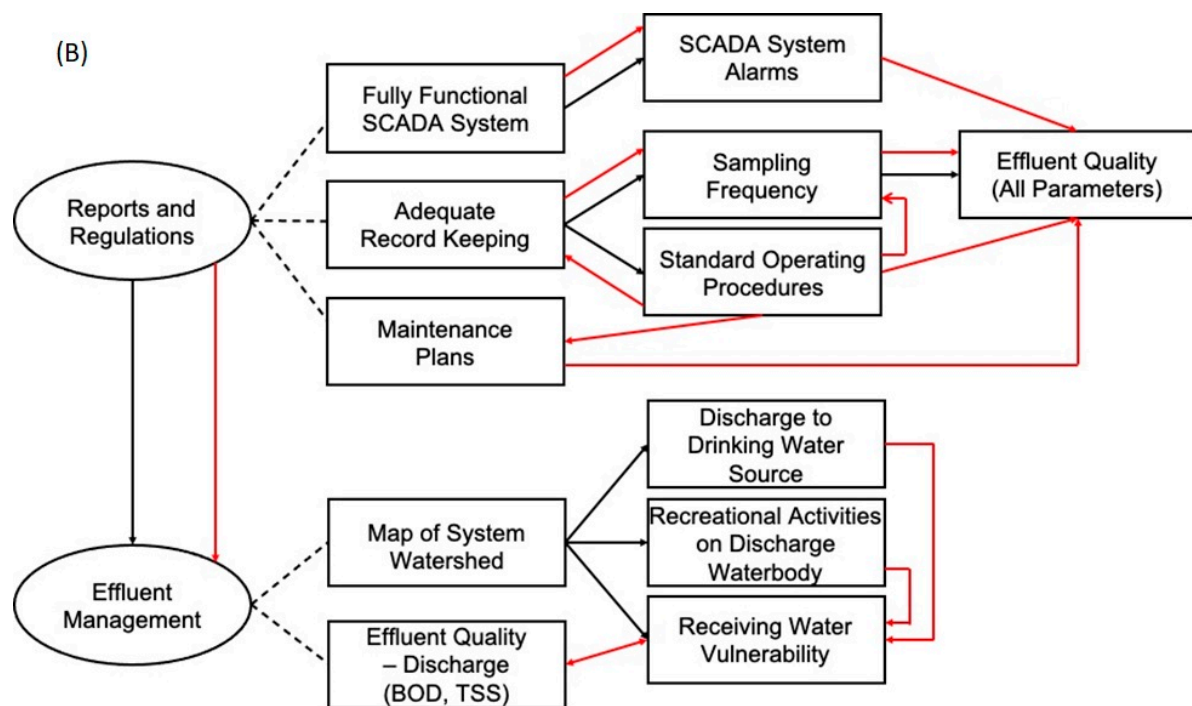


Figure 2. Cont.





**Figure 2.** (A) Risk propagation due to operational practices; (B) technical hazards highlight the accumulation of risk along the sanitation chain.

### 3.5. SSP Implementation

The risk mitigation and management approach of an SSP provides increased knowledge about a sanitation system to the critical stakeholders involved in, or impacted by, daily operations, and provides actionable pathways to incremental risk mitigation. This research shows that hazard identification and risk assessment for decentralized, centralized, and MTA systems each require specific SSP team members and hazard checklists. Work by Black and McBean [5] found that water safety planning development needs to be community led and community specific. How each community develops stakeholder teams, hazard identification, and risk assessment processes is for each community to decide. The SSP approach offers a highly adaptable management framework to guide the work. The hazard checklist developed for this study was informed by WHO and INAC documentation, as well as relevant federal policies. Future efforts to develop a First Nations-informed SSP approach will require the consideration and integration of multiple knowledge and value systems. Significant research exists on the use of sanitation sustainability indices (SSI) to evaluate availability and functionality of sanitation systems. These metrics provide a focus on parameters related to both public health and sustainability that are not currently included in the hazard checklist developed for this study (potential exposure to hazardous materials, longevity of the system design, etc.) [37–39]. These characteristics may be valuable additions to a First Nations SSP approach. Additionally, important research has been completed understanding the value of Two-Eyed Seeing and the use of Traditional Ecological Knowledge to indigenize water research and governance [40–42]. These bodies of knowledge could inform the SSP process to make the framework meet the needs of the communities.

If implemented thoughtfully, an SSP approach can increase understanding of hazards and risks along the sanitation chain and help to operationalize management strategies and improvement mechanisms [18,23,40]. Indigenous drinking water governance literature has advocated for increased agency and recognition of Indigenous voices in policymaking, including better relationships and revised power dynamics between Indigenous communities and government agencies [5,6,22]. Although wastewater systems have not been explicitly evaluated in previous water policy studies, the same principles apply. Regulatory

structures are an example of a “power over” dynamic between the federal government and Indigenous communities [7,22], whereas we assert that SSPs represent a change to a “power with” dynamic. SSPs have the potential to be a community-driven, bottom-up approach that could help to re-envision Indigenous wastewater system governance in a way that not only considers risk throughout a system, but also allows stakeholders to understand and manage important hazards and risks in their systems.

### 3.6. Study Limitations

Given the qualitative and subjective nature of the work undertaken in this study, the authors wish to identify limitations and qualifications to consider when interpreting the results of this study. First, we recognize that we bring a non-Indigenous perspective to our analysis of the hazards present in Indigenous community wastewater systems. Our perspectives are defined by white, non-Indigenous, and science-based ontologies that we recognize do not always align with perspectives held by Indigenous communities; our evaluation of wastewater hazards is therefore derived from definitions of risk from our training in risk management.

The results presented in this study represent a desktop study of First Nations sanitation systems in Atlantic Canada which relied on past system assessment reports. The reports focused predominantly on the operational and infrastructural components of centralized systems and highlighted the lack of information available for decentralized systems and MTAs. We seek to provide an initial consolidation of relevant data used in sanitation safety plans and a recommendation for future research in this field, particularly by drawing attention to the deficit of studies undertaken to resolve wastewater concerns in Indigenous communities in Canada in all three system types. Community-based and participatory research is needed to evaluate the validity of an SSP method in practice. Indigenous stakeholders, specific to the type of wastewater treatment approach employed in a community, need to be involved in any future studies related to SSPs to ensure that Indigenous stakeholders have the chance to participate and direct this research.

## 4. Conclusions

Through applying an SSP evaluation to 29 Atlantic First Nations sanitation systems, key stakeholders were identified, known and unknown risk was determined, and the accumulation of risk along the sanitation chain within communities was explored. Using the SSP framework, the majority of risks within wastewater systems were either known, and high risk, or unknown due in part to limited record keeping and limited system documentation. In many cases hazardous events included in the checklist were not applicable, outlining the importance of community specificity during the SSP evaluation, which is largely dependent on system type (centralized versus decentralized) and owner/operation status (First Nations owned and operated versus MTA). This work found that decentralized systems and MTA arrangements have poorly characterized risk levels. The SSP checklist allowed identification of risks in centralized systems, in contrast to traditional regulatory compliance regimes. Relationships between hazard categories and hazardous events were complex, interconnected, and compounded by the plurality of stakeholders in both First Nations communities and federal agencies. The SSP framework could provide several benefits to First Nations communities that previous methodologies have not, including increased and intentional communication with stakeholders, the presence of a bottom-up “power with” focus and augmented agency, and holistic hazard evaluations for a range of system types that consider factors beyond regulatory compliance.

**Supplementary Materials:** The following are available online at <https://www.mdpi.com/article/10.3390/w13111454/s1>, Figure S1: SSP Framework, Table S1: Hazardous events checklist, Figure S2: Stakeholder and sanitation process diagram, Figure S3: Hazards categorized by risk level.

**Author Contributions:** All authors contributed significantly to this work in the following ways: conceptualization, K.L. and A.S.; methodology, K.L. and M.F.; formal analysis, K.L., T.S., and M.F.; data curation, K.L. and T.S.; writing—original draft preparation, K.L., T.S., and M.F.; writing—review and editing, K.L., T.S., M.F., and A.S.; visualization, K.L.; supervision, A.S.; project administration, K.L. All authors have read and agreed to the published version of the manuscript.

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**Data Availability Statement:** The data presented in this study may be available in a redacted form on request from the corresponding author. The data collected from the system assessment reports are not publicly available due to the Ownership, Control, Access, and Possession (OCAP) principles in First Nations information management.

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