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CANADIAN FIELD EPIDEMIOLOGY PROGRAM – 50 YEARS

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Contact the Editorial Office

ccdr-rmtc@phac-aspc.gc.ca
613.301.9930

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The cover image represents the commemorative 50th anniversary icon celebrating five decades of the Canadian Field Epidemiology Program.

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CANADIAN FIELD EPIDEMIOLOGY PROGRAM – 50 YEARS

Guest Editor:
Louis Wong is Co-Program Director of the Canadian Field Epidemiology Program at the Public Health Agency of Canada, alongside Dr. Kathleen Laberge. A graduate of the program, his work focuses on applied epidemiology, public health systems, and workforce capacity development, with an emphasis on strengthening field epidemiology practice. He has experience across federal, provincial, local, and hospital settings, bringing a systems perspective to surveillance and response. He is currently a Doctor of Public Health candidate, with research interests in integrated surveillance, syndemics, and systems science.

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COMMENTARY

Fifty years of the Canadian Field Epidemiology Program (1975–2025): Reflecting on the past, shaping the future

Louis Wong[1]*, Anja Bilandzic[1], Kathleen Laberge[1]

Abstract

Since 1975, the Canadian Field Epidemiology Program (CFEP) has strengthened Canada's public health capacity by training field epidemiologists through a two-year, service-oriented model that integrates formal learning with field placements and mentorship. Established at the request of the provinces and territories and modelled after the United States' Epidemic Intelligence Service, CFEP has evolved into a nationally distributed surge and analytic capability embedded across jurisdictions.

Over five decades, trainees and alumni have supported outbreak and emergency response, strengthened surveillance systems, and produced applied evidence that has informed control measures and policy, spanning foodborne and environmental events, severe acute respiratory syndrome (SARS), H1N1, COVID-19, and emerging One Health threats.

The CFEP's impact also reflects deliberate workforce development through structured mentorship, cohort-based learning, and alumni networks that extend expertise across federal, provincial, territorial, academic, and international settings.

As public health risks grow more complex due to climate-related hazards, rapid digital change, and challenges to trust, this commentary argues that CFEP must remain adaptive, deepen cross-sector partnerships, and embed equity, reconciliation, and systems thinking to sustain Canada's health security over the next 50 years.

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Affiliation

[1] Regulatory, Operations and Emergency Management Branch, Public Health Agency of Canada, Toronto, ON and Saint-Hyacinthe, QC

***Correspondence:**

cfep-pcet@phac-aspc.gc.ca

Introduction

In 1975, the Government of Canada established the Canadian Field Epidemiology Program (CFEP) to strengthen public health capacity across the country. Created to build expertise in outbreak investigation and surveillance, CFEP has since become a key part of national health security infrastructure.

This thematic issue showcases the work of current CFEP trainees, illustrating how applied epidemiology continues to shape Canada's response to complex health challenges. From infectious disease outbreaks to climate-related hazards, CFEP trainees have provided the expertise and agility that underpin our public health system. As we celebrate five decades of impact, we also ask: what does the next 50 years demand of us?

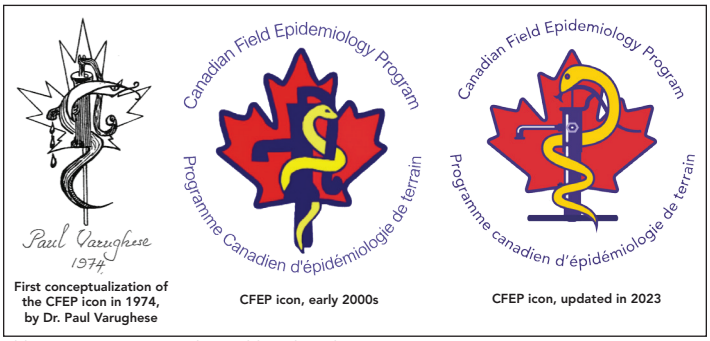
Historical foundations and evolution

The CFEP, first known as the Canadian Field Epidemiology Training Program, was modelled after the United States' Epidemic Intelligence Service and launched at the Laboratory Centre for Disease Control in 1975 (1) at the request of provinces and territories. It is designed as a two-year "learn-by-doing" training program, combining formal training with field placements embedded within provincial, territorial, and local health authorities (1,2). This "learn-by-doing" approach yields immediate system benefits, as trainees support public health priorities during training rather than only after program completion (3).

From its inception, CFEP's identity was symbolized by three key elements (**Figure 1**):

- The maple leaf, representing the program's national scope
- The serpent from the staff of Asclepius, a universal symbol of health and medicine
- A water pump, a nod to John Snow's historic removal of the Broad Street pump handle in 1854 to halt a cholera outbreak

Figure 1: The evolution of the Canadian Field Epidemiology Program icon



First conceptualization of the CFEP icon in 1974, by Dr. Paul Varughese | CFEP icon, early 2000s | CFEP icon, updated in 2023

Abbreviation: CFEP, Canadian Field Epidemiology Program

In CFEP's icon, the pump handle is restored, which signifies that modern field epidemiology is not only about removing hazards but also about restoring population health. This visual identity reflects the program's longstanding mandate:

> *"To strengthen public health practice in Canada through the provision of training and service which foster excellence in the practice of applied epidemiology."*

In 1997, CFEP became a founding member of the Training Programs in Epidemiology and Public Health Interventions Network (TEPHINET), joining a global network of 84 field epidemiology training programs (4–6). Following the severe acute respiratory syndrome (SARS) outbreak in 2003, CFEP transitioned into the newly created Public Health Agency of Canada (PHAC) in 2004 (4), aligning its surge capacity with national emergency coordination. In 2016, CFEP earned TEPHINET accreditation, affirming its competency-based training standards against international benchmarks (4,5). In 2022, CFEP was reaccredited with Distinction and Merit in Emergency Response (5).

Strategic contributions to public health

Over five decades, CFEP has delivered value across multiple dimensions of Canada's public health system, as described below.

Outbreak and emergency response

The CFEP trainees have been Canada's backbone for rapid response during public health crises, establishing a practice-oriented ethos anchored in mentorship and rapid deployment. From foodborne outbreaks in the 1970s to SARS in 2003, H1N1 in 2009, and COVID-19 in 2020, CFEP trainees and alumni have provided surge capacity for case finding, contact tracing, epidemiologic analysis, and the establishment of surveillance systems (**Table 1**). Their work has informed control measures, guided policy decisions, and shaped national public health emergency protocols. Across successive public health challenges, CFEP trainees have remained central to Canada's early detection and response efforts for emerging pathogens and issues.

Table 1: Examples of Canadian Field Epidemiology Program (CFEP) scientific communication products through the years

Year	Responses where CFEP was involved
1982	An epidemiologic assessment of unexplained deaths in a children's hospital (7)
1987	Outbreak of toxic encephalopathy caused by eating mussels contaminated with domoic acid (8)
1997	A long, multinational *Salmonella* outbreak traced to a single widely distributed contaminated alfalfa seed lot, highlighting how modern food supply chains can rapidly spread illness across borders and why coordinated surveillance and stronger food safety controls are essential (9)
1998	A large 1997 Pacific Northwest outbreak linked to raw oysters across multiple jurisdictions showed how warmer coastal waters can amplify *Vibrio* risk and why strong, coordinated surveillance and rapid control actions (advisories/bed closures) are critical to prevent widespread illness (10)
2007	Canada's first nosocomial outbreak of community-associated methicillin-resistant *Staphylococcus aureus* among healthy newborns and postpartum mothers in a Toronto maternal-newborn unit, underscoring the public health importance of rapid detection and strong infection-prevention controls to stop health care spread of emerging community strain (11)
2007	Use of a Web forum and an online questionnaire in the detection and investigation of an outbreak (12)
2015	Coordinated multi-province surveillance in Canada's 2008 listeriosis outbreak traced illness to contaminated ready-to-eat deli meat and ongoing plant contamination, underscoring the need for enhanced listeriosis surveillance, tighter control of *Listeria* monocytogenes in ready-to-eat food facilities, and focused risk reduction guidance for institutions serving high risk groups (13)
2021	Identification of an unusual cluster of human granulocytic anaplasmosis in the Estrie region, Québec (14)
2021	A COVID-19 outbreak in a remote First Nations community in British Columbia linked to social gatherings and household transmission, which was effectively contained through a rapid, community-led public health response (15)

Abbreviation: CFEP, Canadian Field Epidemiology Program

As with comparable field epidemiology programs internationally, CFEP's early emphasis reflected the dominant public health threats of the time: infectious disease detection and outbreak response (6,16,17). Today, the operating context is broadening. Trainees are increasingly mobilized to address syndemics and the cascading health impacts associated with climate change. This shift underscores the importance of maintaining an adaptable workforce capable of addressing complex, multi-hazard public health threats, while embracing the One Health approach, as demonstrated by a trainee's contribution to the response to Canada's first human case of highly pathogenic avian influenza.

Public health surveillance system strengthening

The CFEP trainees assess, enhance and implement surveillance systems using standardized frameworks to ensure that Canada's public health intelligence remains robust and fit for purpose. Recently, trainees worked on substance-related harms, sexually transmitted and blood-borne infections, heat-related illnesses, COVID-19, and numerous other topic areas that reflect the breadth of public health surveillance work across Canada.

Systems are often evaluated for the first time, resulting in actionable recommendations, and contributing to a legacy of quality improvement. These initiatives have led to improvements in communicable disease reporting, integration of laboratory data, and adoption of digital tools (18).

Workforce development and networks

As of June 2026, CFEP has trained 239 field epidemiologists over its 50-year history. The CFEP alumni have become a driving force behind Canada's public health leadership, shaping outbreak response, national policy, surveillance innovation, and strategic emergency management. Over the program's history, CFEP graduates have advanced into some of the most influential public health roles in the country. Canada has had both a Chief Public Health Officer and a Deputy Chief Public Health Officer who are CFEP graduates. Beyond federal leadership, CFEP alumni have served as provincial Chief Medical Officers of Health, Chief Provincial/Territorial Epidemiologists, directors of public health intelligence and surveillance, and senior leaders across federal and provincial health ministries, local public health units, academia, and international organizations. Their expertise has informed national policy development, strengthened surveillance frameworks, and contributed to global health security.

A big part of this success comes from the mentorship built into the program. Trainees receive steady guidance from both CFEP staff and their placement site supervisors, which helps them grow their technical skills, navigate real-world investigations, and build confidence in their judgment. This support has been an important part of shaping the leaders that CFEP has produced.

The CFEP has also fostered collaboration between health systems and trusted colleagues through informal networks. Through strong connections within cohorts, among the broader alumni community, and throughout placement sites across Canada, CFEP trainees and graduates have become part of something greater than their individual training journeys. These informal networks mean that typically, someone "knows someone" when new public health situations arise, and this facilitates knowledge sharing opportunities. This function has been particularly useful when dealing with public health emergencies requiring unified action.

Canadian Field Epidemiology Program today: Adapting to a changing landscape

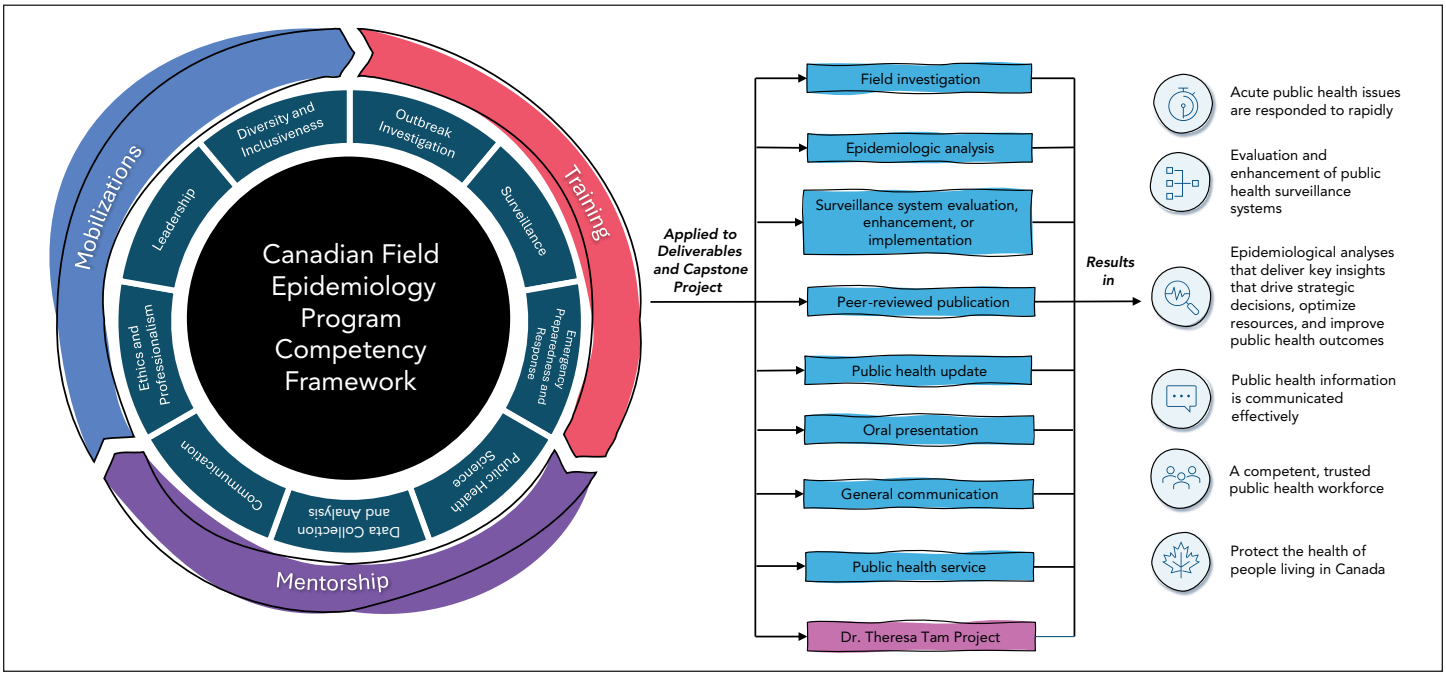
The CFEP remains highly relevant in today's complex health environment. Each year, it recruits a multidisciplinary cohort of five to ten trainees with backgrounds in epidemiology, public health and preventive medicine, nursing, veterinary sciences, and allied health, and places them in diverse settings for two years of immersive, service-oriented learning. The CFEP competency framework emphasizes outbreak investigation, epidemiologic analysis, surveillance evaluation, and communication, all of which are essential skills in public health practice (5). These competencies are reinforced by CFEP's core values of excellence, integrity, collegiality, respect, adaptability, and impact, shaping not only what trainees learn, but how they work with partners and communities. The CFEP delivers its mandate through a competency-based training model (**Figure 2**). Trainees develop the necessary knowledge, skills, and professional attitudes through a standard curriculum, supervised deployments in response to public health events, and structured mentorship provided by both the program and placement sites.

A vision for the future

A vision for the future begins with a clear understanding of what has changed. In today's public health landscape, climate-related events are becoming more frequent and disruptive; emerging pathogens (e.g., COVID-19, mpox) and re-emerging pathogens (i.e., measles) are having devastating impacts, and surveillance and response tools are changing rapidly with advances in artificial intelligence. Equity and reconciliation are essential values that underpin effective public health action, and we have learned that trust in public health cannot be assumed.

A future-oriented CFEP should build on its strong foundation while continuing to adapt to the realities of public health. This means diversifying recruitment and training pathways to reflect

Figure 2: The Canadian Field Epidemiology Program model



the communities and contexts that public health serves, and strengthening interdisciplinary and cross-sector collaboration across public health, animal health, clinical care, laboratories, emergency management, social services, and community organizations. It also means reinforcing global partnerships and advancing the evolution of field epidemiology through a distinctly Canadian lens that reflects our geography, federal-provincial-territorial realities, and commitments to equity and Indigenous rights. Finally, future planning should emphasize leadership and systems thinking so that graduates can navigate complexity, respond to misinformation and mistrust, and support public health action that is timely, culturally safe, and effective.

A foundational pillar for Canada's public health

The CFEP is more than a training program; it is an engine of Canada's public health capacity. For 50 years, it has helped Canada detect, investigate, and respond to health threats by developing skilled field epidemiologists and by contributing directly to surveillance and response efforts while trainees are still learning. The CFEP trainees and graduates have supported response operations, strengthened surveillance systems, and informed policies that protect communities across the country.

In the future, CFEP should deepen and formalize engagement with its graduates as a core asset for mentorship, recruitment, training placements, strengthening the training ecosystem, and extending the program's reach. This is timely, as a CFEP alumni network is being established, creating a natural platform to support sustained connection, leadership development, and ongoing contributions to Canada's public health capacity.

Looking ahead, the direction is clear: remain responsive to a shifting risk landscape and equip field epidemiologists to act early, lead confidently, and deliver effective public health action in complex systems. This issue honours CFEP's legacy and highlights the work of current field epidemiologists, reaffirming the program's commitment to remain agile, inclusive, and prepared for future health security challenges.

Authors' statement

LW — Conceptualization, writing–review & editing
AB — Conceptualization, writing–review & editing
KL — Conceptualization, writing–review & editing

Competing interests

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The evolution of applied field epidemiology training in Canada: The last fifty years, and a vision for the future

Benjamin Hetman[1]*, Esmé Lanktree[1], Carolyn Dohoo[1], Joanne Stares[1], Marc-André Bélair[1], Lisa Jensen[1]

Abstract

In Canada, successive crises (e.g., severe acute respiratory syndrome [SARS] in 2003, H1N1 in 2009, COVID-19 in 2019) have not only tested the response capacity of the public health workforce, but reshaped how field epidemiologists are trained. Over five decades, federal applied epidemiology training in Canada has evolved from a small, in-person program focused on outbreak investigation to a multidisciplinary, nationally coordinated training ecosystem integrating emergency management, health equity, climate responsiveness, and technological fluency. This commentary reflects on that evolution and considers the future of the Field Epidemiology Training Program in an era of intersecting and accelerating public health needs.

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Affiliation

[1] Training and Development Unit, Centre for Emergency Preparedness, Public Health Agency of Canada, Ottawa, ON

***Correspondence:**

ceptraining-formationcmu@phac-aspc.gc.ca

Introduction

Looking back: The evolution of federal applied epidemiology training in Canada in response to public health emergencies

Applied epidemiology training for public health practitioners has been a core part of the Canadian federal public service for over 50 years. Beginning in the early 1970s, Epidemiology in Action (EIA) was established as an instructional model for applied epidemiology training in surveillance and outbreak investigation in Canada. The country's Field Epidemiology Training Program (FETP) was formally established in 1975 and named the Canadian Field Epidemiology Program (CFEP). Since its founding, EIA training has formed the basis of classroom instruction and has since helped to shape 50 cohorts of Canadian field epidemiologists (1).

Major public health emergencies have informed the priorities of CFEP training throughout the program's history. For example, the 2003 severe acute respiratory syndrome (SARS) outbreak exposed critical weaknesses in national coordination and surge capacity (2) and highlighted the importance of field epidemiology training in Canada. The subsequent creation of the Public Health Agency of Canada (PHAC) in 2004 formalized a federal commitment to strengthening applied epidemiology capacity and removing barriers to coordinated public health response. In 2006, a dedicated training unit was established within PHAC public health field services to provide the formal instructional component of CFEP and support broader workforce development. This unit, formalized in 2010 and now known as the Training and Development Unit (TDU), became responsible for delivering structured classroom training required under global FETP standards and accreditation (3), while also supporting ongoing professional development for field and adjacent staff.

The 2009 H1N1 pandemic further reinforced the need for scalable training models (4), improved technical fluency to interpret and appraise data (5), and enhanced coordination across jurisdictions. The event also increased interest in training related to vaccinology, vaccine hesitancy, and the role of vaccine campaigns in outbreaks. The TDU adapted its FETP training to suit, introducing new vaccinology training to its repertoire, and bolstering EIA case studies to include more focus on person-to-person disease outbreaks. Training on statistical software was introduced, focusing on data management, spatial epidemiology, and time series analysis. The TDU expanded its role to fill gaps and strengthen capacities as a result of non-pandemic emergencies as well. For example, training on cultural competency and mass gathering event surveillance was developed rapidly to support the public health needs of a large

influx of Syrian refugees in 2016. This training was adapted in subsequent years to support asylum seekers at the Canadian border and refugee centres.

Results

Lessons learned from earlier emergencies were magnified during the COVID-19 pandemic, which accelerated transformation in both scope and modality of applied epidemiology training (**Table 1**). As the public health workforce adapted to decentralized working conditions, the TDU also pivoted training to enable a wider reach and improved use of resources. The necessity for timely online training for specific tasks also became evident. For example, a gap in training for methods in contact tracing was identified, leading to a collaborative effort between the TDU and Health Canada to rapidly develop and deliver a new virtual course on this subject. While earlier training models required travel, adapting select courses to the virtual environment enabled increased capacity building among less resourced or remote health units, created greater opportunities to build networks across jurisdictions, and changed the resources required to operate the program (e.g., more varied skillsets for course development, but fewer in-person facilitators for training delivery).

In 2019, the TDU broadened its mandate to include emergency preparedness training for federal public health staff in Canada, coinciding with the start of the COVID-19 pandemic. The TDU developed tiered, self-directed online learning for the Public Health Emergency Management (PHEM) curriculum, to enable learners to select the level of specialty required for their anticipated roles in an emergency response. This pivot toward a broad and inclusive approach to emergency management in Canada underscored that emergency management literacy was no longer exclusively the domain of specialized field responders. Public health professionals across disciplines require working knowledge of incident management systems, situational awareness reporting, risk communication, and operational coordination. As part of this new approach, foundational PHEM training is now mandatory for all staff at PHAC, and CFEP trainees must complete additional specialized training in this stream.

Discussion

A modern approach to field epidemiology training: Embedding equity, climate, and cultural humility

Each year, the Chief Public Health Officer (CPHO) of Canada releases a report on the state of public health in Canada. These annual reports highlight current evidence on priority public health topics and provide aspirational guidance for the development of public health programming. For example, a recurring theme in recent CPHO reports has been health equity, which also became a key focus of the revised *Core Competencies for Public Health in Canada* (6–11). In recent years, CFEP training has therefore included offerings on race-based data for public health and applied learning on the Two-Spirit, lesbian, gay, bisexual, transgender, queer, intersex, + other sexual and gender diverse communities (2SLGBTQI+) epidemiology to support the collection and interpretation of disaggregated data, the application of equity lenses in surveillance and outbreak investigations, and culturally responsive engagement.

Table 1: Timeline of events affecting field epidemiology training

Year	Milestone
1973	Epidemiology in Action (EIA) training developed
1975	Canadian Field Epidemiology Program (CFEP) formally established
2003	SARS pandemic
2004	Creation of the Public Health Agency of Canada (PHAC)
2006	CFEP sister programs launched: Field Services Training Unit and Canadian Public Health Service (CPHS)
2010	Field Services Training Unit launched as a formal independent entity to support CFEP and CPHS
2014	Just-in-time training for the 2014–2016 Ebola outbreak
2019	Field Services Training Unit renamed to Training and Development Unit (TDU)
2020	Just-in-time training on contact tracing for COVID-19. The EIA is adapted for virtual delivery and content tailored to the COVID-19 era
2021	Launch of public-health-focused R training and training on 2SLGBTQI+ epidemiology (both part of the core curriculum)
2022	Launch of Emergency Management and Public Health online training, TDU's first mandatory training for all PHAC employees
2024	Launch of the TDU Brunch and Learn/Know Before You Go learning series, providing just-in-time training on emerging issues in public health in Canada and globally Collaboration with Training Programs in Epidemiology and Public Health Interventions Network (TEPHINET) to make scientific manuscript writing modules available in French
2025	Launch of training (core curriculum) on race-based data

Abbreviations: CFEP, Canadian Field Epidemiology Program; CPHS, Canadian Public Health Service; EIA, Epidemiology in Action; SARS, severe acute respiratory syndrome; TDU, Training and Development Unit; TEPHINET, Training Programs in Epidemiology and Public Health Interventions Network; 2SLGBTQI+, Two-Spirit, lesbian, gay, bisexual, transgender, queer, intersex, + other sexual and gender diverse communities

Limitations

Technological fluency has become paramount in public health and field analyses, prompting major shifts in the Canadian FETP training landscape. For example, over the past decade, R software has become one of the most popular open-source data-languages in public health and epidemiology, enabling powerful analytical methods, professional data visualizations, and scalable database management across public health units (12,13). Training in R has therefore become a core component of the CFEP curriculum and has attracted many trainees from public health jurisdictions across Canada. The TDU's approach to R training includes topical case studies and examples that emphasize responsible data governance and stewardship, reproducible workflows, and the importance of ensuring analysts adopt 'do-no-harm' approaches when sharing and publishing results.

Conclusion

Looking forward: A vision for the future of field epidemiology training in Canada

As outlined above, the evolution of federal applied epidemiology training in Canada has historically been shaped by reactions to public health crises. For example, the SARS epidemic prompted institutional reform, resulting in the creation of PHAC. The response to H1N1 emphasized operational scalability, and coincided with the formation of a formal and dedicated training unit. Finally, the COVID-19 pandemic accelerated digital transformation and broadened emergency management training beyond field staff. Future preparedness requires moving beyond reactive adaptation, toward anticipatory capacity building. Training programs must prepare public health employees not only for known threats but for uncertain and intersecting challenges, including climate instability, misinformation and disinformation, demographic shifts, and widening health inequities. This requires cultivating a new generation of field epidemiologists with strong technical and domain expertise who are also empathetic, aware, and equipped with the interpersonal skills needed to enable systems thinking and work effectively across sectors.

In an era where social media influence has the potential for great monetary or political gain, misinformation and disinformation have become some of the most serious risks to public health (14,15). Public health relies on accurate and timely dissemination of information to educate the public about ways to avoid or mitigate health risks. Artificial intelligence has the potential to amplify misinformation and disinformation, but it also presents new opportunities across several aspects of field epidemiology. Training the next generations of field epidemiologists to optimize evolving technologies, while recognizing their limitations and critically thinking about results, will be an ongoing, but important challenge.

Training modalities will continue to adapt to the accessibility needs of the public health workforce, accommodating non-traditional working environments and supporting a variety of learning needs and preferences. For example, courses that were once delivered as week-long intensive sessions may be broken down into smaller modules delivered over longer time periods, interspersed with intersession activities to apply the knowledge learned. A variety of mediums will continue to be explored, including recorded videos, collaborative work, case studies, webinars, discussion panels, podcasts, and online synchronous and asynchronous platforms. Training options, such as complex simulations, online gaming modalities, and virtual reality exist, but they must be assessed for accessibility before implementation.

Field-based learning must remain central, not only to strengthen operational readiness but to cultivate cross-jurisdictional relationships at the responder level. At the same time, training must intentionally build the capacity to recognize whose voices and perspectives are missing and to facilitate inclusion before an emergency occurs. By continuously adapting training to public health realities, the program aims to encourage future generations of CFEP trainees to pair scientific and operational excellence with empathic, human-centred responses.

Authors' statement

BH — Conceptualization, writing–review & editing
EL — Conceptualization, writing–review & editing
CD — Conceptualization, writing–review & editing
JS — Conceptualization, writing–review & editing
M-AB — Conceptualization, writing–review & editing
LJ — Writing–review & editing

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ORCID numbers

Benjamin Hetman — 0000-0002-9435-5771
Esmé Lanktree — 0009-0000-8243-2410
Marc-André Bélair — 0009-0005-7828-6728

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Strengthening radon surveillance in British Columbia: Insights from a qualitative evaluation of the British Columbia Radon Data Repository

Bridget Irwin[1,2]*, Jiayun Angela Yao[2,3], David McVea[2,3]

Abstract

Background: Radon is a carcinogenic gas that is the leading environmental cause of lung cancer in non-smokers. While its health risks are well-known, exposure to radon is variable and hard to determine, impeding risk assessment and mitigation. The British Columbia Centre for Disease Control (BCCDC) operates the British Columbia Radon Data Repository (BCRDR) to aggregate radon test results in support of research and public health action. This study evaluates the BCRDR, focusing on its usefulness and acceptability to those who contribute to and use the repository.

Methods: Between November 2024 and July 2025, five contributors of radon data to the BCRDR and six users of radon data from the BCRDR were interviewed. In addition, six data holders, five data users, and 74 members of the public completed web surveys. Interviews and surveys were analyzed qualitatively using inductive thematic content analysis to generate themes.

Results: Overall, users and contributors find the BCRDR useful and acceptable. Contributing data holders described the data submission process as quick and easy, and felt that the BCCDC addressed concerns. The repository supported a wide range of uses by a variety of stakeholders, most of whom found the data valuable. Respondents provided recommendations to further strengthen the repository.

Conclusion: The findings affirm the BCRDR's value for both those contributing data and those using it. Responses can inform enhancements to the existing provincial repository and guide the development of future radon surveillance systems as well.

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Affiliations

[1] Canadian Field Epidemiology Program, Centre for Emergency Preparedness, Regulatory, Operations and Emergency Management Branch, Public Health Agency of Canada, Ottawa, ON

[2] Environmental Health Services, British Columbia Centre for Disease Control, Vancouver, BC

[3] School of Population and Public Health, University of British Columbia, Vancouver, BC

***Correspondence:**

bridget.irwin@bccdc.ca

Introduction

Radon is a carcinogenic gas formed during the natural breakdown of uranium in soil and rock. Radon poses minimal risk outdoors, where it quickly dilutes (1), but it can accumulate to high levels indoors. Globally, prolonged exposure is the leading cause of lung cancer among non-smokers, contributing to over 3,000 deaths each year in Canada alone (1,2). To reduce this risk, Health Canada recommends home remediation when average indoor radon concentrations exceed 200 Bq/m^3 (3). Nevertheless, exposure to any level of indoor radon increases the risk of lung cancer (3).

Radon enters buildings through cracks and other openings, and indoor concentrations vary significantly according to the characteristics of the geography and built environment. Radon levels are highest in regions with elevated uranium levels, including northern and interior British Columbia (BC) (3). However, even within neighbourhoods of similar geology, indoor radon levels can differ between buildings because of design, age, ventilation, and maintenance (4,5). Given these factors, and because it is colourless and odourless, the only way to know if a building has elevated radon is to test for it, either using a self-

test kit or hiring a certified radon measurement professional (3). In Canada, testing and remediation are largely self-driven and hindered by a lack of awareness: only 58% of households had heard of radon in 2023, and just 12% of non-apartment households that were aware of the gas had tested for it (6).

While the health effects of radon are well-documented, assessing risk can be difficult due to variability in exposure and limited testing. Although many countries maintain national radon databases, most rely on cross-sectional survey data and are not designed to function as centralized, continuously updated surveillance repositories (7). In Canada, radon surveillance is not standardized, and the available measurement data have historically been disjointed and difficult to access, held separately by the various entities that have conducted testing. The lack of a comprehensive system has made it difficult to characterize radon exposure across the country and has hindered action and mitigation.

To address this for the Province of BC, the BC Centre for Disease Control (BCCDC) launched the BC Radon Data Repository (BCRDR) in 2021. The BCRDR and its development have been described elsewhere (8). The repository aggregates indoor radon measurements from volunteer data holders into a single system for research, risk assessment, and action. The data are cleaned and anonymized according to a data sharing agreement (DSA) and are available to researchers on request. Repository data are also displayed in the public-facing BC Radon Map, which maps summary statistics at different geographies. As of July 2025, the BCRDR contained 45,060 total measurements from over 23,000 presumed unique buildings.

As the first of its kind in Canada, the BCRDR represents an important advancement in radon surveillance. However, there is an opportunity to further improve the function and utility of the repository, particularly as calls grow for a similar, national level radon surveillance system. This study evaluates the experiences of those who contribute to and use the BCRDR. The objectives were to 1) understand the acceptability of the BCRDR from the perspective of data contributors; and 2) describe how stakeholders use the BCRDR and identify areas for improvement. The findings will inform enhancements to the existing provincial repository and may guide the development of radon data repositories in other jurisdictions, both in Canada and internationally.

Methods

Study design

To formally evaluate the BCRDR, this qualitative study adapted methods from the European Centre for Disease Prevention and Control's *Data quality monitoring and surveillance system evaluation* handbook (9) and the United States Centers for Disease Control and Prevention's *Updated Guidelines for Evaluating Public Health Surveillance Systems* (10). Informed by the study objectives, two surveillance system performance attributes were addressed: acceptability and usefulness. A summary of these attributes is presented in **Table 1**.

Study participants

Three relevant stakeholder groups were identified:

1. Radon data holders, including all individuals and organizations collecting indoor radon data in BC, regardless of whether they contribute these data to the BCRDR

2. British Columbia Radon Data Repository users, including researchers and public health practitioners who use the BCRDR data tables/BC Radon Map in their work

3. Members of the public, who access the BC Radon Map

Categories were not mutually exclusive, and several contributors were also users of the BCRDR.

Data collection

To inform the evaluation, three web-based surveys were developed using Checkbox (summarized in **Table 2** and presented in **Appendix**, **Supplemental material**), each tailored

Table 1: Attributes assessed in the British Columbia Radon Data Repository surveillance system evaluation

Attribute	Definition in the context of the BCRDR	Methods	Analysis/synthesis
Acceptability	The willingness of radon data providers to participate in the BCRDR surveillance system, now and in the future.	Survey of data holders	Qualitative thematic content analysis of open-text survey fields
		Semi-structured interviews with data holders	Qualitative thematic content analysis of interview transcriptions
Usefulness	The usefulness of the BCRDR and the associated British Columbia Radon Map for informing public health action and contributing to the prevention and control of adverse health outcomes related to radon exposure.	Survey of data users	Qualitative thematic content analysis of open-text survey fields
		Semi-structured interviews with data users	Qualitative thematic content analysis of interview transcriptions
		Public web survey	Qualitative thematic content analysis of open-text survey fields

Abbreviation: BCRDR, British Columbia Radon Data Repository

Table 2: Summary of the surveys used to assess the acceptability and usefulness of the British Columbia Radon Data Repository

Audience	Description	Date	Distribution	Responses
Data holders	The data holders survey sought to understand the experiences of radon data holders contributing data to the BCRDR. Questions covered four domains: Background information (e.g., tests conducted per year, information collected) Acceptability of participation (e.g., concerns about participation, time and resources required to participate) Reporting and dissemination (e.g., frequency of reporting, awareness of BCRDR/BC Radon Map uses) General feedback (e.g., challenges, suggestions for improvements)	Launched May 2025. Results extracted August 7, 2025.	Distributed by email to all 41 known radon data holders from across the province, including 12 current BCRDR contributors and 29 data holders who have never participated in the repository.	Eight survey responses received, including six from current/former contributors and two from data holders who have never participated. An additional five interviews with data holders were completed, for an overall response rate of 31.7%.
Data users	The data users survey aimed to explore how the BCRDR and BC Radon Map are used in practice and to collect feedback on their functionality. Questions covered five domains: Background information (e.g., role/organization, ways of using the data) Satisfaction with the various elements of the data/map (e.g., timeliness, accessibility, ease of interpretation) Usefulness of the data/map (e.g., changes to policy/practice resulting from the data/map, elements/variables missing) Acceptability of using the data/map to inform work (e.g., comfort level, concerns) General feedback (e.g., challenges, suggestions for improvement)	Launched May 2025. Results extracted August 7, 2025.	Distributed by email to stakeholders at 17 organizations believed to be using the data, including local and provincial public health and the ministries of health, housing, and education.	Four responses received, including two from users of the map, one from a user of the data tables, and one from a user of both the map and tables. An additional six interviews with data users from five organizations were completed, for an overall response rate of 52.9%.
Public	The public web survey was intended to gather feedback from the general public on the BC Radon Map, specifically on its usefulness for assessing risk. Questions covered four domains: Background information (e.g., role, age, FSA of residence) Radon knowledge before and after using the map (e.g., of health risks, of spatial distribution) Usefulness of the map (e.g., usefulness for assessing risk, functionality of the map, intended actions) General feedback (e.g., challenges, suggestions for improvements) A chance to win a $100 gift card was offered as an incentive to encourage participation	Launched on the BC Radon Map webpage November 2024 (to coincide with Radon Action Month). Remained active until April 2025. Results extracted April 22, 2025.	Link to survey was displayed at the top of the map to capture general users.	Seventy-four responses received.

Abbreviations: BC, British Columbia; BCRDR, British Columbia Radon Data Repository; FSA, Forward Sortation Area

to a different stakeholder group. The data holders survey assessed experiences contributing to the BCRDR and was distributed to all 41 known radon data holders across the province between May and August 2025. The data users survey examined how the BCRDR and BC Radon Map are used in practice and was distributed between May and August 2025 to stakeholders at 17 relevant organizations, including local and provincial public health and provincial ministries of health, housing, and education. The public survey gathered feedback from users of the BC Radon Map on its usefulness for increasing knowledge and assessing risk. It was promoted on the map website between November 2024 and April 2025, and participants could enter a draw for a $100 gift card as an incentive. All surveys were pilot tested prior to launch.

To supplement the information collected from the surveys, interviews were also conducted with a subset of key informants, prioritizing the data holders who contribute the most measurements and the users who formally requested BCRDR data. Interviews lasted 30–90 minutes in duration and took place virtually via Microsoft Teams or Zoom using a semi-structed interview guide (Appendix, Supplemental material). Interview questions were adapted from the surveys and were open-ended, designed to elicit more detailed feedback. With the permission of the interviewees, all interviews were recorded and transcribed. This study is considered a program evaluation and was thus exempt from research ethics board approval.

Data analysis and synthesis

Guided by Braun and Clarke's framework (11), inductive thematic content analysis was used to identify key themes emerging from the survey and interview data by stakeholder group and surveillance attribute. One author conducted the primary analysis, reading interview transcripts multiple times

and noting trends, inconsistencies, and contraindications across the data. The author then coded the transcripts and generated themes using a latent approach and then discussed the codes and themes with the broader research team to ensure clarity, consensus, and consistency with the data. Finally, themes were refined and supporting quotations were selected from interviews to represent each theme.

Findings

Results are organized according to the themes derived from the qualitative analysis in relation to each surveillance attribute. Participant details are summarized in **Table 3** and **Table 4**, while recommendations based on the findings are presented in **Table 5**.

Table 3: Participant details

Participant number	Data collection type	Relationship to BCRDR
P1	Interview	Current data provider and user of the BCRDR data and BC Radon Map
P2–P4	Interview	Current data provider and user of the BC Radon Map
P5	Interview	Current data provider and user of the BCRDR data
P6, P9, P10	Interview	User of the BCRDR data
P7, P8	Survey	User of the BC Radon Map
P11, P12, P16, P17	Survey	Previous data provider
P13, P15	Survey	Data holder that has never contributed data
P14, P18	Survey	Current data provider
P19–P92	Survey	Public user of the BC Radon Map

Abbreviations: BC, British Columbia; BCRDR, British Columbia Radon Data Repository

Table 4: Participants by role/organization

Role/organization	Number of participants (n=92)
Academic institution	4 (4.3%)
Federal government	3 (3.3%)
Local government	1 (1.1%)
Member of the public	42 (45.7%)
Non-governmental radon organization	7 (7.6%)
Provincial government	1 (1.1%)
Public health practitioner	16 (17.4%)
Realtor	2 (2.2%)
Regional public health authority	4 (4.3%)
Researcher	5 (5.4%)
Other	5 (5.4%)
Prefer not to say	3 (3.3%)

Acceptability

Five current BCRDR contributors were interviewed, while an additional eight completed surveys (six current/former contributors and two data holders who have never contributed). From the coding framework, four themes relating to acceptability were generated.

Data holders were willing to participate, despite initial concerns

Most current contributors were willing to participate in the BCRDR and would choose to do so again if given the chance. While respondents recalled some initial concerns surrounding privacy and confidentiality, these were largely resolved through discussions with the BCCDC and a DSA outlining data anonymization and ownership principles. One contributor noted that "confidentiality is important to us, so we don't work with everybody, but I think between the way the data was being shared with the public and then the confidentiality agreement that we were able to sign with BCCDC, we were good to share the data to the point that we are sharing it" (P3). Among the two data holders who have never contributed, both cited privacy concerns, but were open to further discussions with the BCCDC.

Onboarding and data submission were generally straightforward

Contributors generally reported no issues onboarding to the BCRDR and praised BCCDC staff for their support, with one sharing "we had a person who [would] just tell us everything we need[ed] to know…so it was actually super easy" (P1). One contributor described an 18-month delay in signing the DSA, referring to the experience as "painful" (P2). However, they acknowledged that this occurred during the COVID-19 pandemic and was not typical. Overall, contributors appreciated the simplicity of the data submission process, with data sent in a spreadsheet via email. One disclosed that "I work with a variety of other groups with whom I need to share data, and sometimes I need to try to upload it to their portal or something, and that's a nightmare" (P3).

Participation in the British Columbia Radon Data Repository did not pose a significant burden

Time spent on repository-related activities, including extracting, cleaning, and submitting the data, was minimal, although a handful of contributors reported that it wasn't a priority for them, and so could be challenging. As one respondent put it, "finding the time to actually get those two hours, that's the hard part. But the actual labour, once I find the time to do it, is not that bad" (P5). Annual data submission was considered appropriate given the long-term nature of radon testing, and one respondent noted that "radon testing is an annual thing really…a year is about right" (P5).

Table 5: Summary of recommendations resulting from the British Columbia Radon Data Repository evaluation

Recommendation	Specific actions
Strengthen trust, reciprocity, and engagement with data holders to maximize the acceptability of participation in the BCRDR	• Continue emphasizing the privacy protections and anonymization processes outlined in the data sharing agreement during recruitment. • Follow up with non-contributing data holders to address outstanding concerns. • Improve reciprocity by providing periodic updates to contributors on how the BCRDR data are being used.
Maintain the current low-burden data submission process to ensure participation in the BCRDR is easy for contributors	• Maintain the simple spreadsheet-based data submission process and the current annual submission frequency, which aligns well with radon testing cycles. • Continue to provide onboarding guidance and support for new contributors. • Review internal processes related to data sharing agreements to minimize onboarding delays. • Where feasible, provide minor support to further reduce workload (e.g., templates, gentle reminders during data submission periods).
Enhance awareness of the BCRDR and BC Radon Map to encourage usefulness	• Continue to promote the BCRDR and BC Radon Map as a trusted, authoritative public resource. • Strengthen outreach to ensure the existence and availability of the BCRDR and BC Radon Map are widely known.
Improve the clarity, interpretation, and risk communication of the BC Radon Map for lay audiences	• Continue to refine the messaging on the BC Radon Map to emphasize that all homes should be tested regardless of map colour. • Add clearer explanations and caveats about the limitations of radon mapping. • Develop a short tutorial embedded directly in the map to explain the various features and functions. • Add clearer action-oriented messaging to the map (e.g., "you should test your home regardless of the map result"). • Add plain-language definitions of the map indicators (e.g., 95th percentile, different geographic levels).
Increase the transparency and usefulness of the BCRDR and BC Radon Map through increased context and granularity	• Improve transparency around sample sizes and uncertainty (e.g., warnings when data are sparse). • Encourage more data collection in under-tested regions to improve the spatial resolution of the data. • Explore opportunities to incorporate additional variables, contextual information, and filters wherever possible (e.g., filters for building type, mitigation system, integration of non-residential testing data, information on geology, lung cancer rates, local testing resources, etc. in the map pop-up boxes).

Abbreviations: BC, British Columbia; BCRDR, British Columbia Radon Data Repository

Perceived value of contributions was mixed

Knowledge of how BCRDR data are being used in practice varied among contributors. While all were aware of the BC Radon Map, there was more uncertainty surrounding the data tables, and many did not know the specifics of their usage, leading them to question the value of their participation. One provider commented "I can see it being a problem if nobody's requesting it…what are we holding this for?" (P1). Some contributors expressed that receiving results and deliverables from the BCRDR may increase their motivation to share, with one stating that "it would be nice to know…if I knew that something was happening with [the data], it might help" (P2). Others were less concerned about the uses of the data, and one explained "I have my own data…I'm not generally looking for other [data]" (P3).

Results

Usefulness

Six users of the BCRDR data tables and/or BC Radon Map were interviewed and 78 surveys were received (four from professional users of the BCRDR data tables/BC Radon Map and 74 from members of the public). From the coding framework, six themes relating to usefulness were generated.

The British Columbia Radon Data Repository data and British Columbia Radon Map supported diverse uses

British Columbia Radon Data Repository users mainly used the data tables for research, while the map supported a broader range of purposes, such as identifying under-tested areas, informing interventions, and driving policy changes. Indeed, many stakeholders felt that the BCRDR had contributed to recent BC building code amendments, which require all new builds to install radon rough-ins, with one affirming that "the work done through this map…has enabled the BC building code to…no longer have different zones" (P2). Users also described the map as a trusted source to point to when engaging with communities and external partners. As one user said, "the fact that it's from the BCCDC, it is a powerful tool" (P4).

While all stakeholders found the BCRDR useful, opinions on its importance varied. Some described having a single source of data for the whole province as essential, whereas others saw it as more supplementary, noting that "it's interesting [but] I wouldn't

say it plays a pivotal role" (P3). Among public users, feedback was overwhelmingly positive and 90% of respondents rated the map as very useful for assessing their likelihood of living in a high radon home. Most reported increased knowledge of the health effects (70.3%) and spatial distribution (87.8%) of radon after viewing the map, and more than half intended to get their home tested.

Some users had concerns about radon mapping

Most users felt comfortable using the BC Radon Map in their work, with one stating that "it's a very robust radon map by global standards now" (P1). Despite this, many noted the limitations of radon mapping in general, such as masking local variation and oversimplifying risk. As one user observed, "peoples' tendency seems to be look at a map, see 'oh, it's not that bad in my region, therefore I don't need to test', when the reality of radon is even if a very small number of homes in your region have elevated radon, there's no way of telling if you're one of them" (P3). Differences in radon exposure likelihood by building type were also downplayed in the map, with users noting "if [a person] lives in a 17-story apartment building… they probably have negligible risk. If [a] person [is] in a single-family detached house…their risk is an order of magnitude higher, but they look at the same map and it's [low risk] for both of them" (P5). Users acknowledged the BCCDC's efforts to mitigate these issues and felt the map had addressed them to the extent possible through design choices (e.g., colours) and messaging.

Interpretation could be challenging for lay users

Professional users of the BC Radon Map found it easy to interpret after an initial learning period, but many felt it could confuse lay users. One user remarked that "I've heard [BCCDC staff] explain some of the…different ways you could display the data, and I thought, 'oh, that's really interesting, but I don't think your average person is going to interpret it that way'" (P3). Public feedback confirmed this, and several respondents were unsure whether they should test their homes for radon based on the information in the map. For example, one respondent who lived in an area with very few homes above the threshold felt that the map offered little practical value since the recommendation was to test regardless. Users from all groups suggested that a tutorial be developed and incorporated directly into the map.

Granularity was insufficient for some users

Opinions on the granularity of the data varied by user location, with those in regions with smaller sample sizes reporting limited utility. Several users noted that it's hard to make a generalized statement to assess risk and public respondents, in particular, requested finer geographic detail beyond municipalities (the smallest level currently available).

Additional information would enhance usefulness

British Columbia Radon Data Repository users of all types expressed a desire for additional information, such as more filters and contextual data. Although data holders rarely collect these details at present, which makes implementation difficult in practice, suggested future additions, if the data become available, include filters for dwelling type, presence or absence of a radon mitigation system, and whether the test occurred before or after remediation. One user remarked that "if you had data showing people with rough ins…or conversely, people who've had full mitigation by a certified mitigator…that would be awesome" (P1). Users also requested that measurements from workplaces, schools, and daycares be included on the map to increase the number of data points. They also asked for additional contextual information in the pop-up box when a region of the map is selected, such as geologic radon concentrations, lung cancer rates, and local testing resources.

Discussion

This evaluation examined the acceptability and usefulness of the BCRDR, two attributes critical to surveillance system sustainability and impact (8,9). To the authors' knowledge, this study is the first formal evaluation of an integrated radon surveillance database to date.

Overall, respondents viewed the repository positively but identified some opportunities for improvement. Acceptability was high among data providers, who described onboarding and data submission as quick and easy, requiring minimal additional time or resources. Concerns about privacy and confidentiality, while pervasive, were largely resolved through the DSA, and no other major challenges were reported. Some providers requested greater reciprocity, however, noting that they rarely received feedback on how their data are used. This created some uncertainty about the value of continued participation, and enhanced communication may therefore improve motivation and strengthen trust between data providers and the BCCDC.

Usefulness was also rated highly, and respondents from different stakeholder groups used the BCRDR for diverse applications, such as assessing the likelihood of living in a high radon home, guiding research, and informing program planning and policy. While most users found the information valuable, some areas for improvement emerged, largely centred around the BC Radon Map. Interpretation was identified as a challenge for lay users in particular, and the potential harms of misinterpretation, a concern frequently raised in radon mapping literature (12), were highlighted. Many users identified the inclusion of additional data as key in reducing misinterpretation, as well as in improving the overall utility of the BCRDR, and called for contextual information (e.g., geologic features, lung cancer rates), measurements from non-residential buildings (e.g., daycares, workplaces) and expanded data filters (e.g., dwelling type, mitigation status), along with a map tutorial.

The themes identified in this evaluation can be used both to improve BC's existing provincial radon surveillance system

and to guide the development of similar systems, ensuring that acceptability and usefulness remain central to their design. Specifically, the findings underscore the importance of a streamlined data submission process to minimize the burden of reporting on contributors, as well as the need for transparent data governance principles and open and ongoing communication. They also highlight the value of incorporating other relevant information wherever possible to maximize usefulness across stakeholder groups, and the need to design maps and other data products with a lay audience in mind, with priority given to simplicity and ease of interpretation to reduce the risk of misinterpretation. Such lessons will be particularly important as the BCCDC continues to support other provinces and territories across Canada in aggregating and mapping their own radon data holdings, with the goal of eventually creating an integrated national repository based on the BCRDR. They may also inform the enhancement of international radon surveillance programs, many of which have highlighted similar challenges related to data integration, accessibility, and usability (13–16).

Limitations

This study had a few limitations. First, response rates were low among both radon data holders (31.7%) and users (52.9%), resulting in potential bias. Indeed, respondents who provided feedback may have been more engaged with the BCRDR than those who did not, and more likely to view it favourably as a result. This is particularly important when assessing the acceptability of the surveillance system, as limited feedback was received from data holders not currently contributing to the repository, who may hold systematically different perspectives. Similarly, the public survey recruited participants directly through the map website and therefore likely over-represents individuals who are already aware of radon and its health risks compared to the general population. The findings may therefore overestimate the acceptability and perceived usefulness of the BCRDR.

Conclusion

The BCRDR is generally acceptable and useful to stakeholders. Insights from this evaluation can guide enhancements to the provincial system and inform future national-level radon surveillance, both in Canada and abroad.

Authors' statement

BI — Conceptualization, methodology, investigation, formal analysis, writing–original draft
DM — Conceptualization, methodology, supervision, writing–review & editing
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Competing interests

None.

ORCID numbers

Bridget Irwin — 0000-0002-5932-1891
David McVea — 0000-0003-4019-130X

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Appendix

Supplemental material is available upon request to the author: bridget.irwin@bccdc.ca

Wastewater surveillance as an early warning indicator for norovirus: Validating wastewater signals against clinical indicators in British Columbia, Canada, 2021–2025

Bridget Irwin[1,2]*, Natalie Prystajecky[2,3], Mayank Singal[2,4], Sharon Relova[2], Anya Smith[2], David McVea[2,4]

Abstract

Background: Norovirus is the leading cause of acute gastroenteritis globally and causes significant morbidity. Despite this, norovirus is not reportable to the public health system in most jurisdictions, making it challenging to detect and control local transmission. Wastewater-based epidemiology is a potential tool for narrowing this gap, allowing for non-invasive, population-level surveillance.

Objective: In this study, it assess wastewater-based epidemiology as a surveillance tool for monitoring norovirus in British Columbia, Canada, by comparing norovirus wastewater signals to norovirus-related hospital admissions and genogroup I (GI)-related emergency department (ED) visits.

Methods: More than six thousand (n=6,167) wastewater samples from 12 municipal treatment plants were collected between January 10, 2021–September 27, 2025 and pooled to generate a population-weighted average for the province. Norovirus hospital admissions and GI-related ED visits were extracted for the same period from the Discharge Abstract Database and the National Ambulatory Care Reporting System, respectively, and were compared with wastewater signals using time-lagged cross-correlation analyses.

Results: Time-lagged cross-correlation analyses indicate significant positive correlation overall between unadjusted norovirus wastewater concentrations and norovirus hospitalizations (Spearman's ρ=0.69, $p<0.01$) and GI-related ED visits (Spearman's ρ=0.84, $p<0.01$), with wastewater leading hospitalizations by two weeks (Spearman's ρ=0.71) and aligned with ED visits (Spearman's ρ=0.83).

Conclusion: The findings support the validity of using wastewater-based epidemiology for monitoring norovirus at the population-level and suggest that it may provide an early warning signal for severe norovirus activity requiring hospitalization, prompting a more timely response.

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Keywords: norovirus, gastrointestinal illness, wastewater surveillance, wastewater-based epidemiological monitoring, public health surveillance, validation study, early-warning indicator

Affiliations

[1] Canadian Field Epidemiology Program, Centre for Emergency Preparedness, Public Health Agency of Canada, Ottawa, ON

[2] British Columbia Centre for Disease Control, Vancouver, BC

[3] Department of Pathology and Laboratory Medicine, University of British Columbia, Vancouver, BC

[4] School of Population and Public Health, University of British Columbia, Vancouver, BC

***Correspondence:**
bridget.irwin@bccdc.ca

Introduction

Norovirus is the leading cause of acute gastroenteritis worldwide and causes significant illness (1,2), estimated at over 677 million cases globally per year (1,2), including over three million in Canada (3). Spread through fecal-oral or vomit-oral routes, norovirus presents with rapid onset of nausea, vomiting and diarrhea and is highly infectious, with fewer than 100 viral

particles required to cause illness (4). This low infectious dose, combined with extended and asymptomatic viral shedding, short-lived immunity and strong environmental persistence, results in efficient transmission and frequent outbreaks (4).

While most norovirus cases resolve within one to two days with supportive treatment, young children, the elderly and people with medical co-morbidities may develop complications resulting in hospitalization or death (4,5). Globally, norovirus is estimated to cause over 200,000 deaths and to cost $60.3 billion USD each year (over $80 billion CAD) due to healthcare costs and productivity losses (2,6). In Canada, hospitalization costs are estimated to exceed $21 million CAD (7).

Despite its health and economic impacts, norovirus is not considered a disease of public health significance in most jurisdictions, including in British Columbia (BC), Canada, where reporting is only required for facility-based outbreaks and laboratory confirmation is not mandatory. Although the national incidence of laboratory confirmed norovirus cases is collected and reported weekly by the National Enteric Surveillance Program, a 2014 to 2015 study found that just 14.5% of Canadians experiencing acute gastroenteritis sought medical care, and only 12.5% of those were ordered to undergo diagnostic testing (8). This low rate of health care seeking and testing means that the disease is systematically underrepresented in surveillance databases and its true burden is difficult to assess.

Wastewater-based epidemiology (WBE) gained prominence during the COVID-19 pandemic as a valuable public health surveillance tool, particularly in situations where clinical testing is limited. Wastewater-based epidemiology involves extracting viral information from fecal matter and offers several benefits over traditional surveillance, including that it provides a non-invasive, population level estimate of disease prevalence (9–12) and that it captures both symptomatic and asymptomatic infections (11,13). Wastewater-based epidemiology may also have economic benefits and has been shown to be more cost-effective than clinical surveillance in some settings, particularly those with high disease severity, minimal routine clinical surveillance and high intervention effectiveness (11,14,15). Furthermore, there is evidence to suggest that WBE can detect some viruses prior to symptom onset. This may allow it to be used to predict disease activity in the community and guide interventions, though the extent of this lead time varies across temporal and geographic contexts (10,11,13,16,17).

Given its success for COVID-19, WBE is increasingly being adapted to monitor other pathogens such as norovirus. Indeed, WBE has the potential to improve norovirus surveillance by allowing for routine monitoring of the burden of illness and temporal trends in the community, as well as providing valuable information on the emergence of new outbreaks and variants of the disease. Such information can guide public health actions to reduce transmission and may also provide an early warning to healthcare facilities, supporting preparedness efforts and the implementation of preventative measures.

Wastewater-based epidemiology for norovirus has been explored globally (18–29) and several studies have found that wastewater signals correlate relatively well with both outbreak counts (18,29–31) and individual case counts (21,23,31,32); however, few researchers have investigated long term trends in these relationships and little work has been done to explore WBE as an early warning indicator. Given these gaps and building on previous work, this study seeks to evaluate WBE as a tool for monitoring severe norovirus in BC by assessing correlation between norovirus concentrations in wastewater and clinical indicators over a multi-year period.

Methods

Wastewater sample collection and processing

Between January 10, 2021 and September 27, 2025, influent wastewater samples were collected one to five times per week from 12 predominantly urban wastewater treatment plants (WWTPs) across BC. Combined, these facilities treat the waste of approximately 57% of the population (3.2 million people), including the majority of Metro Vancouver. At each treatment plant, 24-hour composite samples were collected using autosamplers and one litre of coarsely screened raw influent was extracted. Samples were refrigerated prior to shipping and were transported in coolers on ice to the BC Centre for Disease Control laboratory within 48 hours of collection for immediate processing. Wastewater processing methods are described in full in **Appendix**, **Supplemental material**. Briefly, samples were homogenized and concentrated by centrifugal filtration before being subjected to automated RNA extraction. Extracted ribonucleic acid (RNA) was tested for the presence of genogroup I (GI) and genogroup II (GII) norovirus using multiplex real-time quantitative polymerase chain reaction (RT-qPCR), with a spiked in synthetic DNA used as an inhibition control. A standard curve generated with synthetic DNA was used to quantify norovirus in the samples. Assays demonstrated high linearity with a lower limit of detection of cycle threshold (CT) 35, and viral concentrations were calculated as genome copies per millilitre of wastewater using RT-qPCR results and sample-specific conversion factors.

Clinical data

Hospitalization data for BC residents were extracted from the Discharge Abstract Database (DAD) for the time period, January 10, 2021 to September 27, 2025. All 81 acute care facilities in BC must report to the DAD, which captures up to 25 diagnoses per admission using International Classification of Diseases, 10th revision, Canada (ICD-10-CA) codes (33). Cases were included in this study if a diagnosis of acute gastroenteropathy due to norovirus (ICD-10-CA code A08.1)

was recorded in any position. Emergency department (ED) visit data for BC residents were extracted for the 30 BC EDs included in the National Ambulatory Care Reporting System (NACRS) during the same time period. The NACRS includes data on approximately 76.4% of all provincial ED visits and captures up to three complaints per visit using Canadian Emergency Department Information System (CEDIS) codes (34). Cases were included in this study if a presenting complaint of diarrhea (CEDIS code 254) or nausea and/or vomiting (CEDIS code 257) was recorded in any position.

Statistical analyses

Statistical analyses and data visualizations were performed using R Studio version 2023.06.1 (35). For ease of comparison, clinical and wastewater data were down sampled to a single measurement for each epidemiological week of the study to create an evenly spaced dataset with 246 observations. For hospitalizations and ED visits, cases were summed per epidemiological week of presentation. For the wastewater samples, viral concentrations of GI and GII were summed to determine the overall norovirus load and the resulting values were normalized by the WWTP's daily flow rate to adjust for variation in day-to-day wastewater volume using the following formula:

virus copies per litre × flow in litres per day = virus copies per day

Weekly weighted average norovirus concentrations were then calculated to account for WWTPs serving different percentages of the population and sampling occurring at different frequencies, as described in Appendix, Supplemental material.

The data were not normally distributed, so non-parametric measures of analysis were used. First, crude correlation between norovirus wastewater concentrations and clinical indicators was assessed using Spearman's rho coefficient (ρ) (36). Next, time lagged cross-correlations were calculated to determine at what shift peak synchrony occurred between the wastewater concentrations and the clinical indicators. Positive time lagged cross-correlation lag times indicated that wastewater signals preceded the clinical indicators, while negative lag times indicated that wastewater signals lagged the clinical indicators (37,38). Time lagged cross-correlations were generated using the ccf_boot function in the R package "funtimes" (37), which accounts for potential autocorrelation in wastewater concentrations and clinical indicators by repeatedly resampling the data to ensure the results are reliable (37,39). All analyses were performed both on the unadjusted wastewater data and on wastewater data normalized for flow. Locally estimated scatterplot smoothing with a span of 0.02 was applied to both the wastewater and clinical timeseries data to reduce short-term noise while preserving overall trends.

Results

A total of 6,167 influent wastewater samples were collected over the study period, of which 94.3% were positive for norovirus GI and 99.9% were positive for norovirus GII. During the same period, there were 1,252 hospital admissions related to norovirus (ranging from 0–24 admissions per week), where norovirus was the most responsible diagnosis for 46.3% (median position=2; interquartile range [IQR]: 3) and 237,365 ED visits related to GI symptoms (ranging from 595–1,502 visits per week), where diarrhea or nausea/vomiting was the primary presenting complaint for 93.4% (median position=1; IQR: 0). The ages of the individuals admitted to hospital and presenting to the ED are summarized in **Table 1**. Hospitalizations were a mean of 63.04 years (± 27.36), while ED visits were a mean of 35.98 years (± 27.38).

Table 1: Age characteristics of norovirus-related hospital admissions and gastrointestinal-related emergency department visits in British Columbia, 2021–2025

Age group (years)	Hospital admissions n (%)	Emergency department visits n (%)
0–4	61 (4.87%)	42,329 (17.83%)
5–11	49 (3.91%)	20,390 (8.59%)
12–18	34 (2.72%)	11,800 (4.97%)
19–29	45 (3.59%)	36,014 (15.17%)
30–39	70 (5.59%)	29,320 (8.59%)
40–49	51 (4.07%)	19,827 (8.35%)
50–59	88 (7.03%)	19,545 (8.23%)
60–69	177 (14.14%)	21,005 (8.85%)
70–79	233 (18.61%)	19,276 (8.12%)
80 and older	421 (33.63%)	17,840 (7.52%)
Unknown	23 (1.84%)	19 (0.01%)
Total	1,252	237,365

Overall, trends in norovirus wastewater mirrored hospitalizations and ED visits, with wastewater and clinical indicators highest in the winter and spring each year and lowest in the summer and fall for both unadjusted (**Figure 1**, **Figure 2**) and flow-normalized (Figure 1, Figure 2) wastewater. Crude correlation analyses showed moderate-strong positive correlation between norovirus concentrations and hospitalizations (Spearman's ρ=0.69; $p<0.001$) and ED visits (Spearman's ρ=0.84; $p<0.001$), and these findings held when wastewater was normalized for flow (hospitalizations: Spearman's ρ=0.62; $p<0.001$; ED visits: Spearman's ρ=0.76; $p<0.001$).

Figure 1: Weekly norovirus hospital admissions and norovirus wastewater concentrations in British Columbia, 2021–2025

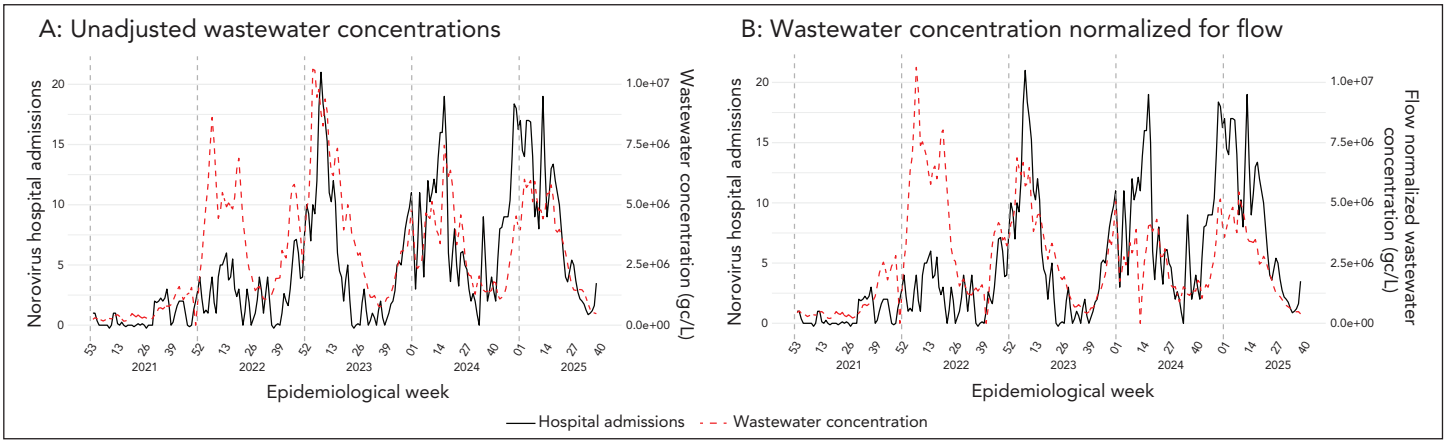
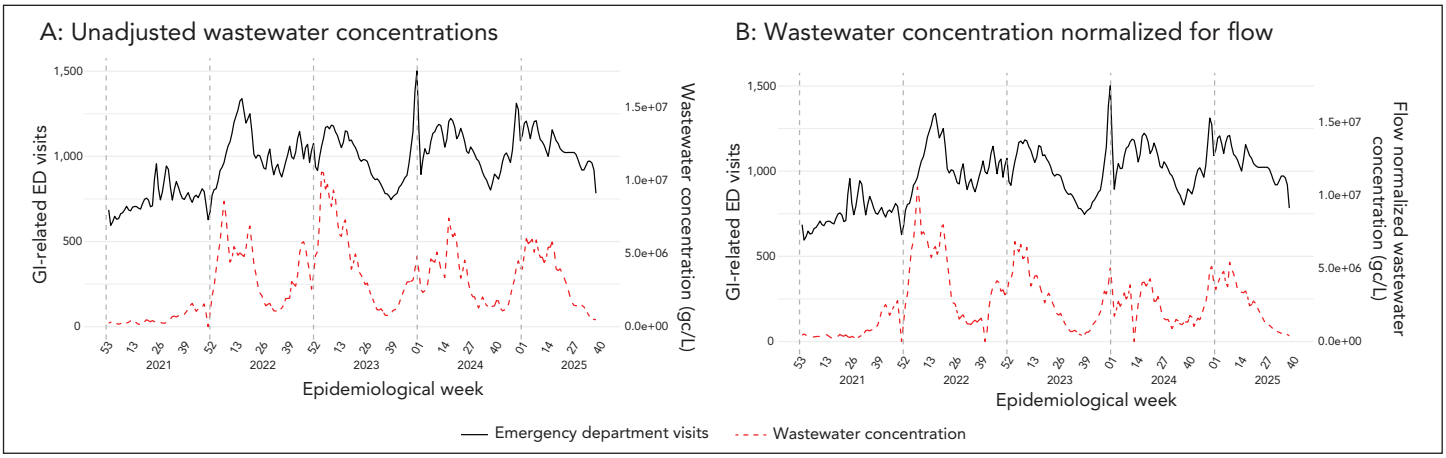


Figure 2: Weekly gastrointestinal-related emergency department visits and norovirus wastewater concentrations in British Columbia, 2021–2025



Abbreviations: ED, emergency department; GI, genogroup I

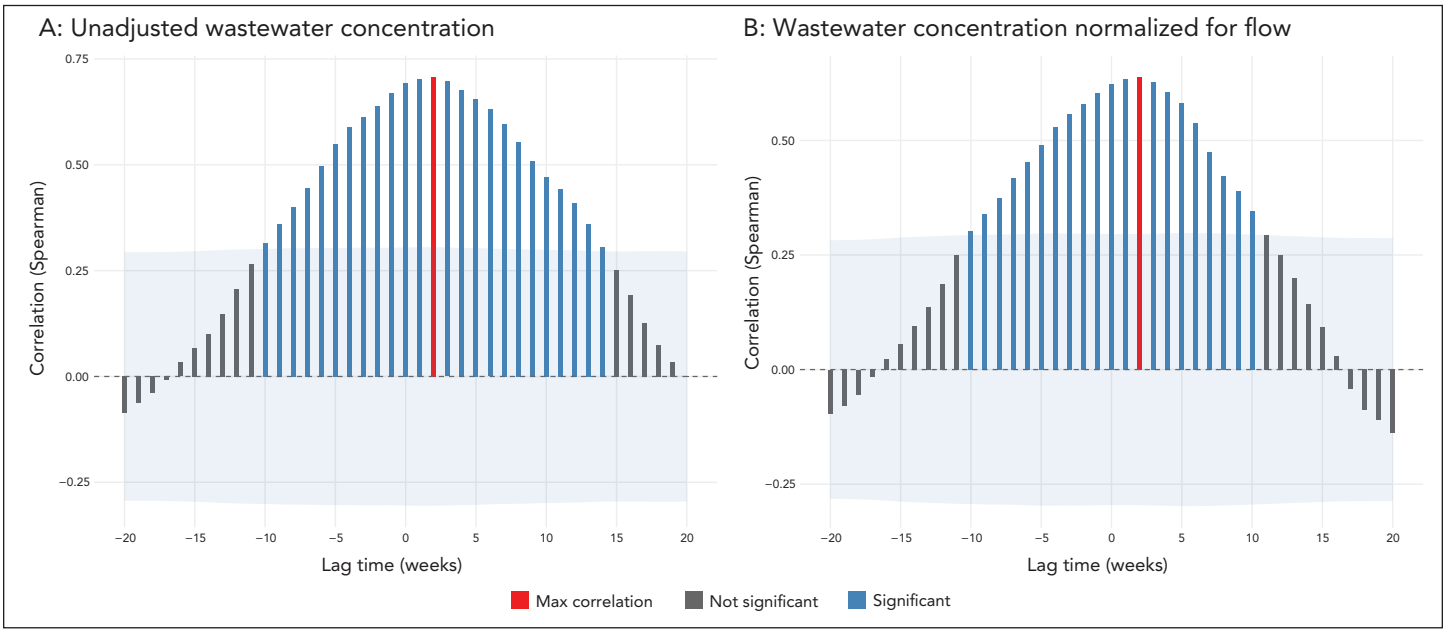
Time lagged cross-correlation analyses were performed to assess the temporal relationships between wastewater concentrations and hospitalizations (**Figure 3**) and ED visits (**Figure 4**). The strongest correlation between the wastewater signal and hospital admissions occurred when wastewater preceded admissions by two weeks (unadjusted wastewater: peak synchrony=2, Spearman's ρ=0.71; flow-normalized wastewater: peak synchrony=2, Spearman's ρ=0.64). The strongest correlation between the wastewater signal and ED visits occurred when the signals were not shifted (unadjusted wastewater: peak synchrony=0, Spearman's ρ=0.83), or when wastewater lagged ED visits by one week (adjusted wastewater: peak synchrony=−1, Spearman's ρ=0.76).

Discussion

This study evaluated the validity of WBE as a surveillance tool for monitoring norovirus in BC by comparing wastewater concentrations to hospital admissions and ED visits over a 4.75-year period. While clinical indicators underestimate true disease burden and are an imperfect comparator, wastewater signals correlate with well with both hospital admissions and ED visits. This indicates that norovirus levels in wastewater reflect real-world illness trends and may serve as a valid proxy for disease incidence where individual cases are not reportable. This is consistent with the findings of previous research and adds to the evidence supporting the use of WBE for norovirus surveillance (18–32).

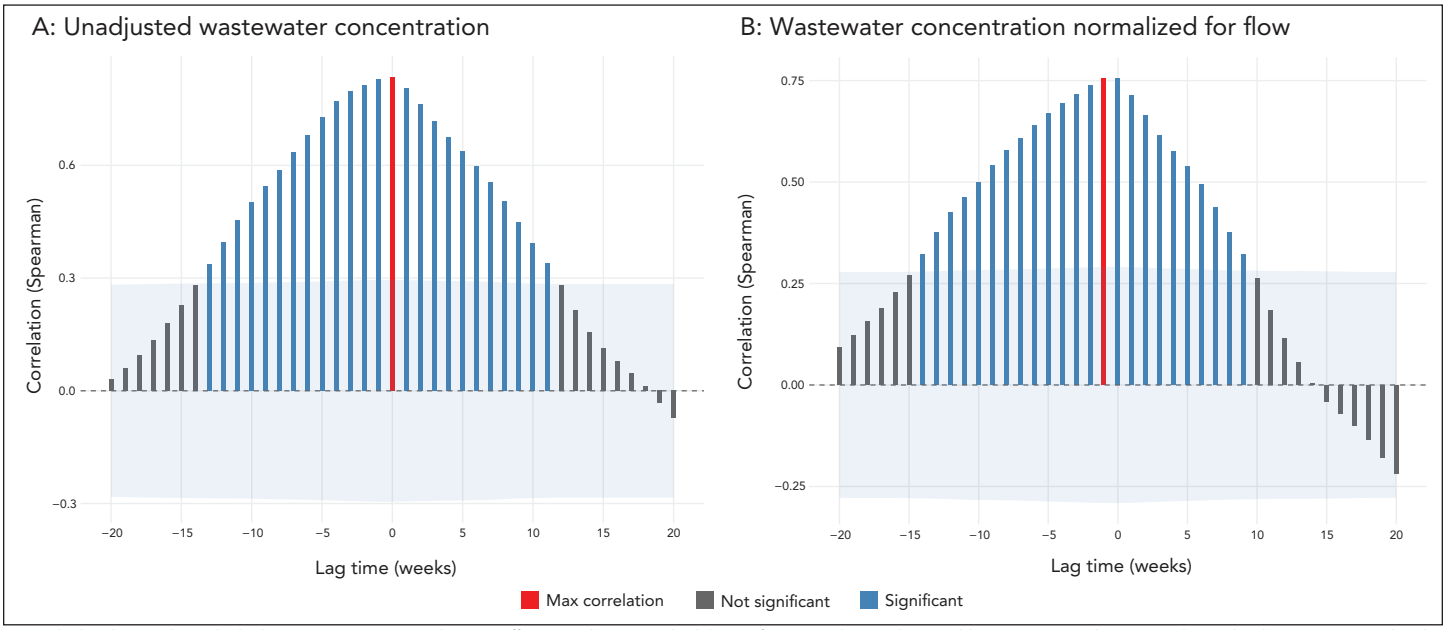
Time lagged cross-correlations showed that increases in wastewater signals preceded increases in norovirus-related hospital admissions by approximately two weeks, suggesting that wastewater may provide an early warning of severe norovirus disease. This may afford healthcare facilities critical lead time to consider resource allocation and implement strategies to prevent further transmission, such as enhanced screening and cleaning protocols. Conversely, the highest correlation between wastewater signals and ED visits occurred when neither was shifted (unadjusted wastewater) or when ED visits preceded wastewater by one week, indicating that both occur around the same time, with wastewater signals potentially lagging ED visits.

Figure 3: Bootstrapped time-lagged cross correlation between norovirus hospital admissions and norovirus wastewater concentrations in British Columbia, 2021–2025



Note: The lag that produces the highest Spearman's R (correlation coefficient) is shown in red, while significant correlations shown in blue. Bootstrapped cross-correlation distributions generated under the null hypothesis of no association are represented by the shaded grey area

Figure 4: Bootstrapped time-lagged cross correlation between gastrointestinal-related emergency department visits and norovirus wastewater concentrations in British Columbia, 2021–2025



Note: The lag that produces the highest Spearman's R (correlation coefficient) is shown in red, while significant correlations shown in blue. Bootstrapped cross-correlation distributions generated under the null hypothesis of no association are represented by the shaded grey area

This discrepancy may be attributable to several factors. Emergency department visits tend to capture initial healthcare seeking early in the course of illness, whereas admissions represent more severe cases with complications that develop following norovirus infection. Emergency department visits may therefore align more closely with community transmission at any given time. The use of down sampling to reduce the data to a weekly frequency may also have masked lead time within the ED visit data itself, particularly given the short incubation period of norovirus, which ranges from 12 to 72 hours (4). Indeed, norovirus shedding has been found to peak around 2–5 days after infection, suggesting that wastewater detection is likely to occur around the same time as or even after symptom onset, potentially limiting the ability of WBE to provide an early warning for this pathogen. Furthermore, the lack of observed lag between wastewater signals and ED visits versus hospitalizations

may reflect the quality of the clinical data itself, which captures GI-related illness more broadly, as opposed to norovirus specifically. Nausea, vomiting and diarrhea can have a range of etiologies, both infectious and non-infectious, and a recent study looking at children presenting to ED with GI symptoms found that only 36.5% tested positive for norovirus on a rectal swab or stool culture (40). The data had a baseline of at least 500 GI-related ED visits per week and this background noise may reduce temporal precision, making it difficult to detect a lead-lag relationship even where one truly exists.

Limitations

Our findings should be interpreted with several limitations in mind. First, the lack of gold-standard norovirus case data drove us to use hospital indicators, which are incomplete and are sensitive to changes in care-seeking behaviours. For example, the study coincided with the COVID-19 pandemic, which led to a 15% reduction in ED visits in BC (41). While GI-related visits had largely returned to baseline by mid-2021 (41), the clinical data may not provide a stable estimate of GI illness across study years. Second, norovirus-related hospital admissions were identified using ICD-10-CA diagnostic code A08.1, which captures both noroviral enteritis and small round structured virus enteritis (42). As a result, some of the hospitalizations included in this analysis may not be due to norovirus but to other, similar viruses, which may follow a different seasonal pattern. Third, the populations captured by the wastewater and clinical data sources used in this study do not always overlap. The WWTPs sampled were predominantly located in urban areas in southern BC, and the ED visit data were similarly sourced from a subset of 30 primarily urban acute care facilities. In contrast, hospital admissions data were reported by all facilities across the province. Differences in population coverage may have influenced the magnitude or timing of the observed associations. Similarly, while generally thought to provide a good approximation of community-level trends, wastewater surveillance is not able to capture fecal contributions from certain populations, such as those who use diapers. Given that norovirus commonly affects infants and young children, and that vomiting is a more prominent symptom than diarrhea in this age group (4), wastewater data may underestimate the true burden of norovirus. Finally, by aggregating data for the whole province, the analysis may have masked regional differences in the strength and direction of the association between wastewater and clinical indicators at smaller spatial resolutions. Future research should assess how the wastewater data and clinical indicators correlate sub-provincially and over different temporal periods to better understand their value in capturing and predicting local norovirus activity.

Conclusion

Like many non-reportable diseases, norovirus is highly underrepresented in existing surveillance databases and clinical indicators capture only the most severe cases that require medical intervention, providing a poor approximation of population-level burden of illness. The findings demonstrate the value of WBE, suggesting that it serves as a valid measure of disease trends and can be used to monitor norovirus activity and inform the implementation of norovirus prevention and education strategies. While its usefulness for predicting GI-related ED visits remains unclear, the results suggest WBE may also serve as an early warning indicator for severe disease requiring hospitalization, enabling health system planning and preparedness. As such, the results strengthen confidence in WBE as a strategy for reducing gaps in norovirus surveillance in BC and beyond.

Authors' statement

BI — Conceptualization, methodology, investigation, formal analysis, writing–original draft
NP — Conceptualization, methodology, investigation, writing–review & editing
MS — Conceptualization, methodology, writing–review & editing
SR — Conceptualization, methodology, writing–review & editing
AS — Conceptualization, methodology, writing–review & editing
DM — Conceptualization, methodology, supervision, writing–review & editing

Competing interests

None.

ORCID numbers

Bridget Irwin — 0000-0002-5932-1891
Natalie Prystajecky — 0000-0001-6421-7434
David McVea — 0000-0003-4019-130X

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Disclaimer

Access to data provided by the Data Stewards is subject to approval but can be requested for research projects through the Data Stewards or their designated service providers. The following data sets were used in this study: The Discharge Abstract Database (DAD) and The National Ambulatory Care Reporting System (NACRS).

All inferences, opinions, and conclusions drawn in this publication are those of the authors, and do not reflect the opinions or policies of the Data Stewards. This data was provisioned under ISP 21-051.

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Appendix

Supplemental material is available upon request to the author: bridget.irwin@bccdc.ca

EPIDEMIOLOGIC STUDY

Mixed-methods evaluation and enhancement of Peel Public Health's heat-related illness emergency department visit surveillance system, 2018–2024

Sean Colyer[1,2]*, Maureen Horn[2], Lydia Cheng[2], Jessica Deming[2], Monali Varia[2]

Abstract

Background: Climate change contributes to increased heat events, which are associated with negative health outcomes. Peel Public Health, a health unit in Ontario, has conducted emergency department (ED) visit surveillance during heat events since 2018 using Acute Care Enhanced Surveillance data.

Objective: To optimize local public health surveillance of heat-related illnesses, a mixed-methods evaluation of system usefulness and representativeness was conducted and the system was enhanced through retrospective observational analyses.

Methods: The surveillance usefulness was evaluated through semi-structured interviews with ten recipients of the surveillance product and representativeness by determining the impact of data by patient address compared to hospital address over 2018–2024. Retrospective analyses of 2018–2024 data identified associations between heat events and surveillance ED indicators. Findings informed surveillance revisions.

Results: Interviewees interpreted the original surveillance product as a high-level real-time snapshot of downstream health outcomes, useful for situational awareness and understanding of whether ED visits were increasing. Recommendations included adding key messages, thresholds/ranges and subgroup information. Representativeness evaluation showed that 27.2% of ED visits by Peel residents were at non-Peel hospitals and 14.0% of Peel hospital ED visits were by non-Peel residents. Daily counts of heat-related illnesses were significantly associated with heat event days (incidence rate ratio: 6.43, 95% confidence interval: 3.86–10.71).

Conclusion: A revised surveillance product was implemented for 2025 including standard deviations, aberration alerts adapted from preexisting criteria, ED visits based on hospital address and stratification by three subgroups (aged older than 65 years and younger than five years, and elevated heat vulnerability) to increase usefulness for situational awareness.

Affiliations

[1] Centre for Emergency Preparedness and Response, Public Health Agency of Canada, Ottawa, ON

[2] Region of Peel Public Health, Mississauga, ON

***Correspondence:**
sean.colyer@phac-aspc.gc.ca

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Keywords: heat events, heat-related illness, extreme heat, climate change, health vulnerability, public health surveillance, surveillance evaluation

Introduction

Climate change remains an escalating challenge. In Canada, temperatures have increased at roughly double the global mean rate between 1948–2016 (1). As a largely urban population subject to the urban heat island effect, Peel region (Brampton, Mississauga and Caledon) is particularly vulnerable (2). Future heat events and, consequently, related health impacts are expected (1–3).

The association between heat events and morbidities is documented; encompassing a broad range of both primary effects and secondary exacerbations (4–7). Several subgroups are at known elevated risk for heat-related illnesses (HRIs), including low education, seniors, racialized groups, outdoor workers and those in areas with limited tree cover (3,8,9). In Peel region, 7.8% of residents were low income (2020), 15.0% had no certificate/diploma/degree (2021), 68.8% were a visible minority (2021), 137,420 worked outdoors (2016) and seniors (older than 65 years of age) are estimated to make up 21% of the population by 2041 (3,8). Public health surveillance is critical to monitoring changes in heat exposure across subgroups and heat-related health outcomes.

Peel Public Health's HRI surveillance system monitors HRIs by use of the Acute Care Enhanced Surveillance (ACES) chief complaint syndromic emergency department (ED) visit data in all three Peel EDs (Brampton Civic Hospital, Credit Valley Hospital, Mississauga Hospital) across seven indicators (HRIs [environmental, "ENVIRO" syndrome plus chief complaint of heat stroke, heat syncope, or heat exhaustion]; sunburn; asthma; cardiovascular; mental health; respiratory, total ED visits) (10–13). Data were defined by patient residence address (Peel region). Plots of daily counts of the indicators are juxtaposed with temperature and air quality data (14,15). The plots and data (**Appendix**, **Supplemental material**, Figure S1) are distributed to internal Peel Public Health recipients during heat warnings. To optimize surveillance for local public health situational awareness, a mixed-methods evaluation of system usefulness and representativeness was conducted and the system was enhanced through retrospective observational analyses.

Methods

Evaluation: Usefulness

All ten surveillance product recipients, including staff who work on surveillance and in communicating notable findings to municipal partners, physicians and the general public, participated in recorded semi-structured one-on-one one-hour interviews over Microsoft Teams. This included senior leadership and analytic staff, such as an Associate Medical Officer of Health, directors and managers, specialists and epidemiologic staff working across health protection, emergency management and public health surveillance functions. The core interview questions are given in Appendix, Supplemental material, List S1. An inductive, descriptive thematic approach by a single analyst was used to analyze the interview data. No formal qualitative coding software or existing frameworks were employed.

Evaluation: Representativeness

The public located physically within Peel region is the population at risk monitored via Peel Public Health's HRI surveillance. The original surveillance restricted the ACES data by address of residence, regardless of the hospital address in Ontario; however, National Ambulatory Care Reporting System data showed that more than 20% of ED visits by Peel residents in 2023 were at non-Peel hospitals (*personal communication, March 2025*). This evaluation aimed to determine the impact of this practice. Two ACES datasets, one defined by Peel patient address and one defined by Peel hospital address (2018, when Peel started HRI surveillance, to 2024), were compared to determine the proportion of ED visits by Peel residents at non-Peel hospitals and the proportion of Peel hospital ED visits by non-Peel residents.

Enhancement: Retrospective quantitative analyses

The retrospective quantitative analyses assessed associations between heat warning days (defined as days during the heat warning (16), plus two days following) and daily ED visit counts for the surveillance indicators. For HRIs, sunburn, and dehydration, Fisher's exact tests were conducted comparing days under a heat warning (binary exposure) and days with one or more ED visits for the surveillance indicator (binary outcome). For all indicators, negative binomial regression analyses comparing days under a heat warning (binary exposure) and daily count of ED visits (continuous outcome) were conducted (without any confounder inclusions). These analyses were conducted among all ED visits at Peel hospitals from May to September (Peel's warmest months that experience heat warnings), 2018 to 2024, among the overall population and among the subgroups: older than 65 years; younger than five years; individuals living in areas with elevated heat vulnerability (residential five-digit postal code mapped to most likely census tract within quintiles 4 or 5 of Peel Public Health's Heat Vulnerability Index [HVI], highest risk) (17). Prior work developed this index using principal component analysis of adaptive capacity, sensitivity and exposure.

Enhancement: Surveillance product revision

The surveillance product revision implemented lessons learned from the above analyses. Additionally, the aim was to produce systematic alerts to ACES syndrome count aberrations as opposed to visual inspection. These alerts were conducted among all ED visits at Peel hospitals. The established ACES alert metrics were applied to the surveillance indicator ED visit daily counts among the overall population as well as three subgroups (17).

Three cumulative sum alerts were used: 1) C1: daily counts are standardized relative to mean values as z scores; C1 is the sum of z for the current day and previous seven days' counts; 2) C2: daily counts are standardized relative to mean values as z scores; C2 is the sum of z for the current day and seven days' counts ending two days prior to the current day; and 3) C3: sum of C2 from the current day and the previous two days, but only if the previous two days did not generate alerts.

Statistical Process Control (SPC) alerts (means and standard deviations [SDs] based on the preceding 14 days): 1) extreme: daily count is greater than three SDs above the mean; 2) on edge: any two of the last three days are greater than two SDs above the mean; and 3) trend: fifth day of five consecutive days of increasing counts. All analyses were conducted in Stata 18.0.

Results

Evaluation: Usefulness

All ten surveillance report recipients were interviewed and responses were organized into four themes: interpretation, actions taken, data gaps and usefulness and optimization.

Respondents thought the product was a simple, helpful, real-time snapshot of ED visits that was easy to interpret. It was seen as a sentinel, providing reassurance regarding the effectiveness of mitigation measures. Many thought the absence of thresholds or ranges made it difficult to discern aberrations and make conclusions.

The surveillance product provoked very few direct actions. Heat interventions were reported to be more anticipatory and largely already in place with the declaration of the heat warning, aimed at getting people into cool spaces.

Partners generally do not use other data sources, besides media and weather alerts, informally. The main outstanding data gap pertained to HRIs not receiving hospital care. Many recipients were mindful that certain subgroups that may be at higher risk and/or more isolated may not visit the ED (e.g., community-based seniors, newcomers, outdoor workers, underhoused).

The surveillance product was reported to be useful as a high-level communication tool for situational awareness, to ensure ED visits aren't increasing. Some recipients could not appreciate if the product was useful given its unknown consequences. Suggestions included thresholds, subgroup information, and introductory key messages.

Evaluation: Representativeness

The representativeness retrospective analysis contrasted full-year 2018–2024 datasets. Of the 2,804,724 ED visits made by Peel residents, 762,305 (27.2%) were at a non-Peel hospital; 331,133 of 2,373,552 ED visits at Peel hospitals (14.0%) were by non-Peel residents.

Enhancement: Retrospective quantitative analyses

There was a total of 60 ED visits for HRIs from May to September, 2018–2024, of which 10 (15.4%) were by individuals aged older than 65 years and four (6.7%) were for children aged younger than five years. Of the 60 ED visits, 41 (68.3%) were by Peel residents, of which 18 (43.9%) were mapped to Peel Public Health's HVI quintiles 4 or 5 (highest risk) (17). There were 1,023,873 total ED visits in this time period, of which none had missing age and 710 (0.07%) had missing postal code data (only used for the elevated heat vulnerability subgroup).

Among the overall population, 26 of the 890 days that were not part of a heat warning (2.9%) had one or more HRI ED visit, compared to 31 of the 181 heat warning days (17.1%)—a significant positive association between heat warning days and HRI ED visits (p=0.00, **Table 1**). This was also seen among individuals aged older than 65 years (0.6% vs. 2.8%, respectively, p=0.02) and individuals at elevated heat vulnerability (0.6% vs. 7.2%, p=0.00).

Among the overall population, there was a more than six-fold increase in the daily rate of HRI ED visits for heat warning days relative to days not part of a heat warning (incidence rate ratio [IRR]: 6.43, 95% confidence interval [CI]: 3.86–10.71, **Table 2**). This association was also significant among individuals aged 65+ (IRR: 4.92, 95% CI: 1.42–16.98), and individuals at elevated heat vulnerability (IRR: 12.78, 95% CI: 4.56–35.86).

There were negative associations between heat warning days and the daily rate of ED visits in the overall population for both asthma (IRR: 0.95, 95% CI: 0.91–0.99, Table 2) and respiratory (IRR: 0.94, 95% CI: 0.89–0.99) indicators. Similar, though generally non-significant, associations were seen among individuals aged 65+ and individuals at elevated heat vulnerability. These associations were stronger and significant among individuals aged younger than five (asthma: IRR: 0.68, 95% CI: 0.59–0.78; respiratory: IRR: 0.80, 95% CI: 0.71–0.91).

Enhancement: Surveillance product revision

Both CuSum and SPC alerts were calculated and examined, however only the latter were adopted. The CuSum alerts were triggered for some below-average counts as a mathematical artifact and deemed unhelpful. The SPC alerts were incorporated with amendments: in addition to the "extreme" alert with the criteria of the count being more than three SDs above the mean, an alert was incorporated with the criteria of more than two SDs above the mean (Appendix, Supplemental material, Figure S2). For these alerts, and the "on edge" alert, to smooth out anomalies the preceding 30 days (instead of 14 days) were used for means and SDs. Additional "trend" alerts were incorporated, reflecting three, four and five days of consecutive increases.

Discussion

This evaluation informed revisions to Peel's HRI surveillance by incorporating evidence-based thresholds, new indicators, expanded subgroup analyses (older adults, younger children,

Table 1: Cross tables and Fisher's exact tests between presence of a heat warning[a] and presence of one or more surveillance indicator emergency department visits, all Peel hospital emergency department visits, May–September, 2018–2024

Surveillance indicator	No heat warning, N=890 days				Heat warning[a], N=181 days				*p*-value[b]
	No ED visit		One or more ED visits		No ED visit		One or more ED visits		
Overall population									
Heat-related[c]	**864**	**97.1%**	**26**	**2.9%**	**150**	**82.9%**	**31**	**17.1%**	**0**
Sunburn	**855**	**96.1%**	**35**	**3.9%**	**167**	**92.3%**	**14**	**7.7%**	**0.03**
Dehydration[d]	816	91.7%	74	8.3%	167	92.3%	14	7.7%	0.88
Individuals aged older than 65 years									
Heat-related[c]	**885**	**99.4%**	**5**	**0.6%**	**176**	**97.2%**	**5**	**2.8%**	**0.02**
Sunburn	890	100%	0	0.0%	180	99.4%	1	0.6%	0.17
Dehydration[d]	861	96.7%	29	3.3%	177	97.8%	4	2.2%	0.64
Individuals aged younger than five years									
Heat-related[c]	888	99.8%	2	0.2%	179	98.9%	2	1.1%	0.14
Sunburn	889	99.9%	1	0.1%	181	100%	0	0.0%	1.00
Dehydration[d]	715	80.3%	175	19.7%	155	85.6%	26	14.4%	0.12
Individuals at elevated heat vulnerability[e]									
Heat-related[c]	**885**	**99.4%**	**5**	**0.6%**	**168**	**92.8%**	**13**	**7.2%**	**0**
Sunburn	875	98.3%	15	1.7%	174	96.1%	7	3.9%	0.08
Dehydration[d]	855	96.1%	35	3.9%	176	97.2%	5	2.8%	0.67

Abbreviation: ED, emergency department
[a] Heat warning days defined as days when the heat warning was in effect, plus the two days following each heat warning event
[b] Fisher's exact test used due to low counts; significant results ($p<0.05$) are bolded
[c] Heat-related illnesses defined as the environmental (ENVIRO) syndrome plus mention in the chief complaint of heat stroke, heat syncope, or heat exhaustion
[d] Dehydration ED visits defined by the "DEHY" Acute Care Enhanced Surveillance (ACES) syndrome (dehydration), where age is at least three years. This is in correspondence with ACES products
[e] Individuals at elevated heat vulnerability includes Peel residents whose home residence was mapped to quintiles 4 and 5 of Peel Public Health's Heat Vulnerability Index (i.e., highest risk)

Table 2: Negative binomial regression models (incidence rate ratios) between presence of a heat warning[a] and daily count of surveillance indicator emergency department visits, all Peel hospital emergency department visits, May–September, 2018–2024

Surveillance indicator	Overall population		Individuals aged older than 65 years		Individuals aged younger than five years		Individuals at elevated heat vulnerability[b]	
	IRR[c]	95% CI[d]	IRR[c]	95% CI[d]	IRR[c]	95% CI[d]	IRR[c]	95% CI[d]
Heat-related[e]	**6.43**	**3.86–0.71**	**4.92**	**1.42–16.98**	4.92	0.69–34.91	**12.78**	**4.56–35.86**
Sunburn	**2.13**	**1.14–3.98**	-	-	-	-	2.15	0.8–5.43
Asthma	**0.95**	**0.91–0.99**	0.95	0.90–1.003	0.68	0.59–0.78	0.95	0.90–1.006
Cardio	0.99	0.96–1.01	0.97	0.93–1.006	0.72	0.49–1.08	0.97	0.94–1.002
Mental health	0.98	0.94–1.02	0.95	0.84–1.07	0.82	0.24–2.78	0.97	0.91–1.03
Respiratory	**0.94**	**0.89–0.99**	0.95	0.87–1.04	**0.80**	**0.71–0.91**	**0.93**	**0.87–0.995**
Dehydration[f]	0.86	0.48–1.53	0.66	0.23–1.88	0.41	0.05–3.40	-	-
Headache[g]	**0.95**	**0.91–0.99**	1.00	0.92–1.09	1.01	0.58–1.76	0.98	0.92–1.04
Total ED visits	1.00	0.99–1.01	1.00	0.98–1.02	0.96	0.92–1.01	1.00	0.99–1.02

Abbreviations: CI, confidence interval; ED, emergency department; IRR, incidence rate ratio; -, not conducted due to small counts
[a] Heat warning days defined as days when the heat warning was in effect, plus the two days following each heat warning event
[b] Individuals at elevated heat vulnerability includes Peel residents whose home residence was mapped to quintiles 4 and 5 of Peel Public Health's Heat Vulnerability Index (i.e., highest risk)
[c] Incidence rate ratios from negative binomial regressions
[d] Confidence interval; significant results are bolded
[e] Heat-related illnesses defined as the environmental (ENVIRO) syndrome plus mention in the chief complaint of heat stroke, heat syncope, or heat exhaustion
[f] Dehydration ED visits defined by the "DEHY" Acute Care Enhanced Surveillance (ACES) syndrome (dehydration), where age is at least three years. This is in correspondence with ACES products
[g] Headache ED visits defined as the "HEAD" ACES syndrome (non-traumatic undifferentiated headache)

vulnerable residents) and improved representativeness and automation. Recipient consultation and retrospective analyses justified its continuation.

The main conclusions from the usefulness evaluation were the recommendations of thresholds/alerts, key message summaries and data about known subgroups with elevated risk. The ACES data fields are limited (demographic data limited to sex, age and five digits of postal code; no capture of unhoused) but remained the core data source due to its real-time nature. Subgroups for those aged 65 years and older and children younger than five years were incorporated.

Since ACES data include the first five digits of each patient's postal code, the patients were mapped to their most likely census tract and linked to Peel Public Health's established HVI quintiles, which limited the analysis to Peel residents (17). Individuals living in HVI quintiles 4 and 5 (highest risk categories) were grouped into a new "Individuals at elevated heat vulnerability" subgroup. This subgroup was inherently limited to individuals with a Peel residence. The underhoused group is excluded from this category but would now be captured more generally through the representativeness work.

The ACES ED visits to Peel hospitals were selected as they were considered more representative of people exposed to heat within Peel than data based on Peel residents seeking care at any Ontario hospital. Each approach has trade-offs: using Peel hospital visits may miss some locally-exposed residents who sought care outside the region, while using only Peel residents may include those not exposed in Peel and would exclude those without an Ontario address, such as visitors from outside the province or those who are underhoused. Focusing on Peel hospital ED visits also better reflects those who would benefit from Peel Public Health interventions. This surveillance is not intended to be a comprehensive census of all HRI cases.

The main finding of the retrospective quantitative analyses was the strong and significant positive association between heat warning days and HRI ED visits, in the overall population as well as individuals aged older than 65 years and individuals with elevated heat vulnerability. This corresponds with extant research (4–7) and justifies the continued surveillance.

The negative associations between heat warning days and the daily rate of ED visits for both asthma and respiratory surveillance indicators were reasoned to be a spurious association stemming from the analysis being limited to May to September and these indicators usually seeing their heights in the spring and fall (18). Also, individuals with these respiratory conditions may have greater health awareness during heat events.

There were few notable findings otherwise. Interviewees were not deterred by the seemingly low counts of direct HRIs or few resultant actions. They were aware that the surveillance represented a downstream outcome that was not expected to show large aberrations related to heat events; this "negative finding" was reassurance of the region's mitigation measures.

Additional revisions to the surveillance included (Appendix, Supplemental material, Figure S2): introductory orientation page, two indicators added (dehydration and headache), expansion to May to September (versus June–September), visualized SD ranges, expanded HRI definition corresponding with ACES and increased automation.

Limitations

This evaluation had several limitations. The interviews were limited by an informal methodology that did not use coding software or established qualitative framework. The ACES data are limited by chief complaint information and resultant surveillance indicator algorithmic allocation. The relatively small number of HRI ED visits observed during the evaluation period limits the sensitivity of this surveillance approach for detecting temporal trends. The ACES data also has very limited fields, precluding the ability to further categorize individuals at elevated HRI risk, including underhoused individuals. Lastly the SPC alerts incorporated into the surveillance had limited specificity, often alerting to non-concerning aberrations, however still underlining notable changes.

Conclusion

Climate change is an unremitting challenge with population health implications, requiring monitoring of changes in health impacts. Evaluation of Peel Public Health's HRI surveillance has resulted in a better-informed and more comprehensive product launched in 2025 and represents a potential example or inspiration for other jurisdictions.

Authors' statement

SC — Conceptualization, methodology, formal analysis, writing–original draft, writing–review & editing
MH — Conceptualization, writing–review & editing, supervision
LC — Writing–review & editing
JD — Conceptualization, writing–review & editing
MV — Writing–review & editing, supervision

Competing interests

The authors are employed by the Public Health Agency of Canada and Peel Public Health; however, this work was conducted as part of routine public health practice and the author(s) declare no competing interests.

ORCID numbers

Sean Colyer — 0000-0003-3238-7302
Maureen Horn — 0009-0004-8687-6077
Jessica Deming — 0009-0004-1021-0930
Monali Varia — 0000-0003-0881-0027

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Ethics

The evaluation was conducted using routinely collected public health surveillance data that were de-identified prior to access by the study team. As this work constituted a surveillance system evaluation for public health practice rather than human subjects research, Research Ethics Board approval was not required.

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Appendix

Supplemental material is available upon request to the author: sean.colyer@phac-aspc.gc.ca

Figure S1: Example of the original heat-related illness surveillance plots and data before evaluation
List S1: Core interview questions
Figure S2: Title page and first page of the revised surveillance product (report from July 21, 2025)

Developing and piloting an interactive syphilis surveillance dashboard through user-centred design: An implementation report from Interior Health, British Columbia

Temuulen Enebish[1], Barbara Gauthier[2]*, Jonathan Malo[2]

Abstract

Background: Syphilis rates have risen in Canada and British Columbia (BC), increasing the need for timely, small-area intelligence. In BC, 1,983 cases of infectious syphilis were reported in 2024, representing a rate of 34.8 cases per 100,000 population. An additional 27 cases of congenital syphilis were also confirmed. Routine quarterly reporting limits responsiveness when incidence shifts quickly.

Objective: To describe the development, implementation, and early evaluation of an interactive surveillance dashboard for syphilis in Interior Health (IH), delivering monthly indicators at the Local Health Area (LHA) level.

Methods: An internal dashboard was developed using user-centred design and iterative stakeholder engagement. The dashboard integrates case, testing, and denominator data to display monthly indicators, 12-month trends, and LHA-level patterns, with role-based access and privacy safeguards for authorized users.

Results: Perceived usefulness, simplicity, and acceptability were assessed using Likert ratings and structured feedback. In a pilot with 11 users across key IH program groups, overall impression, ease of use, usefulness, and program fit were rated 5.0/5, 4.9/5, 4.9/5, and 4.6/5 (n=8–9). Users described value for prioritizing LHAs, planning interventions, and briefing decision-makers.

Conclusion: An interactive, LHA-level dashboard was feasible within existing systems and acceptable to pilot users, with perceived improvements in timeliness and clarity. Effects on downstream public health outcomes remain to be evaluated. The approach may be transferable to similar jurisdictions.

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Keywords: syphilis, surveillance, dashboard, user-centred design, implementation science, public health informatics

Affiliations

[1] Canadian Field Epidemiology Program, Centre for Emergency Preparedness, Public Health Agency of Canada, Ottawa, ON

[2] Interior Health, Kelowna, BC

***Correspondence:**
barbara.gauthier@interiorhealth.ca

Introduction

Syphilis incidence has risen sharply in Canada and British Columbia (BC) over the past decade (1,2). Provincial rates remained below three per 100,000 throughout the early 2000s before beginning a sustained increase. Infectious syphilis cases reached 1,428 in 2021 (27.5 per 100,000), the highest in 40 years (2), and increased further to 1,983 in 2024 (34.8 per 100,000) (3). Congenital syphilis underscores the public health importance of rising transmission among females of reproductive age. In BC, female infectious syphilis cases have been strongly shaped by concurrent housing instability,

substance use, and mental illness, and maternal cases often involve recent sexually transmitted infection (STI) history and factors that may affect access to prenatal care (4). The 27 cases confirmed in BC in 2024 highlight the continuing importance of prevention, timely testing, and early antenatal diagnosis (3). Within Interior Health (IH), one of BC's five regional health authorities serving approximately 830,000 residents in the southern interior, cases increased from 54 in 2019 to 228 in 2024, representing a 278% increase in the rate over the same period (5).

Timely, small-area intelligence is essential for regional authorities to monitor transmission, identify emerging clusters, and allocate resources, yet routine quarterly and annual static products leave gaps in responsiveness. In IH, review previously relied on provincial quarterly reports supplemented by ad hoc analyst-generated tables to obtain Local Health Area (LHA) detail, limiting timely interpretation and requiring repeated data preparation. Local Health Areas are BC's standard sub-regional geography for service planning, typically containing 5,000–60,000 residents. Digital public health dashboards can support timely situational awareness, but their usefulness depends on clear indicator definitions, regular refresh cycles, and usability and governance considerations (6). Pairing testing volumes and positivity with case counts further supports targeted action beyond passive case reporting. In BC, centralized testing through the BC Centre for Disease Control (BCCDC) Public Health Laboratory provides complete testing data, an enabler not available in all jurisdictions.

Peer-reviewed descriptions of dashboard development, governance, and early-stage evaluation in Canadian regional public-health contexts remain rare. Publishing this early evaluation lets other jurisdictions learn from replicable design and governance choices before long-run effectiveness data are available. The objectives of this early evaluation were to: 1) describe the user-centred design (UCD) and governance approach used to develop the dashboard; 2) describe its implementation within IH's existing surveillance infrastructure; and 3) assess perceived usefulness, simplicity, and acceptability among primary users after the initial pilot period.

Methods

Setting and participants

The dashboard was implemented as an internal decision-support tool for IH teams involved in syphilis prevention and response: Epidemiology and Surveillance, Communicable Disease, Sexual and Reproductive Health, Medical Health Officers, and senior public health decision-makers. Outputs are provided for IH residents with infectious syphilis at the LHA level, with privacy safeguards applied throughout. Eleven primary users were purposively sampled and invited by email to participate voluntarily. Nine completed the Likert ratings, and two additional participants provided qualitative feedback without completing the questionnaire.

Dashboard development

Development followed a UCD process with end users across the program groups described above. In the discovery phase, semi-structured interviews and workflow mapping identified core use cases (e.g., routine monitoring, situational awareness, planning) and pain points (e.g., fragmented information sources, static reports, inconsistent refresh cycles). In the subsequent iterative phase, low-fidelity mock-ups, including simple wireframes and greyscale click-throughs used to test information architecture before coding, were reviewed collaboratively in short cycles. Brief usability assessments of evolving prototypes were conducted, and feedback was incorporated into successive releases. The process converged on three core view types: 1) an overview page anchored by a concise key performance indicator (KPI) tile row; 2) dedicated trend views; and 3) small-area LHA analysis views.

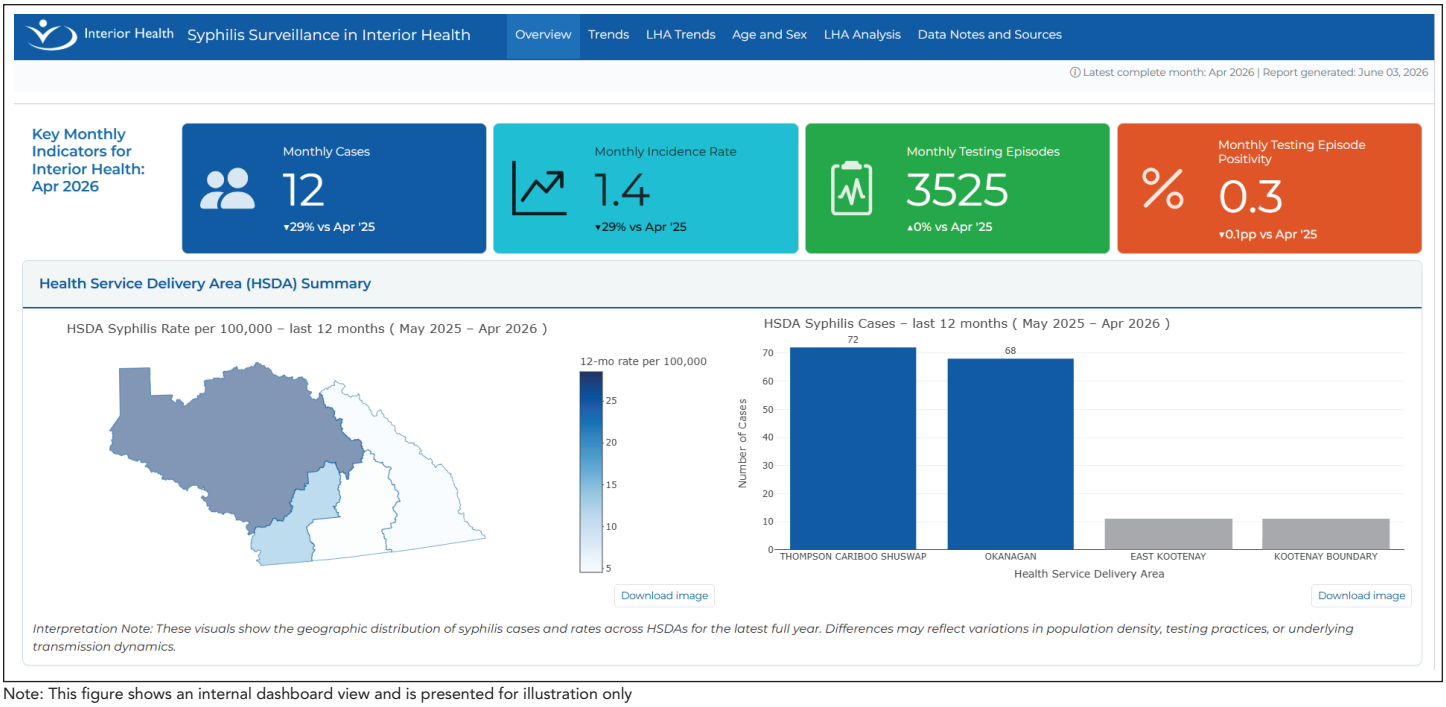
Design choices emphasized clear labels, predictable filters, and responsive performance (page load and filter responses under approximately three seconds on typical analyst laptops over the corporate network).

Implementation

The dashboard was built as an R Quarto dashboard rendered to Hypertext Markup Language (HTML), and published in a secure internal IH environment with monthly data refreshes. It integrates three data streams: the infectious syphilis case line list (stage, key event dates, geography), monthly laboratory testing volumes by LHA, age, and sex, and population denominators. Postal codes from the case line list are mapped to LHAs using the BC Stats standardized conversion file ensuring that case, testing, and denominator data align to the same boundaries and that rates and positivity are computed consistently across streams. Because of data access restrictions for sensitive STI data, surveillance data are manually extracted and curated each month with quality checks applied during refresh. The refresh currently requires approximately two hours of dedicated analyst time per month for extraction, quality assurance, and publication, performed by one epidemiologist with backup coverage.

The dashboard includes an Overview page with KPI tiles for monthly cases, incidence rate, testing episodes, and testing episode positivity plus Health Service Delivery Area (HSDA) summary visuals (**Figure 1**), alongside separate trends, LHA Trends, Age and Sex, and LHA Analysis pages. Export functions for filtered aggregates and figures support briefing work; indicator definitions and the refresh standard operating procedure are in supplementary materials (**Table 1** summarizes capabilities).

Figure 1: Dashboard overview



Note: This figure shows an internal dashboard view and is presented for illustration only

Table 1: Data sources and dashboard capabilities

Data stream	Source	Key fields	Primary dashboard use
Infectious syphilis cases	Provincial case line list (IH residents)	Stage, dates, postal code, sex, age	Official surveillance counts, incidence rates, trends
Laboratory testing	Public Health Laboratory (BCCDC)	Test counts by month, LHA, age, sex	Testing episodes, testing episode positivity
Population estimates	BC Stats	Population by LHA, age, sex	Rate denominators

Abbreviations: BC, British Columbia; BCCDC, British Columbia Centre for Disease Control; IH, Interior Health; LHA, Local Health Area

Governance framework

Governance measures prioritized privacy while maximizing operational utility. Access to the dashboard is role-based, with user agreements specifying permitted uses. Because the dashboard is restricted to authorized internal users, counts are displayed without routine small-cell suppression. However, LHA rates based on fewer than 20 cases are flagged as unstable with guidance on cautious interpretation. Maps aggregate to LHA to minimize re-identification risk. Data are drawn from authoritative internal sources within existing privacy frameworks, including the BC *Freedom of Information and Protection of Privacy Act* (FOIPPA) (7). An advisory group of epidemiology, privacy, and program representatives reviewed indicator definitions, refresh cadence, rate-stability guidance, and release practices, providing lightweight change control. Accessibility followed web content accessibility guidelines (WCAG) guidance (8).

Outcome measures

Addressing objective 3, an early pilot evaluation was conducted with the 11 primary users aligned with standard surveillance evaluation attributes (9,10). Attributes most relevant to early implementation and routine use (usefulness, simplicity, acceptability) were prioritized. A structured feedback guide was used to collect Likert ratings on overall impression, ease of use, usefulness, and program fit, with prompts on examples of use, most valuable feature, and requested changes. Items were rated on a 5-point scale (1=strongly disagree or very poor; 5=strongly agree or excellent). Feedback was requested on September 9, 2025, and responses were received over the following month, after users had access to the dashboard for a median of approximately four weeks. Nine participants completed the Likert ratings, and two additional participants provided qualitative feedback only. Both forms of feedback were incorporated into the thematic synthesis. An informal visual review of layout, labelling, and readability was also conducted, and processed data files were verified to contain no personal identifiers. However, a formal expert usability evaluation was not conducted. Ratings were summarized descriptively and open-ended responses were synthesized into themes. Formal pre-post comparison of timeliness and decision-making efficiency against prior static products was out of scope for the early pilot because baseline metrics were not captured pre-implementation. Capturing these metrics is planned for the three- to six-month follow-up, which will quantify sustained adoption and timeliness (e.g., days from month-end to publication).

Ethics review

This work consisted of routine public health surveillance plus an early service-evaluation component. The dashboard itself is a routine surveillance product conducted under the *Public Health Act* within IH's data stewardship framework and does not display personal identifiers. The component relevant to project ethics screening was the informal feedback collection from project team members, which under IH practice would fall under the A pRoject Ethics Community Consensus Initiative (ARECCI) project-level screening rather than full research ethics board review. Participation was voluntary, feedback is reported in aggregate, and quotes are de-identified.

Results

Primary outcomes

Addressing objective 3, nine of the eleven invited primary users completed the Likert ratings across the five stakeholder groups, and two additional users contributed qualitative feedback. Ratings were strong (**Table 2**): overall impression 5.0/5 (n=9), ease of use 4.9/5 (n=9), usefulness 4.9/5 (n=9), and program fit 4.6/5 (n=8).

Table 2: Pilot ratings summary (Likert scale 1.0–5.0)

Attribute	Mean (1.0–5.0)	n
Overall impression	5.0	9
Ease of use	4.9	9
Usefulness	4.9	9
Program fit	4.6	8

Secondary outcomes

Structured feedback highlighted the dashboard's clarity, ease of navigation, and value for consolidating information previously scattered across multiple sources. Users reported that filterable trends and geographic views improved routine situational awareness and focused discussion during monitoring meetings. One clinician wrote: "Seeing the areas that are most affected… and the trends for the areas where we have implemented more testing options and more enhanced follow up… are our interventions working or not?" Suggestions focused on minor usability refinements (e.g., an abbreviations box, sticky table headers, higher-contrast bars, improved layout on smaller screens).

Pilot users also perceived improved timeliness of routine monitoring and clearer communication of recent changes to leadership during the pilot period. Local Health Area views supported prioritization for outreach and partner services, and monthly trends helped participants monitor patterns relevant to intervention planning between provincial quarterly cycles. One participant noted: "If we are seeing more cases in a particular area… I can see if the positivity or cases are actually increasing to help advocate for additional services." One-click image export reduced ad hoc preparation for recurring planning artifacts. These perceived improvements will be quantified against baseline workflow measures at follow-up.

Intervention experience

Three practical challenges emerged during iterative development and were corroborated in pilot feedback: small-area volatility required careful visual cues to avoid over-interpretation (addressed with consistent denominators, rolling windows, and guidance notes); harmonizing data definitions across streams needed upfront effort and a governance cadence; and balancing accessibility with privacy required iterative parameter setting with stakeholder input. None of these impeded early use, but they informed the roadmap and evaluation design.

Discussion

Key findings

Addressing objectives 1 and 2, an interactive syphilis surveillance dashboard was developed and implemented integrating monthly indicators, 12-month trends, and LHA-level spatial patterns. The UCD process and governance approach enabled rapid iteration while maintaining privacy safeguards and accessibility. Addressing objective 3, early use suggests the tool is acceptable and useful for routine monitoring and planning, with pilot users reporting perceived improvements in timeliness and clarity of information flow.

Comparisons

The approach that was used aligns with published guidance on rapid-cycle, user-centred methods for population health surveillance dashboards, which emphasize iterative prototyping with end users, clear indicator definitions, and lightweight governance over lengthy upfront specification (6,11). Expanding provincial quarterly products with LHA-level views would likely have addressed some information needs, but it would have been less able to address the interactivity and refresh-cadence gaps stakeholders identified and would still have required analysts to assemble ad hoc briefing materials. The dashboard is designed for internal operational use with role-based access and privacy safeguards, distinguishing it from publicly available STI dashboards, such as Centers for Disease Control and Prevention AtlasPlus, (12) and making it suited to small-area program management between provincial reporting cycles.

Implications for practice

For regional public health teams, a lightweight, interactive dashboard may streamline routine monitoring, shift effort from data preparation to interpretation, and strengthen cross-program communication. Early engagement and frequent feedback cycles were critical to aligning features with actual workflows.

The approach used may be adaptable to other communicable diseases (e.g., gonorrhea, chlamydia) and jurisdictions with similar data streams, governance structures, and analytic capacity. Potentially transferable elements include the UCD workflow, the Overview page layout shown in Figure 1, the use of separate Trends, LHA Trends, Age and Sex, and LHA Analysis pages, and the privacy and access governance pattern. Integrating testing volumes and testing episode positivity with case counts can support targeting of areas with low testing uptake, moving beyond passive case surveillance toward more actionable intelligence for intervention planning.

Limitations

Limitations align with the evaluation objectives. Regarding objectives 1 and 2, the dashboard reflects a single regional context and may require adaptation elsewhere. Manual monthly data extraction, required because of privacy and access restrictions for STI surveillance data, limits refresh frequency relative to automated pipelines and is resource-intensive to sustain. Jurisdictions considering similar approaches should weigh available analytic capacity against competing public health priorities. Secure automated data integration within existing privacy frameworks is planned for future work.

Regarding objective 3, findings are based on self-reported perceptions from a small sample of early adopters who were purposively invited and already engaged with surveillance modernization. This may have biased ratings upward and limited generalization to less-engaged users. The evaluation measured perceptions rather than behavioural change or downstream outcomes, and was conducted after a short period of use, so quantitative adoption and satisfaction metrics are preliminary. Attributes like timeliness benchmarks and data-quality dimensions require longer observation windows. Because baseline workflow measures were not captured pre-implementation, reported improvements in timeliness and decision-making are perceived rather than demonstrated. Effects on downstream outcomes, such as case finding and congenital syphilis prevention, were not formally evaluated and are planned for follow up in three to six months.

Data availability

The underlying case and laboratory datasets contain personal health information and are not publicly shareable. Requests for aggregated indicators and metadata may be considered by IH, subject to applicable governance and privacy review (7).

Conclusion

A UCD process and iterative engagement of end users produced an interactive, LHA-level syphilis surveillance dashboard tailored to routine surveillance needs and decision-making, while prioritizing privacy and accessibility. Early pilot feedback indicated perceived improvements in timeliness and clarity of information flow, suggesting that UCD can be a useful approach to modernizing public health surveillance at a regional scale. Demonstrated effects on downstream public health outcomes remain to be evaluated. The approach may be adaptable to other conditions and jurisdictions with similar data streams, governance structures, and analytic capacity.

Authors' statement

TE — Conceptualization, methodology, software, formal analysis, investigation, data curation, writing–original draft, writing–review & editing, visualization, project administration
BG — Supervision, resources, project administration, writing–review & editing
JM — Conceptualization, supervision, writing–review & editing

TE conceived and led the work and all authors contributed to interpretation and approval of the final manuscript.

Competing interests

The authors declare no competing interests.

ORCID numbers

Temuulen Enebish — 0000-0002-5038-9144
Barbara Gauthier — 0000-0002-0959-3207
Jonathan Malo — 0000-0002-3569-3738

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Red Cross and Red Crescent Movement responses to viral hemorrhagic fever outbreaks: A mixed-method evaluation of information management practices for Safe and Dignified Burials

Douglas Lau[1,2]*, Arwen Barr[2], Marguerite Gollish[2], Maria Munoz-Bertrand[2]

Abstract

Background: Ebola and Marburg are viral hemorrhagic fevers (VHFs) with pronounced epidemic potential. Safe and Dignified Burials (SDBs) are a key pillar of humanitarian responses to VHF outbreaks, with Red Cross and Red Crescent (RCRC) National Societies often supporting implementation. The SDB information management (IM) toolkit is a collection of tools and templates that provides guidance for SDB IM across the RCRC Movement.

Objective: To identify lessons learned from the implementation of the SDB IM toolkit and the broader approach to SDB IM in the RCRC Movement, focusing on acceptability, simplicity, and flexibility.

Methods: A sequential mixed-method study design was used, with preliminary findings from key informant interviews guiding development of a subsequent online survey. Procedures for SDB data collection, analysis, and reporting were reviewed, along with how these outputs informed operational decision-making.

Results: Eight interviews and 208 survey responses were analyzed. Acceptability of SDB IM was generally high, though uneven awareness of the SDB IM toolkit and gaps in communicating the strategic value of SDB IM limited broader uptake. Simplicity was viewed favorably, with clearly established workflows and a phased approach to implementation; however, overly detailed guidance documents, limited IM-specific training and insufficient opportunities for hands-on data collection undermined ease of implementation. Flexibility was evident across outbreak settings, though limited analysis and reporting capacity within some National Societies reduced operational adaptability.

Conclusion: While gaps remain, this evaluation highlights the role of SDB IM in supporting data-informed VHF outbreak responses. Strengthening coordination, increasing awareness, expanding IM capacity and supporting greater local ownership may further enhance readiness for future responses.

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Keywords: Ebola, Marburg, viral hemorrhagic fever, Safe and Dignified Burials, information management, Red Cross and Red Crescent

Affiliations

[1] Canadian Field Epidemiology Program, Centre for Emergency Preparedness, Public Health Agency of Canada, Ottawa, ON

[2] Canadian Red Cross, Ottawa, ON

***Correspondence:**
doug.k.lau@gmail.com

Introduction

Ebola virus disease (EVD) and Marburg virus disease (MVD) are severe, often fatal, viral hemorrhagic fevers (VHFs) with pronounced epidemic potential (1). Case fatality ratios are estimated at approximately 50%, though past outbreaks have ranged from 24%–90% (2,3). Unsafe handling of bodies during burials is a well-recognized source of VHF propagation, with studies linking substantial secondary transmission to direct contact with the deceased, their bodily fluids or contaminated materials (2–5). The persistence of VHF outbreaks underscores the ongoing risk to global public health, with nine EVD and seven MVD outbreaks reported to the World Health Organization (WHO) between 2020 and 2025 (2,3,6).

Although the evidence base for Safe and Dignified Burial (SDB) effectiveness is still nascent, several studies have demonstrated their role as critical interventions in reducing transmission (7–9). Consequently, SDBs have become a key pillar in humanitarian responses to VHF outbreaks, with Red Cross and Red Crescent (RCRC) National Societies, supported by the International Federation of Red Cross and Red Crescent Societies (IFRC), taking leadership roles in implementation (10,11).

Routinely collected operational data from SDB activities can support monitoring of outbreak dynamics and intervention outcomes (9); however, maintaining reliable data flows during epidemic scenarios remains challenging (12). These considerations highlight the value of structured SDB information management (IM) in supporting implementation and operational decision-making.

Safe and Dignified Burial information management

During VHF outbreaks, National Societies often lead SDB implementation, in collaboration with local authorities and other humanitarian partners. While specific processes vary by context, implementation generally follows a similar workflow. When a death meeting epidemiological risk criteria set by local authorities is reported, trained burial teams are dispatched. After obtaining consent, burial teams conduct culturally appropriate burials while maintaining rigorous infection prevention and control measures. Multiple burials may be conducted concurrently across districts or regions, reflecting the scale of outbreaks and corresponding operational demands (13). If additional human resource capacity is required within National Societies, the IFRC surge mechanism facilitates the rapid deployment of trained international delegates to complement existing in-country response capacity (14).

The SDB IM approach is a structured system for collecting, analyzing and utilizing operational data from SDB activities. Under the guidance of an IM focal point, burial team supervisors collect information on the deceased, which is collated and analyzed to generate routine reports, with technical support from the IFRC as needed. These outputs are designed to support situational awareness and are shared with decision-makers to inform operational planning.

To streamline SDB IM implementation, the British Red Cross and IFRC developed the SDB IM toolkit—a package of guidance, tools and templates designed to promote a standardized approach to SDB IM (**Table 1**). Building on lessons learned during the 2013–2015 West Africa EVD outbreak response, the toolkit was formalized in its current form in 2019 and has since been promoted as a framework for SDB IM across RCRC Movement. This evaluation is the first systematic effort to review and refine the approach.

Evaluation objective

The overall objective was to identify lessons learned from implementation of the SDB IM toolkit and the broader approach to SDB IM, with a specific focus on the attributes of acceptability, simplicity and flexibility.

Table 1: Safe and Dignified Burial information management toolkit contents

Toolkit component	Description
SDB IM toolkit main guide	Primary guidance document for the SDB IM toolkit. Provides an overview of toolkit components, recommended IM dataflows, activities and timelines; as well as guidance on data protection and information sharing.
Volunteer and staff training guide	Defines human resource requirements and training plans for field implementation of SDB IM.
Data collection guide	Provides templates, key considerations and recommendations for SDB data collection.
Alerts and activities analysis	Introduces a framework for the analysis of SDB outcomes, with key indicators like the percentage of completed burials along with demographic and geographic distributions.
Resistance and failure analysis	Describes a recommended approach to tracking instances of community resistance to SDBs.
Capacity and planning analysis	Specifies key considerations for coordination of large-scale SDB operations with many active burial teams.
Coordination and gap analysis	Gives guidance on the overall coordination of SDB IM and highlights potential gaps to monitor.

Abbreviations: IM, information management; SDB, Safe and Dignified Burial

Methods

A sequential mixed-method design was adopted, with preliminary findings from key informant interviews (KIIs) guiding development of a subsequent online survey. Practical experiences with SDB data collection, analysis and reporting were reviewed, along with how resulting insights supported operational decision-making. Data were analyzed and mapped to the attributes of acceptability, simplicity and flexibility, linking findings to the usability and operational value of the SDB IM approach: 1) acceptability was defined as the willingness of RCRC volunteers, staff and delegates to engage with the toolkit and broader IM approach, including collaboration with external partners; 2) simplicity was defined as the degree of ease with which the SDB IM toolkit and overall IM approach could be applied during outbreak responses; and 3) flexibility was defined as the extent to which the SDB IM toolkit and overarching IM approach could accommodate varying operational demands.

Key informant interviews

Key informants from National Societies and the IFRC were purposively recruited following predefined criteria (**Table 2**). Recruitment began with an initial set of key informants and expanded through snowball sampling. For each KII, a tailored interview guide was used, with questions adapted to each informant's areas of expertise (**Appendix**, **Supplemental material**, Table S1). Key informants were asked to reflect primarily on their most recent VHF outbreak experience, while drawing on prior outbreaks, where relevant, to provide additional context. Interviews were conducted with one facilitator and one notetaker, in English or French, during 45-minute sessions on Microsoft Teams (Microsoft 365).

Collection and analysis of interview data followed a modified approach to the Rapid Research Evaluation and Learning method, which focused on generating timely, actionable insights without a standalone analysis step (15,16). Following each KII, facilitators and notetakers reviewed notes to reconcile interpretations and document emerging themes on a shared and routinely updated synthesis sheet. Two authors then reviewed this synthesis sheet to identify overarching themes and iteratively refine subsequent interview guides to address remaining areas of inquiry.

Survey

Building on preliminary findings from KII, an online survey was administered to further assess implementation of the SDB IM approach across the attributes of acceptability, simplicity and flexibility. Eligible participants were identified through collaboration with focal points from selected National Societies and IFRC, focusing on individuals involved in SDB field implementation after the 2013–2015 West Africa EVD outbreak (Table 2).

The survey was deployed using KoboCollect (KoboToolbox). It included both closed- and open-ended items, with skip logic to tailor questions based on participant experiences. Participants were encouraged to provide responses in relation to their most recent VHF outbreak experience. Survey data were analyzed using Microsoft Excel and R Studio (v2025.05.1+513).

Ethical statement

As this evaluation was part of routine programming, formal ethical review was not sought. Data collection nevertheless followed ethical principles laid out in the Declaration of Helsinki (17). All key informants and survey participants were informed of study objectives, the voluntary nature of participation, and their ability to ask questions or withdraw. Data were anonymized, securely stored and deleted after analysis.

Results

Eight KIIs were completed between December 11, 2024 and May 21, 2025 (**Table 3**). Despite some variation, perspectives were markedly consistent across key informants. As interviews progressed, insights began to converge toward saturation, supporting the robustness of the dataset.

Between August 1, 2025–August 25, 2025, 256 survey responses were received. After excluding 48 records that did not meet inclusion criteria, 208 responses were retained for analysis (**Figure 1**, **Figure 2**, **Table 4**).

Table 2: Inclusion and exclusion criteria

Criteria	Key informant interviews	Survey
Inclusion criteria	Key informants were eligible if they: were RCRC Movement volunteers, staff, or delegates; and had experience after the 2013–2015 West Africa EVD outbreak, in at least one of the following: SDB program development, or SDB training facilitation, or SDB field implementation.	Participants were eligible if they: were RCRC Movement volunteers, staff, or delegates; and had experience with SDB field implementation after the 2013–2015 West Africa EVD outbreak.
Exclusion criteria	Key informants were not eligible if they: had no direct involvement in SDB activities; only had relevant experience from the 2013–2015 West Africa EVD outbreak or earlier; or were unavailable to participate in an interview.	Participants were not eligible if they: had no direct SDB field experience; only had field experience from the 2013–2015 West Africa EVD outbreak or earlier; or provided incomplete survey responses.

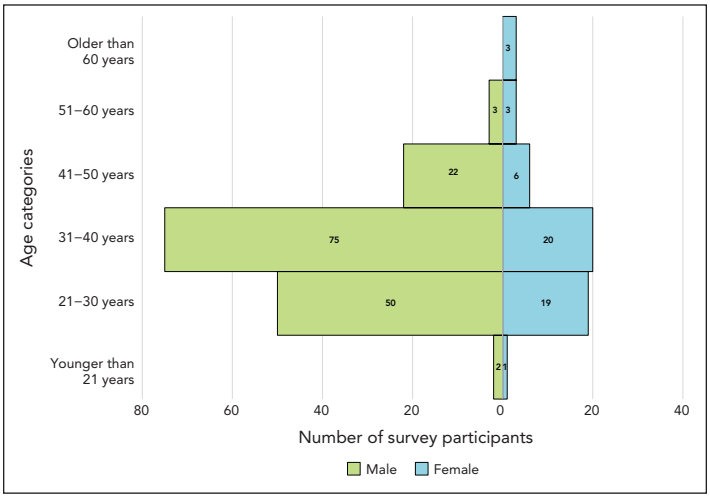
Abbreviations: EVD, Ebola virus disease; RCRC, Red Cross and Red Crescent; SDB, Safe and Dignified Burial

Table 3: Key informants, affiliation and experience

ID	RCRC affiliation	Sex	Experience with SDBs
KII 1	IFRC headquarters (Geneva)	Female	Coordinated SDB activities during multiple VHF outbreaks.
KII 2	Canadian Red Cross	Female	Facilitated SDB training; deployed as IFRC delegate to multiple VHF outbreaks.
KII 3	Canadian Red Cross	Female	Developed SDB Emergency Response Unit concept and handbook; facilitated SDB training; deployed as IFRC delegate to multiple VHF outbreaks.
KII 4	British Red Cross	Female	Developed SDB IM toolkit; deployed as IFRC delegate to multiple VHF outbreaks.
KII 5	Guinea Red Cross	Male	Coordinated SDB activities during multiple VHF outbreaks.
KII 6	IFRC Regional Office for Africa (Nairobi)	Male	Remote SDB IM support; deployed as IFRC delegate to multiple VHF outbreaks.
KII 7	Democratic Republic of the Congo Red Cross	Male	Coordinated SDB activities during multiple VHF outbreaks.
KII 8	Uganda Red Cross	Male	Coordinated SDB activities during multiple VHF outbreaks.

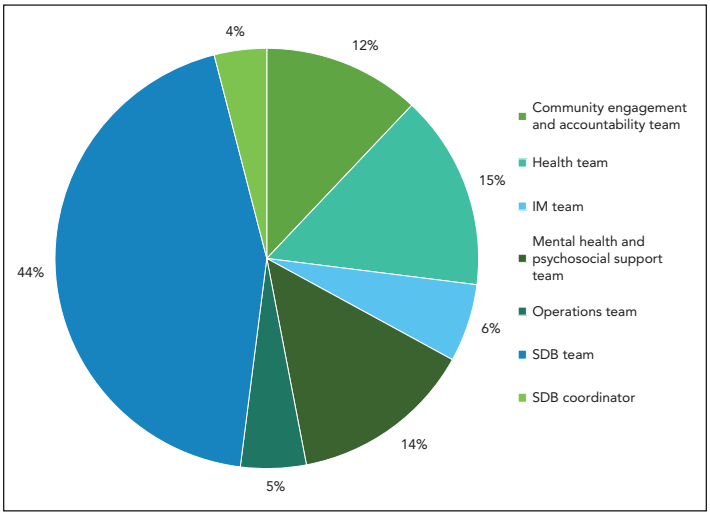
Abbreviations: IFRC, International Federation of Red Cross and Red Crescent Societies; IM, information management; SDB, Safe and Dignified Burial; VHF, viral hemorrhagic fever

Figure 1: Age and sex of survey participants[a]



[a] n=208; 25.9% female and 74.1% male

Figure 2: Survey participants, by role in most recent response



Abbreviations: IM, information management; SDB, Safe and Dignified Burial

Table 4: Survey participant characteristics

Participant characteristics	n (%)
SDB-related experience[a]	
Completed SDB training	190 (91.3%)
Burial team supervisors	44 (21.2%)
Burial team members (supervisors and non-supervisors)	160 (76.9%)
Performed SDB data analysis and reporting	79 (38.0%)
Made operational decisions during VHF outbreaks ("decision-makers")	67 (32.2%)
Personnel category	
RCRC volunteers	140 (67.3%)
RCRC staff	59 (28.4%)
RCRC delegates	6 (2.9%)
Not reported/missing	3 (1.4%)
National Society Affiliation	
British RC	6 (3.0%)
Canadian RC	2 (1.0%)
Democratic Republic of Congo RC	17 (8.0%)
French RC	2 (1.0%)
Guinea RC	152 (73.0%)
Tanzania RC	6 (3.0%)
Uganda RC	23 (11.0%)
Not reported/missing	0

Abbreviations: RC, Red Cross; RCRC, Red Cross and Red Crescent; SDB, Safe and Dignified Burial; VHF, viral hemorrhagic fever

[a] Participants reported Safe and Dignified Burial preparedness or response experience across 11 countries: Burundi, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Guinea, Kenya, Rwanda, Sierra Leone, Sudan, Tanzania and Uganda

Acceptability

Across contexts, the overarching approach to SDB IM was generally well accepted. Following training, 75.0% of burial team supervisors felt "very" or "mostly confident" collecting SDB data (Appendix, Supplemental material, Table S2). Despite the sensitivities of collecting information from bereaved families, 66.3% of burial team members were "very" or "mostly comfortable" fulfilling this role, though additional training on

community engagement was commonly requested in free-text responses. Among decision-makers, 85.1% found SDB reporting outputs to be "very" or "mostly useful" and 82.1% said these reports "consistently" or "frequently" impacted their decision-making.

Key informants also described multifaceted and mutually beneficial relationships between National Societies and local authorities from different outbreak contexts. For instance, Ministry of Health (MoH) representatives attended RCRC-led SDB training and MoH surveillance alerts helped inform the day-to-day deployment of burial teams. Where available, burial team members followed MoH testing protocols for community deaths, with positive results potentially initiating a cascade of MoH-led response activities like contact tracing and ring vaccination. Furthermore, SDB data summaries were routinely shared with local authorities and other humanitarian partners at interagency coordination meetings.

Despite these strengths, awareness of the SDB IM toolkit was notably uneven across RCRC personnel. Although some key informants—and 15.2% of survey participants involved in analysis and reporting—indicated no prior awareness of the toolkit, documents shared by National Societies showed that templates from the toolkit were nevertheless being used, suggesting indirect or partial dissemination without accompanying guidance. Key informants further noted that the value of SDB IM was often not clearly communicated to National Society leadership and RCRC teams outside SDB operations. Heavy workloads for burial teams were also noted, alongside frustration with terminology that classified SDB outcomes as "successful" or "failed." Key informants indicated that such language did not adequately reflect the complex social and operational realities of burial activities, particularly in situations involving community resistance or incomplete burials despite appropriate efforts and could negatively affect team motivation.

Simplicity

Key informants described clear SDB IM workflows and a solid foundation of SDB training to prepare them for field implementation. They further commended the toolkit's ability to facilitate a phased approach to implementation; for instance, starting with a limited set of essential data points before expanding to more detailed reporting as responses progressed. Survey findings were also aligned, with 77.5% of burial team supervisors indicating that SDB data collection forms were "very" or "mostly easy" to understand, and 85.0% of decision-makers noting that SDB reports were "very" or "mostly clear" in providing actionable intelligence.

In terms of challenges, key informants familiar with the SDB IM toolkit reported that the accompanying guidance documents were too text-heavy, too detailed and overly prescriptive without taking local operational environments into account. These challenges were commonly reported as a barrier to field-level utilization. Participants further noted the need for more IM-specific training, hands-on practice with data collection and regular refresher training to sustain readiness over time.

Flexibility

The SDB IM approach demonstrated versatility across outbreak settings with varying linguistic, cultural and operational needs. Key informants noted that the toolkit supported both paper-based and mobile data collection, enabling National Societies to adapt activities to differing levels of human resource capacity and connectivity. They also appreciated the availability of key documents in French and English, reflected in survey findings where 97.4% of participants reported receiving training in an appropriate language.

The flexibility of the SDB IM approach was reportedly constrained by limited data analysis and reporting capacity within National Societies. For instance, while 72.2% of survey participants involved in SDB analysis and reporting received pre-developed reporting templates, 34.2% were only able to adapt these templates to local contexts "with difficulty" or "not at all." Key informants and survey participants also commonly highlighted opportunities to strengthen IM capacity among National Society personnel with the aim of reducing reliance on technical support from the IFRC.

Discussion

Acceptability of the SDB IM approach was broadly positive, but several gaps limited its wider adoption. Burial teams routinely gathered essential information, often in close collaboration with local authorities, feeding into established IM workflows that supported data-informed decision-making during outbreaks; however, uneven awareness of the SDB IM toolkit among RCRC personnel, along with gaps in communicating the strategic value of IM and the heavy operational demands placed on burial teams, reduced overall acceptability.

Simplicity of the IM approach was viewed favourably, though several practical challenges limited ease of implementation. Clearly defined workflows enabled teams to carry out core IM tasks, while the toolkit's phased approach allowed activities to start simply and expand as response needs evolved; however, overly detailed guidance documents, limited IM-specific training and insufficient opportunities for practice with hands-on data collection undermined simplicity.

Flexibility of the SDB IM approach was evident across outbreak settings with differing linguistic, cultural and operational needs. The availability of both paper-based and mobile data collection tools, along with key documents in different languages, enabled National Societies to adapt implementation to local capacity and connectivity constraints; however, limited data analysis and reporting capacity within some National Societies constrained

the flexibility of operations, highlighting the need to further strengthen IM capacity to support greater local leadership across the IM workflow.

Strengths and limitations

This evaluation benefited from engagement with a diverse group of RCRC Movement personnel with extensive experience across SDB responses, enabling triangulation of findings from multiple sources; however, several limitations should be considered. Key informants were purposively selected, meaning some perspectives may have been underrepresented. Survey responses were unevenly distributed across National Societies, with a large proportion originating from the Guinea Red Cross. This reflects differential response rates rather than differences in sampling and sensitivity analyses, which excluded these responses, yielded similar results. Recall bias may have affected responses due to the long time elapsed since some outbreak experiences. Researcher bias was also possible, given the study team's affiliation with the RCRC Movement, although the use of standardized tools and team-based analysis helped mitigate this risk. Finally, the evaluation was not designed or powered to assess differences by sex or other demographic characteristics, which may influence operational roles and experiences during outbreak responses.

Recommendations

Based on these findings, practical, implementation-focused recommendations were developed to strengthen the SDB IM approach. First, coordination of SDB IM could be strengthened by promoting regular communication across RCRC Movement entities, providing structured orientations on the SDB IM toolkit for National Society personnel, and implementing pre- and post-deployment briefings for international delegates supporting SDB IM. Second, awareness of the SDB IM toolkit could be increased by promoting consistent use of the toolkit across responses, demonstrating the value of data-informed decision-making during outbreaks, and supporting leaders to reinforce the strategic importance of SDB IM. Third, greater localization of SDB IM implementation could be supported by increasing involvement of National Society personnel across all stages of SDB IM, enabling contextual adaptation of tools and workflows while maintaining core standards, and promoting mentorship with stepwise handover of SDB IM functions to National Society personnel. Finally, SDB IM training could be expanded by allocating dedicated time for SDB IM-specific competencies and practical data collection exercises, and providing regular refresher training to sustain operational readiness over time.

Conclusion

While gaps remain, this evaluation highlights the role of the SDB IM approach in VHF outbreak response across the RCRC Movement. Strengthening coordination, increasing awareness of the toolkit, expanding IM capacity and supporting greater local ownership may further enhance readiness for future responses.

Authors' statement

DKL — Conceptualization, methodology, formal analysis, investigation, data curation, writing–original draft, writing–review & editing, visualization, supervision, project administration
AB — Conceptualization, methodology, formal analysis, investigation, writing–review & editing, project administration
MG — Conceptualization, formal analysis, investigation, writing–review & editing, project administration
MMB — Conceptualization, methodology, writing–review & editing, supervision

Competing interests

None.

ORCID numbers

Douglas Lau — 0000-0003-2155-6270
Marguerite Gollish — 0000-0001-6170-8430
Maria Munoz-Bertrand — 0000-0002-6242-8702

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Appendix

Supplemental material is available upon request to the author: doug.k.lau@gmail.com

Table S1: Key informant interview question guide
Table S2: Survey results

"Those fires I had to work through was a learning": An evaluation of the Eeyou Istchee Daily Smoke Monitoring Report

Anna JW Manore[1,2]*, Jason Coonishish[3], Isabelle Duguay[1]*, Colleen Fuller[1], Juliette Ottereyes[4], Environmental Health Team[1]

Abstract

Background: In 2023, Eeyou Istchee experienced a record-breaking forest fire season, causing unprecedented damage to interconnected land, ecosystems, and cultural infrastructure. Acute health impacts of forest fires can be severe, including respiratory and cardiovascular problems, and heat-related illness. From May 2023 to September 2023, the Cree Board of Health and Social Services of James Bay (CBHSSJB) shared verbal updates on smoke, fire, and heat at daily meetings with public health and broader emergency response partners. In 2024, CBHSSJB formalized these verbal updates into a daily written report, distributing publicly available information via email to inform a timely public health response.

Objective: To evaluate the usefulness of the *Eeyou Istchee Daily Smoke Monitoring Report* (shortened to the "Report") following the first season of implementation and identify potential improvements.

Methods: The evaluation was co-developed with key partners using participatory approaches, with evaluation objectives focusing on the Report's usefulness for decision-making with respect to smoke, fire, and heat. Key informant interviews (n=6) were carried out with Report recipients, and results were summarized using thematic analysis.

Results: Recipients described the Report as useful and a source of reassurance about current conditions in Eeyou Istchee. Suggested improvements included the addition of more visuals, plainer language, and supporting recipients seeking additional information to complement the Report (i.e., more specific than daily updates at a regional level).

Conclusion: Opportunities for improvement identified through this evaluation informed updates to the Report for 2025 and beyond, and may also be applied by other Indigenous organizations developing or enhancing their own environmental monitoring and reporting processes.

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Keywords: environmental health, forest fire, Indigenous health, Cree health, Eeyou Istchee, surveillance evaluation, thematic analysis

Affiliations

[1] Public Health Department, Cree Board of Health and Social Services of James Bay, Mistissini, QC

[2] Canadian Field Epidemiology Program, Centre for Emergency Preparedness, Public Health Agency of Canada, Montréal, QC

[3] Emergency Measures and Disaster Planning, Cree Board of Health and Social Service of James Bay, Chisasibi, QC

[4] Office of Fire Protection, Capital Works and Services, Cree Nation Government, Montréal, QC

***Correspondence:**
anna.manore@phac-aspc.gc.ca;
isabelle.duguay@ssss.gouv.qc.ca

Introduction

"*Since time immemorial, forest fires have always been present in Eeyou Eenou Istchee and across Canada, shaping forests and ecosystems. Our ancestors understood fire as a natural force, one that could both renew and destroy, and they learned how to live with it.*"—Reggie Tomatuk, Planning Programming and Research Officer, Cree Board of Health and Social Services of James Bay Regional Public Health

Severe forest fires have occurred in recent years in Canada and globally (1–5). Despite longstanding Indigenous knowledge,

understanding and practices for how to live with fire, recent wildfires have had disproportionate impacts on Indigenous populations for reasons including remote geography and limited firefighting resources (6–9). These impacts are expected to intensify as climate change increases the frequency and severity of wildfires (10–14).

Unprecedented forest fires in 2023 burned 11% of Eeyou Istchee (5,11,15), which is an area of over 400,000 km^2 located along the east coast of James Bay and inland and home to approximately 20,000 Eeyouch/Eenouch (Cree). Eight of the nine Cree First Nation communities served by the Cree Board of Health and Social Services of James Bay (CBHSSJB) were evacuated due to fire between June 2023 and August 2023, resulting in negative physical, emotional, mental, and spiritual impacts on Eeyouch/Eenouch. Fires and smoke led to intermittent road closures, impacting the movement of people, supplies, and food in and out of communities. Changes to land had both immediate and long-term impacts on territory, wildlife, and plants crucial for hunting, fishing, and other ways of connecting with Cree culture (9,11).

In Canada, wildfire smoke reporting and risk communication are primarily implemented through centralized tools, such as the Air Quality Health Index (AQHI), which translate ambient PM2.5 and co-pollutant measurements into standardized public health guidance. The AQHI may have limited sensitivity to wildfire smoke—specific exposure patterns and local variability during extreme fire events (16,17). This approach is less accessible and contextually appropriate in Indigenous communities, where structural inequities, language differences, and limited integration of Indigenous governance and knowledge systems may reduce the effectiveness of risk communication and protective actions (18). Cree emergency response teams need to make quick, informed decisions about use of remote transportation routes to ensure continuity of community food supplies, use of traplines, and preparation for evacuations of medically vulnerable individuals. Public health response includes liaison roles, coordination of clean air spaces and sheltering in place resources, distribution of N95 masks outside of clinic settings, public health messaging, and surge capacity. During the 2023 fires, the CBHSSJB regional Environmental Health Team was requested to provide daily regional information on smoke, fire, and heat to partners to inform such actions. With no pre-existing surveillance product, team experts reviewed the fragmented data available and used this to provide verbal updates of relevant information.

In 2024, a structured daily report was developed to monitor fire activity, forecast smoke movement across the territory, track air quality measures, and predict maximum heat (*Eeyou Istchee Daily Smoke Monitoring Report*, shortened to the "Report") (**Appendix**, **Supplemental material**, Figure S1–S2 and Table S1) to improve the delivery and use of this surveillance service. The Report was evaluated for its usefulness in supporting public health action following the first season of implementation. This evaluation directly responds to an expressed need for enhanced environmental monitoring, coordination, and communication during emergencies in Eeyou Istchee (12,19).

With a significant proportion of the population in Eeyou Istchee being particularly vulnerable to the health impacts of smoke, fire, and heat, monitoring with timely communication and coordination between adaptive response partners is crucial for managing a rapid response to the complex needs arising from these increasingly severe events.

Methods

Evaluation planning

In keeping with the Miyupimaatisiiun Research Principles of collaborative planning, execution and interpretation, as well as previous work on evaluation in Indigenous contexts (20–22), this evaluation was co-developed with 2024 Report producers and recipients (**Table 1**).

Table 1: Producers and recipients of the 2024 and 2025 *Eeyou Istchee Daily Smoke Monitoring Report*

Report producers	2024 report recipients	2025 report recipients[a]
CBHSSJB Environmental Health	CBHSSJB Environmental Health CBHSSJB Emergency Measures CBHSSJB Communications Community Miyupimaatisiiun Centres (CMCs) and Hospitals, as needed Cree Nation Government (CNG) Office of Fire Protection	CBHSSJB Environmental Health CBHSSJB Emergency Measures CBHSSJB Communications Community Miyupimaatisiiun Centres (CMCs) and Hospitals Cree Nation Government (CNG) Office of Fire Protection CNG Regional and Community-based Public Safety Officers CBHSSJB Occupational Health

Abbreviations: CBHSSJB, Cree Board of Health and Social Services of James Bay; CNG, Cree Nation Government
[a] Recipients were added to the distribution list at varying dates throughout the 2025 forest fire season

Discussion groups identified key questions that were used to develop evaluation objectives. Questions and objectives were mapped to United States Centers for Disease Control and Prevention *Updated Guidelines for Evaluating Public Health Surveillance Systems* attributes reflecting usefulness and data quality (23) (**Table 2**). Usefulness is the degree to which the Report *"contributes to the prevention and control of adverse health-related events"* related to smoke and wildfires, *"including an improved understanding of the public health implications of such events."* Data quality *"reflects the completeness and validity"* of the information contained in the report. While a broader internal evaluation of the Report also employed a

Table 2: Evaluation objectives and corresponding key questions identified by 2024 *Eeyou Istchee Daily Smoke Monitoring Report* producers and recipients

Evaluation objectives	Key question(s)
Contextualize the resources required to produce and distribute the Report	How far did the Report go (i.e., reach)? Would different "levels" of reporting (i.e., shorter reports on quiet or calm days) meet folks' needs?
Describe actions taken as a result of the Report	How far did the Report go (i.e., reach)?
Describe how the Report was used by those who received it, and how it supported decision-makers in Eeyou Istchee in their response(s) to smoke, fire, and heat	How far did the Report go (i.e., reach)? Does the format serve the intended audience, or could it be improved? Is the frequency of the Report acceptable? Would different "levels" of reporting (i.e., shorter reports on quiet or calm days) meet folks' needs?
Identify which sections or aspects of the Report are more or less useful to those who received it	Does the Report include the information necessary for decision-makers? Which information in the Report is most useful for decision-makers? Is there any information that's not needed?

Abbreviation: Report, *Eeyou Istchee Daily Smoke Monitoring Report*

survey, a review of social media messaging, and a comparison of reported and recorded temperatures, this article focuses solely on the assessment of usefulness through qualitative methods.

Key informant interviews

In the summer of 2025, six semi-structured interviews (45–60 minutes each) were conducted with 2024 Report recipients. Invitations for key informant interviews were extended via email, focusing on organizations and communities that responded to heavy smoke or fire in 2024 (the first season of Report implementation). A convenience sample was made of all willing participants. A conversation guide was co-developed with producers and recipients based on the key questions (Appendix, Supplemental material, List S1) and walked through example reports from both 2024 and 2025 (Appendix, Supplemental material, Figure S1–S2). Interviews were conducted via Microsoft Teams, including transcription and recording with prior consent. Transcripts were reviewed by a co-author and shared with key informants for validation.

Thematic analysis

Thematic analysis was conducted in Microsoft Excel using *a priori* and emergent themes (**Table 3**). These were structured into content themes and action themes. The analysis followed a structured, iterative process involving initial familiarization with the data, systematic coding of themes, identification of emergent themes, and refinement to enhance transparency and analytic rigour. A member of the CBHSSJB Public Health Department served as a second reviewer, coding two anonymized interview transcripts and discussing findings with a co-author to ensure coherence.

Table 3: *A priori* and emergent themes employed in thematic analysis of key informant interviews

Evaluation objectives	Origin	Themes
1,2,3,4	Overall aspects of the Report (*a priori*)	Actions informed by the Report
		Recipients' priorities within the Report
		Report format and frequency
2,3,4	Sections of the Report (*a priori*)	Air quality
		Temperature
		Wind
		Visibility
		Report recommendations
3,4	Emergent themes	Reporting as reassurance
		Learning and preparedness
		Jurisdictions and coordination

Abbreviation: Report, *Eeyou Istchee Daily Smoke Monitoring Report*

Ethical considerations

Public health surveillance evaluation falls outside the CBHSSJB definition of research (21). However, in keeping with Miyupimaatisiiun Research Principles (20) and First Nations Principles of ownership, control, access, and possession (OCAP®) (24), the evaluation protocol was discussed with the CBHSSJB Research Office during planning, and the manuscript was reviewed by the Research Advisory Committee (RAC) of the CBHSSJB. Key informants were assured of confidentiality, informed about the evaluation objectives and methods advised how their information would be used, and provided verbal or written consent before participation.

Results

Key informant interviews

Interviewees were employees of CBHSSJB (Miyupimâtisîun [n=2], Emergency Measures [n=1], Public Health [n=2]) and the Cree Nation Government Office of Fire Protection (n=1). This represented four of five groups who received the Report in 2024 (i.e., before the distribution list was expanded in 2025).

Theme: Actions informed by the report

The Report objectives are: 1) to monitor fire, smoke, air quality, and temperature conditions in Eeyou Istchee to support a rapid public health response, and 2) to determine when criteria are met for activation and de-activation of an Activated Public Health Incident Management System (IMS) structure.

Actions potentially informed by the Report varied according to the roles of recipients and the severity of the situation (**Table 4**).

Table 4: Actions potentially informed by the *Eeyou Istchee Daily Smoke Monitoring Report*

Evaluation objectives	Theme	Observations
1,2,3,4	Actions potentially informed by the Report	According to key informants, the Report could have been used to inform the following: • Increasing staffing or approving overtime • Increasing environmental monitoring • Conducting public communications • Providing information, reassurance, and support to colleagues and community partners • Rescheduling community activities or services (i.e., garbage collection) • Communicating with outdoor workers to wear masks if air quality is poor • Deploying clean air spaces (i.e., coordinating with Public Safety Officers to block building ventilation systems) • Conducting health risk assessments to support prioritization for potential evacuations • Coordinating the evacuation of vulnerable populations or entire communities (i.e., logistics, identifying vulnerable populations, being in contact with local emergency coordination teams)

Abbreviation: Report, *Eeyou Istchee Daily Smoke Monitoring Report*

Additional results of the thematic analysis are summarized according to key questions in **Table 5**, and by theme in **Table 6**.

Report priorities identified by recipients

Air quality was mentioned as a priority in five interviews, followed by temperature and recommendations for public health action (three each).

Theme: Format and frequency

All key informants praised the visual elements of the Report (i.e., maps) for being quick to read and easy to share. The Report often refers to specific communities, which recipients appreciated being able to quickly scan for their own community, or communities where they or their colleagues have loved ones. However, this format creates an information gap for health risks to Eeyouch/Eenouch on the land or highways (i.e., outside of communities). Sending the Report by email in the morning made it easy to check at the beginning of the workday, easy to search for later, and saved time by eliminating the need to seek information elsewhere.

While recipients appreciated daily reporting, a scaled-back Report on days when air quality and temperature are below thresholds of concern would also fulfill this need. One recipient suggested sending out only the first page of the 2025 Report on

Table 5: Mapping of objectives and key questions to thematic analysis results

Evaluation objective(s)	Key question	Summary of results
1,2,3	How far did the Report go?	Recipients reported sharing information in the Report with Provincial Civil Security organisations, Community Fire Chiefs, CMC Staff and Clients, Community Emergency Management Committees, and concerned community members.
1,3	Would different "levels" of reporting meet recipients' needs?	Multiple recipients cited the daily Report as reassuring and indicated a "scaled back" Report on days with no concerns would also meet their needs. One recipient suggested an abbreviated report similar to the 2025 first page on such days.
3	Did the format serve the intended audience, or could it be improved?	Recipients praised the more visual elements of the Report, while opinions on more text-heavy components were mixed. Some recipients expressed a desire for a more summarized version that could be shared more broadly. Receiving the Report as an email generally works. Interviews appreciated that information was delivered directly to them in the morning without having to seek it out, and that it was searchable in their inboxes later in the day.
3	Is the frequency of the Report acceptable?	Generally, yes. Report recipients appreciated the daily update, and twice-daily in case of heightened concerns and/or quickly changing circumstances. However, recipients also described situations where decision-making required information very specific to a given time or location (i.e., beyond the scope of a daily report at the regional level).
4	Does the Report include information necessary for decision-makers in the response to smoke, fire, and heat?	Generally, yes. Suggestions for additional information to add included air quality at locations outside of communities.
4	Which information in the Report is most useful for decision-makers?	Most recipients mentioned smoke and air quality as a priority when reading the report. Other sections identified as priorities were temperature, and recommendations for public health action.
4	Is there any information that's not needed?	The general sentiment was captured by one interviewee who said, "it's all interesting and it's all useful." However, information on wind and visibility were described as potentially less useful if there are no active fires or heavy smoke in the territory.

Abbreviations: CMC, community Miyupimaatisiiun centre; Report, *Eeyou Istchee Daily Smoke Monitoring Report*

Table 6: Summary of thematic analysis results and corresponding opportunities for improvement

Theme	Observation(s)	Opportunities for improvement
Recipients' priorities within the Report	Air quality was mentioned most often as a priority among recipients, followed by temperature and recommendations for public health action	Continue reporting on air quality and temperature, and providing written recommendations
Format and frequency	Visual elements of 2025 Report were appreciated, while the paragraphs of written text were described as "very lengthy"	Additional visual elements (i.e., maps or infographics); highlighting key words or locations
Format and frequency	Recipients appreciated being able to quickly scan the Report for the name of their own and neighbouring communities; however, Eeyouch/Eenouch often live and travel outside of communities	Include locations beyond communities; prioritise a more regional summary
Format and frequency	The morning timing of the Report was useful for planning the workday; important to have information on smoke, fire, and heat on hand for daily coordination meetings	Continue daily (morning) reporting, and twice-daily reporting as appropriate
Format and frequency	Recipients appreciate daily reporting, and there were no objections to a scaled-back report on days with no concerns	Continue daily reporting; consider sending out only the 2025 first page on days where there are no concerns
Air quality	Current and future smoke and air quality were critical for contextualising health risks and informing public health interventions (e.g., determining sites to receive evacuees)	Continue reporting on both current and future smoke and air quality
Temperature	Information on temperature informed the public health response to heat, and to compound hazards of heat and smoke	Continue reporting on temperature; adapt recommendations for heat when both smoke and heat are present
Wind	Wind information was useful due to its influence on smoke and fire behaviour, but is potentially less relevant if there are no fires or smoke to be impacted	Report on wind only if there are major threats to a community from fire or smoke; support recipients in finding trusted information on wind specific to their situation
Visibility	Visibility can be critical information in determining if road or air travel between communities is possible (i.e., for evacuations or resupply), but is potentially less relevant when air quality is good	Report on visibility only if there are major threats to a community from fire or smoke; support recipients in finding trusted information on visibility specific to their situation
Report recommendations	Recommendations in the Report guided recipients' conversations with community partners and participation in emergency response meetings	Continue providing written recommendations in the Report
Report recommendations	Recipients appreciated recommendations tailored to specific audiences (e.g., daycares, workplaces, event planners), communities, or buildings, and incorporating Cree traditional knowledge	Continue tailoring recommendations to reflect context-specific audiences and realities
Reporting as reassurance	Information on smoke and forest fires was a source of reassurance for multiple recipients, about their own communities and neighboring communities where they, their colleagues, or patients may have loved ones	Continue daily reporting including a regional overview to all recipients
Jurisdictions and coordination	Interviews underscored the importance of clear roles and responsibilities among partners in emergencies related to smoke, fire, and heat	Collaborate with partners to clarify roles and responsibilities via discussions, tabletop exercises, or other means as appropriate in advance of future forest fire seasons; where possible, indicate a responsible party or parties when providing written recommendations
Learning and preparedness	Previous experiences with forest fires were a source of learning that could be applied to future forest fire seasons	Reflect on lessons learned and apply them to future forest fire preparedness activities; host pre-season discussions or training sessions

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such days (i.e., a map of current air quality and a brief summary of anticipated air quality and temperature).

Twice-daily reporting was appreciated when recommendations were particularly time-sensitive (e.g., closing windows during the day or overnight) or anticipated to change throughout the day. Recipients noted the importance of having information readily available for emergency response meetings.

Theme: Air quality and temperature content

Both air quality and temperature were noted as priority topics within the Report as this information was used to respond to health risks from smoke and heat. When communities are under threat of evacuation, the smoke forecast was described as "critical" in determining appropriate sites to receive evacuees. One interviewee described an experience from 2023 (prior to the written Report):

"For [COMMUNITY A], there was a second evacuation. And we evacuated to the sister community next door, which is [COMMUNITY B], and that really helped making those decisions. I was kind of worried that the community we had chosen at first, but then once we had this report, [COMMUNITY B] only had that smoke for maybe an hour, and then the wind shifted and they were OK for about two or three days."

Temperature information informed decision-making around potential health hazards and fire behavior:

"If we had an emergency and if the temperature is kind of humid and cold, the fire slows down. So, it gives you those hours to work on something."

Theme: Wind and visibility content

Wind and visibility information were useful when they impacted existing smoke and fire(s) and informed evacuation and travel decisions during emergencies:

"If there's no visibility, you can't get people out."

"We had a window of maybe three or four hours to the wind was going to shift so the highway would be accessible to go home. And we had to plan a convoy to go up with the 18-wheelers so they can bring in food, gas and also bring in the people that went to a, to a hockey tournament. There was […] people stuck in [COMMUNITY] that wanted to go home."

Theme: Report recommendations content

Report recommendations informed conversations with colleagues and community partners, and guided recipients' participation in emergency response meetings:

"People always want a written recommendation."

"[At] local emergency team meetings, that's the first thing they ask: What are the recommendations from Cree Health Board?"

Recommendations tailored to specific audiences (e.g., daycares, work places, event planners) were also appreciated, with daycares in particular as a key audience since closures can have widespread impacts in a community. Recipients also suggested tailoring recommendation to reflect the realities of buildings or infrastructure in Eeyou Istchee (e.g., preventing smoke from entering gaps in windows or doors), and incorporating or acknowledging Cree traditional knowledge:

"Traditionally they would just use a cloth, and they would wet it with water, and it would be the filter for smoke. Again, I guess it comes back to traditional ways of doing things that were also comforting and reassuring."

Emergent theme: Reporting as reassurance

Information on smoke and forest fires from the Report was a source of reassurance for recipients regarding their own community and neighboring communities where they, their colleagues, or patients may have loved ones:

"When there's fires within our region, whether they be in [COMMUNITY] or…. We have a lot of the community, there's family there, you know, so they do, they do worry. And so, to ease their worry, I call a meeting… So, I just update them where so they can concentrate on work where they don't have to think about, OK, my family over there, I wonder how they're doing."

Emergent theme: Jurisdictions and coordination

Recipients emphasized the importance of clear roles and responsibilities in emergency situations, and a desire for clarity around who would be responsible for carrying out the recommendations provided in the Report (e.g., communicating with partners and the public, blocking gaps in windows or doors, or making changes to ventilation systems).

Emergent theme: Learning and preparedness

Recipients reflected on how past forest fire experiences had been a source of learning, and how that learning could be applied to future forest fire seasons:

"*When [COMMUNITY A] evacuated to [COMMUNITY B]. That's how we found out that that happens. When they got to the, to the gyms, there was smoke coming in and that smoke, it kind of followed them from [COMMUNITY A], you know? And there was smoke coming in, so they had to block their ventilation system at those schools. And that's when we said, hey, this could happen to us too, back home like, so we prepared for that.*"

Discussion

Report recipients expressed appreciation for "useful" and "critical" information specific to Eeyou Istchee delivered to them directly, and a desire for more visual elements and plain language. Future reporting seasons might therefore prioritize a shorter report with more visual elements (i.e., maps or infographics) or issuing a scaled-back report on days below thresholds of concern.

Smoke, air quality, and heat were identified as priority topics for informing public health response, while wind and visibility were useful in the context of impacts on existing fire(s) or smoke. When wind and visibility informed decision-making (i.e., evacuations, transportation convoys), these decisions required specificity beyond the scope of a daily Report at a regional level.

To address this gap, one approach suggested by the evaluation team was to support recipients in seeking this information from trusted sources by continuing to include web links in the Report, holding training sessions, or developing guidance documents. Training sessions or tabletop exercises could also be used to address other emergent themes (i.e., the importance of jurisdictions and coordination in emergency response, applying learnings from past fires to future fires).

The Report was a source of reassurance among recipients with respect to their own and neighbouring communities, consistent with a lack of information being documented as a source of distress among First Nations people experiencing forest fires elsewhere in Canada (25). This expressed usefulness of the Report echoes the call for tailored communication and coordination strategies from trusted sources in the context of prolonged smoke and forest fire seasons (18,26,27).

This evaluation noted a number of challenges that are shared among jurisdictions in Canada, namely clarification of roles and responsibilities, and the need for specific public health guidance when smoke and heat occur simultaneously (28). In Canada, wildfire and heat health responses rely on centralized tools (e.g., AQHI and heat warnings) that emphasize standardization but may have limited local relevance and uptake (16,17). In contrast, this intervention (i.e. the Report) aligns with evidence from Indigenous and community-based emergency responses showing that culturally grounded, locally governed risk communication enhances trust, comprehension, and protective action during wildfire smoke, heat events, and other public health emergencies (18). Other challenges, such as summarizing and responding to conditions over a vast geographic area, are shared by Indigenous, rural, and remote jurisdictions (28–30).

While interviews focused on 2024 Report recipients, the distribution list expanded significantly in 2025, and additional recipients for 2026 and beyond (e.g., Elders' homes) were identified during this article's development. New recipients in 2025 were not included in key informant interviews, underscoring the importance of continuous evaluation and improvement.

Limitations

This evaluation relied primarily on qualitative thematic analyses based on a small, purposive sample of key informants (n=6). Convenience sampling could introduce potential selection bias and incomplete capture of organizational perspectives, which constrains transferability. Analyses of public communications and temperature data were descriptive, temporally bounded, and selective in scope, which limits generalizability. Engagement metrics and forecast observation comparisons reflect proxy measures of reach and exposure and do not assess behavioural impact or other report components (e.g., air quality), representing additional sources of measurement bias.

Conclusion

The *Eeyou Istchee Daily Smoke Monitoring Report* was considered useful and was a source of reassurance for recipients. Opportunities for improvement identified through this evaluation may also be relevant to other Indigenous organizations developing or enhancing their own environmental monitoring processes. These include the incorporation of additional visual elements, the use of plainer language, a streamlined report when conditions remain below thresholds of concern, and measures to help recipients access additional trusted information when needed for decision-making. Overall, the Report is a new health protection tool that complements the understanding Eeyouch/Eenouch have always had about living with fire as a natural force.

Authors' statement

AM — Conceptualization, data curation, formal analysis, investigation, methodology, project administration, writing–original draft
JC — Conceptualization, methodology, validation, writing–review & editing
ID — Conceptualization, methodology, resources, supervision, writing–review & editing
CF — Conceptualization, methodology, resources, supervision, writing–review & editing
JO — Conceptualization, methodology, validation, writing–review & editing
Environmental Health Team — Conceptualization, methodology, resources, validation, writing–review & editing

Contributors

During the evaluation period (November 2024–September 2025), the Regional Environmental Health Team at the Public Health Department of the CBHSSJB included (in alphabetical order): Emmanuelle Beauvais-Lacasse, Dr. Max Boulet, Maya Côté, Justine Daoust-Lalande, Dr. Catherine Dickson, Dr. Tavis Hayes, Imi Khailat, Paul Meillon, Haylee Petawabano, and Reggie Tomatuk. Each member of the team contributed to the planning of this evaluation through group discussion, or to the planning, preparation, or distribution of the *Eeyou Istchee Daily Smoke Report*. Additionally, Dr. Catherine Dickson reviewed the full evaluation report, which formed the basis for this article.

Competing interests

The authors note no competing interests.

ORCID numbers

Anna JW Manore — 0000-0002-3377-1608

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Appendix

The Daily Smoke Monitoring Report included information on air quality, smoke forecasts, fire activity, health recommendations, temperature, wind and visibility. A detailed description of data elements, sources and rationale is available in the supplementary materials hosted on Open Science Framework (OSF). https://osf.io/nxewh/overview?view_only=cd44372ccee6452cb0d81d0938ed8b2a

Figure S1: Example of daily smoke monitoring report (2024)
Figure S2: Example of daily smoke monitoring report (2025)
Table S1: Data elements of the *Eeyou Istchee Daily Smoke Monitoring Report*
List S1: Conversation guide

CCDR

CANADA COMMUNICABLE DISEASE REPORT

Public Health Agency of Canada
130 Colonnade Road
Address Locator 6503B
Ottawa, Ontario K1A 0K9
ccdr-rmtc@phac-aspc.gc.ca

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