The Identification of Cryptic Viral Lineages in Wastewater: Protecting the Privacy of Canadians in Wastewater Surveillance

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Executive Summary

Wastewater monitoring for public health surveillance is a rapidly growing field. Despite being used for decades, no policy at the federal, provincial, or municipal level specifically addresses the collection of wastewater data. More recently, scientists have found cryptic viral lineages in wastewater which are specific to their hosts and can be used to identify the individuals carrying them. However, unlike collecting wastewater samples, the identification of an individual carrying a cryptic viral lineage is invasive and infringes upon their right to privacy. A balance must be struck between protecting the privacy of individuals and protecting the health of all Canadians. It is imperative to set policies governing the collection of cryptic lineage data and setting the ethical reviews required for the identification of cryptic lineage hosts if necessary.

Establishing a decision-making flowchart will help guide scientists in deciding when it is appropriate to identify the host of a cryptic lineage, ensuring an individual is only identified when it is absolutely necessary to protect the health of Canadians. Because tracing back the source of a cryptic lineage infringes upon the right to privacy, ethical reviews will be established to ensure the privacy of Canadians is minimally affected and that communities being surveilled are involved with the collection of cryptic lineage data. And finally, we will implement transparent communication pathways so that the goals, methods, and outcomes of wastewater surveillance and identification of cryptic lineages are understood by all.

Key Recommendations

1. Develop a decision-making flowchart to guide the investigation of cryptic viral lineages back to their source.
2. Establish ethical reviews for wastewater surveillance projects that detect cryptic viral lineages.
3. Set up transparent communications pathways to communicate the detection of cryptic viral lineages and ethical reviews to the community being surveilled with wastewater surveillance.

Introduction

Wastewater Surveillance

Though wastewater surveillance has been used for decades to detect outbreaks of waterborne diseases, the discovery that SARS-COV-2 could be detected in wastewater caused this method of public health surveillance to explode in use by municipal, provincial, and federal governments during the COVID-19 pandemic, becoming an essential part of public health surveillance (Ahmed et al., 2019; Boehm et al., 2023). When a person is infected with some viruses or bacteria they shed the pathogen in their stool, regardless of whether they are symptomatic for the disease or not (Grassly, Shaw, and Owusu, 2024). In wastewater monitoring and surveillance, sewage samples from wastewater treatment plants or community sewage infrastructure are taken and analyzed to monitor the health of the community over time (Levy et al., 2023). Genetic material from microbes in the sample can be extracted and quantified to measure the prevalence of a disease in a community, allowing for rapid detection of disease outbreaks (Grassly, Shaw, and Owusu, 2024). Research into which viruses can be detected in wastewater is ongoing.

Surveillance of wastewater serves several purposes. Most commonly, wastewater surveillance is used to detect pathogens and monitor disease outbreaks, but it has also been used to monitor the spread of antimicrobial resistance and patterns of use of illicit substances (Doorn, 2022). Several major benefits have driven the adoption of wastewater surveillance by governments and institutions. Unlike clinical sampling, wastewater monitoring is not dependent on people seeking treatment for disease symptoms and can detect infections in asymptomatic hosts. As a result, wastewater surveillance provides a more accurate picture of disease transmission within a community, allowing for rapid detection of outbreaks and introduction of public health interventions (Karthikeyan et al., 2021). Wastewater surveillance is a cost-effective, non-invasive alternative to clinical sampling and can be easily adopted, even in places with limited access to health care and clinical testing (Grassly, Shaw, and Owusu, 2024). Surveillance is typically conducted on the community scale, where samples are taken from wastewater infrastructure downstream of a community, such as a wastewater treatment plant (Scassa et al., 2022). More targeted surveillance can also be conducted by testing samples from infrastructure prior to the wastewater entering the main public system (Scassa et al., 2022).

At the centre of public health surveillance is the tension between protecting the health of the entire population and protecting the privacy of individuals. Surveillance may infringe upon the individual's right to privacy as set by the Canadian Charter of Rights and Freedoms but may be necessary to protect the health of all Canadians (The Government of Canada, 1982). As such policies for public health surveillance have been set at both the federal and provincial levels. The Public Health Agency of Canada (PHAC) sets public health surveillance at the federal level,

including wastewater monitoring. In Quebec, public health surveillance is governed by the Public Health Act (Légis Québec, 2001). Proposed public health surveillance must pass an ethical review conducted by the Institut National de Santé Publique du Québec and is periodically reevaluated by the ethics board (Légis Québec, 2001). If identifiable information is to be collected the proposed surveillance must also undergo ethical review by the Commission d'accès à l'information. The current goals of public health surveillance in Quebec are to: obtain an overall picture of the health of Quebec's population, monitor public health trends, and detect emerging threats. Wastewater testing projects are conducted at the federal, provincial, and municipal levels of government (Hrudey et al., 2022). However, there is currently no policy specifically addressing wastewater surveillance at any government level.

Cryptic Viral Lineages

The data from wastewater surveillance is traditionally not considered identifiable information, as wastewater samples are most frequently taken from centralized public infrastructure (Scassa et al., 2022). However, recent studies into cryptic viral lineages- groups of similar viruses that do not match known circulating lineages but have been identified in wastewater- have shown it is possible to trace some information in wastewater back to a single person (Smyth et al., 2022; Shafer et al., 2024). There are two current hypotheses for the source of cryptic viral lineages: that they are from humans with unsampled infections, or that cryptic viral lineages are introduced to wastewater by an animal reservoir (Shafer et al., 2024). The rapid pace of viral evolution means viruses, such as SARS-Cov-2, mutate within the infected individual, especially in cases of long-term persistent infections (Markov et al., 2023). If the infection is not cleared by the host, the virus mutates, eventually becoming unique to the person carrying the cryptic lineage. It remains unclear what impact, if any, these cryptic viral lineages may have on their hosts. Because cryptic lineages are unique to a single host, the DNA sequence from a cryptic lineage can be used to identify the individual carrying the viral lineage. Cryptic lineages may also be detected in animal populations and indicate an expanding host range for a virus. Smyth et al. (2022) detected four cryptic lineages in New York City wastewater that remained confined to a specific area for several months, indicating a potential animal source, rather than a human host (Smyth et al., 2022). All four lineages had accumulated mutations that allowed them to infect cells with receptors from humans, mice, and rats, further suggesting these cryptic lineages were from an animal reservoir.

In 2024, Shafer et al. detected the cryptic lineage WI-CL-001 in municipal wastewater in the US (Shafer et al., 2024). Schafer et al. were able to trace the lineage back to its source at a single commercial building but could not identify the host of the cryptic lineage as further ethical review was required (Schafer et al., 2024). The ability of scientists to identify individuals using

cryptic lineages raises ethical questions about privacy and the collection of identifiable information. Wastewater samples are taken from public infrastructure, not from individuals, and therefore can't be considered personal or identifiable information (Scassa et al, 2022). Currently, wastewater is considered abandoned material, and as such wastewater surveillance is not subject to the same ethical considerations as human research (Scassa et al., 2022). In 2019 the Quebec Court of Appeal ruled that the reasonable expectation of privacy does not extend to abandoned DNA, in part due to the fact that methods of collecting DNA from abandoned materials, such as trash, is non-invasive (Supreme Court of Canada, 2019; Scassa et al., 2022). However, identifying the host of a cryptic lineage requires invasive sampling and represents a greater threat to the privacy of an individual, and as such, requires greater ethical oversight and regulations than standard wastewater testing.

The detection of cryptic viral lineages raises several unanswered ethical questions not posed by traditional wastewater surveillance: When should a cryptic lineage be traced back to its host? How can the privacy of the individual carrying the cryptic lineage be protected, while still ensuring proper public health interventions are taken, if needed, to protect the community? What actions should be taken if an individual carrying a cryptic lineage is identified?

There is a need for a policy specifically addressing wastewater surveillance and the collection of cryptic lineage data. As use of this technology expands, it becomes imperative to establish policies and ethical guidelines that address the collection and usage of identifiable information in the form of cryptic viral lineage data during wastewater surveillance to protect both the health of the general public and the privacy of individuals. We propose:

1. Making a flowchart to establish a clear set of circumstances for when identifying the host of a cryptic viral lineage is appropriate.
2. Seeking ethical approval for identifying the host of a cryptic viral lineage prior to beginning wastewater surveillance to allow for rapid identification of the host when the lineage is detected.
3. Establishing transparent communications pathways to communicate the wastewater surveillance project and ethical reviews with the public.

Policy Recommendations

1. Decision-making flowchart

Due to the lack of research, the public health implications of cryptic lineages remain unclear. These variants often circulate undetected by standard public health surveillance methods, but may, over time, contribute to adverse outcomes or trigger new outbreaks. Ethical constraints surrounding individual privacy currently limit the use of data traceable to infected persons. This policy introduces a decision-making flow chart designed to guide the assessment of whether investigating these risks is warranted.

The assessment should be guided by the following four core questions. These questions serve to evaluate the potential significance, spread, source, and risk of the detected lineage.

Question 1: What mutations does the cryptic lineage have?

Cryptic SARS-CoV-2 lineages frequently harbor spike protein substitutions that enhance receptor binding, promote immune evasion, and increase viral fitness. The following mutations—classified by region—have been observed in cryptic lineages and are known to augment infectivity or transmissibility:

1. **Receptor-Binding Domain (RBD) Mutations (Spike Protein)**
    - **N501Y:** Increases ACE2 binding affinity and is epidemiologically linked to higher transmissibility (Leung et al., 2021; Liu et al., 2022). Detected in some cryptic lineages (e.g., NYC Lineage D).
    - **E484K / E484A / E484Q:** Substitutions at residue 484 reduce neutralization by multiple monoclonal antibodies and convalescent sera (Greaney et al., 2021; Wang et al., 2021). Cryptic lineages such as MO45 carry E484A, while WI-CL-001 carries E484Q, both of which confer partial immune escape (Gregory et al., 2023; Shafer et al., 2024).
    - **Q493K / Q493R:** Enhance binding to human and murine ACE2 and diminish neutralization by select antibodies (Suthar et al., 2021; Sullivan et al., 2022). In NYC cryptic lineages (Lineages A and C), Q493K correlated with increased pseudovirus entry compared to ancestral SARS-CoV-2 (Smyth et al., 2022).
    - **Q498H / Q498Y:** Strengthen spike–ACE2 interactions—especially with murine receptors—and confer partial escape from convalescent sera (Rao et al., 2022; Smyth et al., 2022; Gregory et al., 2023). Found in MO45 and NYC Lineages A/C.

- **T478K:** Analogous to Delta, T478K enhances viral entry and modestly evades neutralizing antibodies (Greaney et al., 2021; Gregory et al., 2023). Present in MO45.
- **K417T:** Reduces binding of certain class-1 neutralizing antibodies; observed in MO45 and related cryptic lineages (Greaney et al., 2021; Gregory et al., 2023).
- **N460K:** Appears in WI-CL-001 and enhances ACE2 binding affinity in combination with other RBD changes (Shafer et al., 2024).

2. **N-Terminal Domain (NTD) Deletions/Insertions (Spike Protein)**
   - **Δ144 / Δ143:** Deletions at positions 143–144 disrupt the antigenic supersite targeted by a broad range of NTD-directed neutralizing antibodies, facilitating immune escape (McCallum et al., 2021; Smyth et al., 2022). These deletions recur in NYC cryptic lineages (Lineages A, B, and D).
3. **Furin Cleavage Site Adjacent Mutation (Spike Protein)**
   - **P681H / P681R (Spike-S1/S2):** Located adjacent to the S1/S2 furin cleavage site, these substitutions enhance spike processing and syncytium formation, thereby contributing to increased transmissibility (Zhao et al., 2021; Lubinski et al., 2022). Observed sporadically in NYC and Missouri cryptic lineages.
4. **Non-Spike Regions**
   - **R203K + G204R (Nucleocapsid):** Co-occurring nucleocapsid substitutions that increase viral replication, fitness, and pathogenesis in vitro (Syed et al., 2021). Found in NYC cryptic lineages (Lineages A and D), correlating with higher RNA production relative to wild-type SARS-CoV-2 (Smyth et al., 2022).

If a cryptic lineage carries any of these mutations, it is likely closely related to a variant of concern and considered important to investigate.

Question 2: How many sightings have there been? How many independent detections have occurred?

A cryptic lineage must be detected independently at multiple locations and time points to be flagged as potentially significant and to guide targeted surveillance efforts. Below, we summarize the number of sightings and independent detection events for four representative cryptic lineage markers: MO45, Q493K, Q498Y, and WI-CL-001.

MO45 Lineage

The MO45 lineage has been observed exclusively in Missouri, USA, where it was first detected in a single wastewater treatment catchment in early 2022 and persisted with multiple repeat detections (over ten positive samples) in the same sewershed until at least October 2022 (Gregory et al., 2023). No MO45-like sequences have been reported outside this one catchment.

Q493K Mutation

The Q493K substitution has independently appeared at least eight times worldwide. In New York City, two distinct cryptic lineages (NYC Lineages A and C) each harbored Q493K and were repeatedly detected in the same sewershed over multiple sampling points (Smyth et al., 2022). Beyond NYC, single detections of Q493K-bearing cryptic RBD fragments occurred in at least three separate UK locations (London, Sheffield, Glasgow) and in additional U.S. states' wastewater catchments, but typically each instance was isolated to one sampling site and one time point (Gregory et al., 2022; Rushford et al., 2022).

Q498Y Mutation

Q498Y has been independently identified in approximately three distinct cryptic lineages. In New York City, both Lineage A and Lineage C contained Q498Y and were each detected repeatedly over time in the same municipal sewershed (Smyth et al., 2022). Outside NYC, isolated single-sample detections of Q498Y were reported in UK wastewater but did not persist over multiple time points.

WI-CL-001 Lineage

WI-CL-001 is a cryptic lineage confined to Wisconsin, USA, and has not been documented elsewhere. It was first observed in January 2022 from a municipal wastewater treatment plant and subsequently traced—via upstream sampling—to a single office building, where it was detected repeatedly over approximately five dates spanning six months (Shafer et al., 2024).

Question 3: Where has it been detected?

Cryptic SARS-CoV-2 lineages have been identified exclusively through municipal wastewater surveillance, predominantly in large urban catchments rather than within discrete high-risk facilities (Smyth et al., 2022; Shafer et al., 2024; Rushford et al., 2022). Specifically:

Urban Wastewater Catchments:

- Multiple cryptic lineages were repeatedly detected in a single New York City sewershed serving over 100,000 inhabitants (Smyth et al., 2022).
- WI-CL-001 was first observed in a Midwestern U.S. treatment plant and subsequently traced to one office building, without evidence of spread to other municipal sites (Shafer et al., 2024).
- In the United Kingdom and other European cities (e.g., London, Sheffield, Glasgow), cryptic RBD-focused sequences (e.g., E484A + T572N) arose in distinct wastewater treatment plants unlinked to clinical isolates (Rushford et al., 2022).

Absence in High-Risk Institutional Settings:

- No peer-reviewed data demonstrate cryptic lineage detection within nursing homes, hospitals, schools, or daycare centers. Routine clinical surveillance in these high-risk environments has not uncovered unique cryptic genomes undetected by broader community sequencing (Smyth et al., 2022; Shafer et al., 2024).

Question 4: How much interface is there between animals and humans?

Cryptic SARS-CoV-2 lineages may arise from either persistent human infections or animal reservoirs; consequently, evaluating the proximity between potential animal hosts and human populations is critical for risk assessment. In two well-characterized examples, animal–human interface differs markedly:

- Shafer et al. (2024) traced the WI-CL-001 lineage to a single individual working in a commercial building, with no evidence of nonhuman involvement. Because WI-CL-001 carried mutations consistent with human adaptation and was never detected in animal or environmental samples, the animal–human interface is minimal—shedding occurred exclusively via human waste into the sewer system (Shafer et al., 2024).
- In contrast, Smyth et al. (2022) identified four cryptic lineages confined to one New York City sewershed over several months. Each lineage possessed spike substitutions (e.g., Q493K, Q498Y, E484A) that facilitate infection of both human and rodent ACE2 receptors, strongly indicating a rodent reservoir. Urban rats inhabiting sewers that collect human waste create a direct interface: infected rodents shed virus into shared infrastructure, generating repeated detections in downstream sampling (Smyth et al., 2022).

Based on the answers to the above questions, decision-makers should assess:

- Whether the lineage poses a potential individual or public health risk
- Whether further investigation is ethically and logistically feasible
- Whether the risk-benefit ratio supports further action

If all or most indicators point to elevated concerns (e.g., significant mutations, repeated detections, high-risk locations, and animal-human interface), the policy recommends initiating a targeted investigation.

If the indicators do not suggest immediate concern, the policy advises ongoing monitoring, with reassessment should new data emerge.

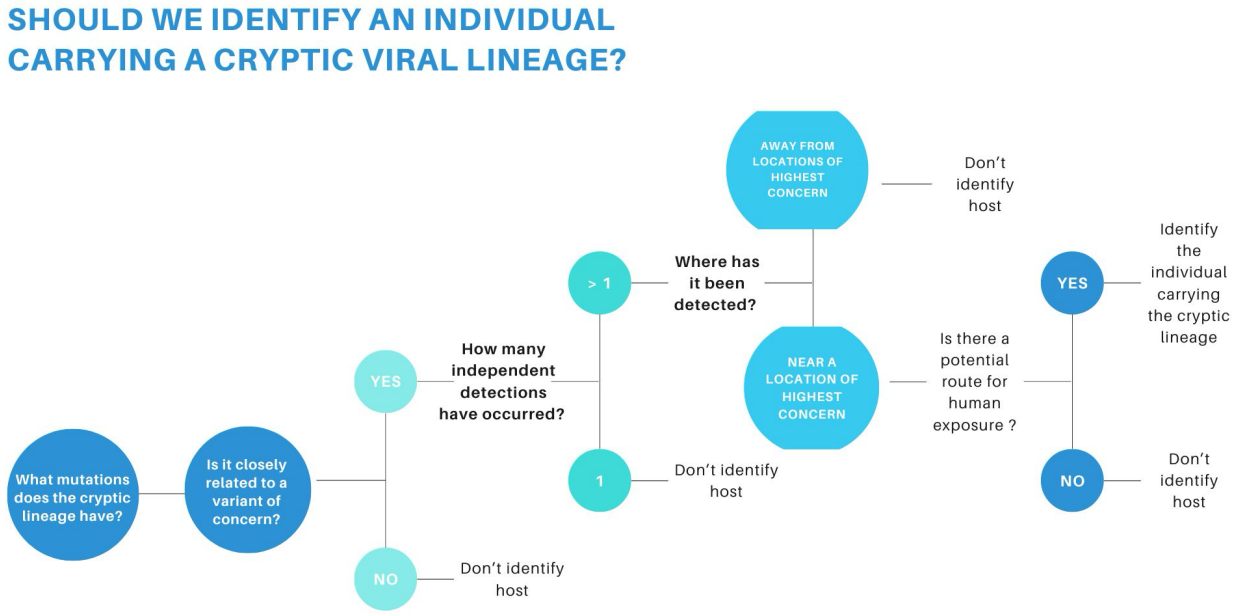

Figure 1. Example of the proposed decision-making flowchart.

2. Ethical Requirements and Reviews

Wastewater data is collected from public infrastructure and therefore delivers results at a population level. As a result, wastewater surveillance is not considered a risk to the privacy of individuals and does not require ethical review. However, identifying the individual carrying a cryptic viral lineage requires collection of personal data. This process raises significant concerns about privacy, consent, and potential stigmatization, so thorough ethical oversight is essential to protect individuals' rights while balancing the public health benefits. Moreover, these reviews ensure that data management, communication, and community engagement are conducted responsibly and transparently. We propose two phases of ethical review for surveillance of cryptic lineages:

- Ethical approval for identifying the hosts of cryptic lineage prior to beginning wastewater surveillance and the collection of cryptic lineage data
- Annual continuing delegated review of the surveillance project

Clearance from Ethics Board Prior to Beginning Wastewater Surveillance for Cryptic Lineages

Prior to beginning public health surveillance, we will set up an ethics board according to the guidelines from Canada's Interagency Advisory Panel on Research Ethics and seek ethical approval for wastewater surveillance and the identification of individuals carrying cryptic viral lineages (Government of Canada, 2023). Approval prior to beginning wastewater surveillance and continuing ethical reviews will allow for rapid identification of the host of a cryptic lineage before the signal disappears.

- Required members of the ethics board
    - At least one member of the board will be a member from the community/neighbourhood being surveilled
    - At least 2 members with expertise in the field of wastewater surveillance
    - One ethics expert
    - One member with expertise in public health law
- Prior to beginning the ethical review, researchers must:
    - Participate in a Human Ethics Training course
        - Ex.Tri-Council Policy Statement 2 (TCPS2) Course on Research Ethics (CORE)
        - Establish periodic refresher sessions and workshops on emerging issues
    - Establish clear protocols for data storage, access, and destruction of data collected during the surveillance project.
    - Draft consent forms for participants for approval by the ethics board
        - Required forms include:
            - Informed consent agreement
            - Agreements for data storage
                - These forms must include an explanation of future use of data, if any.
                - Data storage agreements must also include methods available for participants to withdraw their consent.
    - Develop a defined protocol for reporting any ethical breaches or data mismanagement issues.

Continuing Delegated Review

After initial ethical approval for wastewater surveillance and identification of individuals carrying cryptic viral lineages, continuing delegated ethical reviews will occur annually or at the discretion of the ethics board, whichever comes first, to provide dynamic oversight. The

delegated review will take place according to the requirements set by the TCPS2, and the delegated board will contain at least one community member (Government of Canada, 2023). Follow-up meetings and ad hoc reviews may be scheduled in response to emerging ethical challenges as individual-level data collection progresses. The continuing delegated ethical review will serve as a continuing learning process, allowing the project to incorporate feedback from community stakeholders and audit findings.

- At least two members of the initial ethics board are required to conduct a delegated review
- At least one of the delegated reviewers must be a community member

Addressing Systemic Bias and Historical Injustices

While wastewater surveillance at the population level typically poses minimal privacy concerns, efforts to identify individuals carrying cryptic viral lineages must be approached with an awareness of systemic bias and historical racism in public health surveillance. Historically marginalized communities have disproportionately borne the burden of intrusive data collection and punitive public health responses. These legacies necessitate an explicit commitment to equity and justice in the development of ethical frameworks.

- Ethical review boards must evaluate not only technical protocols but also the social and historical contexts in which surveillance occurs. This includes assessing whether certain communities may be overrepresented in monitoring due to infrastructural, demographic, or geographic factors.
- A member of the community being surveilled must be a member of the review board and delegated review board to ensure the interests of the community drive the ethical review of the wastewater testing project.
- All researchers will be required to take a training course addressing biases and cultural assumptions in public health.

Transparent Communication Channels

Part of the responsibility of the researchers is to ensure the surveillance project and the possible need to identify the host of a cryptic lineage is clearly communicated with the community being surveilled. Transparent communication channels must be set up to allow for dialogue between community members and scientists conducting wastewater surveillance.

- Researchers must prepare accessible materials that explain the ethical oversight process in simple language.
- Regular community meetings and periodic public reports will be conducted to maintain transparency and build trust throughout the surveillance project

Policy Communication

The Importance of Public Communication

When creating science policy, especially in domains such as **wastewater surveillance**, **environmental monitoring**, or other forms of **public health surveillance**, **public outreach becomes essential**. It is foundational to the **success**, **acceptance**, and **smooth implementation** of the policy.

Communication strategies must be designed to: 1-Foster trust, 2-Promote transparency, 3- Avoid the spread of misinformation
Without clear and accessible communication, even well-intended policies can be **misinterpreted** by the public and provoke **resistance**.

For example, during the **COVID-19 pandemic**, wastewater surveillance was used as an effective tool to track **viral outbreaks** at a population level. However, some communities reacted with great concern, mistakenly believing that such efforts could track **individual health data** or infringe on **personal privacy** (Nainani et al., 2024). These misconceptions, if left unaddressed, can spark **fear**, **anger**, and active **opposition** to scientifically beneficial programs.

More broadly, **misinformation** has been shown to derail public health efforts. A study by **Roozenbeek et al. (2020)** found that individuals exposed to misinformation about COVID-19 were less likely to follow public health guidelines, including **mask-wearing** and **vaccination**. In other words, misinformation does not only shape opinions but alters **individual behaviour** in ways that can hinder collective well-being.

In the context of **environmental monitoring**, where public cooperation is often implicit, building **trust** through **transparent communication** is key to success.

Principles of an Effective Communication Strategy

A well-designed public communication strategy must clearly explain:

- **What is being monitored** (e.g., aggregate viral loads, not personal data);
- **How the data is collected and processed;**
- **Why surveillance is important.**

This information must be presented in **clear language** that is accessible to **non-specialist audiences**, avoiding jargon while maintaining **scientific integrity**.

One good example is the **U.S. Centers for Disease Control and Prevention's (CDC)** *National Wastewater Surveillance System (NWSS)*, which explicitly states its **privacy safeguards** and **public health goals**. By emphasizing these principles in its public messaging, the CDC was able to gain **community support** and encourage **local participation** (CDC, 2023).

Communication Platforms

Dedicated Website

A cornerstone of our communication strategy is the creation of a **dedicated website** — an **accessible**, **adaptable**, and **transparent** platform for public engagement.

The website will:

1. Ensure **wide access** to diverse audiences;
2. Serve as a **centralized platform** for accurate and up-to-date information;
3. Promote **transparency** by disclosing important policy details (methodologies, ethical considerations, privacy policies).

Our proposed website will include several key components:

- **Overview** of the policy and its purpose (plain, accessible language);
- **Infographics and data visualizations** for wastewater surveillance of **cryptic viral lineages;**
- A **sample interactive quiz** — to demonstrate how data interpretation is conducted (not to test the user);
- **Privacy policy documentation** — explaining that no individual-level data is collected or traceable;
- **FAQs** addressing common public concerns on wastewater and environmental surveillance;
- **Feedback and question submission forms** — enabling public dialogue.

The website will emphasize **visual learning aids**, **intuitive navigation**, and **bilingual support** where appropriate.

QR Code Campaign

To further increase public engagement, we propose a **QR code campaign**. QR codes are a **user-friendly** approach to direct the public to online resources, especially the website.

We envision placing QR codes in the following public locations:

- **Street signs** in areas with ongoing monitoring;
- **Stickers** at community centers, libraries, or local health clinics;
- **Handouts and posters** at community events, universities, or public transit stations;
- **Information booths** at public events.

These QR codes will be strategically designed to be **visually appealing** and labelled with **approachable prompts**, in line with the principle of **"passive invitation"** to engage.

Reaching Diverse Audiences

By using both **digital** (website) and **physical** (QR code outreach) platforms, we aim to reach a **diverse audience** with our policy — including those who may not traditionally engage with or be familiar with **scientific policy**.

As emphasized by **Brossard and Scheufele (2013)**, **well-designed digital platforms** can improve **science literacy** and encourage **dialogue** rather than one-way communication.

While this strategy does not currently include live forums or town halls, we believe the **website-QR communication strategy** is an important **first step** toward building a more **reciprocal model** of scientific communication between policymakers and the public.

Policy Focus: Managing the Potential Identification of Individuals Through Wastewater Surveillance

Ethical Challenges and the Need for Policy

Wastewater-based epidemiology (WBE) is a powerful public health surveillance tool that typically monitors **population-level trends** and does not seek to identify individuals. However, recent advances in **high-resolution sequencing** and the emergence of **cryptic viral lineages** in wastewater have raised the possibility that surveillance could, under certain conditions, inadvertently lead to the identification of a **single infected individual** (Shafer et al., 2024).

Such situations introduce significant **ethical** and **privacy challenges** that current public health frameworks were not originally designed to address. A **clear** and **ethically grounded policy** is urgently needed to guide decision-making when potential **individual identification** arises.

Ethical Principles: Privacy, Proportionality, and Public Trust

The principle of **privacy** is foundational in public health ethics (Nuffield Council on Bioethics, 2022). While **wastewater** is legally considered **abandoned material** in Canada (Scassa et al., 2022), tracing surveillance data to an individual crosses into the realm of **personal data collection** — triggering **heightened ethical obligations**.

International ethical frameworks, such as the **Council for International Organizations of Medical Sciences (CIOMS) guidelines** and Canada's **Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2)**, emphasize that **identifiability**, **consent**, **risk of harm**, and **public interest** must all be carefully weighed when personal data is involved (Government of Canada, 2022).

Furthermore, the **proportionality principle** requires that any intrusion into privacy must be **necessary**, **justified**, and **minimized** (World Health Organization, 2017). This is especially crucial in communities with histories of **discriminatory surveillance** or **systematic marginalization** (WHO, 2019).

Recommended Ethical Approach

Ethical Review Before Identification Efforts

No attempt to identify an individual should proceed without **review and approval** by an **independent ethics board**, following the structure recommended in **TCPS2** and **INSPQ ethical standards** (Légis Québec, 2001).

The ethics board should include:

1. **Community representatives;**
2. **Public health ethics and law experts;**
3. **Wastewater surveillance scientists;**
4. **Equity and anti-racism experts.**

Criteria for Ethical Approval

The board must evaluate:

- The **level of public health risk** posed by the cryptic lineage;
- Whether the risk **cannot be mitigated** without identification;
- The potential for **harm** to the individual or community;

- The **least intrusive means** to achieve public health protection;
- **Community input** on the appropriateness of proceeding.

Public health necessity — not curiosity or scientific interest alone — must drive any approval to identify individuals (WHO, 2017; Nuffield Council on Bioethics, 2022).

Transparency and Public Communication

The public should be informed in advance (via communication strategies) that:

- **Wastewater surveillance** is community-level by design;
- Identification of individuals is only possible under **rare**, **exceptional circumstances;**
- Such actions would undergo **strict ethical review** with **community oversight.**

If an identification effort is approved, **transparency** should be maintained — while fully protecting the **identity of individuals** involved.

Respect for Identified Individuals

If an individual is identified:

- Their **consent** should be sought for any **medical intervention;**
- Any interaction should be **supportive**, **non-coercive**, and **confidential;**
- The goal is **public health protection** and **individual care**, not punishment;
- Data should be **securely stored** and **destroyed** when no longer needed.

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