Genomic Monitoring of Pathogens in Water

Funding Overview

EXECUTIVE SUMMARY

Genome Canada is launching a targeted genomic initiative, **Genomic Monitoring of Pathogens in Water** (GeMPaW) in April 2023 that will strengthen, complement and add value to existing pathogen monitoring efforts in Canada.

Building on the Genome Canada–led Canadian COVID-19 Genomics Network (**CanCOGeN)** and existing federal efforts in genomic surveillance of emerging pathogens (EPs) and antimicrobial resistance (AMR), we are undertaking this initiative using applied genomics surveillance data to inform public policy decisions in Canada.

According to the WHO[1], genomic surveillance is the consistent monitoring of pathogens and analyzing of their genetic similarities and differences. Significant challenges related to genomic monitoring of water include a siloed approach to detecting and reporting on pathogens, a lack of data standards and harmonization, a lack of national coordination, and a critical need to advance data-sharing and genomic monitoring to inform policy decisions.

AMR is a global concern that threatens to return humanity to an era before antibiotics. As a result, in 2017, the Government of Canada—in collaboration with provincial and territorial partners and other key collaborators—published a framework to support and implement the WHO's Global Action Plan on AMR and strengthen collaboration, governance, information-sharing and sustainability (**Tackling Antimicrobial Resistance and Antimicrobial Use: A Pan-Canadian Framework for Action**).

Genome Canada's GeMPaW initiative will put Canada in a ready state for future pandemics by developing and adopting high-quality, actionable, standardized genomic testing for EPs and AMR in water using a "One Health" lens.

This initiative utilizes a collaborative, multisectoral and transdisciplinary approach to:

- Address the threat of (re)emerging pathogens, with a focus on pathogens that can be detected in water and have been prioritized by the Public Health Agency of Canada (PHAC). Broad pathogen detection through multi-pathogen monitoring and genomic characterization in water may also be considered.
- Address the threat of AMR, including antibiotic resistant bacteria and antibiotic resistant genes.

[1] World Health Organization, Global genomic surveillance strategy for pathogens with pandemic and epidemic potential, 2022–2032 **https://www.who.int/publications/i/item/9789240046979**

- Advance genomic monitoring of antibiotic resistant genes with a focus on the six "ESKAPE" pathogens prioritized by the WHO: *Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa* and *Enterobacter.*
- Advance understanding of the connections between people, animals, plants and their shared environments (a "One Health" approach) in relation to pathogen genomic monitoring.
- Increase the value of pathogen monitoring data through national data-sharing, data standards, data analysis and data visualization to strengthen an evidence-driven approach for future pandemic preparedness.
- Develop knowledge mobilization strategies to support the utilization of genomic data and associated metadata in public health and policy decisions.

We will be launching this initiative in three parts with a combined total investment of $10 million. The three funding opportunities that will make up the portfolio are:

- The Community Coordination and Collaboration Hub (C3 Hub) (April 2023 launch)
- Regional EP/AMR monitoring teams (Winter 2024 launch)
- Indigenous-led monitoring in northern and remote communities (Timeline to be determined with Indigenous communities)

Genome Canada is working with diverse partners to leverage investments and ensure ecosystem cohesion on the cost-effectiveness and coordination of genomic monitoring of pathogens and AMR in water.

1. OVERVIEW

Emerging infectious diseases are caused by pathogens that newly appear in a geographic area or whose incidence increases rapidly.[2] Mostly zoonotic in origin, these have become more prevalent in recent years, as evidenced by the recent emergences of Zika virus, COVID-19, Ebola virus and monkeypox.[3] A crucial tool for detecting these diseases is an early genomic monitoring signal to detect, track and act. For instance, monitoring of unprocessed sewage[4] emerged during the COVID-19 pandemic as a practical, low-cost solution for population-wide monitoring across the globe. However, it needs to be coordinated, accessible and integrated with other screening methods to inform public health strategies.

[2] World Health Organization. Regional Office for South-East Asia. (2014). A brief guide to emerging infectious diseases and zoonoses. WHO Regional Office for South-East Asia. **https://apps.who.int/iris/handle/10665/204722**
[3] Cleaveland, S., Haydon, D.T., Taylor, L. (2007). Overviews of Pathogen Emergence: Which Pathogens Emerge, When and Why? In: Childs, J.E., Mackenzie, J.S., Richt, J.A. (eds.) *Wildlife and Emerging Zoonotic Diseases: The 4.*
[4] Biology, Circumstances and Consequences of Cross-Species Transmission. *Current Topics in Microbiology and Immunology* (Vol. 315). Springer, Berlin, Heidelberg. **https://doi.org/10.1007/978-3-540-70962-6_5**
[4] Wastewater monitoring comes of age. Nat Microbiol 7, 1101–1102 (2022). **https://doi.org/10.1038/s41564-022-01201-0**

Antimicrobial resistance (AMR) occurs when pathogens evolve mechanisms that reduce or eliminate the effectiveness of antimicrobial medicines.[5] The global impact of this phenomenon is tremendous: 4.95 million human deaths per year globally are associated with AMR, and 1.27 million deaths are directly attributable to it. AMR may cause more deaths by cancer by the year 2050 by some estimates. Climate change is likely to exacerbate this trend, given the positive correlation between temperature and the rate of infections caused by many bacterial pathogens. Human behaviour—including overuse of antibiotics—has led to pathogens that are resistant to medicines, allowing the re-emergence of pathogens that were on a decline.

The WHO has identified the need for coordinated and inclusive access to genomic monitoring through its 10-year **Global Genomic Surveillance Strategy**. Genomic monitoring strategies across the world are now moving from an individual testing approach toward a more collective, effective and cost-efficient approach. To facilitate rapid intervention and prevent the spread of infectious diseases, strategies that enable economical, early and efficient detection are key. However, some challenges persist within this space.

For instance, current genomic monitoring initiatives are inefficient, and there are important bottlenecks and barriers around data generation and (most importantly) data-sharing and data analytics. There is a lack of access to relevant data sets and accompanying contextual information. In addition, genomic monitoring initiatives in Canada are fragmented, with a lack of coordination between provinces and between and within sectors (i.e., academia, public health, private and government). There are limited data standards and protocols along with a lack of data harmonization and strategies or platforms to share and visualize data across Canada. There are also important challenges related to equity and inclusion—particularly concerning northern, remote and isolated communities in Canada, many of which are home to First Nations, Métis people or Inuit. These communities still do not have access to structured genomic monitoring initiatives and have been excluded from water-based pathogen and AMR genomic monitoring initiatives. Early pathogen detection in such settings is critical, given that deficits in existing health systems can exacerbate onward transmission and increase poor health outcomes for local populations.

Medical, veterinary, food and environmental sciences are separate fields of expertise at the institutional level in most countries, often located in different institutes and funded by different organizations. This has led to inefficient exploitation of new techniques, redundant or overlapping research activities, and suboptimal systems for assessing risk and managing emerging threats, possibly leading to important missed opportunities to inform public policy decisions. Humans are not the sole consumers of antimicrobial agents. Antimicrobials are employed throughout our food chain to improve crop yields and reduce infections and mortality in agriculture and fisheries, for example. Therefore, when designing and implementing an AMR strategy, a "One Health" approach is advised.

[5] Council of Canadian Academies, 2019. When Antibiotics Fail. Ottawa (ON): The Expert Panel on the Potential Socio-Economic Impacts of Antimicrobial Resistance in Canada.

A "One Health" approach recognizes that humans, animals and our environment are closely connected. It enables improved integration and alignment of different genomic monitoring systems in Canada across research areas. Wastewater-based monitoring of AMR is promising, with a capacity to provide vital information for mitigating the spread of AMR. This includes assessing antibiotic resistance genes (ARGs) that circulate among human populations; identifying key hotspots for the evolution and dissemination of resistance; informing epidemiological and human health risk assessment models; and quantifying removal efficiencies by domestic wastewater infrastructure. ARGs are mobile genetic elements that can pass between a population of bacteria and among different species of bacteria (i.e., horizontal spread). ARGs have contributed to the rapid dissemination of AMR among several bacterial genera. Effective monitoring methods for ARGs allow for abiotic and biotic remediation strategies for the removal and reduction of antibiotics and ARGs from the environment.

Building on the successes and lessons learned during the implementation of **CanCOGeN**, the GeMPaW initiative incorporates:

- The value of cross-sectoral collaboration (between the federal government, public health labs, academic groups and the private sector).
- The need to advance efficient, sustained and timely (meta) data-sharing and data integration practices in Canada.
- The imperative of harmonized data analysis and data standards across multiple domains to drive policy.

Generating data is only part of the genomics process. While CanCOGeN focused on individual genomic monitoring, building capacity and sharing data, GeMPaW will utilize community genomic monitoring data to inform public policy.

Along with Genome Canada's other challenge-driven initiatives, this initiative will work across the ecosystem to mobilize academic, public and non-profit sector partners to tackle this complex challenge.

2. OBJECTIVE

The objective of the GeMPaW initiative is to enhance the adoption of best practices for high-quality, actionable, standardized testing for water-based pathogen and AMR genomic monitoring to inform public policy decisions.

Through this initiative, we aim to:

- Advance data standards, data analysis and data-sharing across Canada to ensure a coordinated effort around the genomic monitoring of pathogens and antimicrobial resistance (AMR) in water.
- Maximize available capacity to undertake water-based pathogen and AMR genomic monitoring (e.g. equipment and high-quality personnel developed through CanCOGeN and other initiatives).

- Influence policy through real-world evidence and best practices to inform public health, agricultural and environmental decisions.
- Develop mechanisms through which data from water-based pathogen and AMR genomic monitoring can be integrated, adopted and used by regional, federal and global administrative groups.
- Establish strategic partnerships between academic groups and public users, such as public health laboratories and ministries of agriculture or environment across Canada.
- Develop processes that will improve Canadian resilience and pandemic preparedness.
- Position Canada as a global leader in discussions of water-based pathogen and AMR genomic monitoring, including data standards and policy.

Given the highly connected nature of the "One Health" system, emerging pathogens and AMR are a rising threat to all sectors of the ecosystem: humans, animals and the environment. Monitoring and tracking these threats will help us understand the challenge and inform public policy decisions to better mitigate AMR and proactively manage emerging pathogens. This Initiative approach will bring together diverse partners to support these monitoring and data utilization efforts through coordinated research and implementation activities.

GeMPaW aims to support public health and other public sector institutions through complementary activities that are well suited to research (e.g., data, technology and socio-economic problems). This initiative will build on the success of CanCOGeN in providing the structures for public health and other government institutions to collaborate with the academic research community.

3. PORTFOLIO APPROACH

A distinguishing feature of the GeMPaW initiative will be the creation of an integrated portfolio of diverse regional projects. By adopting a portfolio approach, it will be possible to synergize the deliverables of the regional projects toward broader national outcomes and impact.

In addition, the Community Coordination and Collaboration Hub (C3 Hub) will act as the executive secretariat and provide strategic leadership to ensure the coherence, coordination and integration of the regional monitoring projects to drive national impact. The C3 Hub will focus on cross-cutting themes, such as data standardization, visualization, integration and coordination, as well as connectivity with genomic monitoring in Indigenous communities. In addition, the C3 Hub will use the integrated concept of "One Health" to link and standardize data and coordinate policy to bridge systemic gaps across the animal, human and environment continuum. Finally, the C3 Hub will drive uptake, implementation and adoption by using knowledge mobilization tools.

The C3 Hub will ensure that regional monitoring projects in the portfolio can connect, convene and learn from each other regularly so the group can collectively support the Initiative's research—and drive knowledge mobilization and implementation—to achieve the intended

impact at the public policy level.

4. FUNDING OPPORTUNITIES

There is $10 million available from Genome Canada to support three GeMPaW funding opportunities . These will include the Community Coordination and Collaboration Hub (C3 Hub), regional monitoring projects, and Indigenous-led monitoring in northern, remote or isolated communities.

1. Community Coordination and Collaboration Hub (C3 Hub)

The C3 Hub will act broadly as connector, ensuring that emerging pathogen and antimicrobial resistance (AMR) genomic monitoring data are used to inform public policy decisions.

The C3 Hub will develop, coordinate and implement a portfolio operation plan for the GeMPaW initiative. The plan will include aspects of administration (e.g. project management, meetings and reporting), data (e.g. governance, storage and analytics) and knowledge mobilization (e.g. communication, engagement and policy). Moreover, the plan will describe mechanisms to connect and learn from the First Nation, Inuit and Métis monitoring projects and other international programs in water genomic monitoring forEP and AMR . Where appropriate, the C3 Hub will be responsible for harmonizing data processes (e.g., standards, metadata and protocols) and developing a single point of entry for data resources (e.g. datasets, tools and pipelines). It will work with the regional portfolio projects to address data-sharing challenges and build national and international data standards that benefit Canadian and global genomic monitoring communities for water-based pathogens and AMR. **A maximum of $3 million is available from Genome Canada, and 1:1 co-funding will be required.**

This funding opportunity will be launched in April 2023.

2. Regional EP and AMR monitoring teams

Six regional teams will be funded to implement water-based monitoring programs for emerging pathogens (EPs) and antimicrobial resistance (AMR). The academic teams are required to have the support of public sector end users, such as public health laboratories and ministries of agriculture or environment. End-user support could include playing a direct role on the project team, providing co-funding or committing to review pilot deliverables for broader regional adoption and policy framing. Water sources for monitoring include, but are not limited to, sewage, wastewater treatment plants, saltwater, freshwater and groundwater. Promoting collaborations between researchers and public institutions and/or scientists is a core aspect of this initiative.

To support these objectives, the teams will work closely with the C3 Hub to:

- Implement a genomic monitoring program for water detectable pathogens and AMR that is meaningfully supported by public sector end users.

- Develop best practices for a high-quality test for genomic monitoring of water detectable emerging pathogens and AMR.
- Harmonize data standards, including analytic tools and visualization.
- Share project outputs, including data, best practices and protocols, to encourage adoption beyond the project and to maximize portfolio impact.
- Foster collaboration between academics, public health labs and government agencies.
- Where appropriate, build capacity through data generation to support the overall program objectives of improving data-sharing, visualization and analytics to support water detectable pathogen and AMR genomic monitoring activities.

The focus of the regional monitoring teams is not data generation. However, there may be a need to build capacity in this regard. Priority will be given to data-sharing, visualization and analytics to support water-based pathogen and AMR genomic monitoring activities.

A maximum of $6 million is available ($1 million per Genome Centre) from Genome Canada; 1:1 co-funding will be required.

The funding opportunity will be launched in Winter 2024.

3. Indigenous-led monitoring in northern and remote communities

This component of the GeMPaW initiative is specifically intended for genomic monitoring projects in northern and remote communities that meet one of the following three criteria:

- It is led by community-based Indigenous researchers and/or organizations.
- It takes place on Indigenous land.
- It incorporates Indigenous knowledge.

The objective of Indigenous-led monitoring in northern and remote communities is to:

- Advance genomic monitoring approaches that use water sources—including sewage, wastewater treatment plants, saltwater, freshwater, groundwater, well water or drinkable water—to respond to the needs and priorities of Indigenous communities.
- Advance genomic monitoring capacity-building and knowledge mobilization in Indigenous communities.
- Prioritize pathogens that are detectable in water of particular importance to Indigenous communities.
- Support Indigenous data sovereignty and information governance as they relate to Indigenous-led genomics monitoring.

There will be approximately $1 million available from Genome Canada. Co-funding is NOT a requirement. This funding opportunity for Indigenous-led monitoring in northern and remote communities will be shaped in consultation with the applicant lead(s), including timelines and scope.