PRIMER

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Antimicrobial resistance in Canada's wastewater systems: Emerging risks

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Key insights

- Antimicrobial resistance (AMR) is a serious and growing threat to human health. It is already causing significant illness and death worldwide, including in Canada. If not addressed urgently, it will continue to undermine the effectiveness of life-saving medical treatments and lead to major social and economic costs.
- Antimicrobial-resistant bacteria (ARB) and genes are present in wastewater and treatment systems. However, scientific understanding of how treatment plants reduce, spread, or unintentionally amplify these organisms is still evolving. Important knowledge gaps remain, underscoring the need for continued research and for water utilities to stay informed and ready to adapt as new evidence and guidance emerge.
- There is no clear guidance yet on best practices for water utilities. That said, addressing AMR will require a coordinated One Health approach across human, animal, and environmental systems. As science and policy evolve, the role of water utilities will need to be considered as part of this broader response.

Why is AMR a growing concern?

AMR develops through the overuse, misuse, and improper disposal of antibiotics, antifungals, and other antimicrobials in healthcare, veterinary medicine, industry, and agricultural settings. As resistance increases, many life-saving medical treatments become less effective and jeopardize food and animal production worldwide.[1]

Glossary of Acronyms

AMR: Antimicrobial Resistance
ARB: Antimicrobial Resistant Bacteria
ARG: Antimicrobial Resistant Genes
ECCC: Environment and Climate Change Canada
PHAC: Public Health Agency of Canada
WWTP: Wastewater Treatment Plant

ARB are already responsible for a significant and growing number of deaths. Researchers estimate that between 1990 and 2021, ARB caused more than one million deaths each year. Without improved antimicrobial stewardship, this number is projected to increase by 75 percent by 2050.[2]

These effects are already being felt in Canada. In 2018, resistant bacterial infections contributed to more than 14,000 deaths. Of these, 5,400 deaths — nearly 15 every day — were directly attributable to AMR. This means the infections would likely have been treatable with first-line antibiotics.[3]

Beyond the health impacts, AMR carries a substantial economic burden. In 2018 alone, the reduced labour productivity linked to AMR lowered Canada's gross domestic product by an estimated $2 billion.[4]

Wastewater systems in the broader AMR landscape

Sewage systems and wastewater treatment plants (WWTPs) can act as reservoirs that collect and potentially release antimicrobials, ARB, and antimicrobial resistance genes (ARGs). Wastewater from hospitals, pharmaceutical manufacturing, veterinary facilities, and agricultural operations often contains elevated concentrations of antibiotics and ARB.

WWTPs are primarily designed to remove nutrients and disease-causing pathogens using physical processes and bacterial treatment. However, certain conditions within treatment systems can allow resistance genes to persist and, in some cases, increase in prevalence. As a result, when treatment processes do not sufficiently remove or reduce ARB, these bacteria can accumulate within WWTPs and be discharged into rivers, lakes, and other receiving waters through treated effluent.

In addition, antimicrobial resistance genes can transfer to other bacteria within treatment systems and the surrounding environment. This process enables resistance to spread further.[5] It also creates potential pathways for human exposure, including through irrigation of agricultural land and contaminated water supplies.[1]

We are still working to understand the direct pathways between antimicrobial resistance and human health. At the same time, it is clear that the spread of AMR through humans, animals, and the environment is interconnected. Addressing AMR, therefore, requires a cross-sector, One Health approach that recognizes the close connection between human, animal, and environmental health.[5,6]

The role of wastewater in the development of AMR

To understand how WWTPs contribute to the spread of antimicrobial resistance, it is helpful to consider three key mechanisms: occurrence, selection, and transmission.

Occurrence: The presence of AMR in the environment

Canada does not currently have a national system to monitor AMR in wastewater or the broader environment. This reflects a global challenge, as standardized environmental monitoring for AMR remains limited.

To address this, the Public Health Agency of Canada (PHAC) released an Environmental Surveillance Strategic Framework for Antimicrobial Resistance in November 2025. The framework outlines how PHAC could lead environmental AMR surveillance, including monitoring in water systems. While it recognizes the role of water and wastewater in AMR, it does not define any actions for water utilities to take.[7]

Despite the lack of routine monitoring, several studies in Canada and internationally have detected ARB and ARGs in wastewater. Research has identified antibiotic-resistant bacteria in WWTPs that carry the same resistance genes found in clinical settings.[8,9]

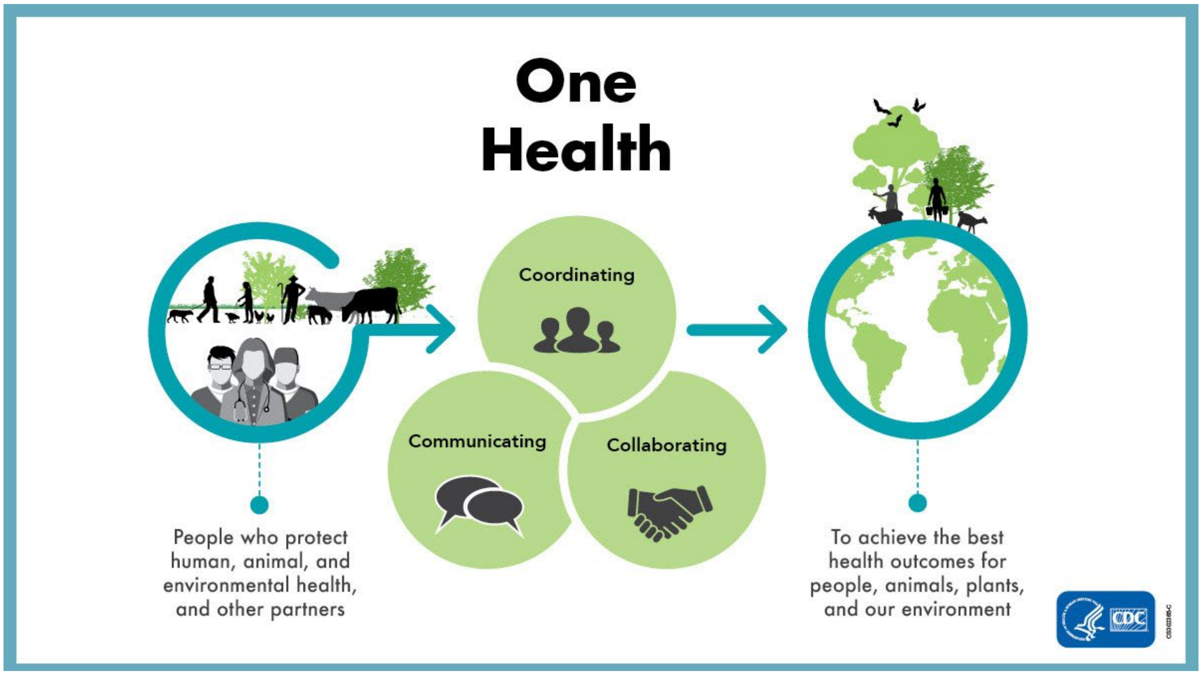

Figure 1: A One Health approach involves coordination between multiple sectors to protect human, animal, and environmental health. Image credit: Centers for Disease Control and Prevention (2025). Reference to the image does not constitute endorsement or recommendation by the CDC. The image is available on the CDC's website for no charge.

For example, Freeman and her team (2018) measured eight antimicrobial resistance genes in treated wastewater after a plant in Regina, Saskatchewan upgraded its processes with bioreactors and enhanced UV disinfection. Six of the eight resistant genes were found at higher levels downstream of the plant than upstream. While concentrations decreased further downstream, most did not return to upstream levels.[10]

Although this single study cannot represent conditions in wastewater across Canada, it aligns with broader evidence showing that WWTPs can act as sources of antimicrobial-resistant genes and bacteria.

At the same time, studies also point to specific wastewater sources as hotspots for AMR. Hospitals, veterinary facilities, agricultural operations, and pharmaceutical manufacturing sites often contain higher levels of antibiotics, ARB, and ARGs.[1,11]

In a 2015 study of a WWTP in Girona, Spain, fluoroquinolones, which are a class of commonly used antibiotics, were found in higher levels in hospital wastewater than in urban wastewater. However, similar levels of ARGs were detected in both sources. Although hotspot environments may contribute elevated levels of antibiotics, resistant genes, or bacteria in some cases, studies like this suggest that such patterns are not consistent across all regions or for all elements of AMR.[12]

Selection: Conditions that allow resistant strains to develop and thrive

Beyond simply containing AMR, wastewater systems contain characteristics that can favour the survival and growth of antimicrobial-resistant bacteria. These include antibiotic residues, nutrients, and other chemical and physical properties.

Through Environment and Climate Change Canada's (ECCC) monitoring program for pharmaceutical and personal care products, wastewater treatment plants are sampled for 135 different compounds, including antimicrobials.[13] Many antimicrobials are not fully broken down in the human or animal body. Between 30 and 90 percent of antimicrobials can enter wastewater in an active form.[1]

The continued presence of these substances in wastewater creates selective pressure that allows ARB and ARGs to persist and increase within WWTPs.

Although ECCC has observed declines over time in some antimicrobial concentrations, residues are still detected in raw sewage entering the plant, in treated effluent, and in biosolids. The types and levels of residues vary depending on the community and chemical properties of each antimicrobial, such as how strongly it binds to solids.[13]

Other treatment conditions also may influence AMR. These include temperature fluctuations during treatment, the presence of heavy metals, and pH levels.[1] Microplastics are another emerging concern. They can readily form biofilms and carry antibiotic residues, which can enable them to become potential vectors for ARB and ARGs.[10]

Transmission: Pathways to humans, animals and the natural environment

Most research on AMR in wastewater focuses on where resistance is found and how it persists within treatment systems. Less is known about how AMR spreads through the environment to humans.[14]

Research by PHAC identifies surface water and soil as potential transmission routes. This raises concerns about resistance accumulating in agricultural soils irrigated with reclaimed water or fertilized with biosolids. Drinking water is another possible exposure pathway, although current evidence is limited and does not quantify direct human health impacts from environmental AMR.[15]

Additional studies have examined airborne particles released from AMR hotspots, including WWTPs, as a potential transmission route. However, this pathway is not well characterized and remains an area of ongoing research.[14,16]

Reducing AMR through wastewater treatment: What we know so far

There is currently no standard guideline or best practice for using wastewater treatment to remove or reduce AMR bacteria or genes. While individual studies provide useful insights, more research is needed before consistent, evidence based guidance can be developed.

Many treatment processes significantly reduce overall bacteria levels. However, resistant genes can persist in treated effluent and enter downstream environments.[17]

Some studies suggest that higher doses of UV disinfection can reduce antimicrobial-resistant material. Others show that combining UV with chlorine disinfection may be more effective than either method alone. In some cases, additional pretreatment or oxidizing agents may be required to achieve better results.[1]

Evidence on the efficacy of chlorination is mixed. Some studies find it effective at reducing ARB and ARGs, while others do not.[16] There is also concern that chlorination byproducts may encourage genetic processes that promote resistance.[10]

Coagulation has emerged as a potentially effective and lower cost option for removing resistance genes, though findings are still limited. Overall, researchers have identified promising approaches. However, no single treatment strategy has emerged as a clear solution.[10]

Where we stand and where we're headed

Current research consistently shows that WWTP effluent contains some level of antibiotic residues, ARB, and ARGs. However, without standardized national monitoring, it is difficult to fully understand how widespread they are in wastewater or other environmental reservoirs.

Most of the existing monitoring efforts focus on antimicrobial use in healthcare and veterinary settings. While this is important, integrating environmental AMR into public health surveillance is also necessary to support informed policy and long-term risk management.

Although many uncertainties remain, staying informed about emerging science and policy is increasingly important for the water sector. Both PHAC and the World Health Organization support expanding surveillance to include environmental AMR.

PHAC's Environmental Surveillance Strategic Framework for Antimicrobial Resistance provides an important step forward. While next steps for municipalities are not yet clearly defined, collaboration with water utilities will be essential if environmental surveillance efforts expand.[4]

Given the growing public health risks posed by antimicrobial resistance, water utilities will need to remain informed, adaptive, and engaged as evidence and guidance continue to evolve.

Research initiatives and additional resources

Advancing Canadian Water Assets (ACWA), University of Calgary: Graduate research opportunities focused on AMR in wastewater.

Government of Canada (GRDI): Antimicrobial Resistance – One Health Project (AMR-OH)

Global Water Research Coalition (GWRC): AMR Science Brief

Global Water Research Coalition (GWRC): Quantifying and Addressing the Contribution of Water and Wastewater to the Emerging Risk of Antimicrobial Resistance

McMaster Health Forum / PHASES Collaborative: Rapid synthesis of environmental antimicrobial resistance (AMR) knowledge and surveillance in Canada

Public Health Agency of Canada (PHAC): Pan-Canadian Action Plan on Antimicrobial Resistance

World Health Organization (WHO): Global action plan on antimicrobial resistance

Public Health Agency of Canada (PHAC): Environmental Surveillance Strategic Framework for Antimicrobial Resistance

References

1. La Rosa, M. C., Maugeri, A., Favara, G., La Mastra, C., Magnano San Lio, R., Barchitta, M., & Agodi, A. (2025). The Impact of Wastewater on Antimicrobial Resistance: A Scoping Review of Transmission Pathways and Contributing Factors. Antibiotics, 14(2), 131. https://doi.org/10.3390/antibiotics14020131

2. Naghavi M, Vollset S, Ikuta K et al. (2024). Global burden of bacterial antimicrobial resistance 1990–2021: a systematic analysis with forecasts to 2050. The Lancet, 2024; 404, 1199-1226. https://doi.org/10.1016/S0140-6736(24)01867-1

3. Council of Canadian Academies (2019). When Antibiotics Fail. Ottawa (ON): The Expert Panel on the Potential Socio-Economic Impacts of Antimicrobial Resistance in Canada. Available from: https://www.cca-reports.ca/reports/the-potential-socio-economic-impacts-of-antimicrobial-resistance-in-canada/

4. Public Health Agency of Canada (2023). Pan-Canadian Action Plan on Antimicrobial Resistance. Available from: https://www.canada.ca/en/public-health/services/publications/drugs-health-products/pan-canadian-action-plan-antimicrobial-resistance.html

5. Despotovic, M., de Nies, L., Bhanu Busi, S., Wilmes, P. (2023) Reservoirs of antimicrobial resistance in the context of One Health. Current Opinion in Microbiology, Volume 73, 2023,102291, ISSN 1369-5274, https://doi.org/10.1016/j.mib.2023.102291

6. Global Water Research Coalition (2024). Quantifying and Addressing the Contribution of Water and Wastewater to the Emerging Risk of Antimicrobial Resistance. Available from: https://globalwaterresearchcoalition.net/resource/antibiotic-resistance-in-the-water-environment/

7. Public Health Agency of Canada (2025). The Public Health Agency of Canada's Environmental Surveillance Strategic Framework for Antimicrobial Resistance: Pathways to Action – Advancing the Pan-Canadian Action Plan on Antimicrobial Resistance. Available from: https://www.canada.ca/en/public-health/services/publications/drugs-health-products/environmental-surveillance-strategic-framework-antimicrobial-resistance.html

8. Szczepanowski, R.; Linke, B.; Krahn, I.; Gartemann, K.H.; Gützkow, T.; Eichler, W.; Pühler, A.; Schlüter, A. Detection of 140 clinically relevant antibiotic-resistance genes in the plasmid metagenome of wastewater treatment plant bacteria showing reduced susceptibility to selected antibiotics. Microbiology 2009, 155, 2306–2319. https://doi.org/10.1099/mic.0.028233-0

9. Odih EE, Sunmonu GT, Okeke IN, Dalsgaard A.2023.NDM-1- and OXA-23-producing Acinetobacter baumannii in wastewater of a Nigerian hospital. Microbiol Spectr 11:e02381-23. https://doi.org/10.1128/spectrum.02381-23

10. Freeman, C. N., Scriver, L., Neudorf, K. D., Hansen, L. T., Jamieson, R. C., & Yost, C. K. (2018). Antimicrobial resistance gene surveillance in the receiving waters of an upgraded wastewater treatment plant. FACETS, 3(1), 128–138. https://doi.org/10.1139/facets-2017-0085

11. Sambaza, S.S., and Naicker, N., Contribution of wastewater to antimicrobial resistance: A review article, Journal of Global Antimicrobial Resistance, Volume 34, 2023, Pages 23-29, ISSN 2213-7165, https://doi.org/10.1016/j.jgar.2023.05.010

12. Rodríguez-Mozaz, S., Vaz-Moreira, M. J., Varela Della Giustina, S., Llorca, M., Barceló, D., Schubert, S., Berendonk, T. U., Michael-Kordatou, I., Fatta-Kassinos, D., & others. (2015). Occurrence of antibiotics and antibiotic resistance genes in hospital and urban wastewaters and their impact on the receiving river. Water Research, 69, 234–242. https://doi.org/10.1016/j.watres.2014.11.021

13. Gewurtz, S.B., Auyeung, A.S., Teslic, S. et al. Pharmaceuticals and personal care products in Canadian municipal wastewater and biosolids: occurrence, fate, and time trends 2010–2013 to 2022. Environ Sci Pollut Res 32, 5022–5039 (2025). https://doi.org/10.1007/s11356-025-36007-0

14. Taing, L., Whitelaw, H., Wilson, M. G. (2025). Rapid synthesis of environmental antimicrobial resistance (AMR) knowledge and surveillance in Canada. McMaster Health Forum & PHASES Collaborative. Available from: https://www.mcmasterforum.org/docs/default-source/product-documents/rapid-responses/rapid-synthesis-of-environmental-antimicrobial-resistance-(amr)-knowledge-and-surveillance-in-canada.pdf?sfvrsn=55203084_3

15. McCubbin KD, Anholt RM, de Jong E, Ida JA, Nóbrega DB, Kastelic JP, Conly JM, Götte M, McAllister TA, Orsel K, Lewis I, Jackson L, Plastow G, Wieden HJ, McCoy K, Leslie M, Robinson JL, Hardcastle L, Hollis A, Ashbolt NJ, Checkley S, Tyrrell GJ, Buret AG, Rennert-May E, Goddard E, Otto SJG, Barkema HW. (2021). Knowledge Gaps in the Understanding of Antimicrobial Resistance in Canada. Front Public Health. 2021 Oct 20;9:726484. doi: 10.3389/fpubh.2021.726484

16. Gao, Y., Li, X., Fan, X., Zhao, J., Zhong-Xing, Z. (2022). Wastewater treatment plants as reservoirs and sources for antibiotic resistance genes: A review on occurrence, transmission and removal, Journal of Water Process Engineering, Volume 46, 2022, 102539, ISSN 2214-7144, https://doi.org/10.1016/j.jwpe.2021.102539

17. Cydzik-Kwiatkowska, A., Zielińska, M. Bacterial communities in full-scale wastewater treatment systems. World J Microbiol Biotechnol 32, 66 (2016). https://doi.org/10.1007/s11274-016-2012-9