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Environmental pathways of antimicrobial resistance: A One Health case study

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Key Messages

- Antimicrobial resistance (AMR) is an environmental public health issue that extends beyond clinical and agricultural settings into households, wildlife, and drinking water systems.
- A One Health approach is essential for understanding and responding to AMR, as resistant organisms are emerging and spreading across interconnected human, animal, and environmental systems.
- Everyday environmental pathways such as pet food, wildlife, and drinking water play a role in contributing to AMR pathways.
- Research indicates that some underserved and Indigenous communities, especially those that rely on small or aging drinking water systems, experience higher levels of AMR in their drinking water. This is likely due to environmental contamination and limited resources for system maintenance, upgrades, and ongoing water quality monitoring.
- Environmental public health professionals (EPHPs) play a critical role in AMR surveillance by supporting early detection, performing risk assessments, and protecting communities through public education and awareness.

Introduction

Excessive and improper use of antimicrobials across healthcare, agriculture, and other sectors has contributed to the development of antimicrobial resistance (AMR) in bacteria, parasites, viruses, and fungi. This in turn reduces the effectiveness of medicines, including antibiotics, antivirals, antifungals, and antiparasitics used to treat human infections, resulting in increased morbidity, mortality, and healthcare costs from infections caused by treatment-resistant pathogens, predicted to increase without coordinated action.^{1,2} AMR is widely recognized as a complex public health challenge that extends beyond hospitals, farms, and clinical prescribing practices.³ Environmental pathways shaped by human behaviour, animal populations, ecosystems, and the built environment play a critical role in the emergence, persistence, and spread of resistant organisms. The One Health framework explicitly connects human, animal, and environment health through coordinated and cross-sector collaboration, facilitating a comprehensive approach to managing environmental health risks.⁴ For environmental public health professionals (EPHPs), understanding and applying a One Health approach to AMR is essential for

developing effective surveillance, risk assessment, and prevention strategies aimed at reducing the spread of AMR across interconnected systems.

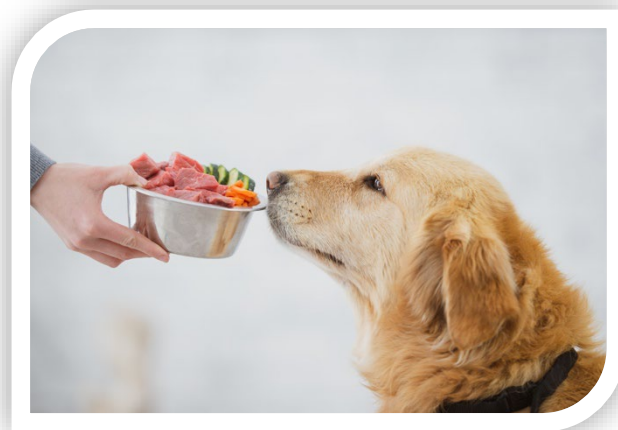
This case study explores three examples designed to illustrate the role of environmental public health in addressing AMR using a One Health lens. Each example highlights a different exposure pathway:

1. Raw dog food as a vector for resistant pathogens
2. Wildlife populations as both indicators and contributors to the spread of AMR across ecosystems
3. Drinking water systems as reservoirs and transmission routes for antimicrobial resistance

Together, these examples demonstrate how AMR can be introduced, amplified, and transported across ecosystems, highlighting the importance of integrated, cross-sectoral approaches aligned with One Health principles. Such an approach facilitates the linkage of human, animal, and environmental data to support early detection of emerging threats and inform targeted intervention strategies to reduce the spread of AMR organisms.

Example 1: Raw dog food as a vector for resistant pathogens

Background: Over the past decade, [raw meat-based diets for pets](#) have increased in popularity.^{5,6} Many pet owners are drawn to these diets because of perceived health benefits, despite limited clinical evidence demonstrating positive outcomes.^{7,8} Documented concerns around raw meat-based diets include: 1) exposure to pathogens, 2) introduction and amplification of AMR organisms, and 3) a nutritionally unbalanced diet.^{5,7} There are various pathways by which AMR can transfer to meat either at the production site or along the food processing chain; however, pet food production is not as strictly regulated as food intended for human consumption.⁹



Studies have shown that raw meat-based diets for dogs are frequently contaminated with multidrug-resistant bacteria, including *Escherichia coli*, *Salmonella*, *Campylobacter jejuni*, and *Enterococcus*, with some strains resistant to critical antibiotics.¹⁰⁻¹² Dogs fed raw meat-based diets are significantly more likely to shed resistant bacteria in their feces. These organisms can persist in household environments,

contribute to environmental contamination, and be transmitted to humans through direct and indirect contact.^{13,14}

One Health relevance: From a One Health perspective, the household practice of providing raw meat-based diets to pets represents a common interface between food systems, domestic animals, and human environments. People who feed their pets raw meat-based diets may not be aware of the possible human health risks within the household and how to mitigate them. Fecal shedding of resistant bacteria by pets can also introduce AMR organisms into soil, stormwater systems, parks, and recreational spaces, extending transmission pathways beyond the household into the environment. EPHPs can support reducing AMR risks through educating the pet food sector and pet owners on the importance of safe pet food handling and preparation, including hand hygiene, and the importance of immediate fecal cleanup to minimize risks. It is also important to remember that food products intended for pets do not go through the same food safety regulations as humans and can carry pathogens. Awareness of non-human exposure pathways for resistance bacteria can aid community-level exposure assessments and outbreak investigations.

Example 2: Wildlife populations as both indicators and contributors to the spread of AMR across ecosystems

Background: AMR has been detected in free-ranging wildlife with no direct exposure to antibiotics, a result of antimicrobials used in human medicine, veterinary care, and agriculture reaching the environment.¹⁵ A recent systematic review and meta-analysis found resistant *E. coli*, *Salmonella*, and *Campylobacter* across multiple wildlife species, including ungulates such as deer, elk, and moose.¹⁶ Wild birds (especially seagulls), wild boar, wild rodents, foxes, raccoons, and bats can also act as reservoirs contributing to AMR.^{17,18}



The presence of AMR in wildlife reflects environmental contamination from human activities such as agricultural runoff, wastewater discharge, and inadequate waste management systems. Wildlife can acquire resistant bacteria through contact with contaminated water, soil, or food sources.^{16,19} They subsequently act as mobile reservoirs, redistributing AMR across ecosystems through physical movement, water, soil, and vectors such as arthropods.^{15 20}

Despite growing evidence, data on AMR prevalence in wildlife remain limited and dependent on wildlife surveys as there is no systematic surveillance system to monitor AMR in wildlife populations.¹⁶ Further research is needed to better understand the role and magnitude of environmental reservoirs within the AMR cycle and the public health implications.^{20,21}

One Health relevance: Human activities have led to an increased risk of AMR in wildlife populations.¹⁵ Wildlife now plays an important role in the AMR cycle and can serve as an important indicator of environmental contamination and identification of AMR hotspots.^{15,22} Many species can function as both sentinel animals (signaling the presence of resistant pathogens in the environment) and vectors that contribute to the spread of resistant pathogens. Patterns of AMR detected in wildlife may reflect underlying environmental contamination in water, soil, and food systems, while wildlife movement across landscapes can facilitate wider dissemination through fecal shedding.

EPHPs can help to reduce the risk of AMR by following a One Health approach when addressing public human and urban wildlife encounters (e.g., racoons, rats, seagulls). There may also be a role in advocating for wildlife surveillance, antimicrobial stewardship that reduces environmental loading of antimicrobials, and improving understanding of landscape features or urban environments that affect the likelihood of human and urban wildlife encounters.

Example 3: Drinking water systems as reservoirs and transmission routes for antimicrobial resistance

Background: Although most communities in Canada have access to safe drinking water, AMR has been documented in certain drinking water sources, treatment processes, and distribution systems.²³ Further research is needed to understand the risks posed by AMR in drinking water systems. This is especially important for communities that have experienced long-standing inequities in access to safe drinking water, including some Indigenous communities.²⁴⁻²⁶ A study of cistern-stored drinking water in two First Nations communities in Manitoba identified elevated bacteria and the presence of antimicrobial resistant genes. The untreated source water did not contain the same bacteria or resistant genes, suggesting contamination originating within the treatment and/or distribution system. The presence of antimicrobial resistant genes may have been due to water stagnation and depleted chlorine residual in the cistern, or contamination entering the



cistern from environmental sources, wildlife, or during maintenance or repair activities.²⁶ The growth of biofilms in cisterns could exacerbate the problem by providing an environment conducive to microbial growth and persistence, leading to the accumulation and exchange of resistant genes.²⁷ Other studies have identified AMR genes in treated drinking water systems and distribution systems.^{28,29} The presence of AMR pathogens or genes in drinking water is of concern as it can lead to infection with resistant pathogens and can increase the frequency and severity of waterborne outbreaks.³⁰

One Health relevance: Drinking water systems sit at the intersection of environmental and public health. The presence of AMR genes in drinking water systems does not necessarily indicate immediate risk but acts as an indicator of potential AMR exposure pathways and reflects broader environmental contamination pressures from human activities such as agriculture, industry, wastewater, and severe weather events (e.g., heavy precipitation and flooding), and wildlife (see example 2). These risks may be amplified in some underserved and Indigenous communities that rely on cisterns and small or aging systems.^{24,26}

A One Health approach emphasizes cross-sector collaboration, including meaningful partnerships with communities, and support for community and Indigenous-led water stewardship initiatives. For EPHPs, routine monitoring of water distribution systems for pathogens and resistant genes, particularly in underserved communities, can help identify emerging risks, inform infrastructure improvements, and strengthen risk communication, including maintenance and treatment strategies for drinking water systems.³⁰ This example underscores the importance of integrated surveillance across human and ecological systems, recognizing that drinking water quality can be compromised by upstream contamination from land use, agricultural and human wastewater management, and environmental sources, and further compromised by downstream hazards in system operation and maintenance.

Lessons learned and One Health considerations

Together, these examples highlight that AMR is present in everyday environments and circulates continuously across human, animal, and ecological systems. Household practices, such as feeding raw meat-based diets to pets, can introduce multidrug-resistant organisms into domestic and community settings, increasing opportunities for human exposure through direct contact with contaminated surfaces, soil, and pet waste.^{10,13} The detection of AMR in wildlife, independent of direct antibiotic use, highlights broader environmental contamination driven by human activities, including wastewater

discharge, agricultural runoff, and land use practices.^{16,19} Wildlife serves both as indicators of environmental contamination and as reservoirs capable of transporting resistant organisms across ecosystems. Drinking water systems, particularly in small or underserved communities, demonstrate how the built environment can function as both a reservoir and indicator of upstream environmental pressures related to land use, wastewater management, and environmental contamination.²⁶⁻²⁹

From a One Health perspective, these case studies demonstrate the need for an integrated One Health surveillance system that bridges veterinary health, environmental monitoring, and public health systems in Canada. Such a system would help to identify antimicrobial resistant hotspots, facilitating timely and coordinated actions. They also highlight important equity considerations, as underserved communities may face disproportionate exposure risks. For EPHPs, applying a One Health framework strengthens early identification of emerging AMR threats, supports coordinated risk communication, and enables cross-sectoral responses that recognize the shared environments and animal populations shaping AMR dynamics.

Implications for environmental public health professionals

AMR illustrates the interconnectedness of humans, animals, and the environment. Applying a One Health approach to addressing AMR enables EPHPS to anticipate risks, strengthen surveillance systems, and foster coordinated responses that protect people, animals, ecosystems, and livelihoods. In practice, addressing AMR through a One Health lens can vary and may include:

- **Cross-sector collaboration:** Build and sustain partnerships with veterinarians, agriculturalists, public health practitioners, Indigenous leaders, water operators, biologists, and other relevant sectors to address shared environmental risks.
- **Surveillance and monitoring:** Contribute environmental data to integrated surveillance systems to support early detection of resistance patterns, environmental contamination, and emerging exposure pathways.
- **Public education and risk communication:** Increase awareness of environmental AMR pathways, including raw meat-based pet diets, wildlife reservoirs, and drinking water systems, while promoting practical risk reduction strategies.
- **Policy engagement:** Inform and influence policies related to antimicrobial use, food safety, water quality, land use, and environmental protection at organizational, community, provincial/territorial, and national levels.

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- **Support community-led solutions:** Engage meaningfully with Indigenous, rural, and underserved communities, recognizing the importance of local governance, traditional knowledge, and cultural approaches to environmental stewardship.
 - **Professional dialogue and capacity building:** Promote ongoing discussion with environmental health professionals about strengthening cross-sectoral partnerships and embedding One Health principles into routine practice.

Together, these One Health actions position EPHPs as key contributors to a coordinated response to support AMR prevention and mitigation efforts across human, animal, and environmental systems.

Further resources

For more information please visit:

- [Government of Canada: One health approach to risk assessment](#)
- [World Health Organization: One Health](#)
- [Pan-Canadian action plan on antimicrobial resistance](#)
- [Public Health Agency of Canada's environmental surveillance strategic framework for antimicrobial resistance](#)

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