Monkeypox (*Orthopoxvirus simian*) in Canada: Human to Animal Exposure Pathway Analysis

Iteration #1: October 20, 2022

This pathway analysis was conducted by a multi-jurisdictional technical working group. The methodology used is intended to generate a preliminary understanding of the pathways and knowledge gaps and does not estimate the risk of these pathways. Research gaps and sources of uncertainty are detailed in the document. The findings and conclusions represent the consensual, but not necessarily unanimous, opinions of the group participants and do not represent the views of the participants' respective organizations.

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Summary

- Animals in Canada may be exposed to monkeypox virus from infected humans through several different pathways, including through both direct and indirect exposure.
- The susceptibility of different animal species in Canada to the currently circulating monkeypox virus clade as well as the infectious dose for susceptible animal species are key knowledge gaps for all pathways.
- Animal exposure through close contact with infected humans is a concern, and can occur in a number of different situations which are relatively well understood. A key step in preventing these types of exposures is targeted education. Guidance has been provided to several different groups in Canada, including to individual monkeypox cases, the general public, the pet industry, and veterinarians.
- Exposure pathways that are less understood but of particular concern due to the possible development of an animal reservoir, include animal exposure through waste from infected humans. It may be possible for animals in Canada, especially wildlife, to be exposed to the virus through both contaminated municipal solid waste (MSW) and wastewater, however, there are several significant knowledge gaps associated with these pathways, such as:
    - the prevalence of infectious virus in human feces and other bodily fluids
    - the environmental stability of the virus under different conditions in different types of solid waste, water, wastewater, and biosolids
- The expertise of other sectors/disciplines, such as waste and wastewater professionals, civil/environmental engineers, environmental specialists, and urban and aquatic wildlife experts will be critical to any further analysis.
- Waste and wastewater management practices can vary significantly across the country and most risk management would likely occur at the municipal or provincial/territorial level. It is therefore recommended that any further analysis focus on specific municipal or provincial/territorial situations and include representatives from the relevant jurisdictions.
- Possible exposure of animals to monkeypox virus in MSW or wastewater are complex One Health issues, with many stakeholders and differing priorities. It may not be feasible to further manage risk from waste for the current monkeypox outbreak in Canada. However, the information in this report is applicable to the long-term management of monkeypox in Canada if needed, as well as to other emerging or zoonotic pathogens that are of current or future concern. Further discussions, research, and analysis in this area is encouraged.

Introduction

Background

In May 2022, the first human cases of monkeypox associated with the current multi-country outbreak were confirmed in Canada. Since then, cases have continued to increase, with 1,410 confirmed cases reported in Canada across 9 provinces/territories as of October 14, 2022 (Government of Canada, 2022a).

As monkeypox is a zoonotic disease, concerns were raised early on regarding the susceptibility and potential exposure of animals in Canada. In June 2022, an Ad-hoc Monkeypox Federal, Provincial and Territorial (FPT) Human-Animal Interface Working Group was formed in order to discuss the evolving science and potential risks at the human-animal interface as well as collaborate on guidance. Further discussions determined that due to the very limited evidence available, a full rapid risk assessment was not feasible/useful at this time but that there was a need to better understand the potential ways animals in Canada could be exposed to the monkeypox virus from infected humans. Scoping discussions revealed that there was particular concern for the potential exposure of animals through waste.

Purpose and Scope

This document was prepared in order to provide a general overview of the potential pathways whereby animals (pets, livestock, and wildlife) in Canada could be exposed to monkeypox virus from infected humans, with a particular focus on exposure through waste. Qualification of the risk from each pathway was not included in the analysis, though it was at times part of the discussion.

Solid waste currently classified and managed as biomedical waste, such as that from monkeypox patients in hospitals of other health care facilities, is out of scope for this report. Most provinces/territories follow standards for handling biomedical waste that were developed by the Canadian Council of Ministers of the Environment in 1992 and which typically includes incineration or sterilization before deposition in a landfill (Walkinshaw, 2011).

This information is to be used by members of the Ad-hoc Monkeypox FPT Human-Animal Interface Working Group and other stakeholders to increase understanding and identify areas where further research or analysis may be needed in responding to the current monkeypox outbreak in Canada. Additionally, this information may be useful in understanding the potential animal exposure pathways for other pathogens that may affect animal or human health in Canada, either currently or in the future.

Methodology

A technical working group, consisting of federal and provincial/territorial representatives from both public and animal health, conducted a pathway analysis in order to diagram hypothetical risk pathways, discuss and document current controls and knowledge gaps, and provide recommendations for further analysis.

Pathway Analysis

Introduction of Monkeypox into Animals in Canada

Main Scenario Pathway

Animals in Canada may be exposed to monkeypox virus from infected humans in several ways: direct contact with infected people or contact with contaminated environments/fomites, municipal solid waste (MSW), or wastewater (Figure 1).

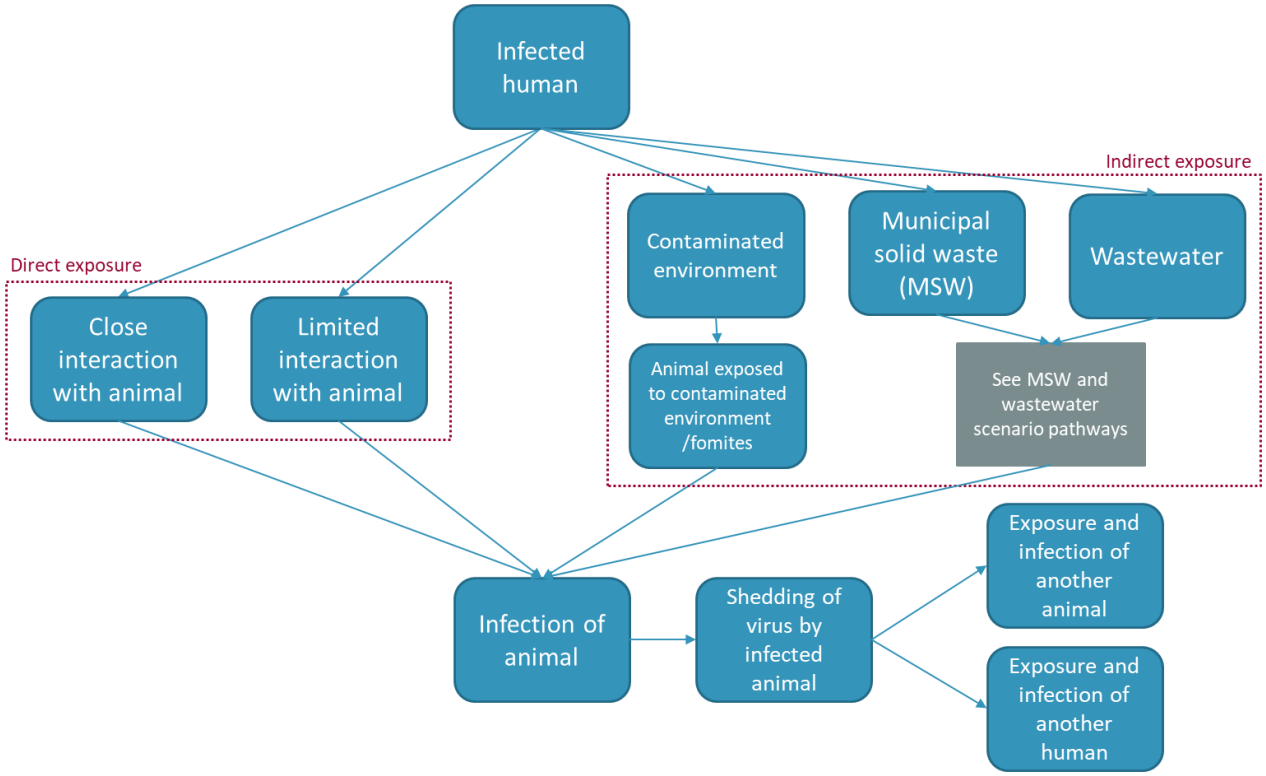

Figure 1. Hypothetical scenario pathway for the introduction of monkeypox virus into animals (pets, livestock, or wildlife) in Canada through exposure to infected humans.

Research Gaps and Uncertainties

Monkeypox has historically been an understudied disease. Additionally, the current global outbreak is primarily due to a clade of the virus (Clade IIb) that differs genetically from the virus causing most previous monkeypox cases and appears to have different characteristics such as modes of transmission and symptoms (World Health Organization, 2022b). There are therefore many important research gaps, including several applicable to this analysis.

The research gaps common to all exposure pathways include:

- the susceptibility of different animal species in Canada to monkeypox virus infection, particularly Clade IIb
- the infectious dose of the virus for susceptible animal species

There are also research gaps related to the exposure of animals through waste, including:

- the prevalence of infectious virus in human feces and other bodily fluids
- the stability of monkeypox virus under different environmental conditions in different types of solid waste, water, wastewater, and biosolids
- the effect of dilution on exposure to an infectious dose
- the access of different animal species to MSW or wastewater along the risk pathways

In addition, there is a lot of uncertainty related to the potential exposure of animals to the virus through the waste pathways due to the significant variation in MSW and wastewater management practices across the country. The management of both MSW and wastewater in Canada is a shared responsibility between federal, provincial/territorial, and municipal governments, therefore it is difficult to understand the potential exposure of animals at a national level.

Animal Exposure to Monkeypox through Direct Contact with Infected People or Fomites

Transmission of monkeypox between humans has largely been through very close contact (e.g. sexual contact), therefore, exposure of an animal through close contact with an infected person is most likely. Close contact may include handling, petting, snuggling, or sharing food. Exposure of an animal through more limited interaction, such as an animal being in proximity to a human case, is considered less likely. Depending on the type of animal (i.e. pet, livestock, or wildlife), this exposure could occur in a number of different settings, including but not limited to households, animal shelters, farms, livestock shows, veterinary clinics, wildlife rehabilitation facilities, or zoos. A human case may also contaminate these environments or objects and an animal could be exposed to the virus through fomites.

There are several actions that have been taken as part of the response to the current monkeypox outbreak in Canada to help prevent/manage direct contact of infected humans with animals. These actions include:

- case/contact management
- federal and provincial/territorial guidance (e.g. British Columbia and Ontario) for the public to avoid contact with animals if infected and if not possible, to cover lesions and wear a mask and gloves
- guidance for the pet industry on likely susceptible animals and what to do if ill
- guidance for veterinary clinics

Although exposure of animals through direct contact or fomites is of concern, these pathways are relatively well understood, even though the range of susceptible species remains unclear. It was determined that the pathways that were the least understood, and therefore required further analysis to understand the pathway, were exposure of animals through MSW and exposure of animals through wastewater.

Animal Exposure to Monkeypox through Municipal Solid Waste

General Municipal Solid Waste Cycle in Canada

Municipal solid waste (MSW) refers to garbage, recyclables, and organics (food and yard waste) from households, businesses, institutions, and construction/demolition sites (Government of Canada, 2017a). Typically, residential waste in Canada is comprised mostly of organics and recyclables (40% each), followed by bulky goods and other materials (10% each) (Environment Canada, 2013). The general MSW cycle consists of the collection of waste from households or other locations, possible sorting at a transfer station, and then transportation to composting facilities, recycling facilities, and landfills. The amount of organics and recyclables processed at composting or recycling facilities respectively, varies across the country due to differences in access to these programs. Approximately 97% of waste requiring final disposal (i.e. not recycled or composted) is sent to landfills and 3% is incinerated (Government of Canada, 2017a).

Scenario Pathway

For introduction of the virus into animals via this pathway, the following steps must occur (Figure 2). First, a human monkeypox case disposes of items contaminated with the virus (e.g. bandages, tissues, left-over food) in a municipal waste container. Exposure of certain animals could occur directly through contact with the contaminated items in residential, commercial, or public waste containers. Otherwise, the virus must survive in these contaminated items during the collection and transportation of the waste to a waste transfer station, where the waste is sorted, or directly to a recycling facility, composting facility, or landfill. At this stage, exposure of animals may occur through direct contact during collection or sorting at a transfer station, or at the landfill, composting or recycling facility, or through contact with leachate (contaminated liquid resulting from the percolation of water through a landfill) or the compost product from a composting facility. Finally, susceptible animals must be exposed to a sufficient dose of viable virus in order to be infected and then shed virus, potentially exposing other animals or humans.

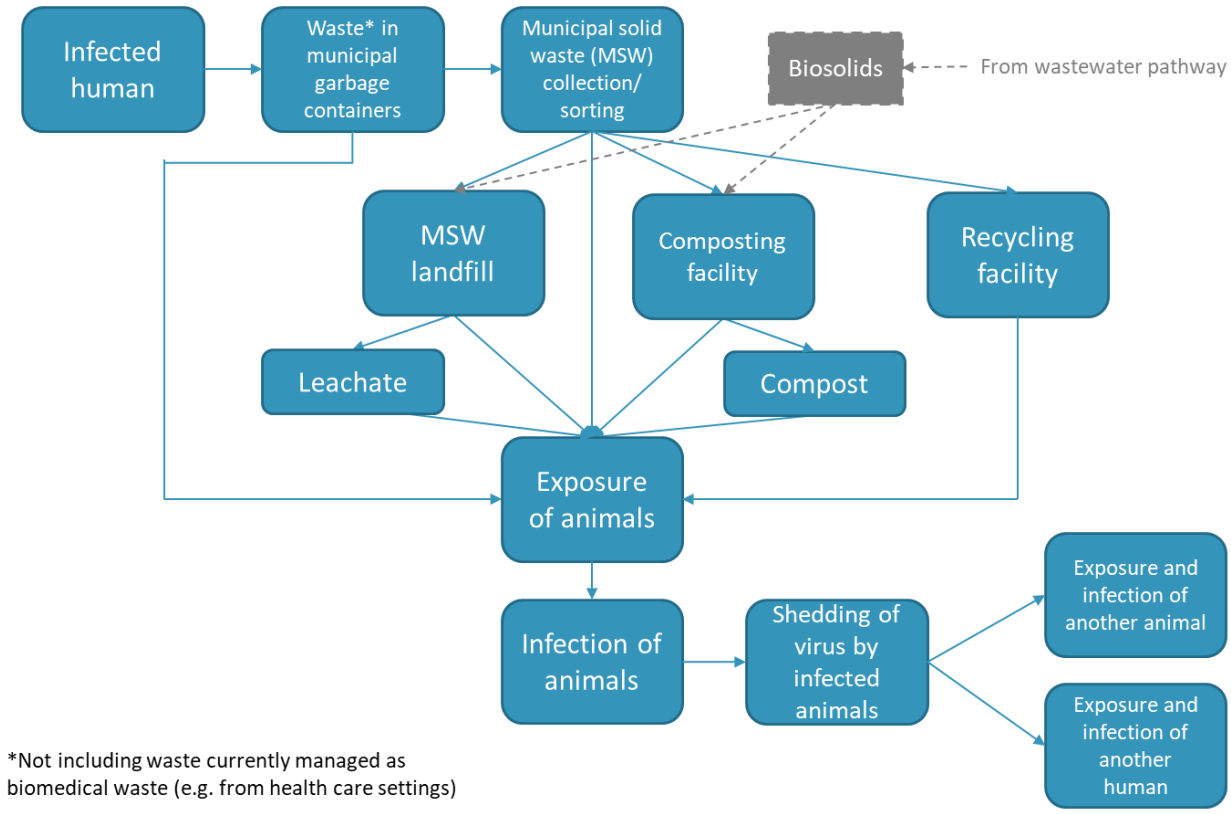

Figure 2. Hypothetical scenario pathway for the introduction of monkeypox virus into animals in Canada from indirect exposure to infected humans through municipal solid waste.

Environmental Stability of Monkeypox Virus in Solid Waste

Monkeypox virus is present in the skin lesions of infected humans and transmission through fomites, such as bedsheets, is known to occur (World Health Organization, 2022a). Monkeypox viral DNA has also recently been detected in several different types of bodily fluids from infected humans, including saliva, although the presence of viral DNA does not necessarily indicate the presence of viable virus (Peiró-Mestres et al., 2022). There is currently very limited information available on the stability of monkeypox virus in the environment, however, in general, poxviruses tend to be relatively stable. An experimental study found that vaccinia virus, a closely related orthopoxvirus, inoculated on food and bandages remained infectious for up to 166 days at 4.5°C (Essbauer et al., 2007). Viruses tend to survive longer at lower temperatures and environmental temperatures of 4.5°C or lower are common for significant parts of the year in Canada. One recent study detected viable monkeypox virus on household surfaces after at least 15 days, although at low titres (Morgan et al., 2022). However, orthopoxviruses are sensitive to UV light, several disinfectants (e.g. 0.5% sodium hypochlorite and chloroxylenol-based household disinfectants), and heat (e.g. autoclaving and incineration) (Public Health Agency of Canada, 2022). There is currently no scientific evidence available on the stability of monkeypox virus on bandages, tissues, or other materials used by human monkeypox cases isolating at home that would likely be disposed of in municipal waste containers.

Animal Species Exposed to Municipal Solid Waste in Canada

There are many different animal species that could potentially be exposed to MSW in Canada. Urban wildlife, such as rodents, raccoons, skunks, opossums, foxes, and coyotes, as well as free-roaming cats and dogs, are well known to access waste in residential, commercial, and public waste containers. Many different types of animals, including birds (such as gulls, ravens, vultures, hawks and owls), bears, rats, free-ranging cats and dogs, coyotes, deer, raccoons, opossums, and bobcats have been noted to be present at landfills in North America (Adams, 2016). Additionally, animals such as wild pigs and potentially other livestock species may be exposed to MSW at landfills or through exposure to contaminated leachate, however, information on these types of exposures is currently not well documented. Some of these species are known or likely to be susceptible to monkeypox, such as some rodent species and opossums (Centers for Disease Control and Prevention, 2022). It is possible that many other species that could access MSW are susceptible as well (Blagrove et al., 2022).

Current Controls/Actions

Overview of Municipal Solid Waste Management in Canada

The management of MSW in Canada is a shared responsibility between federal, provincial/territorial, and municipal governments. In general, MSW is regulated by provinces/territories and managed by municipal/regional authorities and the waste management industry under contract. As of 2014, nine provinces/territories had a waste management legislative framework, policy, or strategy in place with three provinces/territories having one pending (Giroux Environmental Consulting, 2014). The federal government is responsible for regulating the international/interprovincial movements of hazardous waste and developing and helping implement environmental best practices (Government of Canada, 2017a).

General Controls Preventing Animal Exposure to MSW or to Pathogens in MSW

Many larger municipalities in Canada appear to have some methods of limiting animal exposure to MSW before transportation to a composting or recycling facility or landfill. These methods may include animal-proof waste containers, bylaws limiting the amount of time residential waste containers are allowed to be at the curb for collection, trucks and transfer stations designed to limit access by animals, and general rodent/pest control.

In 2014, there were almost 2000 landfills across Canada (Giroux Environmental Consulting, 2014). Due to variation in legislation between provinces/territories and practices within the waste management industry, the design and management of individual landfills can vary (Figure 3). However, most provinces/territories with regulations appear to have some mention of limiting environmental contamination and/or access of animals to the landfill. For example, the British Columbia Ministry of Environment Landfill Criteria for MSW includes specific requirements for landfill design and the handling of leachate in order to prevent contamination of groundwater (British Columbia Ministry of Environment, 2016). These criteria also include specific requirements to limit access by wildlife including the covering of waste, implementing a bird deterrent program, rodent control, and installing bear-proof electric fences in areas of bear habitat. However, unless the main factor that attracts animals to a landfill is removed (often food waste), control strategies will only provide temporary decreases in animal numbers (Adams, 2016). As organics can make up a significant portion of waste being deposited in landfills in Canada – in areas not served by composting facilities up to 50% of the waste sent to landfills will be organics – some animal exposure to MSW in landfills is to be expected.

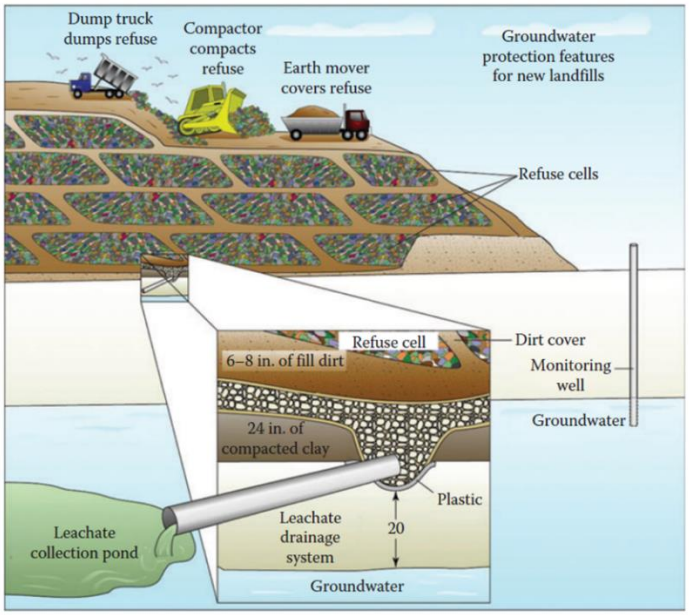

Figure 3. Features of a modern landfill (Adams, 2016).

Municipal organics programs are relatively recent introductions in Canada. In 2019/2020, there were 317 composting facilities reported to the Compost Council of Canada (Compost Council of Canada, 2022). Similar to landfill management, regulations or guidelines in place for composting facilities vary between provinces/territories. However, municipal organics recycling facilities utilize one of two different types of processing: aerobic or anaerobic (Environment Canada, 2013). In brief, aerobic processing (otherwise known as composting) involves different microorganisms decomposing organic materials and converting them into a biologically stable product (Figure 4). This process includes a high-temperature phase (generally above 55°C for three or more days) which reduces or eliminates most pathogens. Anaerobic processing uses microorganisms to break down organic material in the absence of oxygen and may also include high temperatures. There are three products of anaerobic processing: digestate (solid), effluent (liquid), and biogas. In Canada, digestate is required to undergo further treatment (such as composting or drying) prior to being used for example, as fertilizer on fields (Environment Canada, 2013).

Figure 4. Example of an aerobic composting facility (City of Calgary, 2022).

Monkeypox-specific Controls

Generally, at both the federal and provincial/territorial levels, monkeypox is considered a dangerous good in terms of transport. The federal Transportation of Dangerous Goods (TDG) Act classifies monkeypox as a Category A infectious substance, the highest category, which is given to those substances capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals upon exposure (Government of Canada, 2018). As of June 2, 2022, Transport Canada has temporarily allowed the transportation of monkeypox patient specimens as Category B substances (Government of Canada, 2022b). Special guidance on transportation, handling and packaging when disposing of waste applies to these substances. However, the TDG Act does not apply to household waste.

Some provinces/territories and municipalities have provided guidance on disposal of waste from monkeypox cases. For example, in British Columbia, guidance for the general public recommends that if you are ill, to dispose of masks, bandages, or other contaminated materials in a high quality garbage bag and keep in an animal-proof receptacle to prevent access by pets or wild animals (particularly rodents) (BC Centre for Disease Control, 2022). Similarly, for home health care settings, it is recommended that clinical waste or disposable items that may have come into contact with a patient's secretions, biological fluids or skin lesions should be double-bagged. In Toronto, residents under investigation for monkeypox are asked to double-bag food waste and tissues before disposing of them in the green bin and double-bag bandages and gauze before disposing in the garbage as well as ensuring they are in secure bins with the lid closed until pickup (City of Toronto, 2022).

Animal Exposure to Monkeypox through Wastewater

General Wastewater Cycle in Canada

Wastewater is the collective term for two different types of liquid wastes: sanitary sewage and stormwater (Government of Canada, 2017b). Sanitary sewage is the waste from toilets, sinks, showers, etc. from homes, businesses, institutions and industries. Stormwater is the run-off from rooftops, lawns, parking lots, roads, etc. due to rain or melting snow.

In 2017, 86% of Canadians were served by municipal wastewater systems (Government of Canada, 2017b). The general municipal wastewater cycle consists of the collection of sanitary sewage and stormwater through a sewer system, potential treatment at a wastewater treatment plant (WWTP), and then discharge of the effluent (treated or untreated wastewater) into surface water such as an ocean, lake, or river. Additionally, any biosolids, the solids remaining after treatment at a WWTP, must be disposed of.

In 2017, 14% of Canadians were not served by municipal wastewater systems but rather by independent systems (Government of Canada, 2017b). In most cases this will be a septic system. In a conventional septic system, sanitary sewage from homes etc. travels to a septic tank where solids settle out and then the remaining liquid moves into a leaching bed where the liquid is dispersed into the soil and eventually returned to the groundwater (Ontario Rural Wastewater Centre, 2022).

Scenario Pathway

For introduction of the virus into animals via this pathway, the following steps must occur (Figure 5). First, contaminated sanitary sewage from homes, businesses, institutions, etc. enters a septic system or a municipal sewer system or is present in the environment (e.g. outhouses). Exposure of certain animals could occur directly through contact with the raw sewage. Otherwise, the virus must survive in the wastewater in the septic system or as it travels to a WWTP. At a WWTP, the virus must survive any treatment to be present in the final effluent or biosolids. Next, animals must be exposed to the virus. This exposure may occur through direct contact with the sanitary sewage/wastewater within a septic system, municipal sewer system, or in the environment, or through contact with any overflow (untreated wastewater discharged into the environment) or the effluent or biosolids from a WWTP. Finally, susceptible animals must be exposed to a sufficient dose of viable virus in order to be infected and then shed virus, potentially exposing other animals or humans.

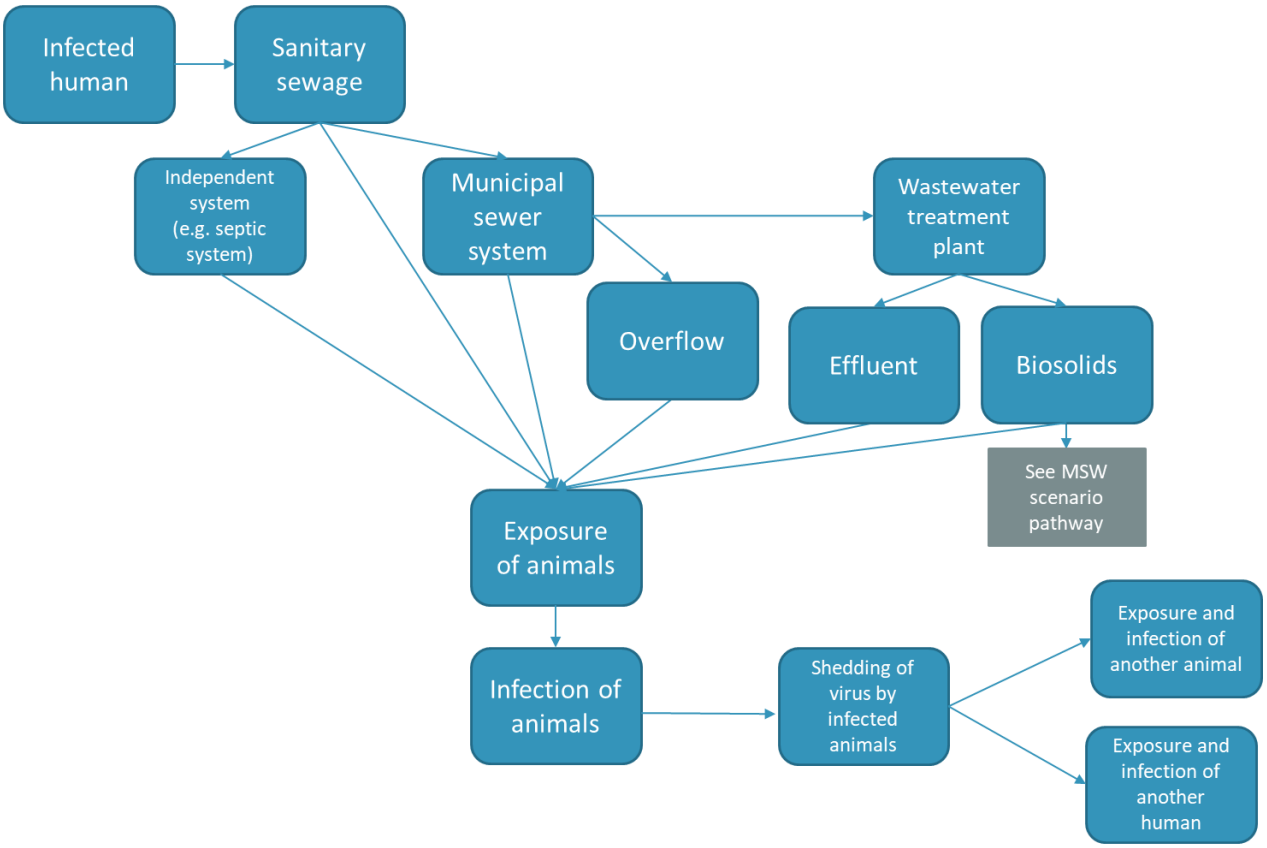

Figure 5. Hypothetical scenario pathway for the introduction of monkeypox virus into animals in Canada from indirect exposure to infected humans through wastewater.

Environmental Stability of Monkeypox Virus in Wastewater

There is currently very limited information on the stability of monkeypox virus in wastewater. An experimental study on a closely related orthopoxvirus found that vaccinia-spiked stormwater kept at 4.5°C remained infectious for up to 166 days (Essbauer et al., 2007). At the beginning of the current monkeypox outbreak, the possibility of using wastewater to monitor human monkeypox cases in an area, similar to COVID-19 wastewater surveillance, was investigated. Monkeypox viral DNA has now been detected in wastewater in several different countries, including Canada (de Jonge et al., 2022; Girón-Guzmán et al., 2022; La Rosa et al., 2022; Sharkey et al., 2022; Wurtzer et al., 2022). However, the viability of the virus in wastewater or in biosolids is not currently known.

Infectious monkeypox virus is well known to be present in the skin lesions of infected humans (World Health Organization, 2022a). However, the presence of infectious virus in bodily fluids is only beginning to be understood. Monkeypox viral DNA has recently been detected in several different types of bodily fluids from infected humans, including feces, urine, semen, and saliva (Peiró-Mestres et al., 2022). Additionally, infectious virus has been isolated from anal and urethral swabs from patients (Moschese et al., 2022). Although infectious virus has not been isolated from feces from infected humans to date, animals infected with monkeypox have been found to shed infectious virus in their feces (Hutson et al., 2009; Patrono et al., 2020). Monkeypox virus from skin lesions may be released in wastewater while

rinsing, showering, or through toilet usage (de Jonge et al., 2022). The laundering of contaminated items has also been noted as a potential issue (Maal-Bared et al., 2022). Some viable virus likely enters the wastewater system, however, its prevalence and persistence is currently unknown.

Animal Species Exposed to Wastewater in Canada

Similar to MSW, there are many different animal species that could potentially be exposed to wastewater in Canada. Rodents, such as rats living in sewers or rodents living near septic systems or WWTPs, are of particular concern due to their ability to access these places and likely susceptibility to monkeypox. If there is discharge of contaminated effluent into bodies of water, other types of wildlife that could potentially be exposed to the monkeypox virus include semi-aquatic mammals (such as muskrats, river otters, beavers, etc.) and marine mammals (such as seals, whales, porpoises, etc.). Other terrestrial wildlife, companion animals, and livestock may be exposed through swimming in or drinking effluent or contact with biosolids applied in agricultural areas, if contamination of these substances with the monkeypox virus is possible. The susceptibility of many of these species is currently unknown (Centers for Disease Control and Prevention, 2022).

Current Controls/Actions

Overview of Wastewater Management in Canada

Similar to MSW, wastewater management is a shared responsibility in Canada. In general, municipalities are responsible for the collection of wastewater and maintenance of WWTPs. However, the federal Wastewater Systems Effluent Regulations (under the Fisheries Act), came into force in 2012 and are the first national standards for wastewater treatment in Canada (Government of Canada, 2017b). These regulations were developed through consultations with provinces/territories, municipalities, Indigenous and other groups and include mandatory minimum effluent quality standards that can be achieved through secondary wastewater treatment. However, these regulations do not include a microbiological requirement, meaning it may be possible for pathogens such as bacteria and viruses to still be present in the effluent.

General Controls Preventing Animal Exposure to Wastewater or to Pathogens in Wastewater

Controls that prevent animal exposure to wastewater primarily include the municipal sewer system or septic system design. There are two types of municipal wastewater collection systems: combined sewer systems and separate sewer systems (Figure 6). Combined sewer systems are an older design where both sanitary sewage and stormwater are collected in the same pipes. Separate sewer systems collect sanitary sewage and stormwater in different pipes. Animals such as sewer rats could be exposed to sanitary sewage in combined sewer systems since these are open to the environment in order to collect stormwater. Additionally, animals could be exposed to sanitary sewage in overflows, a discharge of untreated wastewater directly into surface water during periods of heavy precipitation. Animals are less likely to be exposed to sanitary sewage in separate sewage systems due to limited access to these pipes.

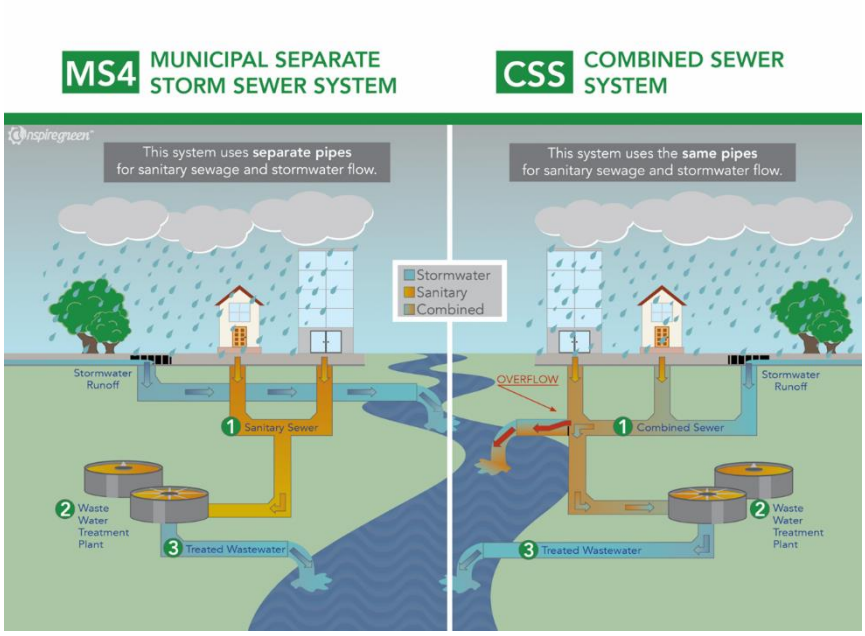

Figure 6. Municipal wastewater collection systems.

After collection, the wastewater may be discharged directly into the environment or may be treated at a WWTP (Figure 7). Treatment at a WWTP may be primary, secondary, or tertiary (Government of Canada, 2017b). Primary treatment consists of removing a portion of suspended solids and organic matter by physical and/or chemical processes. Secondary treatment further removes suspended solids and organic matter using biological treatment processes and secondary settlement. Tertiary treatment removes specific substances of concern (solids, nutrients and/or contaminants) after secondary treatment using a number of physical, chemical or biological processes. Disinfection, such as with UV light or chlorination, is typically included in tertiary or sometimes secondary treatment. As discussed with MSW, orthopoxviruses are sensitive to UV light and many disinfectants (e.g. chlorine) (Public Health Agency of Canada, 2022). The WHO along with other water expert groups have concluded that standard wastewater treatment systems are effective barriers against exposure to enveloped viruses for several reasons, such as decay over time in collection systems and the fact that WWTPs often remove or inactivate viruses equally or more resistant to disinfection (Maal-Bared et al., 2022). However, not all WWTPs in Canada have the same level of treatment. Pathogens that are present in the wastewater are more likely to be present in the effluent if the wastewater is not treated or only undergoes primary treatment. Animals exposed to this effluent would therefore be more likely to be exposed to these pathogens.

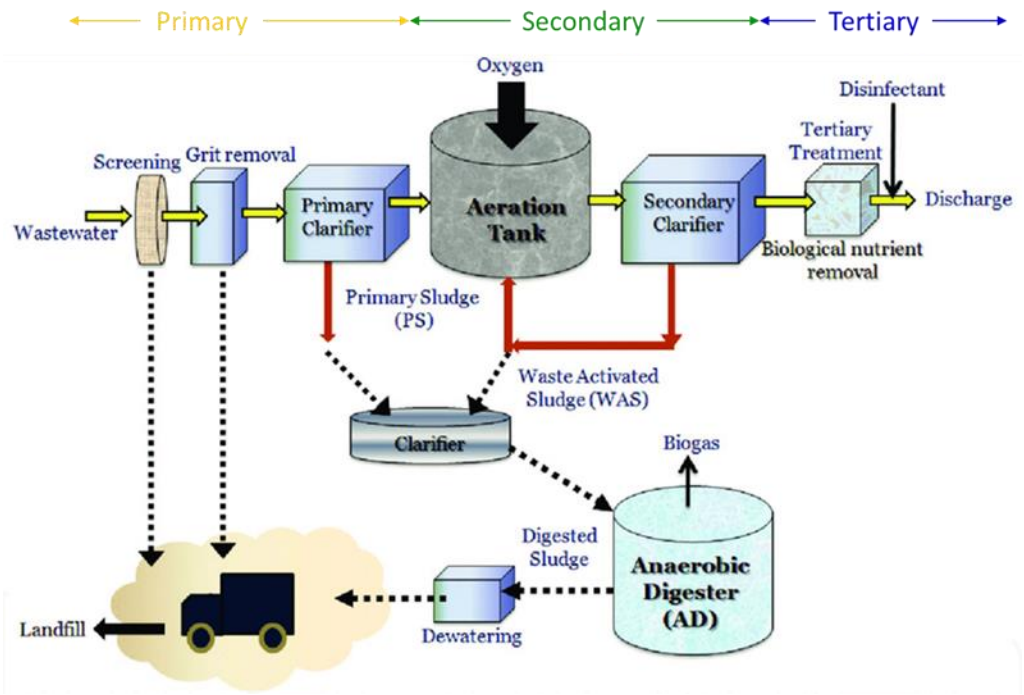

Figure 7. Typical municipal wastewater treatment process (Okoye & Elbeshbishy, 2019).

In 2017, the volume of municipal wastewater discharged with no treatment in Canada was 270 million cubic metres, corresponding to 4.4% of the total volume discharged (Government of Canada, 2020). This includes 164 million cubic metres from combined sewer overflows. However, the level of treatment applied to wastewater varies widely by province and territory (Figure 8). In 2017, the provinces with the highest proportion of wastewater discharged with no or only primary treatment were Newfoundland and Labrador, with 37% of wastewater untreated, and Quebec, with 50% of wastewater only having primary treatment.

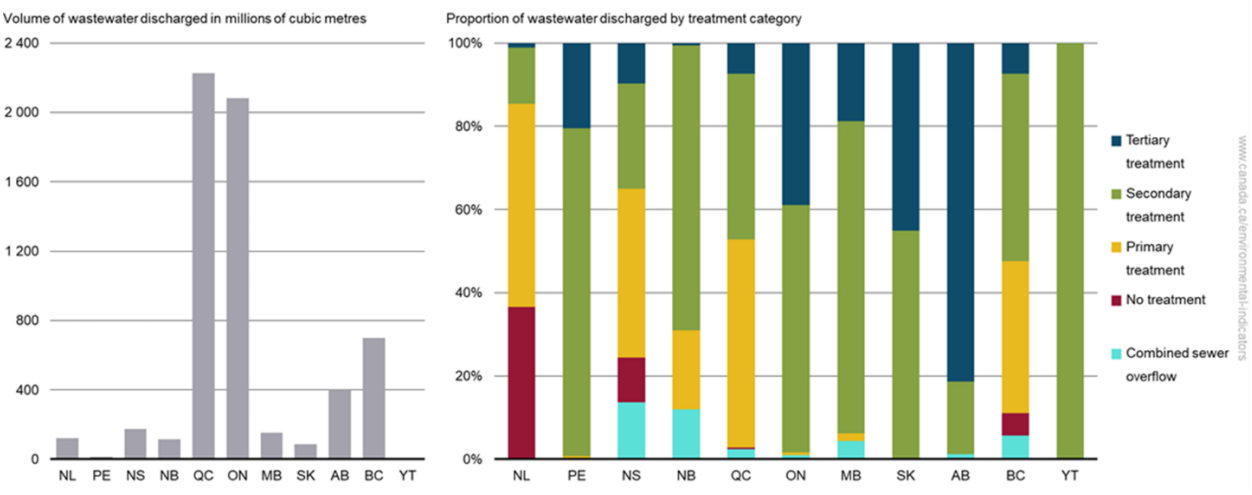

Figure 8. Volume and proportion of municipal wastewater discharged by treatment category by province and territory, Canada, 2017 (Government of Canada, 2020).

It may also be possible for animals to be exposed to pathogens in biosolids, the solids from the wastewater remaining after treatment. The biosolids may be taken directly to a landfill or composted aerobically or anaerobically (Government of Canada, 2021). After composting, the biosolids may be applied to agricultural areas (Ontario Ministry of Agriculture Food and Rural Affairs, 2022). With composting, as discussed with municipal solid waste, the process usually involves higher temperatures, which is likely to kill most pathogens (Environment Canada, 2013). However, if the biosolids are taken directly to a landfill or applied to agricultural areas without further treatment, it may be possible for pathogens to still be present.

In those situations where an independent system is used, the most common type is a conventional septic system (Figure 9). A conventional septic system consists of a septic tank and a leaching bed (Ontario Rural Wastewater Centre, 2022). Wastewater generated in the house is transported to the septic tank, a water-tight often concrete container whose main function is to remove and store the solids present in the wastewater. The septic tank contains anaerobic bacteria which provides about 10-20% of the treatment in a septic system. After approximately two days, the liquid moves out to the leaching bed. The leaching bed consists of perforated PVC pipe embedded in gravel-filled trenches. Percolation of the liquid through the soil removes some solids and aerobic bacteria and chemical reactions further breakdown microscopic solids, which provides the remaining treatment (80-90%) in a septic system. The liquid then eventually returns to the groundwater. In a functioning septic system, it may be possible for animals such as rodents to be exposed to pathogens in wastewater through the leaching bed, however, animal exposure to sanitary sewage or pathogens in wastewater is more likely in malfunctioning or older septic systems, where leakage or inefficient treatment occurs.

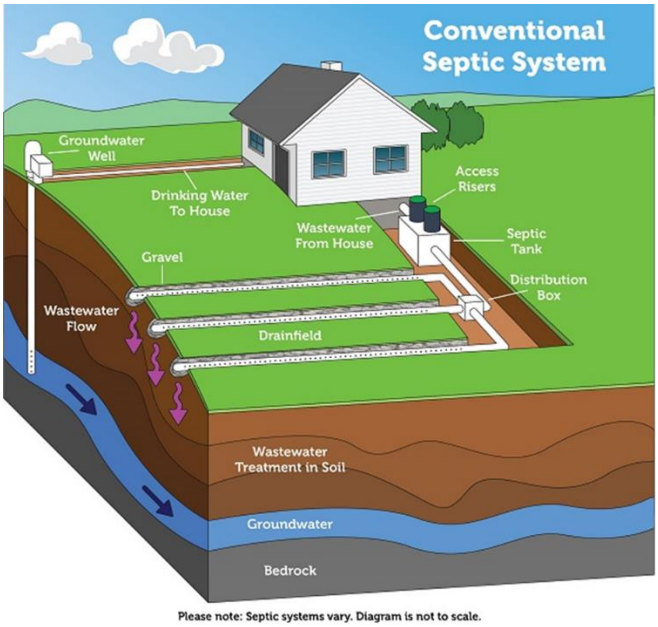

Figure 9. A conventional septic system (Environmental Protection Agency, 2022).

Monkeypox-specific Controls

There are not currently any controls in place specific to monkeypox in wastewater.

Conclusions/Recommendations

It is possible that susceptible animals in Canada could be exposed to monkeypox virus from infected humans through several different pathways, including through MSW or wastewater.

For MSW, exposure is more likely through contact with contaminated waste in residential garbage containers and at landfills. A lot of uncertainty remains on possible exposure through other routes, such as animal contact with composted organic materials. Wildlife are of particular concern, especially rodents, due to their potential susceptibility to monkeypox virus and common presence at landfills, as well as the potential for the development of an animal reservoir.

Due to the possibility that animals may be exposed to monkeypox through the MSW pathway and until more is known, it is recommended to provide/continue to provide guidance on preventing exposure of animals, particularly wildlife, to waste from monkeypox-infected humans. In regards to human monkeypox cases in residential or home care settings, this could include disinfection of waste prior to disposal, preventing access of animals to residential waste containers, and securely disposing of waste (e.g. double-bagging). Depending on the jurisdiction and current regulations in place, awareness and guidance for MSW landfill operators may also be helpful.

For wastewater, exposure is more likely with combined sewer systems, the discharge of raw sewage, only primary treatment (or possibly secondary treatment) of wastewater, septic systems, and untreated biosolids. Wildlife are again of particular concern, due to their higher chance of exposure and the possibility of the development of a wildlife reservoir.

There are several important research gaps related to these pathways that should be addressed. Further information, particularly on the environmental stability of the virus and susceptibility of key wildlife species will be important for any further analysis, which could include research studies, risk assessments, or possibly analytical models. With any further analysis, it will be important to include experts in sectors/disciplines beyond public and animal health, such as waste and water professionals, civil/environmental engineers, environmental scientists, urban and aquatic wildlife experts, and possibly others. As waste and wastewater management practices can vary significantly across the country, and as any risk management would likely occur at the municipal or provincial/territorial level, it is also recommended that any further analysis focus on specific municipal or provincial/territorial situations and include representatives from the relevant jurisdictions.

Possible exposure of animals to monkeypox virus in MSW or exposure of animals to monkeypox virus in wastewater are complex One Health issues, involving many different stakeholders and priorities. Some risk can likely be managed through current guidance, however, further risk management would require more extensive analysis, consultations, and coordination. It is likely not feasible to manage all risk for the current ongoing monkeypox outbreak in Canada, particularly for the wastewater exposure pathway. However, the information in this report is applicable to the long-term management of monkeypox in Canada if needed, and to other emerging or zoonotic pathogens that are of current or future concern. Further discussions, research, and analysis in this area is encouraged.

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