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Short Communication

Implications of inadequate water and sanitation infrastructure for community spread of COVID-19 in remote Alaskan communities

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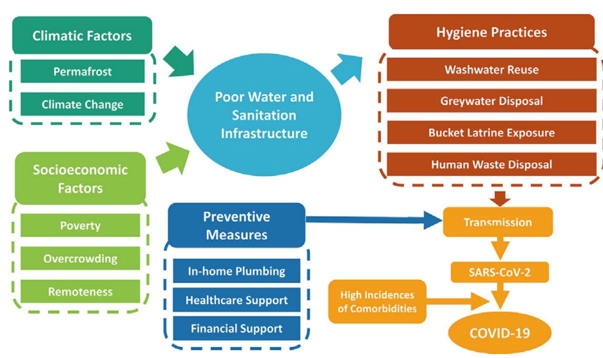
HIGHLIGHTS

- COVID-19 mitigation measures depend on the broader community contexts.
- Like other tribal regions, rural Alaska faces severe water and sanitation challenges.
- Hygiene practices and lack of infrastructure lead to higher risk of COVID-19 spread.
- Existing public health inequities may exacerbate the impacts of COVID-19.

GRAPHICAL ABSTRACT



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ABSTRACT

The novel coronavirus SARS-CoV-2, the causative agent of COVID-19, emerged in the human population in December 2019 and spread worldwide within a few short months. Much of the public health focus for preventing and mitigating the spread of COVID-19 has been on individual and collective behaviors, such as social distancing, mask-wearing, and hygiene. It is important to recognize that these behaviors and health outcomes occur within broader social and environmental contexts, and factors within local communities such as regional policy, historical context, cultural beliefs, and natural- and built environmental characteristics affect underlying population health and the spread of disease. For example, the COVID-19 pandemic has renewed attention to the importance of secure water and sanitation services in protecting human health; many remote Alaskan communities are particularly vulnerable to infectious disease transmission because of inadequate water and sanitation services. In addition, there are a number of socio-economic, physical, and infrastructure factors in rural Alaska (e.g., remoteness,

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household overcrowding, climate change impacts, limited medical facilities, and high prevalence of chronic diseases) that contribute to the potential for more severe COVID-19 disease outcomes in these predominantly Alaska Native communities.

1. Introduction

Coronavirus disease 2019 (COVID-19) is caused by a novel pathogen (SARS-CoV-2) that emerged from a zoonotic reservoir to infect humans in late 2019 in Wuhan, China, spreading across the globe by mid-summer 2020 through efficient human-to-human transmission (Lu et al., 2020b; Zhu et al., 2020). The COVID-19 pandemic has brought renewed attention to the importance of water and sanitation infrastructure to protect human health, and the global inequities that exist in household water security (e.g. Staddon et al., 2020). Access to piped water and sanitation infrastructure likely reduces the transmission of SARS-CoV-2 by facilitating frequent handwashing and by reducing the contact that individuals have with wastewater (Alzyood et al., 2020; Brauer et al., 2020). However, according to United Nations estimates, 75% of households in low- and middle-income countries lack the ability to hand wash with water and soap (UNICEF, 2019), and more than 50% of the world population does not have sufficient sanitation (UNICEF, 2019). Others have recently connected the risk of SARS-CoV-2 infection with these dismal statistics on household water insecurity in low- and middle-income countries, particularly in crowded urban slums (Rafa et al., 2020; Roy et al., 2020; Smiley et al., 2020; Stoler et al., 2020; Zar et al., 2020).

The true burden of household water insecurity, however, extends beyond low-income countries. Household water insecurity also impacts hundreds of thousands of people in higher income countries of the circumpolar north, including the United States (e.g., Deitz and Meehan, 2019; Riggs et al., 2017). A recent analysis of COVID-19 cases on American Indian Reservations and tribal homelands in the contiguous United States found that the primary risk factor behind the incidence of COVID-19 in these populations is a lack of indoor plumbing (Rodriguez-Lonebear et al., 2020). This problem is acute in Alaska, where about 22% of homes in remote Alaskan communities (that lie off the state's limited road system) lack in-home plumbing (DHSS, 2020a), compared to less than 1% nationally (Meehan et al., 2020).

Much of the current focus for preventing and mitigating the spread of SARS-CoV-2 has been on individual and collective behaviors, such as social distancing, mask-wearing, and hygiene. It is important to recognize that these behaviors and health outcomes are nested within a broader eco-social context that includes factors at the local, regional, and national levels, such as policy, historical context, cultural beliefs, race, and natural and built environmental characteristics that affect the health of the underlying population and the spread of disease (Chen and Krieger, 2020; Gravlee, 2020; Joseph et al., 2020; Krieger, 2020).

In this paper, we begin by summarizing what is known about SARS-CoV-2 transmission in wastewater and then describe how water and sanitation insecurity at household- and community level could contribute to an increased risk of SARS-CoV-2 transmission in remote Alaska Native communities. In addition, we characterize the eco-social context of rural Alaska, where overcrowding of homes, lack of transportation options (and associated expense) to hub communities, limited medical facilities, and higher prevalence of chronic diseases, contribute to more severe COVID-19 disease outcomes once the virus has been introduced into these communities. We conclude by describing how communities and tribal health organizations are urgently seeking to address these insecurities of water and sanitation during the COVID-19 pandemic.

2. SARS-COV-2 infection and transmission routes

2.1. SARS-CoV-2 infection

SARS-CoV-2 is a human betacoronavirus with a single-stranded RNA genome, and an enveloped spherical virion (~120 nm) studded with a 9–12 nm long surface spike (S) glycoprotein (Bar-On et al., 2020; Bhowmick et al., 2020; R. Lu et al., 2020b). SARS-CoV-2 S protein binds to angiotensin-converting enzyme 2 (ACE2) receptors on cells leading to infection of respiratory tissues, lungs, and occasionally other organs (Lan et al., 2020). SARS-CoV-2 typically causes a respiratory disease (COVID-19) with a wide spectrum of inflammatory and physiological manifestations (Shang et al., 2020; Zhu et al., 2020). Mild COVID-19 can be virtually asymptomatic, whereas moderate to severe COVID-19 is characterized by diffuse alveolar damage and bilateral pneumonia that can lead to acute respiratory distress and death (Richardson et al., 2020; Zhu et al., 2020). Underlying chronic co-morbidities, including hypertension, obesity, and diabetes, are found in a large fraction of hospitalized patients with COVID-19 (Richardson et al., 2020). Notably, driven by co-morbidities, the American Indian/Alaska Native (AI/AN) population in Alaska has suffered a 5-fold higher rate of hospitalization from severe COVID-19 than the White population in Alaska (Frick and Watkins, 2020). While robust immune responses, including antibody and T cell mediated memory responses, are generated even in mild infections, the duration and efficacy of immune responses upon secondary challenge are poorly understood (Altmann and Boyton, 2020). At present, a number of novel vaccines against SARS-CoV-2 have been granted emergency use authorization after completing clinical trials, and vaccination has begun in several countries including United States, Europe, and India (Bhuyan, 2021; Karpiński et al., 2021; Mellet and Pepper, 2021; Krammer, 2020). The effect of vaccination on mitigating community spread of SARS-CoV-2 is anticipated over the next year, however, new and more transmissible variants of the virus have arisen that may prolong the pandemic and increase rates of hospitalization (Galloway et al., 2021).

2.2. SARS-CoV-2 transmission

The transmission of most genotypes of SARS-CoV-2 is characterized by the basic reproduction number (R_0) of 1.40–6.49, which is comparatively higher than that of other severe beta-coronaviruses (SARS-CoV, MERS-CoV) and influenza viruses (Petersen et al., 2020; Rahman et al., 2020). While not completely understood, it is thought that the transmission of SARS-CoV-2 occurs through multiple mechanisms including cough/sneeze droplets from an infected person, contact with body parts or clothes of infected persons (Hijnen et al., 2020), contact with surfaces contaminated with SARS-CoV-2 due to settled droplets (Chia et al., 2020), and by micro-aerosols produced from respiratory droplets of infected persons due to sneezing, coughing, talking, or normal breathing. It is reported that these micro-aerosols can remain suspended in the air for 1–3 h at room temperature (21–23 °C) and relative humidity of 65%, and are likely the dominant mode of SARS-CoV-2 transmission (Aboubakr et al., 2020).

3. SARS-COV-2 in wastewater

3.1. SARS-CoV-2 and wastewater-based epidemiology

In some human cases, SARS-CoV-2 can infect the gastrointestinal (GI) tract (Villapol, 2020; Lei et al., 2021). The live virus can be excreted into wastewater (raw sewage) (Tran et al., 2020), and SARS-CoV-2 has been reported in river water (Quito, Ecuador) that received untreated sewage (Guerrero-Latorre et al., 2020). However, the role of contaminated wastewater in the risk, spread, and persistence of COVID-19 in communities is poorly understood (Kitajima et al., 2020). SARS-CoV-2 has been found to retain a degree of viability in fecal matter, and viral RNA has been routinely detected in wastewater (Arslan et al., 2020; Bivins et al., 2020). Urban wastewater processing is thought to be generally refractory to survival of live SARS-CoV-2, although non-infectious remnants of viral RNA have been found to persist in wastewater (Kitajima et al., 2020; Medema et al., 2020). In rural Alaska, unprocessed waste disposal methods may increase the duration of live virus persistence and risk of human contact with the virus in wastewater. The approach to understand the spread of a disease in any given community/watershed by testing for its signal in municipal wastewater is known as wastewater-based epidemiology (WBE). It has previously been employed to investigate the incidence of poliovirus (Lodder et al., 2012), norovirus (Kazama et al., 2016) and detect other community- or watershed-level activities including use of pharmaceuticals and personal care products, consumption of narcotics, and exposure to pesticides (Choi et al., 2018; Lorenzo and Picó, 2019). Thus, raw or even processed wastewater is a potentially important environmental signal for COVID-19 infection in humans in a community (Ahmed et al., 2020; D. Lu et al., 2020a; Mao et al., 2020; Murakami et al., 2020).

3.2. Fecal-oral transmission of SARS-CoV-2

SARS-CoV-2 can infect the GI tract and cause intense GI and hepatobiliary symptoms (D'Amico et al., 2020). Although the fecal-oral transmission of SARS-CoV-2 has not been reported to date, recent studies detected SARS-CoV-2 in the feces of an infected person (Kim et al., 2020; Xiao et al., 2020). The related SARS-CoV exhibited transmission by a fecal-oral route (Esper et al., 2010; Isakbaeva et al., 2004; Jevšnik et al., 2013). During the SARS outbreak in 2003, aerosolized SARS-CoV particles from floor drains spread into the bathroom of an adjacent apartment building (in multi-unit housing) (McKinney et al., 2006). Similar transmission of aerosolized SARS-CoV-2 from a bathroom where an infected person took a shower has also been recently reported (Hwang et al., 2021). In addition, the presence of RNA fragments of SARS-CoV-2 in feces, anal swabs, and urine from infected persons has been reported widely (Chen et al., 2020; Kipkorir et al., 2020; Peng et al., 2020). While these studies indicate a serious concern about the capability of SARS-like coronaviruses to spread via wastewater and suggest the possibility of a fecal-oral route of transmission for SARS-CoV-2, as of the time of this writing, this mode of transmission has not been implicated in the spread of COVID-19 outside of hospital settings (D'Amico et al., 2020).

3.3. Recent evidence of SARS-CoV-2 in wastewater in Alaska

The state of Alaska has reported more than 52,000 laboratory-confirmed cases of COVID-19 (7% incidence in the population), and suffered 277 deaths, as of 2nd February 2021, with spread of the virus to every urban and most rural regions of the state (DHSS, 2021). In response to the pandemic, capacity for wastewater sampling, laboratory processing, and validation of a COVID-19 PCR detection assay was developed at the University of Alaska. SARS-CoV-2 RNA was detected in a major community in interior Alaska in July 2020, corresponding to an increase in the epidemic curve in human COVID-19 cases. SARS-CoV-2 RNA has also been detected in several smaller, isolated communities in Alaska, in a trend that mirrors the number of human cases (B. Briggs, E. Bortz, pers. comm.; data not shown). These preliminary studies suggest the utility of this method as an environmental signal for SARS-CoV-2 prevalence to detect unrecognized COVID-19 cases in the community. Genomic tracking of SARS-CoV-2 in wastewater is also possible with application of advanced next-generation sequencing (short read NGS) technology, and has been found to mirror the human diversity of genome variants in the community (Crits-Christoph et al., 2021). New diagnostic assays for targeted genome sequencing of SARS-CoV-2 using short-read or nanopore NGS technology are also being developed (E. Bortz, pers. comm.; data not shown), to broaden community wastewater surveillance, and generate an early signal of the incidence of new variants of SARS-CoV-2 such as the more transmissible B.1.1.7 lineage (Galloway et al., 2021).

4. The eco-social context of remote Alaska

4.1. Remote Alaskan communities

Alaska is characterized by a widely dispersed population with more than 60,000 people living in remote communities of fewer than 1000 residents that are located off the road system and are only accessible by plane or boat. Many of these communities are predominately Alaska Native. From 2006 to 2010, the poverty rate among AI/AN communities in tribal areas was 1.8 times the United States average (32% vs 18%) (Pindus et al., 2017), and the rates of unemployment were also significantly higher. Such socio-economic factors impact the risk of transmission of SARS-CoV-2 as well as disease implications after transmission has occurred in rural Alaska (Table 1).

4.2. Overcrowding in rural Alaskan homes

It is sometimes said that there is little homelessness in remote Alaska because families move in together, creating multi-generational, multi-family households. In remote Alaska, 25–40% of households are overcrowded, compared to the national average of less than 5% (Wiltse and Madden, 2018). According to the United States Department of Housing and Urban Development's (HUD), an “overcrowded” home is defined as having more than one person per room (Blake et al., 2007). Home overcrowding in rural Alaska presents challenges to limiting the spread of the virus once a family member becomes ill with COVID-19. The lack of space restricts the isolation of these family members exposing additional family members to the virus (Table 1).

Table 1
Socio-economic, geographic, and environmental factors that may influence the transmission and spread of SARS-CoV-2 in rural Alaska.

Factors	Effect
Socio-economic	• Overcrowded homes make social distancing more challenging, lead to larger and more susceptible social bubbles – contributing to easier viral transmission and spread. • Overcrowding also restricts the isolation or quarantine of exposed and infected individuals. • Mining and oil industries attract individuals from within and outside Alaska, which increases overall travel, and thus the risk of SARS-CoV-2 transmission. • Unemployment, poor economic conditions, and reduced state/federal support restrict access to medical facilities and water and sanitation services.
Geographic	• Necessity of travel for some health services at regional medical facilities increases the risk of SARS-CoV-2 transmission/spread. • COVID-19 testing and vaccine distribution is more challenging in communities that are geographically isolated. • Development of piped water and sanitation systems are challenged by small, isolated communities and large distances between houses.
Environmental	• Extreme cold and presence of permafrost restricts the development of adequate water and sewer infrastructure. • Degradation of permafrost due to climatic changes impacts water quality, water sources, and existing piped water and sewer infrastructure.

4.3. Implications of remoteness on COVID spread

Remoteness leads to both isolation from services and the necessity for intrastate travel for those services and for economic and subsistence activities. For example, hunting, fishing, and gathering food and water, activities that depend on collective labor and inter-village travel, are essential for household food security, social connection, and cultural wellbeing. Residents also make regular trips to larger communities to purchase food, fuel, and other household needs at lower prices. Additionally, many residents in the rural communities are employed in seasonal or shift work that requires intrastate travel from their homes to fisheries, mines, oil fields, and other distant/remote workplaces. For example, more than 70% of workers in the North Slope Borough (NSB) come from another borough or census area within Alaska (Krieger, 2019) because the well-paid jobs in the oil and gas industry in NSB attract Alaskans from all over the state. Many of these workplaces also employ labor from outside Alaska (about 20% of all workers in Alaska are nonresident; Krieger (2019)) presenting an additional exposure and transmission risk to rural Alaskans as village residents travel between work and home.

Furthermore, the hub-and-spoke tribal healthcare system requires patients to travel regionally for medical care that is unavailable at local clinics. Regional "hub" communities have larger populations (several thousand) compared to smaller surrounding villages and serve as the centers for primary health care and transportation services in their respective regions. Patients requiring more specialized medical care or hospitalization usually must travel on commercial airplanes to nearby cities (e.g., Anchorage, Fairbanks). COVID-19 outbreaks in remote Alaskan communities with inadequate medical facilities place a heavy burden on local commercial air carriers that may only land at some communities a few times per week. As an extreme example, transportation to and from the community of Little Diomede, Alaska is limited to a few months in the summer by small boats when the Bering Strait is free of sea ice, in the winter when planes can land on the sea ice, and the rest of the year by helicopter. Moreover, several air carriers that serve remote Alaska have taken a heavy financial blow due to COVID-19-related travel restrictions, further limiting transportation options to larger medical facilities.

Like many communities across the Arctic, the remoteness of Alaskan communities provided some protection from transmission during the early stages of the pandemic, as city and tribal governments were able to limit travel in and out of their communities (Bennett, 2020). As the pandemic progressed, and travel restrictions were eased (Kitchenman, 2020), cases of COVID-19 began to rise in Alaska's remote regions (Hollander et al., 2020). Although regional and community-led efforts to limit non-essential travel into and between remote villages have been in place, limitations in testing capabilities as well as legal limits on enforcement have impeded the ability of communities to avoid the introduction of SARS-CoV-2 into communities. For example, in late October 2020, the western Alaska village of Chevak (pop. ~1000 residents) reported a sudden surge in cases with nearly 20% of population infected with SARS-CoV-2 virus (Kim, 2020). By late November 2020, all rural regions in Alaska were reporting "high" (>10 cases/100,000) 14-day averaged daily case rates, with Yukon Kuskokwim-Delta region reporting a case rate around 150 per 100,000 (DHSS, 2020b).

5. Household water and sanitation insecurities in remote Alaskan communities

Over 3300 homes in more than 30 of the 190 remote Alaskan communities lack in-home piped water and sewer services, and another 16 are considered "underserved" with 20–50% of homes lacking connection to piped services (ADEC, 2013; DHSS, 2020a). Additionally, a report by Pettit (2014) points out that 18% of AI/AN households in selected AI/AN counties in Alaska had incomplete plumbing and 15% lacked complete kitchen facilities. Residents of unplumbed homes either receive treated water through a closed truck haul service, or they self-haul water in limited amounts from a local watering point or washeteria (usually 5–30 gal at a time) on foot using a wheelbarrow, sled, by snow machine, or four-wheeler (Fig. 1A). In self-haul households, household water quantity used is typically less than 5 gal per person per day (gpcd) (Eichelberger, 2018; Mattos et al., 2020; Thomas et al., 2016), far less than the WHO recommendation of 13.2 gpcd for intermediate water access (Howard and Bartram, 2003). A recent study found that 80% of participating households (out of 43 homes in two remote, rural, unpiped communities in Alaska) reported reusing washbasin water an average of 3 times before changing the water (Mattos et al., 2020), which may increase pathogen exposure (CDC, 2020). Limited access to water in remote Alaskan communities contributes to a significantly higher risk of respiratory infections (Hennessy et al., 2008; Mosites et al., 2020). For example, compared to regions with greater coverage of in-home plumbing, hospitalization rates of children living in unplumbed communities is 3.4 times greater for respiratory syncytial virus (under the age of 5 years) and 30% higher for pneumonia among infants (Hennessy et al., 2008).

Reliable access to clean water and sanitation services in both piped and unpiped communities is challenged by environmental factors, including extreme cold, permafrost, and – increasingly – climate change (Brubaker et al., 2011; Eichelberger, 2019; Sohns et al., 2020). For example, utility systems in remote cold region communities face additional challenges because of continuous and discontinuous permafrost, warming winter conditions that lead to ground instability on the surface and subsurface, warming-induced degradation of permafrost that leads to operation and maintenance issues, high costs of maintenance, and risks for waterborne diseases due to potential breach of water mains (Smith, 1996). In addition to the damage to piped water and sewer infrastructure, climate change is also contributing to problems such as poor water quality, high turbidity, and loss of raw water sources (Cozzetto et al., 2014; Melvin et al., 2017).

5.1. Dilapidating washeterias and community contact locations

For many in unplumbed homes, central community facilities, or "washeterias" (Fig. 1E) provide a critical access point for access to treated water, showers, and laundry (often for a fee). These buildings are usually attached to or housed within the water treatment plant. Several washeterias in rural Alaska have outstanding repair needs but the state and federal support to address such needs has been shrinking over the years (e.g., ADEC, 2013). Many operate at a deficit because of operational costs involved. Others, such as the facility in Newtok, Alaska, are unable to provide service due to inadequate community energy infrastructure (Eichelberger, 2019). Since the start of the COVID-19 pandemic, those who manage washeterias have had to limit access to maintain social distancing. Under conditions of limited access for laundry, households share household washers and dryers thereby increasing their social contacts (Eichelberger, 2019, 2011, 2010; Jepson et al., 2017) - a practice that may increase the potential for exposure to SARS-CoV-2.

5.2. Disposal of 'honey buckets' and greywater

In unpiped communities where pit latrines ("outhouses") are not feasible (due to environmental factors such as high groundwater tables and permafrost), residents use 5-gal bucket latrines (known as "honey buckets") (Fig. 1B) and manually dispose of the collected human waste in centralized collection containers known as hoppers (Fig. 1C) or directly in minimally controlled dumps or sewage lagoons (Fig. 1D). Many homes lack delineated bathrooms to defecate or practice personal hygiene privately. Honey buckets may sit in the entryway separated by a door to the outside and interior, or in the corner of a room separated by a sheet or curtain from the rest of the room. Particularly in communities without collection services, bags of human waste

Fig. 1. Water and sanitation infrastructure in rural Alaska. (A) hauling of water using a four-wheeler, (B) honey bucket, (C) hoppers, (D) sewage lagoons, (E) community washeteria, and (F) a slop bucket for sink drain collection. (picture credits: Aaron Dotson, Kaitlin Mattos).

often accumulate outside of homes for days or weeks while they await transport to the dump or honey bucket lagoon.

Mattos et al. (2020), in their study of two unplumbed remote Alaskan communities, found that bags of sewage sit outside of homes an average of 4–13 days, depending upon the season. It is common for bags to break or get ripped open by animals, spilling their contents near homes. Collected waste can also be spilled during transport to hoppers or dumps, exposing the population to raw sewage from across the community (Chambers et al., 2008; Chambers et al., 2009). These hoppers also leak as they are often conveyed to the dump off the main pathways like boardwalks to avoid spilling to trafficked areas but resulting in spills adjunct to these areas. The lack of proper sanitation facilities and manual transport of human waste in rural Alaska could thus pose a potential infection risk via water or aerosol pathway (Bogler et al., 2020), though there is no evidence yet for fecal-oral transmission of SARS-CoV-2 (D'Amico et al., 2020).

Similarly, households that haul their water must also manually dispose of their greywater. Residents typically collect greywater in a basin or slop bucket (Fig. 1F) and dump it in a convenient place outside of the home, often on the ground not far from foot and vehicle pathways. Some households connect a floor pipe to their sinks and dispose of the water on the ground underneath their raised foundation. It is possible that pathogens in greywater can then be picked up by individuals who come into direct contact with the disposal areas (Chambers et al., 2009). A schematic showing potential transmission routes is presented in Fig. 2. Additionally, the sanitation practices associated with sewage collection and disposal discussed here can lead to comorbidities or pre-existing conditions that can impact the severity of COVID-19.

6. Preventing COVID-19 in a water insecure context

The COVID-19 pandemic has highlighted the long-standing inequities in Indigenous communities throughout the United States (Hathaway, 2020; Kakol et al., 2020; van Dorn et al., 2020; Wilder, 2020), including in water and sanitation infrastructure. By July 2020, tribal communities in the contiguous United States had over four times the incidence of COVID-19 cases compared to the rest of the United States with much of this discrepancy likely due to lack of indoor plumbing (Rodriguez-Lonebear et al., 2020). The Navajo Nation experienced a high death rate per capita early in the pandemic, exacerbated by the lack of safe water sources on the reservation (Abou-Sabe et al., 2020). Temporary hand washing stations, strict stay-at-home curfews, widespread mask usage, and substantial testing efforts have helped limit continued spread of the virus, but long lines at water filling stations and water rationing limit people's ability to take basic precautions against transmission of SARS-CoV-2 and other pathogens (Abou-Sabe et al., 2020; James, 2020).

In Alaska, community leaders recognized early the need to mitigate water insecurity to prevent the spread of SARS-CoV-2 in their communities. Regional entities and tribal health organizations worked together to bulk order and distribute hand sanitizer, bleach, and other sanitary supplies to remote communities. In the Northwest Arctic Borough, special efforts were made to prioritize the distribution of hand sanitizer to homes without indoor plumbing. Tribal health organizations circulated instructions (e.g., YKHC, 2020) to water plant operators for how to make household bleach, which was distributed free of charge to community members. The state of Alaska also distributed high quantities of personal protective equipment (PPE) kits, gloves, and surgical and respiratory masks (Krakow, 2020).

Furthermore, the COVID-19 pandemic has brought attention to the human right to water and sanitation. Water and sewer utilities in Western Alaska have waived fees to encourage residents to use more water for hygiene and to facilitate sanitary disposal of waste (KYUK, 2020). In March 2020, the Alaska Rural Utility Collaborative began reconnecting homes that had been disconnected from running water services due to nonpayment. Others have used CARES Act funding to

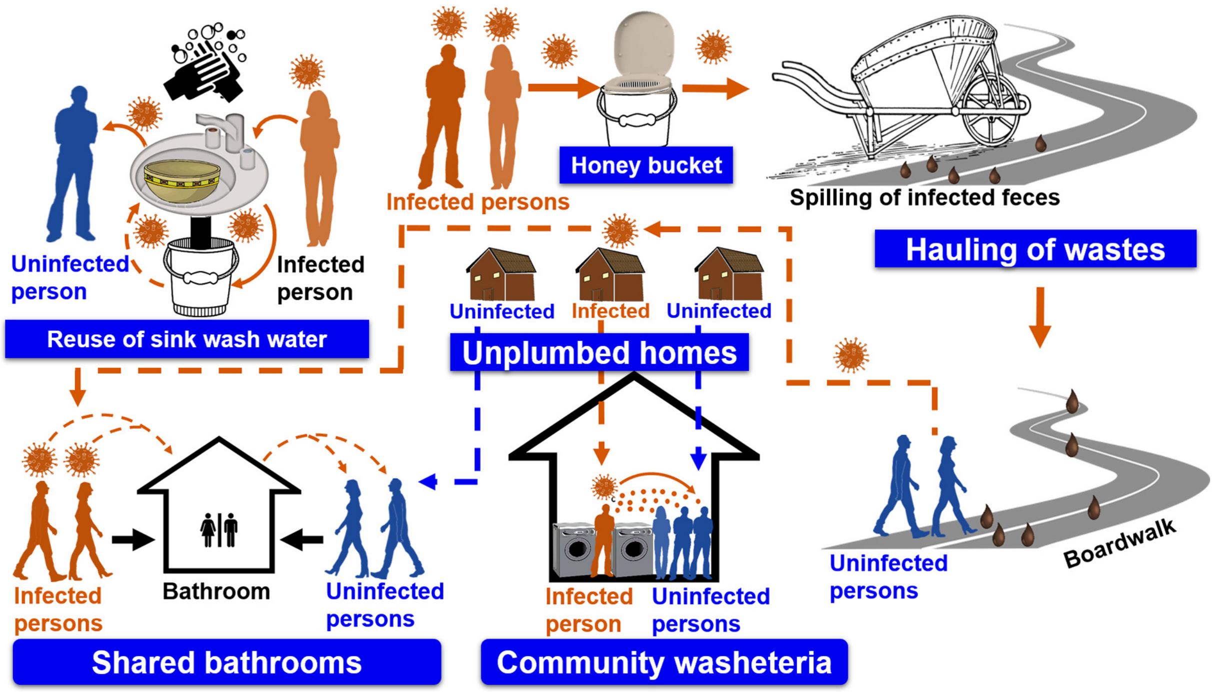

Fig. 2. Potential transmission routes for SARS-CoV-2 in rural Alaska communities.

subsidize water and sewer bills, to provide short-term and intermediate handwashing stations and dry toilets to unpiped households, and to build new homes that include in-home water and sanitation systems (Eurich, 2020; D. Beveridge, ANTHC, pers. comm.). Some communities had to endure long wait times to get allocations of CARES Act funding that was primarily being planned to be spent toward improved water and sanitation infrastructure (Kirk, 2020).

Considering the unique challenges faced by rural Alaska during the COVID-19 pandemic, efforts to enhance water, sanitation and hygiene access in remote communities need to be renewed and increased at the local, regional, state, and federal levels. Stakeholders across remote Alaska have made diligent efforts to reduce disease transmission, increase sanitization efforts, and reduce risk, but the threat of COVID-19 outbreak in remote communities is still very high and the consequences will have significant and far-reaching impacts on the people living there. The provision of in-home plumbing infrastructure, suitable community facilities, adequate healthcare, and appropriate financial support would help protect isolated communities through the current pandemic and provide vital infrastructure necessary for community health under normal conditions. As we continue to navigate in unknown waters and shift to rebuilding, we hope that the inequities highlighted by the COVID-19 pandemic create a renewed focus on the underlying determinants of population health and the importance of access to basic water and sanitation services for all populations.

CRediT authorship contribution statement

S.A., D.L.B., S.D., and L.E. conceptualized the manuscript and contributed to writing the original draft and editing. S.D. and S.A. developed the visualizations. T.H., D.L.B., E.B., B.R.B., P.C., A.D.D., D.M.D., M.B.H., and K.M. wrote sections of the paper and contributed to editing of the manuscript. All authors reviewed and approved the final manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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