SARS-CoV-2 in Wastewater: Tracking COVID 19

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Global Distribution of disease cases and deaths

The ongoing global pandemic of coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has been a Public Health Emergency of International Concern. Officially declared by the World Health Organization (WHO), this disease has spread so quickly it has impacted every corner of the globe and every nation.

SARS-CoV-2 is a member of the family *Coronaviridae* that consists of a group of enveloped viruses with a single-stranded RNA genome. This virus is related to the SARS-CoV-1 which was responsible for the 2002-03 outbreak. Members of this family have been known for some 80 years and are known to cause common colds in humans. Although the major transmission route of SARS-CoV-2 is inhalation from person-to-person and aerosol/droplet, it's transmission via fomites and hands is also well documented. Early in the study of this virus it was found in feces and available evidence indicates that the virus is also present in wastewater, suggesting the need to better understand wastewater as potential source of epidemiological data and potential human health risks.

Around the world, city, state and national leaders are making decisions on how to respond to the COVID-19 pandemic, allocate resources and ultimately reopen communities. Sewage provides a window to view the infection in the community that has the potential to assist in these decisions. Wastewater systems offer a practical approach to identify viruses excreted in the feces of an entire region. This type of surveillance strategy can be useful as an "early warning" system (Xagoraraki and O'Brien, 2020) to determine if re-introduction of SARS-CoV-2 had occurred in a community, or conversely as an assessment of whether exposures have decreased sufficiently following public health interventions, such as lockdown, social isolation, and social distancing. As communities reopen there is a rush to develop approaches to monitor the health of the community to set up further testing of individuals and contact tracing.

Additionally, virome analysis of wastewater opens up future possibilities of detecting novel viruses before their clinical recognition in a community, allowing for preventative measures and allocation of resources to potentially affected areas (Bibby and Peccia, 2013; Fernandez-Cassi et al., 2018; Ng et al., 2012).

To view how the novel coronavirus is spreading around the globe with up-to-date visuals that give context to the data collected on Johns Hopkins University's COVID-19 visit their website at https://coronavirus.jhu.edu/map.html

Occurrence in feces

It is now known that SARS-CoV-2 infects gastrointestinal glandular epithelial cells, is excreted in feces of infected individuals asymptomatic (30 to 50%), those with mild symptoms as well as those severely impacted, and is found in sewage.

Both viable SARS-CoV-2 and viral RNA are shed in bodily excreta, including saliva, sputum, and stool, which are subsequently found in wastewater. It has been reported that SARS-CoV-2 RNA loads could be as high as 10^7copies/mL in diarrhea and 2.5×10^4 copies/mL in urine (Hung et al., 2004). SARS-CoV-2 RNA has been detected in excreta specimens, such as feces and anal/rectal swabs (Gao et al., 2020; Holshue et al., 2020; Jiehao et al., 2020; A. Tang et al., 2020b; Wolfel et al., 2020; Xiao et al., 2020; J. Zhang et al., 2020; W. Zhang et al., 2020). Viral RNA concentrations in feces were determined by several studies to be up to 10^8 copies per gram of feces (Lescure et al., 2020; Pan et al., 2020; Wölfel et al., 2020). Some clinical studies reported prolonged fecal shedding of SARS-CoV-2 RNA for up to seven weeks after first symptom onset (Jiehao et al., 2020; Y. Wu et al., 2020; Xiao et al., 2020). Another study reported that viral RNA could be detected in the stool of 81.8% cases even with a negative throat swab result (Ling et al., 2020). Recent reports implied that significant proportions (17.9–30.8%) of infected individuals are asymptomatic (Mizumoto et al., 2020; Nishiura et al., 2020), and SARS-CoV-2 RNA was detected in the feces of asymptomatic individuals as well (Tang et al., 2020a). In a study evaluating virus dynamics in Zhejiang province at China, it was observed that the median duration of virus in stool was 22 days (interquartile range 17 -31 days), which was significantly longer than in respiratory airways (18 days) and serum samples (16 days) (Zheng et al., 2020).

Persistence

Although two studies (Wang et al., 2020; W. Zhang et al., 2020), demonstrated the presence of culturable SARS-CoV-2 in fecal samples from COVID-19 patients, a more recent study reported that culturable virus was not isolated from feces despite high viral RNA concentrations (Wolfel et al., 2020). However, the persistence of two surrogate coronaviruses, transmissible gastroenteritis (TGEV) and mouse hepatitis (MHV) was analyzed, and the viruses remained infectious in water and sewage for days to weeks (Casanova et al. 2009) with T-99 (time for 2 $\log_{10}$ reductions) of 9 to 49 days at 25°C in pasteurized settled sewage and 7 to 70 days at 4°C. The human coronavirus was much less stable with 1.57 to 2.36 days for T-99 at 23°C (Gundy et al., 2009).

Occurrence in sewage

Concentration and testing for viruses in wastewater have been on-going for more than 70 years. An up to date summary of enteric virus concentrations in sewage can be found at http://www.waterpathogens.org/book/section-i-viruses .

During the SARS outbreak in 2004 in China, SARS-CoV RNA was detected in 100% (10/10) of untreated and 30% (3/10) of disinfected wastewater samples collected from a hospital in Beijing, China receiving SARS patients. Interestingly it has been demonstrated that a similar coronavirus, SARS-CoV-1 can survive in sewage for 14 days at 4°C, and for 2 days at 20°C, and its RNA can be detected for 8 days, even though the virus was inactive (Gundy et al. 2009; Wang et al. 2005)

There have been nine reports to date of the molecular detection of SARS-CoV-2 in wastewater in the Netherlands, USA, France, Italy, Spain, Israel and Australia (Ahmed et al., 2020; Bar-On et al., 2020; La Rosa et al., 2020; Lodder and de Roda Husman, 2020; Medema et al., 2020; Nemudryi et al., 2020; Randazzo et al., 2020; Rimoldi et al., 2020; F. Wu et al., 2020; Wurtzer et al., 2020). Many of these studies were small with only 8 samples collected where as the largest study to date was 26 samples. Between 0 and 100% were positive (average 60%) and some of these studies reported the detection of SARS-CoV-2 RNA in untreated wastewater with concentrations of a maximum of between 10^2 to 10^6 copies per liter. The study in France detected SARS-CoV- 2 RNA in treated wastewater as well, with concentrations of up to nearly 10^5 copies per liter (Wurtzer et al., 2020).

Why monitor?

The SARS CoV2 is not considered a waterborne pathogen; however, like the global surveillance of poliovirus program, this has the potential to provide a view of community infection while public health struggles to monitor individuals.
This could benefit society by:

1. Linking disease cases and infections (via testing) in the community with concentrations in sewage.
2. Monitoring increasing/decreasing spread, speed of spread, second waves, impacts of social distancing, re-opening of cities.
3. Identifying hot spots, providing information on racial and economic disparity and providing early warnings (potential seasonal outbreaks) for health care response.
4. Addressing uptake of vaccination
5. Creating approaches and networks that can be used to mobilize environmental monitoring if another pandemic occurs.

In addition, knowledge on levels and removal by treatment processes when combined with knowledge on persistence and susceptibility to disinfection will provide both the workers at the wastewater facility and the public with greater confidence regarding control of any potential for waterborne transmission.

The Global Water Pathogen Project (GWPP) mission is to be a knowledge resource and hub on water pathogens which will guide the goals for sanitation and achieve safe water around the world using the power of new information technology and tools. In the future it is hoped that the site can serve as a center for global sewage monitoring data. This is a call out for the

GWPP network to come together to assist community environmental health across the world and to further advance our knowledge on SARS-CoV-2 in fecal sludges, sewage and treated wastewater.

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