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The COVID-19 pandemic: Considerations for the waste and wastewater services sector

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ABSTRACT

This article discusses the potential ramifications of the COVID-19 pandemic on waste and wastewater services, focusing on critical points where alternative operating procedures or additional mitigation measures may be advisable. Key concerns are (i) the long half-life of the virus on materials such as waste containers, bags, and in wastewater, and (ii) possible transmission via contaminated waste surfaces and aerosols from wastewater systems. There are opportunities to further the science of wastewater-based epidemiology by monitoring viral RNA in wastewater to assess disease prevalence and spread in defined populations, which may prove beneficial for informing COVID-19 related public health policy.

1. Introduction

As of April 2020, some 93% of the global population (about 7.2 billion people) live in countries with some form of movement restrictions in place [1]. A new coronavirus disease, officially named COVID-19 by the World Health Organisation (WHO), has caused a global pandemic with profound impacts on many aspects of human life [2]. On 11 February 2020, the International Committee on Taxonomy of Viruses announced severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) as the name of the new virus [3]. Unlike all previous pandemics in modern history, COVID-19 is truly a global crisis. Never before have we seen the health care systems of some of the world's most industrialised nations on the verge of collapse [4]. Unprecedented measures (social distancing, school and workplace closure, and restricted intra- and international movement) have been enforced by governments around the world to stop the spread of COVID-19. As the world adapts to unprecedented behavioural and societal changes in response to the threat posed by COVID-19, societal operations, including many essential municipal services must also adapt and change. These essential services such as waste collection and wastewater treatment are routine and indispensable. They play a key role in mitigating infectious disease transmission but are rarely mentioned in public health crises response communications [5–7]. Under current projections waste and wastewater industries are expected to bear significant financial impacts from COVID-19. For example, water utilities in the USA are expected to suffer over $27 billion in financial loss due to revenue reduction and expense increase as a direct consequence of COVID-19 [8].

This perspective article aims to examine the role of waste and wastewater management within the global response to COVID-19. It especially seeks to place lessons from previous epidemics and pandemics in the current context to construct a policy and research road map for the waste and wastewater sectors to join the fight against COVID-19 and future outbreaks of this nature.

2. Morphology, structure and possible transmission routes of SARS-CoV-2

COVID-19 is an infectious disease caused by a novel coronavirus. The COVID-19 pandemic is the third major zoonotic coronavirus disease outbreak in only two decades, following the SARS (Severe Acute Respiratory Syndrome) outbreak in 2002-2003 and the MERS (Middle East Respiratory Syndrome) outbreak in 2012. The disease was first reported to the WHO by Chinese Health Officials on 31 December 2019 as atypical pneumonia of unknown cause [9,10]. The virus is genetically similar to the SARS-CoV coronavirus and is likewise assumed to have crossed the species barrier from animal to human [3,11]. Although its specific origins are yet to be determined, the likely ancestor is a bat coronavirus [10].

The morphology and structure of SARS-CoV-2 has important implications for waste and wastewater services. Each SARS-CoV-2 virion is a small spherical particle (≈100 nm diameter), consisting of a positive-

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sense single stranded RNA genome within a fragile lipid envelope [12]. It is a betacoronavirus in the subgenus Sarbecovirus. Although sometimes referred to as "a type of flu", it is in fact genetically and virologically distinct from influenza viruses as these are negative-sense RNA viruses.

SARS-CoV-2 has spike proteins on its surface that bind to host cell proteins and subsequently aid viral entry. Given their small size, SARS-CoV-2 virions can be transmitted via air as part of aerosols [13]. However, due to the delicate nature of the lipid envelope of SARS-CoV-2 virions, the viral particle may become non-viable (i.e. non-infectious) once the envelope is damaged, even though their genetic fragments may still be detected.

A common method for detecting SARS-CoV-2 is nucleic acid testing using real-time polymerase chain reaction (RT-PCR) technology. These RT-PCR assays can also be modified and adapted to detect and quantify the virus in environmental samples such as wastewater [5].

The transmission behaviour of SARS-CoV-2 also has important implications for waste and wastewater services. SARS-CoV-2 specifically targets host cells containing ACE2 proteins. ACE2 is an enzyme attached to the outer surface (cell membranes) of cells in the lungs, arteries, heart, kidney, and intestines. After infecting and exhausting all resources in the host cell to multiply, the viruses leave the cell in a process known as shedding. Data from clinical and virological studies provide evidence that shedding of the SARS-CoV-2 virus is most significant early in the course of the disease, immediately before and within a few days since onset of symptoms [2]. The SARS-CoV-2 virus has been detected in blood, sputum, respiratory secretions, and faeces from symptomatic patients [2, 14–16]. The contribution of viral shedding from asymptomatic and presymptomatic carriers to SARS-CoV-2 transmission remains in question. While it is likely that viral loads in asymptomatic carriers are relatively low, further research is needed [17].

A preliminary report from the WHO indicates that SARS-CoV-2 is transmitted via droplets and contaminated objects during close unprotected contact between an infector and infectee [2]. Data to date suggest that SARS-CoV-2 is highly contagious, with early reports from China indicating that the virus spread rapidly and sustainably throughout some affected communities [18]. Alarming infection incidents among health care workers, cruise-ship and airplane passengers also point to the likelihood of additional transmission mechanisms in confined spaces with dense populations. Several alternative transmission routes are possible but their validity in this context is yet to be determined [19,20]. Possibilities include transmission via inanimate/environmental surfaces (fomites), aerosols and the faecal-oral route [17,21]. All three are likely to be important in specific circumstances [17], highlighting the need to identify critical control points and implement specific measures to mitigate possible COVID-19 transmission during waste and wastewater collection.

2. Implications for waste services

Fomites are recognised to be key vehicles for the spread of other infectious human viruses (e.g. noroviruses) during outbreaks [22]. Data from SARS-CoV-2 and other coronaviruses suggest that they remain viable in the environment on a range of surfaces for several hours and up to several days (Fig. 1). The survival time of SARS-CoV-2 on hard surfaces and plastic is in the order of days, which suggests that waste materials originating from households and quarantine facilities with positive or suspected COVID-19 patients may contain viable SARS-CoV-2 and could be a source of infection. In the initial stages of this outbreak, waste collection procedures had not been revised to address the potential threat of COVID-19 in the broader community. Effectively, waste from infectee households and quarantine facilities would meet the definition of clinical waste. For instance, the Australian Standard AS 3816:2018 defines clinical waste as "*any waste that has the potential to cause injury, infection, or offence, arising but not limited to medical, dental, podiatry, health care services and so forth*". In other words, strict infection control and hygiene standards are required when collecting waste materials from affected households and quarantine facilities.

Home isolation and pop-up quarantine facilities are common practice in countries significantly affected by COVID-19 so that hospitals can be prioritised for severe cases. In many countries, patients with mild symptoms have been directed to self-quarantine at home. Similarly, hotels and student accommodation are being used by some authorities to quarantine return travellers, including those positive for COVID-19, for at least 14 days. This unprecedented situation presents new and significant challenges for the provision of waste collection services to these locations and a new challenge to the parties responsible for collecting and handling such waste. In terms of waste management, this widespread outbreak is particularly challenging due to the dispersed nature of cases and infected individuals. The importance of using best management practices for waste handling and hygiene (including disinfection of reusable personal protective equipment) should be reemphasised at this time in the context of limiting worker exposure to potentially contaminated waste. Given the potential role of the environment in the spread of SARS-CoV-2 [25], waste collection from households and quarantine facilities with COVID-19 positive or suspected patients is a critical control point.

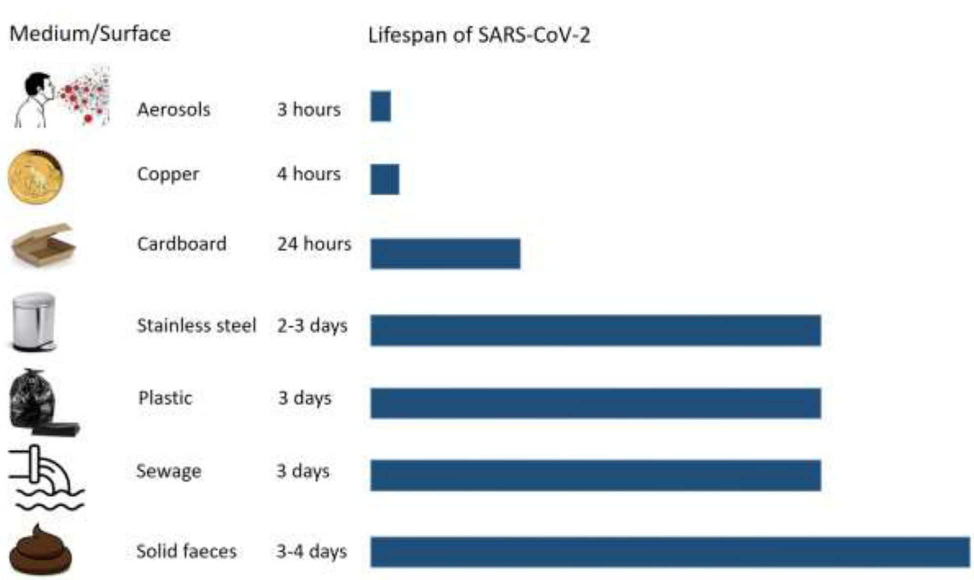

Fig. 1. Lifespan of SARS-CoV-2 in the environment (Refs: [13,23,24]).

According to the Association of Cities and Regions for Sustainable Resource Management (ACR+), there is a trend among the waste management sector in Europe to protect frontline waste workers by providing separate collection services to COVID-19 infected households and quarantine facilities (Fig. 2). A delay in waste collection time of 72 hours (which is the likely life span of COVID-19 in the environment) is also recommended by ACR+. In addition, the collected materials are transported directly to waste incinerators or landfills without any segregation. At the time of this article, it is unclear how many cities or regions within ACR + have implemented this recommended practice. Implementation of the revised waste collection protocol in Fig. 2 is not simple and requires a high level of coordination with the relevant authorities, especially health departments regarding data sharing and privacy protection. Due to privacy concerns, there is very limited or no sharing of patient (or suspected patient) data between health authorities and the waste services sector in most countries around the world. Indeed, the authors are not aware of any suitable data sharing mechanisms currently available or in place that can facilitate coordination between health authorities and other sectors whilst preserving privacy. A data sharing App jointly developed by Apple and Google for contact tracing is a rare example; although this relies on voluntary consent from the patient for identification [26].

3. Implications for wastewater services

During the SARS outbreak in 2003, wastewater aerosols were identified as a 'highly probable' transmission route affecting residents at the Amoy Gardens complex in Hong Kong. The outbreak at that location involved over 300 cases and 42 deaths [27]. Follow up investigations confirmed that high concentrations of viral aerosols in building sewer plumbing were drawn into apartment bathrooms through malfunctioning floor drains when bathroom exhaust fans were running [28]. Virus-laden aerosols originating in the bathroom were subsequently extracted via over-sized bathroom exhaust fans into the building's light well and then spread under prevailing winds to adjacent units up to some 200 m away [29]. Immediately after the investigation, the management committee of the Amoy Gardens complex repaired all defects in the building's plumbing system [28].

The residual uncertainty around the definitive cause of the Amoy Gardens SARS cluster and the likely role of faulty or improperly functioning plumbing highlight the need to review similar housing complexes where individual apartment units are connected via plumbing air vents so as to prevent disease transmission by aerosols. Subsequent research revealed several in-building fixtures in which pathogen laden aerosols can be generated from wastewater such as vacuum and flushometer toilets [30]. Thus, certain steps or locations along the wastewater handling and treatment train, especially in the upstream collection network may be suitable for implementing monitoring or control measures to prevent the spread of COVID-19.

As SARS-CoV-2 virions are excreted in COVID-19 patients' faeces, sewage can also be an important point of surveillance for wastewater-based epidemiology. Several groups, notably in Australia, the Netherlands, Sweden, and the USA have already reported detecting traces of SARS-CoV-2 in wastewater [6,31]. Scientists from the Dutch National Institute for Public Health and the Environment analysed wastewater samples from the Amsterdam Schiphol Airport over several weeks and found that, using RT-PCR, they could detect SARS-CoV-2 within four days of cases being confirmed in the country [2]. Importantly, detection of SARS-CoV-2 RNA in wastewater does not imply that the virus is viable and able to infect humans. Coronavirus in wastewater is relatively short-lived, with 3-$\log_{10}$ reduction in virus titre reportedly occurring within 2–3 days [32]. However, given the genetic similarity of SARS-CoV-2 to the earlier, widely-studied SARS-CoV [33] and the known faecal-oral transmission potential of that virus [15,34–36], it is possible that a similar transmission pathway exists for SARS-CoV-2. For example, positive SARS-CoV-2 infection of gastrointestinal glandular epithelial cells has been reported, suggesting that infectious SARS-CoV-2 virions are secreted from virus-infected gastrointestinal cells, establishing the potential for faecal-oral transmission [19]. The same study also indicated that infectious SARS-CoV-2 had been isolated from faecal samples; although at the time of writing, these data remained unpublished [19]. This contrasts with other research that failed to isolate infectious virus from faecal samples (13 samples taken from four patients) [20] so clearly more work is needed to explore the potential for faecal-oral SARS-CoV-2 transmission.

With careful selection of sampling points along a sewer network, wastewater 'analysis' can be used to obtain information pertaining to

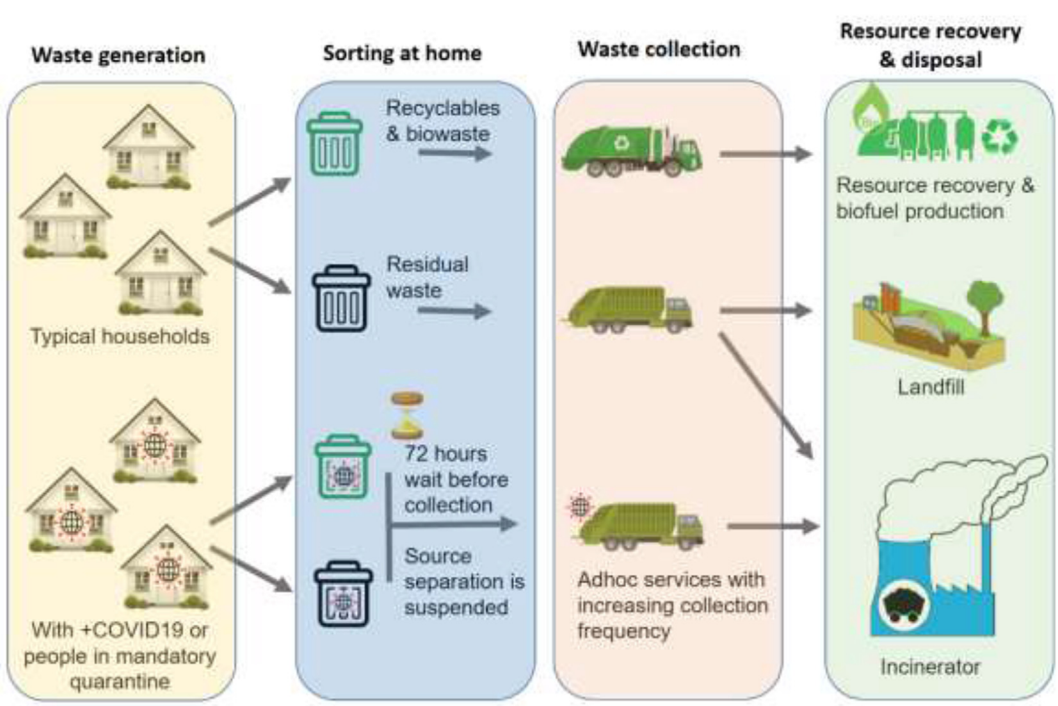

Fig. 2. Current recommendations for municipal waste management during the COVID-19 crisis (Modified from ACRPlus.org).

select populations of varying size, e.g. from a particular quarantine facility, hospital, or local government area, or up to hundreds of thousands of people from a larger catchment area. In the case of SAR-CoV-2 the monitoring technique is based on analytical genomic approaches similar to those used clinically to diagnose suspected COVID-19 patients. This may also be augmented with additional analytical steps to provide a quantitative measure of the targeted viral RNA concentration [5,31]. With further development and using well-designed sampling campaigns with suitable spatio-temporal resolution, wastewater monitoring could well become a useful tool to monitor and assess the incidence of COVID-19 disease within populations to inform related public health policy.

True quantitative assessment of community SARS-CoV-2 infection would be extremely challenging due to the large number of factors involved and the unknown variability in these factors (e.g. large variability in SARS-CoV-2 viral shedding rates between people and also within people at different stages of infection, unknown persistence of viral RNA in wastewater, variable flow conditions in sewer systems) [6,37]. These difficulties, however, do not preclude the usefulness of wastewater monitoring as a semi-quantitative early detection system for SARS-CoV-2 re-emergence (or at worst presence/absence) and potentially also as an ongoing tool for informing jurisdictional policy responses to COVID-19 management. For example, routine wastewater testing could be used to inform when to relax restrictions on population movement or re-open commerce. Having such information available in real-time to inform policy setting would have substantial economic value given the daily cost of COVID-19-related lockdowns. For example, the daily cost of strict economy-wide lockdown in the United States has been estimated at some US$11.5 billion [38]. The challenge thus becomes to design a widely-accepted surveillance system to detect the potential community presence of COVID-19 and for various end users – from public health officials to facility operators – to be able to use these insights in their decision-making. This would include an ability to evaluate the effectiveness of different control measures to suppress COVID-19 such as social distancing and city-wide lock down.

Wastewater monitoring has been successfully used to identify illicit drug hotspots [39], and track and provide early warnings of outbreaks of pathogenic viruses such as Hepatitis A and Norovirus [7]. It is highly likely there could be similar potential value in using wastewater-based epidemiology to inform SARS-CoV-2 responses [40]. Experts have clearly warned of the likelihood that novel viruses, in particular RNA viruses, will continue to present a serious threat to global public health and disease control [11,41]. Although current waste and wastewater management practices such as hospital waste separation and incineration, multi-barrier wastewater treatment and disinfection, and PPE protocols have already been designed to mitigate infectious disease exposure risks for workers and the public, the COVID-19 pandemic has resulted in unprecedented and rapid change. Most businesses and services were under-prepared for this pandemic. Widespread community infection and quarantining can have major impacts on essential services such as waste and wastewater management, and the potential vulnerabilities in the provision of these services are now more apparent than ever before.

4. Conclusion

In the context of the COVID-19 pandemic, this article shows that significant research is needed to assess the *status quo* for pandemic preparedness and response in the waste and wastewater sectors. We need to open up the discussion around potential changes to practice, such as for the collection and handling of waste materials from households and quarantine facilities with positive or suspected COVID-19 patients. Current mitigation practices such as the use of withholding times may do much to reduce the risks to workers handling solid wastes, but additional revisions to procedures may be required and should be considered. There is also a pressing need for data on SARS-CoV-2 prevalence and persistence in wastewater in order to better understand related transmission pathways and to inform appropriate risk management actions for the wastewater sector. Further research into possible aerosol transmission of COVID-19 is also warranted, as lessons from previous outbreaks including SARS-CoV indicated that this pathway was a factor in disease spread. Finally, the ability to detect SARS-CoV-2 in wastewater provides an ideal opportunity to revisit its merits as a data source. Although individual privacy considerations and a need to ensure data security can be a challenge, given the scale, human toll, and financial impact of COVID-19, this research should proceed with urgency.

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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