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Perspective

The potential exposure and transmission risk of SARS-CoV-2 through sludge treatment and disposal

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The coronavirus disease (COVID-19) is a novel acute pneumonia caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), and the outbreak has been declared to be a pandemic by World Health Organization (WHO). SARS-CoV-2 is a single-stranded, non-segmented RNA virus with an envelope structure. After infectious SARS-CoV-2 was isolated from COVID-19 patients' feces and urines, the corresponding RNA in the wastewater and sewage sludge was also observed(Randazzo et al., 2020), implying the possibility of transmission of SARS-CoV-2 through the wastewater treatment plants (WWTPs). In fact, the enveloped viruses have been proven to survive for days to months in the municipal wastewater system. Sewage sludge, the by-product of WWTPs, is also believed to be the reservoir of this new coronavirus due to the enrichment of 30%–50% of pollutants from sewage. The complex organic matters in the sludge could protect the pathogenic virus from inactivation. It was also reported that the virus HKU1 (i.e., human coronavirus) had been detected in sewage sludge with high abundance(Bibby and Peccia, 2013). Therefore, it is imperative to understand the potential exposure and transmission risk of this virus in sludge for the sake of public health.

The coronavirus spread may occur in specific procedures of the sludge treatment and disposal, and the most noteworthy way of virus transmission and exposure is the direct contact with sludge (Fig. 1). In the process of mechanical maintenance, transportation and routine sampling and detecting, workers or operators have high probabilities of being exposed to raw sludge, suggesting that the personal protective equipment and regular disinfection are essential for the epidemic prevention. Furthermore, the inhalation of aerosol is another important exposure route that cannot be ignored. In many procedures of sludge treatment (e.g., biological treatment, sludge dewatering and mechanical agitation), shearing the liquid surface leads to the release of the pathogenic and toxic matrix from sludge into the air in the form of airborne particulate matter. It was found that SARS-CoV-2 could survive in aerosols and remain infectious for several hours (van Doremalen et al., 2020), indicating the possibility of aerosol transmission. Last but not least, the potential ecological risks are also of great concern post the sludge disposal (e.g., land application). Following land-use of the treated sludge, enterovirus in soil may survive from days to months depending on environmental conditions, and subsequent spread through overland or sub-surface flow to surface and ground waters would occur, thus resulting in the potential infection via ingestion or accidental ingestion of contaminated water.

The routine sludge disinfection mainly includes anaerobic digestion, composting, sludge drying, etc. As a mainstream technology, mesophilic anaerobic digestion has positive effects on virus elimination, while the performance could be elevated in thermophilic anaerobic digestion. Similarly, conventional composting could inactivate an average 2–3 $\log_{10}$ units of male-specific coliphages(Viau and Peccia, 2009), indicating that temperature is the main effective factor for viral inactivation. It was also noted that sludge dewatering could remove the viruses by air drying or heat drying, and the acid or alkaline conditioning could further enhance the performance of virus inactivation. Although the conventional sludge treatments are conducive to the virus inactivation in sludge, they may not meet the safety standards during a pandemic, thus requiring more rigorous methods and regulations of sludge treatment and disposal. Disinfectant addition is considered as the preferred emergency sanitation treatments due to the shorter sanitary time. 0.5% or 2% chlorine solutions were suggested to disinfect human excreta during the Ebola outbreak (Silva et al., 2019), and lime stabilization also showed high efficiency for virus elimination in sludge. Both processing conditions should be extremely strict about meeting the minimum requirements, i.e. 10^3 E-coli/100 mL, according to the WHO. On the other hand, reasonable management throughout the process of sludge treatment and disposal are also necessary. In the acute phase of an emergency, the sludge treatment and disposal process should maintain in a closed system to reduce the risks of viral contact with the human and ecologic environment. In China, sludge has been required to be sterilized in the sludge storage tank equipped with mixing units, and sludge dewatering should be carried out in centrifugal dewatering device to avoid human contact as far as possible during the recent COVID-19 outbreak. These programs and suggestions would help to prevent and control the potential spread of the viruses through sludge treatment and disposal.

While limited evidence was found that sludge would play an essential role in SARS-CoV-2 transmission, there is still a need to understand the fate of coronaviruses outside the human host, including their persistence and inactivation mechanisms in sludge, which would help

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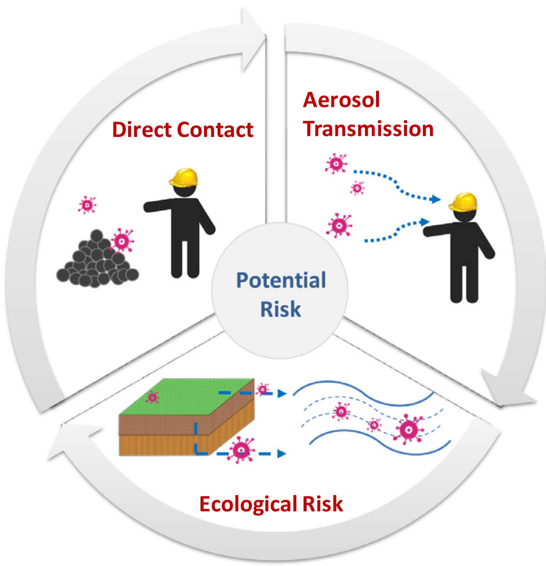

Fig. 1. The potential exposure and transmission risk of SARS-CoV-2 through sludge treatment and disposal.

to reveal their potential risks during sludge treatment and disposal.

1. Efficient extraction and detection methods of coronaviruses in sludge

Most methods mainly aimed at the detection of enteric viruses, which is not suitable for enveloped viruses due to their vulnerable envelope structure. Also, the presence of natural inhibitors (humic acid, heavy metals, etc.) in sludge may have adverse effects on the gene amplification reaction of viruses, causing false-negative results. Therefore, it is necessary to develop the efficient extraction and detection methods of coronaviruses in sludge.

2. Occurrence and distribution of coronaviruses in sludge

Sludge is a complex mixture of various compounds, which would have effects on the survival and fate of the virus. While the microbial environment in sludge contributes to virus elimination via predation, antagonism and nutrition competition, the extracellular polymeric substances (EPS) may play an essential role in providing protection against the virus. Therefore, it is of considerable significance to explore the occurrence and distribution of coronavirus in sludge and to investigate the exposure and secondary transmission risk of virus in sludge.

3. Persistence and disinfection behaviours of coronaviruses in sludge

Although some scenarios have been put forward in the aqueous environment, the persistence in sludge and inactivation with exposure to disinfectants need to be further studied. It is also necessary to evaluate whether the existing sludge sanitation technology would be valid during the epidemic, and to develop novel and efficient technique for the prevention and control of these infectious coronaviruses in sludge.

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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