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Addressing the Associated Risks of COVID-19 Infections from Water and Wastewater Services in Asia through a Decentralised Wastewater Treatment Approach

IGES
Institute for Global Environmental Strategies

Beyond COVID-19

Authors

Pham Ngoc Bao[1], Vu Duc Canh[2] and Bijon Kumer Mitra[1]

1 Institute for Global Environmental Strategies (IGES) (Corresponding author: ngoc-bao@iges.or.jp)

2 The University of Tokyo, Japan

KEY MESSAGES

- Safely managed water supply and wastewater services have been playing key roles in maintaining good water environmental quality, stopping the spread of disease and protecting public health during infectious outbreaks in Asia, including the ongoing coronavirus outbreak 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) strain.

- There is a growing number of scientific research findings and reports around the world recently, which revealed that COVID-19 has been detected in untreated domestic and hospital wastewater, and that it is spreading through human faeces. In order to address this emerging challenge and minimise the associated human health risks, it is essential to have a better understanding on possible routes of COVID-19 infections and contamination across the water and wastewater service chain based on recent scientific findings. Consequently, this will assist local authorities in identifying and implementing appropriate preventive countermeasures to stop possible COVID-19 transmission.

- If COVID-19 can be effectively monitored in infected communities at an early stage through regular virus surveillance in wastewater for COVID-19, together with results from clinical diagnostic testing, even in areas where clinical surveillance is poor, then effective interventions and preparedness actions can be taken as early as possible to restrict the movements of infected population, as well as to minimise the pathogen spread and threat to public health.

- The COVID-19 outbreak has reiterated the need to ensure access to safe and reliable water and wastewater services for all to minimise microbial risks and protect human health during infectious disease outbreaks. However, this goal will not be reached without integrating an innovative solution like a decentralised wastewater management approach into overall wastewater management planning process, especially in developing countries in the region, due to the limitations of conventional centralised wastewater management approaches. The decentralised approach is considered a promising, short and long-term solution, supplementing the centralised wastewater management approach, to minimise the microbial risks of COVID-19 infection. This approach has recently been successfully demonstrated and proven in several ASEAN and South Asian countries (e.g. India), especially in rural and peri-urban settlements.

1. Introduction

The ongoing global pandemic of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), or COVID-19, is causing significant public health impacts across the world, with more than 40 million infected cases reported and more than one million deaths confirmed in over 200 countries according to the latest information from Johns Hopkins University, as of 19 October (JHU, 2020).

It has been recently reported that SARS-CoV-2 can also be present in human faeces (Kitajima et al. 2020; Lin et al. 2020; Wang et al. 2020a; Wang et al. 2005d), which will gradually enter sewerage networks, or is directly discharged into open environment or nearby water bodies. There are also reports stating that RNA (ribonucleic acid) fragments of SARS-CoV-2 can be persistently shed in faeces for a maximum of 33 days even after the patient has tested negative for respiratory viral RNA (Wu et al. 2020a). Some studies demonstrated that RNA concentration could even be detected in SARS-CoV-2 contaminated wastewater at 4-7 days ahead of case detection (WHO 2020b). Both viable SARS-CoV-2 and RNA virus can be shed in human body excretion, including saliva, sputum and faeces, which are consequently disposed of in wastewater (Kitajima et al. 2020). Coronavirus can remain infectious in sewage for a much longer period — up to 14 days at 4°C (Wang et al. 2005d) in low-temperature regions. It is estimated that globally 1.8 billion people are using faecal-contaminated sources for drinking water, so the potential for COVID-19 transmission risk is expected to increase several folds (Bhowmick et al. 2020) if this contaminated wastewater, faecal waste and drinking water supply sources are not properly managed and treated. Therefore, safely managed wastewater and faecal waste from infected, recovering and recovered patients is extremely important, but also poses a significant challenge to stop the spread of infections.

Unfortunately, many developing Asian countries continue to experience severe environmental, public health and economic impacts due to poor sanitation and lack of proper wastewater treatment facilities. It is estimated that more than 80% of generated wastewater in Asia was directly discharged into receiving water bodies without adequate treatment (Bao and Kuyama 2013), causing substantial levels of faecal contamination and microbial risks in drinking water sources, as well as negative impacts on inland and coastal ecosystems. Many rivers and water sources in Asia are highly contaminated; consequently, more than 2 million people die every year, mostly children in developing countries, because of water-related diseases (WHO, 2020a).

Moreover, a centralised wastewater treatment approach, which has successfully been employed in developed countries, has thus far failed to address these challenges in Asia due to massive requirements for initial investment for the construction of wastewater treatment plants themselves as well as a sewage collection network. Consequently, the ratio of properly treated wastewater in the region is relatively low, especially in developing Asian countries. This calls for a paradigm shift from the current centralised wastewater management approach to one that is economically affordable, ecologically sustainable, and easy to use, as well as having low requirements in operation and maintenance. One such promising and sustainable approach, in terms of both cost, flexibility and modularity, resource recovery and possibility of minimising microbial risks to human health, is decentralised wastewater treatment and management, which has recently been successfully demonstrated in several ASEAN countries, especially in rural and peri-urban settlements.

This Issue Brief aims to: (i) facilitate discussion on the need to properly address the existing issue of poor wastewater management in many Asian countries, in order to minimise the human health risks associated with SARS-COV-2 infections; (ii) identify possible routes of SARS-CoV-2 infections and contamination across water and wastewater service chain; (iii) propose preventive countermeasures to stop possible COVID-19 transmission; and (iv) highlight the potential roles of decentralised wastewater management in addressing the associated risks of COVID-19 infection along the water and wastewater service chain.

2. Possible routes of COVID-19 infections and contamination across water and wastewater services

SARS-CoV-2 in faeces

SARS-CoV-2 is known to cause not only respiratory but also gastrointestinal infections (including diarrhoea). In a meta-analysis of 60 studies conducted from six countries (China, South Korea, Singapore, Viet Nam, United States, and United Kingdom) with a total of 4243 patients infected with SARS-CoV-2, the prevalence of gastrointestinal symptoms and diarrhoea were 17.6% and 12.5% (Cheung et al. 2020). Other studies revealed that COVID-19 patients with diarrhoeal symptoms occurred in a range from 3.8% to 24.2% of investigated patients, respectively (Guan et al. 2020; Lin et al. 2020; Pan et al. 2020). To date, a number of studies have reported the presence of SARS-COV-2 in stool samples and anal/rectal swabs from COVID-19 patients by using molecular detection methods. Although the prevalence of SARS-CoV-2 positivity has varied among studies, the presence of SARS-COV-2 in stool specimens was relatively common. Lin et al. (2020) investigated faecal samples of 65 hospitalised patients in Zhuhai, China and found 31 samples (47.7%) were positive. In other studies examining stool samples from COVID-19 patients, the positive detection rates ranged from 21.4% to 89% (Chen et al. 2020; Wu et al. 2020a; Zhang et al. 2020a). Regarding urine specimens, a few studies reported that viral RNA was not detectable in urine specimens from COVID-19 patients (Chen et al. 2020; Pan et al. 2020; Wang et al. 2020c; Xiao et al. 2020).

SARS-COV-2 was shed into the stool of COVID-19 patients over a long duration (up to five weeks from first symptom onset) (Cai et al. 2020; Kim et al. 2020; Pan et al. 2020; Wölfel et al. 2020). Several studies even found that faecal samples remained positive for SARS-CoV-2 RNA fragments after respiratory samples tested negative for SARS-CoV-2 RNA (Chen et al. 2020; Tian et al. 2020). SARS-CoV-2 RNA was also detected in the faeces of infected people who had mild or even no symptoms (Tian et al. 2020). Regarding the concentration of SARS-CoV-2 RNA, up to 10^8 copies/g-faeces were reported (Lescure et al. 2020; Wölfel et al. 2020). The virus concentration had its highest peak during the first week of symptoms and gradually decreased during the duration of the clinical course (Kim et al. 2020; Wölfel et al. 2020). Wölfel et al. (2020) reported that the concentration of SARS-CoV-2 RNA ranged from 10^3-10^8 copies/g-faeces depending on the infection's course.

SARS-CoV-2 in raw and treated wastewater

SARS-CoV-2 is shed in faeces, urine and other human excreta, which subsequently reach the sewerage systems. To date, the presence of SARS-CoV-2 RNA in wastewater has been reported around the world. During the peak of the epidemic (between 5 March and 23 April) in the Parisian area of France, Wurtzer et al., (2020a) examined raw wastewater from three wastewater treatment plants (WWTPs) for the presence of SARS-CoV-2 RNA. All the samples (23/23, 100%) were found positive for SARS-CoV-2. In similar studies conducted in the United States of America, France, Australia and Spain, the detection rates of SARS-CoV-2 RNA in raw wastewater ranged from 22% to 83% (Ahmed et al. 2020; Medema et al. 2020; Randazzo et al. 2020; Sherchan et al. 2020). The range of SARS-CoV-2 RNA concentration in raw wastewater widely varied from 1.2×10^2–3.0×10^6 copies/L. When comparing faeces and wastewater, the concentration of SARS-CoV-2 in wastewater was 3-5 orders of magnitude less than that in faeces. Although these previous studies obviously indicate the presence of SARS-CoV-2 in wastewater, there were few investigations about infectivity of SARS-CoV-2 in wastewater.

To date, only two studies investigated the presence of SARS-CoV-2 in wastewater using both rRT-qPCR and cell culture methods, which can determine the infectivity of viruses (Rimoldi et al. 2020; Wang et al. 2020c). These two studies reported that infectious SARS-CoV-2 was not detected in wastewater by the cell culture method despite the positive detection of SARS-CoV-2 RNA. Since the survival of SARS-CoV-2 in wastewater might vary depending on environmental factors (e.g. pH and temperature, light exposure, organic matters and presence of antagonist microorganisms), more studies are needed to investigate the infectivity of SARS-CoV-2 in wastewater.

Several studies also investigated the presence of SARS-CoV-2 in treated wastewater and river waters (Haramoto et al. 2020; Randazzo et al. 2020; Rimoldi et al. 2020; Sherchan et al. 2020; Wurtzer et al. 2020a). The studies conducted in Japan (Haramoto et al. 2020) and Spain (Randazzo et al. 2020) found SARS-CoV-2 in secondary-treated wastewater with the concentration ranging from 2.4×10^3 copies/L to 2.5×10^5 copies/L. The presence of SARS-CoV-2 RNA up to 10^5 copies/L was also reported in final treated wastewater in a study conducted in France during the peak of the epidemic (Wurtzer et al. 2020a). Currently, there are only two studies investigating the presence of SARS-CoV-2 in river water (Haramoto et al. 2020; Rimoldi et al. 2020). Haramoto et al., (2020) reported all river water samples (0/3) were negative for SARS-CoV-2, indicating the concentration of SARS-CoV-2 was less 3.7×10^2 copies/L (limit of detection). However, Rimoldi et al. (2020) detected SARS-CoV-2 RNA in 67% (4/6) of river water samples. Notably, this study was not able to detect any SARS-CoV-2 RNA in final treated wastewater. Therefore, it was hypothesised that a fraction of untreated wastewater has been directly discharged into surface waters due to non-collected domestic discharges or to the lack of separation of urban runoff waters from domestic effluents (Rimoldi et al. 2020). In addition, it should be noted that the presence of viral genomes determined by molecular methods does not always correlate to the presence of infectious virus particles. In the study of Rimoldi et al. (2020) when testing the positive river water samples with SARS-CoV-2 RNA by rRT-PCR, no infectious SARS-CoV-2 particles were detected by the cell culture method, suggesting a low risk of infection from river waters.

Although several studies quantified the concentration of SARS-CoV-2 in raw and treated wastewater, the efficiency of SARS-CoV-2 removal from WWTPs remained limited. Indeed, Sherchan et al. (2020) detected 3.1×10^3 copies/L of SARS-CoV-2 in raw wastewater, which was close to the limit of detection (1×10^3 copies/L). Additionally, no SARS-CoV-2 RNA was detected in secondary-treated and final treated wastewaters, indicating the concentration of SARS-CoV-2 RNA in treated wastewater was less than the limit of detection (1×10^3 copies/L). Thus, the removal of SARS-CoV-2 was not clear in this study. At present, only Wurtzer et al. (2020a) clearly observed the reduction of SARS-CoV-2 from wastewater treatment plants. In this study, all raw wastewater samples (23/23) were positive for SARS-CoV-2 with a concentration of around 10^7 copies/L. In addition, most of the treated wastewater samples (6/8) were positive for SARS-CoV-2 with a concentration of round 10^5 copies/L. Thus, the concentration of SARS-CoV-2 was reduced 100 times (or 99%) through the wastewater treatment plants in this study (Wurtzer et al. 2020a). However, virus removal efficiency can vary depending on wastewater characteristics and treatment processes applied, so more studies are needed to have better understanding about the removal of SARS-CoV-2 throughout wastewater treatment plants.

Routes of SARS-CoV-2 contamination across water and wastewater service chain

Possible routes of SARS-CoV-2 infection and contamination across the water and wastewater service chain are identified and described in Figure 1. As mentioned earlier, since SARS-CoV-2 has been detected in human faeces, urine or vomit of the infected person, it will gradually enter the sewerage system or, in places where a sewerage system is not available, it will be directly discharged into nearby receiving water bodies. Besides the possible infection hotspots within infected communities, hospitals and quarantine buildings/centres are other major hotspots. Wastewater discharged from hospitals or quarantine building/centres must gradually enter in-situ treatment facilities, before reaching the sewerage systems or directly bypassing into nearby water bodies.

Unfortunately, in many cases in Asian countries, a large percentage of hospital wastewater might not be properly treated and disinfected separately; as a result, this SARS-CoV-2 contaminated wastewater is often discharged into common municipal sewerage system or bypassed directly into nearby receiving water bodies. Direct

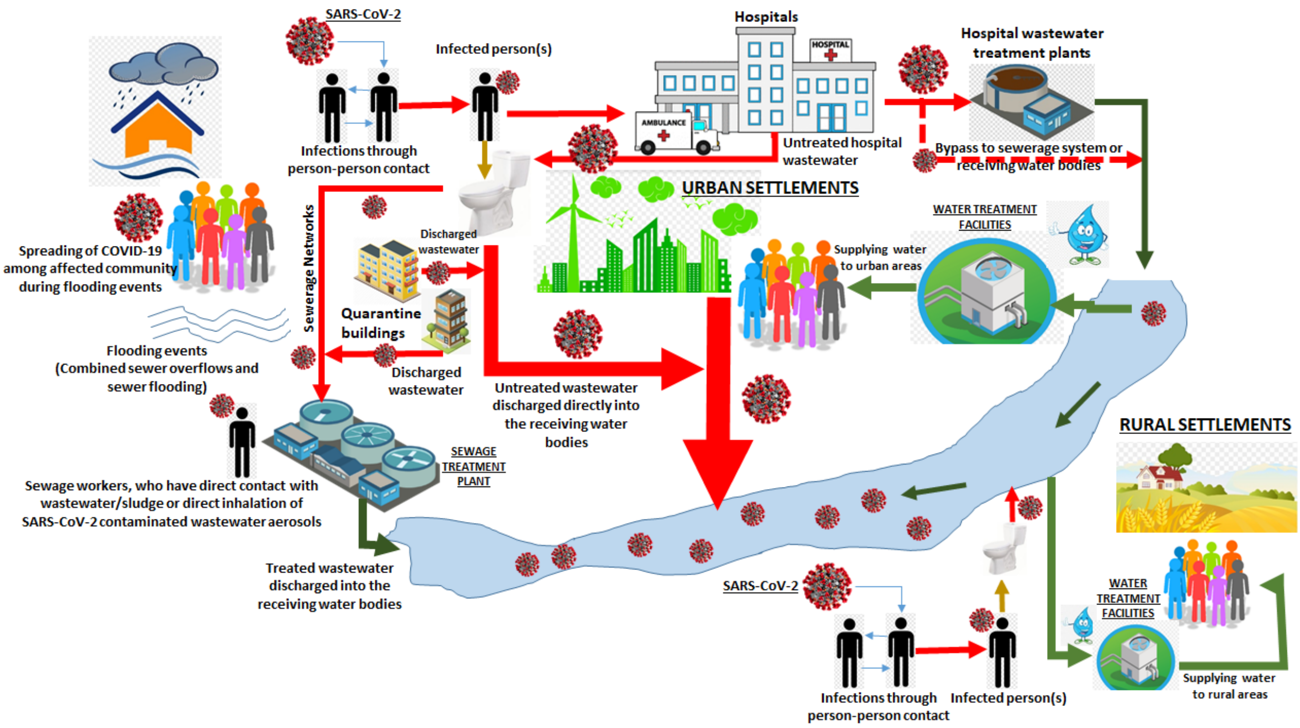

Figure 1. Possible routes of SARS-CoV-2 infections and contamination across water and wastewater services sector (Source: The figure was developed by authors, 2020)

consumption of this SARS-CoV-2 contaminated water source by rural people having no access to water treatment facilities, or having only access to improperly water treatment facilities without disinfection process before discharging into receiving water bodies may pose a risk of infection to these people. In addition, SARS-CoV-2 can be spread among infected communities during heavy flooding events, which often occur in urban areas recently in many big Asian cities. Moreover, sewage workers, who have direct contact with SARS-CoV-2-contaminated wastewater or who have inhaled SARS-CoV-2-contaminated aerosols formed over the uncovered aerobic wastewater treatment process within wastewater treatment plants, will also have a high-associated risk of infection.

Regular virus surveillance in wastewater for COVID-19

Regular virus surveillance in wastewater (also known as wastewater-based epidemiology) is a proven concept in public health, which has been used for decades to assess the success of vaccination campaigns against poliovirus (Nakamura et al., 2015; Manor et al., 1999). Such practice can be replicated as a useful tool to understand the circulation and prevalence of other pathogenic viruses in a human community. Viral pathogens can be shed in the stool of infected individuals at high concentrations and found to be relatively stable in wastewater (Fong and Lipp 2005). Thus, sampling and analysing wastewater

Figure 2. A decentralised wastewater system constructed in Hanoi, using nature-based technologies

can be an alternative approach to study the epidemiology of virus infection in a human community served by the wastewater system. This approach can overcome the limitations of traditional clinical surveillance, which is time-consuming, laborious and expensive. In addition, the clinical test cannot identify asymptomatic patients and so may underestimate the real scale of virus infection. Wastewater surveillance has a long history of use in public health, particularly for investigating the infection of enteric viruses (e.g. poliovirus, norovirus and enterovirus) and their genetic diversity in the human population (Kazama et al. 2016; Nakamura et al. 2015; Prevost et al. 2015).

Several recent studies have reported information on the sensitivity of wastewater surveillance for SARS-CoV-2. In a study conducted in Japan, SARS-CoV-2 was detected in wastewater when 36 cumulative COVID-19 cases were reported, corresponding to only 4.4 cases per 100,000 inhabitants (Haramoto et al. 2020). Similar findings were also observed in a study conducted in the Netherlands since positive wastewater samples were detected when the number of reported cases reached 5-10 cases per 100,000 inhabitants (Medema et al. 2020). Similarly, a study conducted in Spain, SARS-CoV-2 was detected in areas with low COVID-19 prevalence, ranging from 16.69–21.18 cases per 100,000 inhabitants (Randazzo et al. 2020). These studies suggest that monitoring of wastewater for SARS-CoV-2 could be sensitive enough to detect the low prevalence of COVID-19 cases in the local communities. Notably, recent studies conducted in France and the US have reported the presence of SARS-CoV-2 in wastewater several days before the detection of COVID-19 in clinical surveillance (Wu et al. 2020b; Wurtzer et al. 2020b). In addition, SARS-CoV-2 can be detected in wastewater 12–16 days before first confirmed COVID-19 cases in a study conducted in Spain (Randazzo et al. 2020). Thus, there is potential to use regular virus surveillance in wastewater as an early warning tool for the occurrence of COVID-19 in communities, monitoring the status of COVID-19 infection in local communities, evaluating the trends and tracking hotspots, revealing true scale of the coronavirus outbreak. Early warning of infection would provide valuable time for infected communities to implement actions to control the spread of COVID-19.

3. Roles of decentralised wastewater treatment and management in addressing the associated risks of COVID-19 infection

Many Asian countries failed to utilise conventional centralised wastewater treatment and management approaches to address the long standing issues of severe water quality pollution and to minimise the associated microbial risks to human health due to the huge requirements for initial investment for the construction of wastewater treatment facilities and collection systems, including pumping stations. Therefore, this requires a call for a paradigm shift toward alternative approaches or solutions that are affordable to developing countries. A decentralised wastewater treatment and management approach is one such promising and sustainable approaches, which has recently been successfully demonstrated in several ASEAN (e.g. Indonesia, Laos, the Philippines, Thailand and Vietnam) and South Asia countries (e.g. India), especially in rural and peri-urban settlements as both a short (interim solution) and long-term solution in addressing the challenges of water pollution. The decentralised wastewater treatment and management approach offers many advantages and benefits (Figure 3), both in term of economic, environmental and social aspects, compared to the conventional centralised wastewater treatment approach (Table 1).

Table 1. Economic, social and environmental benefits of decentralised wastewater treatment and management

Economic	Social	Environmental
▪ Low investment & time efficient ▪ Design works in multiple settings ▪ Incremental growth ▪ Sustainable revenue source	▪ Improved hygiene ▪ Opportunity for Public-Private Partnerships ▪ Opportunities for local to invest. ▪ Providing a range of low-cost solutions	▪ Water quality improvement ▪ Reduction of microplastics pollution in water bodies ▪ Adaptable to discharge standards ▪ Water reuse and nutrient recovery opportunities ▪ High resilience to the impacts of climate change and less vulnerable to disaster damage ▪ Minimising risks of spreading COVID-19 pandemic into water environment

Figure 3. Advantages of decentralised wastewater treatment and management approach (Source: The figure is prepared by the authors)

For effectively minimising the impact of the potential associated risk of SARS-CoV-2 infection and eliminating chances of transmission, the appropriate disinfection techniques must be implemented in decentralised wastewater treatment facilities. In addition, it is important to improve our understanding of the disruption of SARS-CoV-2 during the disinfection process; Wang et al. (2005d) presented results from the use of chlorine and chlorine dioxide for disinfection of SARS-CoV in wastewater. According to this study, a chlorine concentration of 10 mg/L was able to inactivate 100% of SARS-CoV with a contact time of 10 minutes, resulting in a residual chlorine level of 0.4 mg/L. On the other hand, a chlorine dioxide concentration of 40 mg/L was able to 100% inactivate SARS-CoV in 5 minutes of contact, with a free residual chlorine of 17.59 mg/L. Zhang et al. (2020b) found that in domestic wastewater with high suspended solids, the suspended solids may shield and protect the virus, so high doses of disinfectants may be required. However, the application of high doses could produce disinfection byproducts and ultimately pose an ecological risk. Therefore, optimal doses should be identified for effectively inactivating SARS-CoV-2 without generating disinfection byproducts.

For hospital wastewater, there are a number of commonly-used disinfectants such as liquid chlorine, sodium hypochlorite, chlorine dioxide, ultraviolet radiation and ozone. The choice of appropriate technology will likely depend on various factors such as investment and operational costs, safety, wastewater volume, disinfectant supply and level of operational control. Wang et al. (2019e) has developed a schematic diagram for assisting the selection of disinfection technologies for hospital wastewater based on various factors and its level, including size of hospitals (large and small), costs (high and low), maintenance (easy and complex), and other conditions (removal of spores, and influence by pH).

In addition to the above benefits, decentralised wastewater treatment technologies, if properly designed, constructed, operated and maintained, are expected to effectively remove up to 90% or more of microplastics, an emerging pollutant, from wastewater, with the greatest amount removed by tertiary treatment, such as filtration (WHO, 2019).

Although there are a number of advantages offered by decentralised solutions, many developing Asian countries are still struggling to effectively utilise this approach and maximise its benefits, especially in the context of ongoing COVID-19 pandemic. Lessons learned from several case studies in ASEAN countries, including Thailand (Bao et al., 2020), has showed that in order to facilitate effective implementation and utilisation of decentralised wastewater solutions, the following enabling policies should be considered.

Enabling policies for effective implementation of decentralised wastewater solution

Using the sanitation service chain approach
To ensure the public and environmental safety of both communities and downstream settlements, sanitation needs to be redefined to encompass the entire sanitation chain (containment/on-site sanitation, emptying and collection, transport, treatment and final disposal).

Upgrading the existing on-site sanitation facilities
Upgrading cesspools to septic tanks with a sealed bottom, or other innovative technologies such as solar septic tanks where applicable and affordable, is essential to minimise contaminants leaking into the environment. It is also important to encourage the proper operation and maintenance of onsite household sanitation systems by conducting regular desludging services every three to five years.

Mandating the performance-testing standards for decentralised wastewater treatment technologies
For the decentralised wastewater treatment systems/technologies to be allowed on the market, it is necessary to mandate performance-testing standards to ensure the quality of the products and a sound market.

Decentralised wastewater treatment should be considered an integral part of comprehensive wastewater and sanitation strategies
Decentralised wastewater treatment should be considered an integral part of comprehensive wastewater and sanitation strategies, which can be effectively used to complement the conventional centralised wastewater treatment approach, due to competitive advantages of cost, area and low operation and maintenance requirements, flexibility. However, in order to successfully utilise this decentralised solution, clear zoning using a set of appropriate selection criteria (e.g. population density) is necessary when identifying which area is more suitable for centralised or decentralised wastewater treatment systems.

Development of a city-wide sanitation plan
It is imperative for cities (or provinces) to develop a city-wide sanitation plan that covers a complex mosaic of "centralised, decentralised, on-site sanitation systems" and faecal sludge management, or a blend of these techniques, and then weigh their appropriateness, taking into account population density, local capacity, as well as local sensitivity.

Introducing appropriate public-private partnership models
To ensure the sustainability of the decentralised wastewater treatment systems, many countries are now exploring innovative and viable funding mechanisms to improve and deliver better services. Public-private partnerships are one of these viable mechanisms. In the long term, it is

essential to provide incentives to the private sector so that economic spillovers (i.e. returns on investment in the form of direct benefits and taxes) can be achieved. Some good and successful examples have been observed in ASEAN countries such as the Philippines and Malaysia.

4. Conclusions

Under the ongoing coronavirus outbreak, various scientific evidence has shown that SARS-CoV-2 was detected and spread through human faeces, gradually ending up in sewage/wastewater treatment plants. SARS-CoV-2 was able to maintain its viability (e.g. in raw sewage, hospital wastewater, raw wastewater discharges from quarantine buildings/spots, SARS-CoV-2 contaminated floodwater, and water bodies that originated from faecal discharge of infected patients) for several days in vitro after leaving the faeces. This posed a potential risk to public health, if the waste is not properly handled and treated.

Therefore, precautionary measures, effective interventions and control strategies should be taken to stop the spread of SARS-CoV-2 infections from these possible routes, especially from aerosol transmission in the above mentioned hotspot areas. Meanwhile, workers engaged in the water and wastewater services, particularly at sewage treatment plants, must be equipped with appropriate personal protective equipment, frequently perform handwashing and respiratory hygiene using alcohol hand rub or hand sanitizer, and avoid touching eyes, nose and mouth with unwashed hands.

It can be seen that COVID-19 has reiterated the need to ensure access to safe and reliable water and wastewater services for all, so as to minimise the risks and protect human health during infectious disease outbreaks. However, this goal will not be reached without considering a decentralised wastewater management approach as an alternative or supplementing solution to centralised approach, especially in developing Asian countries, due to the limitations of the centralised wastewater management approach.

In addition, it has been showed that regular wastewater surveillance for viral loads is a useful early-warning and complementary tool to clinical surveillance of COVID-19, which may help: (i) to determine whether the pandemic has been brought under control; (ii) to monitor the changes in the quantity of SARS-CoV-2 over time; and (iii) to facilitate forecasting new possible outbreaks. This is also considered a "cost-effective" measure in the community, as well as effective tool to identify potential hotspots of COVID-19 infection at an early stage. If SARS-CoV-2 can be effectively monitored in a community at an early stage through wastewater-based epidemiology, together with results from clinical diagnostic testing, effective interventions can be proposed and taken as early as possible to restrict the movements of the infected population, as well as to minimise the pathogen spread and threat to public health.

However, in order to replicate and scale up the regular virus surveillance in wastewater for COVID-19 in developing Asian countries, a number of challenges or gaps have been identified (GWOPA; UN Habitat and GIZ 2020) and these challenges must be overcome for effective utilisation of this early-warning tool for stopping the spread of COVID-19 infections, including: (i) lack of access to testing facilities or laboratories for detection of SARS-CoV-2 in water/wastewater/sludge samples; (ii) lack of knowledge and scientific evidence on how SARS-CoV-2 behaves in wastewater and faecal sludge; (iii) unavailability of detailed technical guidance on monitoring in both sewered and non-sewered areas; (iv) lack of protocols or standard methodologies for sampling, collection, treatment, and examining the wastewater for the presence of SARS-CoV-2; (v) prohibitive costs; and finally (vi) inadequate collaboration between water/wastewater utilities and health authorities.

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Institute for Global Environmental Strategies (IGES)

2108-11 Kamiyamaguchi, Hayama, Kanagawa, 240-0115, Japan

Tel: 046-855-3700 Fax: 046-855-3709
URL: www.iges.or.jp