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Review

SARS-CoV-2 in wastewater: Challenges for developing countries

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ABSTRACT

The COVID-19 pandemic that has engulfed the world, has affected the human lives in several aspects. The detection of SARS-CoV-2 in faeces and urine of the infected person, even after viral clearance in the respiratory tract, and its presence in untreated wastewater raises the possibility of fecal-oral transmission in future. The situation is likely to be more aggravated in developing and least developed countries struggling with the problem of ineffective waste disposal system, open defecation, poor sanitation, and limited access to clean drinking water. In this review, the available data on wastewater treatment, sanitation status and healthcare infrastructure from middle- and low-income countries is collected and correlated with the risk associated with the fecal-oral transmission of SARS-CoV-2. The review also highlights the limitation of COVID-19 surveillance through sewage monitoring in these countries owing to the absence of proper sewerage system. An inclusive approach of awareness, prevention, and mitigation from global to the local levels is required to overcome this challenging situation in developing countries.

1. SARS-CoV-2 in wastewater: what is known so far?

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which initially stroked the sea-food market in Wuhan city of China in December 2019, has caused nearly 27 million confirmed cases across 216 countries and has already claimed the lives of more than 0.9 million people around the world as on September 6, 2020 (WHO, 2020a). The single-stranded RNA virus with crown-like (corona) spiky surface belongs to same Coronaviridae family (Mousavizadeh and Ghasemi, 2020), of which other members such as Severe Acute Respiratory Syndrome coronavirus (SARS-CoV or SARS) and the Middle East Respiratory Syndrome coronavirus (MERS-CoV or MERS) were responsible for two previous outbreaks in 2003 and 2012, respectively (Gundy et al., 2009; Aleanizy et al., 2017). Like other members of the family, SARS-CoV-2 is zoonotic and suspected to have originated in bats and jumped to human. The major route for human-to-human transmission is ascribed to respiratory droplets or direct contact (Li et al., 2020). However, since it is genetic similar to SARS-CoV virus that had confirmed faecal-oral transmission, the possibility of similar transmission pathway in

SARS-CoV-2 cannot be undermined (Yeo et al., 2020).

Bibliographic search in Scopus database (as on September 13, 2020) with keywords “SARS-CoV-2” and “Wastewater” or “Sewage” in “Title, Abstract, and Keywords” returned 83 documents (excluding “erratum items”) of which 56.6% (47) are research articles and 27.7% (23) are review articles (Fig. 1). A couple of studies confirmed the presence of SARS-CoV-2 RNA in faecal and urine samples of COVID-19 infected patients or in wastewaters from the affected communities (Nemudryi et al., 2020; Wurtzer et al., 2020; Ahmed et al., 2020; Singer and Wray, 2020; Wu et al., 2020). Presence of infectious SARS-CoV-2 in faeces (Xiao et al., 2020) and urine (Sun et al., 2020) raises the possibility of faecal-oral transmission. Viral RNA concentrations up to 10⁸ copies per gram of faeces have been detected (Kitajima et al., 2020). In a recent study, high level of SARS-CoV-2 (500–18,700 copies/L) was reported in a septic tank of the hospital even after disinfection with sodium hypochlorite (Zhang et al., 2020). The complete deactivation of SARS-CoV-2 was only obtained by using a disinfectant dosage of >20 times of the dosage recommended by WHO.

However, to date, no study conclusively affirmed the fecal-oral

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transmission of SARS-CoV-2 or COVID-19 transmission through treated or untreated wastewater. Few reports suggest that there is a potential risk of fecal-oral transmission of COVID-19 in countries with poor wastewater management (Guerrero-Latorre et al., 2020; Street et al., 2020; Adelodun et al., 2020; Bhowmick et al., 2020). No report highlighted and correlated the data of wastewater treatment, sanitation and healthcare infrastructure from middle- and low-income countries from South-East Asia, Africa and Latin America with possibilities of SARS-CoV-2 transmission from sewage or wastewater.

Most of the studies (Fig. 1) on the “SARS-CoV-2 detection in wastewater” are from advanced countries (Medema et al., 2020; La Rosa et al., 2020) and therefore suggests that monitoring SARS-CoV-2 in the sewage could offer a cost-effective solution for COVID-19 surveillance (Lodder et al., 2020; Randazzo et al., 2020). However, the limitations of COVID-19 surveillance have not been reflected in developing countries. Therefore, the main objective of this perspective is to collect the available data on wastewater treatment, sanitation status and healthcare infrastructure from middle- and low-income countries and correlate it with the possible risks associated with the fecal-oral transmission of SARS-CoV-2 and highlight the limitations of COVID-19 surveillance through sewage monitoring in these countries.

2. COVID-19 in developing nations: potential disaster yet to unfold

The number of infections is increasing rapidly in every part of the world including the low- and middle-income grade countries. The South-East Asia region has reported 4,689,943 cases and 83,400 deaths, while the Africa region has reported 1,083,152 confirmed cases and 22,929 deaths due to COVID-19 as on September 6, 2020 (WHO, 2020a). These countries have high population, poor hygiene and sanitation conditions that renders threat of fecal-oral transmission more plausible (Table 1). The existence of any casual relationship, if any, between sanitation or hygiene status of a nation to the level of COVID-19 infection is a very

important assertion. The percentage of the population not having access to basic sanitation and hygiene across the Asian, African, and Latin American nations have been shown with their COVID-19 incidence ratio (i.e. number of confirmed cases to that of the population) in Fig. 2. Across Asian nations, the COVID-19 incidence ratios are in the same order of magnitude as their sanitation and hygiene status. In Latin American nations, such as Colombia, and the Dominican Republic, a high COVID-19 incidence ratio is observed though their hygiene status are superior to most of the African nations. Except, South Africa the other countries in the continent had a low disease incidence ratio, though their sanitation and hygiene status are remarkably poor. In other words, even if sanitation and hygiene can be indicated as a risk factor for COVID-19, the assessment could be confounded with other risk factors.

There is scarce information on the analysis of wastewater for the presence of SARS-CoV-2 from developing and least-developed nations currently suffering from COVID-19. Recently, a preprint from Turkey confirmed the presence of SARS-CoV-2 in municipal wastewater treatment plant (WWTPs) sludges in Istanbul (Kocamemi, 2020). Detection of high loads of SARS-CoV-2 in natural waters from a low sanitation region in urban streams of Quito (Ecuador) calls for more research to understand the known impact of the virus not just to humans but to livestock and wildlife (Guerrero-Latorre et al., 2020). Analysis of wastewater samples in Ahmadabad city of India showed that the SARS-CoV-2 genetic material in wastewater increased with the increase in the number of active COVID-19 patients in the city (Kumar et al., 2020). The lack of studies on the detection of SARS-CoV-2 in sewage from developing nations coupled with poor hygiene and sanitation and lack of robust wastewater treatment and disposal systems in these countries put them on high risk for potential wastewater-related exposure to SARS-CoV-2 (Usman et al., 2020).

2.1. Wastewater treatment and septage management status

The developing nations are generally poor in treating the wastewater

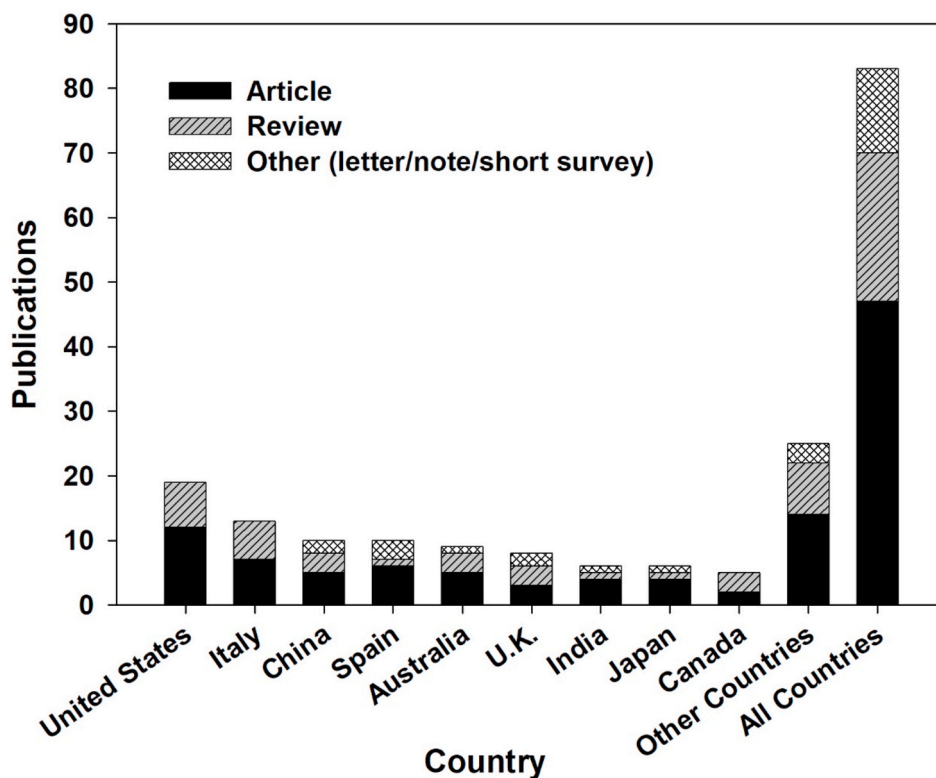


Fig. 1. Type of documents published countrywise (country with minimum five publications) as per bibliographic search in Scopus using keywords “SARS-CoV-2 and Wastewater or Sewage” as on September 13, 2020.

Table 1
COVID-19 and Sanitation status of developing and least developed countries.

S. No.	Country	Population (in billion)	No. of COVID 19 confirmed Cases	No. deaths reported due to COVID 19	Testing Capacity (Tests/1000 people)	**Sanitation (%) (2017)				**Hygiene (%) (2017)		
						At least basic	Limited (shared)	Unimproved	Open Defecation	Basic	Limited (without water or soap)	No facility
Asia												
1.	India	1.4	4,113,811	70,626	35.91	60	13	2	26	60	38	3
2.	Indonesia	0.271	190,665	7940	5.12	73	12	5	10	64	6	29
3.	Pakistan	0.217	298,509	6342	12.48	60	10	20	10	60	32	8
4.	Bangladesh	0.163	323,565	4447	9.89	48	23	29	<1	35	54	11
5.	Myanmar	0.054	1319	8	3.25	64	9	17	9	79	15	6
6.	Afghanistan	0.038	38,398	1412	–	43	10	34	13	38	34	28
7.	Nepal	0.028	45,277	280	26.37	62	14	3	21	48	51	<1
Africa												
8.	Nigeria	0.201	54,905	1054	2.04	39	21	21	20	42	33	25
9.	Ethiopia	0.112	57,466	897	9.08	7	7	63	22	8	51	41
10.	South Africa	0.059	636,884	14,779	64.07	76	15	8	1	44	44	12
11.	Kenya	0.053	35,020	594	8.82	29	22	38	10	25	35	40
12.	Uganda	0.044	3539	39	9.00	18	18	58	6	21	32	47
13.	Ghana	0.030	44,777	283	14.51	18	50	13	18	41	42	17
Latin America												
14.	Colombia	0.050	650,062	20,888	54.56	90	5	2	3	65	4	30
15.	Guatemala	0.018	77,481	2845	–	65	12	19	5	77	21	3
16.	Bolivia	0.012	119,580	5343	21.58	61	17	9	13	25	15	59
17.	Haiti	0.011	8326	212	–	35	27	18	20	23	61	16
18.	Dominican Republic	0.011	98,776	1840	36.66	84	11	2	3	55	16	29

** WHO and UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene. Estimates on the use of water, sanitation and hygiene by country (2000–2017). <https://data.unicef.org/topic/water-and-sanitation/covid-19/>.

^a United Nations (2019).

^b WHO, 2020a.

^c Our World in Data COVID-19 dataset. <https://ourworldindata.org/coronavirus-testing>. Accessed on September 12, 2020.

and fecal sludge effectively and in many cases, the wastewater is discharged into surface water bodies without any treatment. For example, India treats only 37% of wastewater, while the situation in other South-East Asian countries is alarming (Vietnam, 10%; Pakistan, 8%; Philippines, 4%; Indonesia, 1%) (ENVIS, 2019; Khan et al., 2020; World Bank, 2013). Most of the households in cities and towns of developing countries of Sub-Saharan Africa (>85%), Asia (>80%) and Latin America (>50%) are not connected to the sewerage network (Dorji et al., 2019). Moreover, the performances of operational sewage treatment plants (STPs) are not satisfactory. For example, effluents from only about 39% STPs in India could meet the general standards prescribed by the Environmental (Protection) Agency (Central Pollution Control Board, India) for discharge into streams (ENVIS, 2019).

In Bhutan, only 20% of the urban population has access to the public sewerage system (Dorji et al., 2019). In most of the cases, the treatment and disposal of fecal sludge and septage from the onsite sanitation systems are not as per the standards. For example, 80% fecal sludge from urban Dhaka and Khulna cities (Bangladesh) is not safely managed, which leads to the fecal contamination in the environment (Amin et al., 2019). The situation is equally gloomy in Vietnam, Indonesia or Philippines where <10% of septage is treated (World Bank, 2013). This means the risk of partially treated or untreated sewage/wastes from onsite sanitation system from COVID-19 affected areas carrying viruses into water bodies could be quite high. As most rural population use the surface or groundwater without further treatment for daily household activities like washing and cleaning, it would have a direct impact on public health (Treacy, 2019). For viruses present in faeces, water, surfaces or insect vectors e.g. houseflies, cockroaches, and another organism in contact with human faeces might act as possible transmission routes (Heller et al., 2020; Dehghani et al., 2020). The possible transmission of SARS-CoV-2 from wastewater into the wider environment has been illustrated in Fig. 3.

2.2. Sanitation status

According to a recent factsheet, 2.0 billion people in developing countries are still devoid of basic sanitation facilities (WHO, 2019a). The exposure from faecal contamination is only aggravated due to poor handwashing facility. It was estimated that about 829,000 deaths can be attributed to inadequate drinking water, sanitation and hygiene behaviours (Prüss-Ustün et al., 2019). Overly crowded, closely packed, decrepit housing units, devoid of basic needs such as clean water, toilets, sewers, drainage and waste collection, urban slums and informal settlements foster ideal environments for eruption and propagation of infections (Raju and Ayeb-Karlsson, 2020; Sinharoy et al., 2019).

Urban slums, especially in Sub-Saharan Africa which hosts 62% of urban population, may act as the biggest hotspots of COVID-19 across countries (Desai, 2020). Similarly, other developing nations such as Afghanistan, Bangladesh, Nepal, Myanmar, India and Indonesia where the huge urban population (~22–63%) resides in slums could spread COVID-19 due to poor sanitation (World Bank, 2014). Mumbai, the largest city of India has almost half of its population living in hyper-dense dwellings in squalid slums (Desai, 2020). These have been identified as biggest COVID-19 clusters across the country since hygiene can hardly be maintained in such scenarios (Corburn et al., 2020) and social distancing is nearly impossible and rather impractical fostering community infection (Wasdani and Prasad, 2020; Raju and Ayeb-Karlsson, 2020).

Similarly, many Latin American countries face water scarcity and poor sanitation conditions that can have a considerable impact on the spread of COVID-19 (Miller et al., 2020). Similarly, in sub-Saharan Africa, urban poor households were 227% less likely to have access to improved sanitation facilities compared with urban rich households (Armah et al., 2018). Ghana reports open defecation for one in every five households (Adzawla et al., 2020). In Nigeria, a decline in access to piped water in urban areas from 32% in 1990 to 7% in 2015 was reported (World Bank, 2017). Further, in absence of proper solid waste

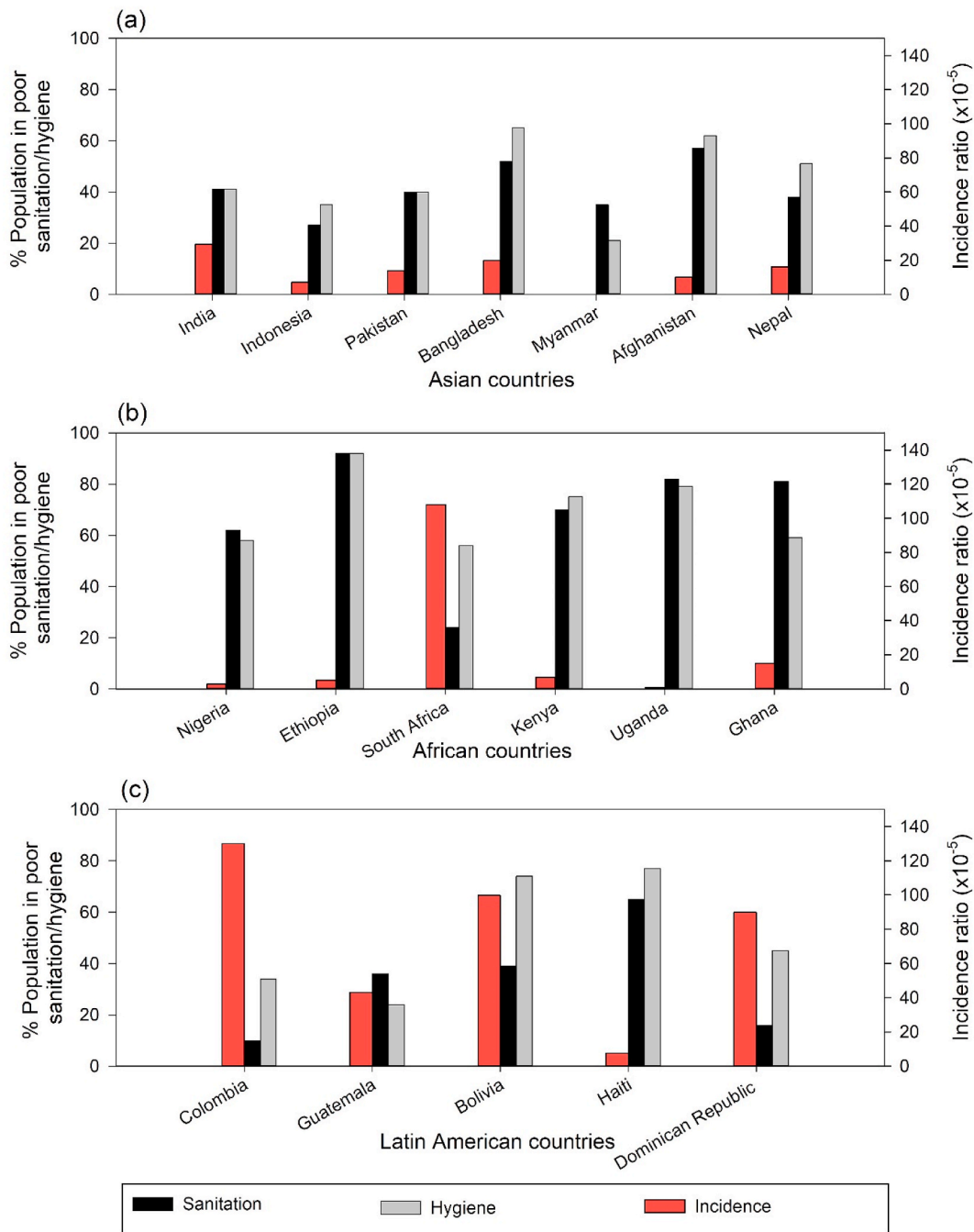


Fig. 2. Casual relation between % of population residing in poor sanitation and hygiene to the COVID-19 incidence ratio in developing countries.

disposal systems and longer viral stability on solid surfaces (up to days), contamination of surface water from domestic or hospital waste is not unlikely (Nghiem, 2020). Studies conducted in African nations suggest river contamination due to direct or indirect discharge of clinical wastes (Bedada et al., 2019; Eze et al., 2017). Similar cases of groundwater contamination from dumping site consisting hospital waste, slaughterhouse, dairy farm, poultry, and fish market have been reported in villages of Asian countries (Samadder et al., 2017; Hoqueei et al., 2019).

2.3. Current healthcare infrastructure

With a large number of marginalized low-income families in the low and middle-income countries facing utmost poverty, the plight of these nations is going to be most miserable in case there is a fecal-oral

transmission. Around 1/5th health care facilities are devoid of water, sanitation and waste management services in the least developed nations (WHO, 2019b). Some of the African countries have just one ICU bed per million people — according to a 2015 study (Murthy et al., 2015). Moreover, there is a dearth of manpower especially of critical care doctors and consultant anaesthetists to run the few ICUs in Sub Saharan Africa (Nuwagira and Mujoora, 2020).

Similarly, Bangladesh has only 1169 ICU beds, totalling to 0.72 beds/100,000 citizens and just 550 ventilators in the country (IEDCR, 2020). In the wake of the impending pandemic threat, the authorities in these countries have set up temporary isolation centres and multi-bed hospitals. However, in absence of a robust sewage treatment system, these are a matter of concern since sewage from hospitals or isolation centres is estimated to have high viral loads and there is a potential

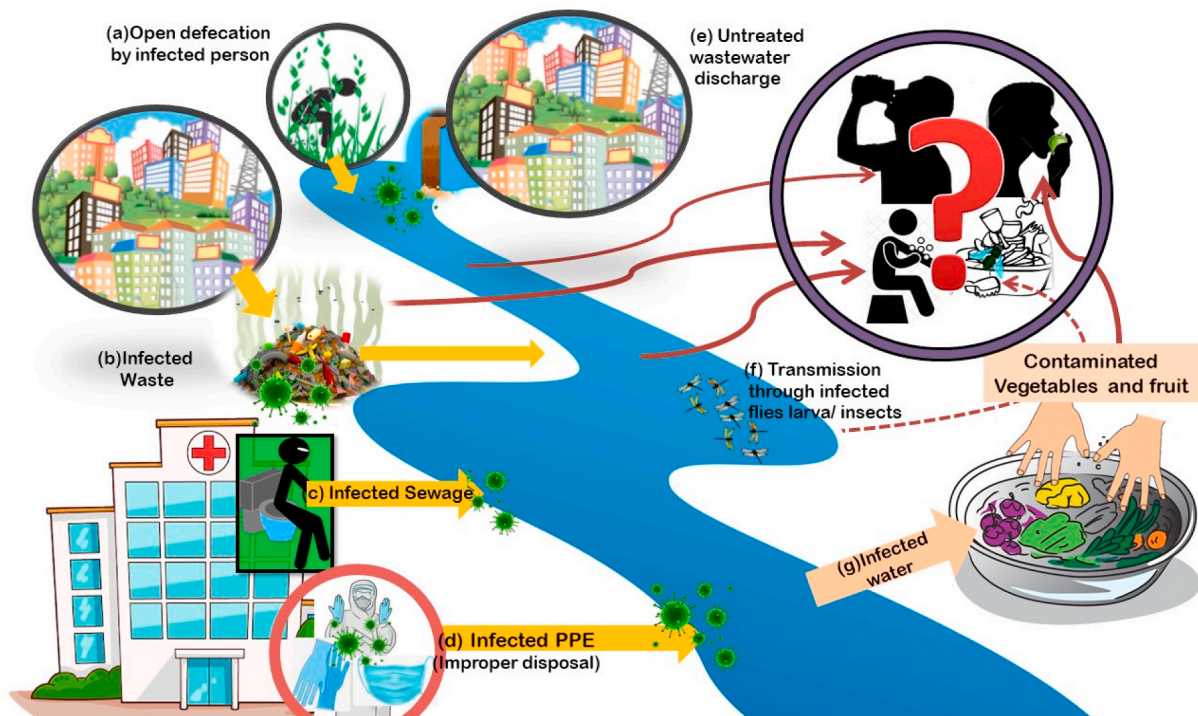


Fig. 3. Possible routes of COVID-19 spread through contaminated water (directly or indirectly) in developing nations due to poor sanitation and hygiene.

threat of fecal–oral transmission or fecal–respiratory transmission through aerosolized faeces (Xiao et al., 2020). Handling and disposal of solid infectious wastes, such as masks and personal protective equipment (PPEs) whose volume is expected to rise due to the COVID-19 outbreak, is another challenge.

2.4. COVID-19 surveillance by wastewater-based epidemiology

The World Health Organization has repeatedly emphasized on COVID-19 testing since early detection is the key to prevent the spread of disease test. Greater the number of tests, easier is to track and limit the spread of the virus. In a comparison of their population, the testing capacity of low and middle-income countries is very low (Table 1). Unlike the developed nations, these countries face constraints of test kits, PPEs, infrastructure and other critical supplies. Under these conditions of limited resources, the possibility of monitoring SARS-CoV-2 in the sewage offers a cost-effective solution for COVID-19 surveillance. Several reports stressed the applicability and viability of wastewater-based epidemiology for early detection, monitoring and surveillance of COVID-19 as SARS-CoV-2 in wastewater have been detected in early stages of COVID-19 outbreak (Daughton, 2020; Hart and Halden, 2020; Sims and Kasprzyk-Hordern, 2020). Moreover, the presence of SARS-CoV-2 in the stool of asymptomatic patients that tested negative in nasopharyngeal samples makes sewage surveillance even more critical (Jiang et al., 2020).

Considering the limited and cost-intensive testing capacity for individual people in low- and middle-income countries, this finding can pave the way for novel approaches for community surveillance by wastewater-based epidemiology. However, wastewater-based epidemiology monitoring and surveillance of COVID-19 and other outbreaks in future is also a challenge for developing countries where the majority of households are not connected to sewerage networking. The current pandemic further stresses the importance and need for investing in wastewater treatment infrastructure and sanitation in developing countries.

3. Prevention and mitigation: what can be done?

It is important not just to understand the prevalence of this virus in the sewage for assessment of the spread of disease, but also to determine its potential environmental transmission. SARS-CoV-2 in human excreta could become airborne during sewage transport to the wastewater treatment plant, the final disposal of treated water (Quilliam et al., 2020). The survival of coronaviruses in water depends on temperature, light exposure, presence of organic matter, and presence of antagonist microorganisms (Collivignarelli et al., 2020). While exposure to solar or UV light and temperature higher than 23 °C causes inactivation of the virus, the presence of organic matter increases their survival while providing an adsorbent surface (WHO, 2020b). Hence there is also an urgent need to ensure that those who are exposed to untreated wastewater are following safe work practices along with proper personal protective equipment (OSHA, 2020). Access to safe sanitation and clean water should be included as comprehensive and multidisciplinary approaches in COVID-19 response plan.

In order to contain the spread of COVID-19, the recommended practices for water, sanitation, and health-care waste need to be adopted both in-home and, in the community, (WHO, 2020b). WHO strongly encourages not to suspend the planning for or implementation of vector control activities around the world, especially in the developing countries. The Ebola outbreak in 2014–2016 undermined malaria control efforts and led to a massive increase in malaria-related illness and death in the three West African countries (WHO, 2020c). Safe drinking-water, sanitation and hygiene interventions may be helpful to reduce risk of faecal contamination of the living environment (Wolf et al., 2019). Frequent hand-washing with soap should be adopted to prevent the spread of infection. Extra attention needs to be given in consuming eatables like vegetables or fruits that might have been washed with wastewater.

Finally, and probably the most important one would be to impart right awareness among the less privileged, and ignorant communities on how to deal with the situation to restrict the widespread infection.

Individual responsibility can surely be a crucial step to mitigate the ever-increasing global pandemic. Detection of SARS-CoV-2 in

wastewater and its possible consequences on human health cannot be undermined and comprehensive strategies need to be formulated in developing nations before it turns more disastrous for the world.

4. Conclusion

- Presence of SARS-CoV-2 in faeces and urine of COVID-19 patient leads to the presence of the virus in the sewage that raises possibility of faecal-oral transmission.
- Surveillance of SARS-CoV-2 in sewage can act as alarming tools to study pandemic outbreaks and take decisions in such challenging times.
- The COVID-19 pandemic along with the challenges of poor sanitation and waste disposal, insufficient wastewater treatment and inaccessibility to clean water in developing nations can lead to worse situations in the long run.
- Awareness of the risks, safe working practices especially hand hygiene, and other preventive measures need to be employed for people coming in contact with wastewater.
- Further research is required for the quantitative estimation of the actual numbers of cases in the community from the viral RNA concentrations measured in the sewage and concentration method for recovery of SARS-CoV-2 from wastewater.

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Declaration of competing interest

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