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COVID-19: ENVIRONMENTAL CONSIDERATIONS FOR WATER RESOURCES MANAGEMENT

Ernest Othieno Odwori

Department of Disaster Management and Sustainable Development, School of Disaster Management and Humanitarian Assistance, Masinde Muliro University of Science and Technology, P.O. Box 190-50100, Kakamega, Kenya.

Email: odworiernest@gmail.com

ABSTRACT: *The rapid spread of COVID-19 worldwide has resulted into countries implementing drastic measures such as imposing lockdowns, travel restrictions, slow down on economic activities, maintaining social distancing etc. These actions have considerably enhanced environmental quality and water resources management on the short-term basis, but on the other hand, it has also had adverse consequences on the environment and water resources management due to the large amounts of SARS-CoV-2-infected medical and domestic waste generated and the lack of initiatives to recycle medical waste in fear of the risk to spread COVID-19 to the people associated with recycling. This paper examines the environmental effects of COVID-19 on water resources management broadly. The study presents a unique opportunity to observe and understand how the environment reacts to sharp reductions in anthropogenic activities. Efforts made to control the spread of COVID-19 have increased water demand and impacted water resources both positively and negatively leading to additional challenges in water resources planning and management. There is an urgent need for interdisciplinary collaborations among researchers studying water and the new challenges faced in this era of COVID-19.*

KEYWORDS: COVID-19 Pandemic, Environmental Considerations, Water Resources Management.

INTRODUCTION

COVID-19, the 2019 coronavirus disease, is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The COVID-19 outbreak was identified in Wuhan, China, in December 2019 (WHO, 2020 a). The World Health Organization (WHO) declared the COVID-19 outbreak a Public Health Emergency of International Concern on January 30, 2020, and a pandemic on March 11, 2020. The COVID-19 pandemic is affecting almost the entire world. According to WHO, COVID-19 spreads primarily from person to person through droplets released into the air when an infected person coughs, sneezes, or even speaks. People can catch COVID-19 if they breathe in these droplets from a person infected with the virus. These droplets are relatively heavy, generally do not travel more than a few feet, and they fall to the ground (or onto surfaces) in a few seconds—this is why social and physical distancing is considered effective in preventing the spread. These droplets can also land on objects and surfaces around the person, such as tables, doorknobs, and handrails. People can become infected by touching these objects or surfaces, then touching their eyes, nose or mouth. This is why it is important to wash one's hands regularly with soap and water or clean with alcohol-based hand rub.

Countries have tried to fight the spread of the virus with massive COVID-19 screening tests and establishing public policies of social distancing. This virus has had both negative and positive environmental effects on water resources management which have been little analyzed. Climate experts have indicated that greenhouse gas (GHG) emissions could drop to proportions never before seen since World War II (Global Carbon Project, 2020). This outcome is mainly due to the social distancing policies adopted by the governments following the appearance of the pandemic. For example, in Hubei province (China), strong social distancing measures were implemented in late 2019. These measures affected the country's main economic activities. Power plants and industries halted their operations and the use of vehicles also decreased considerably. This had a positive impact on the environment and consequently water resources management. Also, the social distancing measures adopted by most governments have caused many beaches around the world to get cleaned up. This as a result of the reduction in waste generated by tourists who visit the beaches. Water pollution in Venice, Italy was significantly reduced due to lockdown as a result water canals of Venice became more transparent compared to the pre-lockdown period (Saadat et al., 2020). Likewise, the surface water quality in the Vembanad Lake in India improved significantly during that country's lockdown period as suspended particulate matter (SPM) dropped by 15.9% compared to the pre-lockdown phase (Yunus et al., 2020). Despite the positive environmental water resources management effects, the new coronavirus has also generated a series of negative effects. For example, in the USA, some cities have suspended recycling programs because authorities have been concerned about the risk of spreading the virus in recycling centers. On the other hand, in the European nations particularly affected, sustainable waste management has been restricted. For example, Italy has prohibited infected residents from sorting their waste. On the other hand, some industries have seized the opportunity to repeal disposable bag bans. Companies that once encouraged consumers to bring their bags have increasingly switched to single-use packaging. These developments have resulted in the increase of domestic waste, both organic and inorganic. Hospitals are also now generating huge amounts of medical waste. Disposal of SARS-CoV-2-infected medical and domestic waste pauses grave dangers to our water resources management.

WHO has mentioned that the main routes of exposure of the virus to humans are inhalation of droplets generated when an infected person coughs, sneezes, or exhales (WHO, 2020 c), however, recent studies have shown that SARS-CoV-2 can be found in the faeces of infected symptomatic and asymptomatic patients (Foladori et al., 2020; Pan et al., 2020; Randazzo et al., 2020; Tang et al., 2020; Xiao et al., 2020; Zhang et al., 2020). Clinical experiments and researches have also reported evidence of SARS-CoV-2 in urine samples of infected patients (Lescure et al., 2020; Ling et al., 2020), and hospital and urban sewage (Medema et al., 2020; Wu et al., 2020). It can be inferred from these studies that the water systems, especially municipal wastewater of areas hit hard by COVID-19 might contain the virus. Recently, SARSCoV-2 has been detected in untreated wastewater in Australia, The Netherlands, USA, and France (Ahmed et al., 2020; Medema et al., 2020; Nemudryi et al., 2020; Wurtzer et al., 2020). This raises serious concerns for the water systems in developing countries like African where we do not have resilient policies for governing water and sanitation systems. This may expose large numbers of people to higher risks of COVID-19.

Although Africa is not yet highly hit by COVID-19, most of the regions have high vulnerability manifested in their weak health, social and economic systems. Wastewater management and sanitary systems in most parts of Africa are still in very poor conditions. Groundwater is the main source for domestic water supply and in most households pit latrines are located in close proximities to shallow hand dug wells supplying the households. This exposes the households to the risk of the pit latrines contaminating the shallow groundwaters from the wells. Consequently, if there are COVID-19 infected patients living in such communities that have their pit latrines closer to their drinking water sources, the risk of getting infected with the virus are high. The behavior of indiscriminate open defection around surface and groundwater sources in Africa has been widely reported (Elisante and Muzuka, 2016; Anornu et al., 2017; Back et al., 2018; Abanyie et al., 2020; Mutono et al., 2020; Owamah, 2020). Through open defecation, the carriers of the virus may unknowingly transmit it through their stool to drinking water sources, which can have a debilitating effect on consumers of such virus-contaminated water. There is also a high risk of exposure to the virus by people that use the same toilets (a common practice in Africa) because the virus may remain in the aerosol or droplet generated during the use of shared toilets built in small spaces without aeration. Apart from the commonly known symptoms of cough, cold, fever, and breathlessness often exhibited by COVID-19 patients, some patients are of late now showing stomach upset, vomiting, and diarrhea as the virus attacks the gastrointestines rather than the previously known lungs. These are not well-known symptoms of the virus and as such most patients may not suspect to have contracted the virus, hence before detection by doctors, the virus may have escalated at the community level.

METHODOLOGY

This study has used an in-depth review of published works on COVID-19 pandemic and expert-interviews with selected stakeholders who included key policymakers, academia, scientists and practioners on water resources management and COVID-19 pandemic impacts.

Environmental effects of Covid-19 pandemic on water resources management.

The global disruption caused by COVID-19 lockdown affected water resources in a number of ways; firstly, the lockdown, travel restrictions and slow down of economic activities led to a positive environmental impact through reduced fossil fuel consumption culminating into reduced green house gas emissions. Reduced resource consumption and waste disposal arising from reduced economic activities led to reduced pollution of our water resources. Similarly, reduced transport and industrial activities resulted into reduced discharge of pollutants into our water systems. Reduced pressure in tourist destinations resulted in clean beaches with reduced pollution to our water bodies. Secondly, key negative impacts of Covid-19 pandemic to water resources management resulted from Personal protection equipment (PPE) use, large number of patients in hospitals, discharge of increased domestic and medical waste and the inability to do waste recycling. Increased medical waste resulted into discharge of hazardous waste into our water bodies. Haphazard disposal of PPE and increased domestic waste resulted into pollution of our surface and ground water resources. Reduced recycling of waste during lockdown resulted into environmental degradation leading to increased water pollution.

Redced water pollution

Water pollution is responsible for 3.5 million deaths in the world (WHO, 2020 b). It is a common phenomenon in most developing countries that domestic and industrial wastes are dumped into rivers without treatment. A drastic improvement in water quality was observed worldwide after the lockdown. During lockdown, water resources experienced positive impacts from the reduction of pollutant loading from industries, vehicle emission, and other sources. Anecdotal evidence indicated reduction in biochemical oxygen demand and coliform levels in rivers as a result of reduction in the loading of nitrous oxide, particulate matter, and other pollutants. Pollution in beaches in places like Acapulco, Barcelona and Salinas reduced drastically, and the water become clear due to low numbers of tourists (Zambrano-Monserrate et al., 2020). Water quality improvement was also reported in Venice (Italy), where clear waters were observed due to the reduction of suspended solids, because of lesser use of motorboats (Braga et al., 2020). In India, the river Ganga and Yamuna reached a significant level of purity due to the absence of industrial pollution on the days of lockdown (Singhal and Matto, 2020).

Disposal of SARS-CoV-2-infected medical waste and municipal solid waste

Disposal of SARS-CoV-2-infected medical waste and municipal solid waste pauses grave dangers to our water resources management. Improper use of medical waste devices and the leakage of medical waste water can cause waste water containing pathogens to pollute groundwater resources through soil infiltration (Xu et al., 2020). SARS-CoV-2 can enter the soil and groundwater by a range of pathways: the disposal and discharge of solid and fluid medical wastes; the discharge of patients' and suspects' faeces, which were found to contain SARS-CoV-2 (Xu et al., 2020); and sputum from suspects and infected people who have not been detected. SARS-CoV-2 was reported to live from 4 to 72 h on environmental surfaces, depending on the nature of the surface material (van Doremalen et al., 2020), however, a recent report from the US Centers for Disease Control and Prevention suggested that the virus can survive for 17 days in the environment (Moriarty et al., 2020).

The disposal of medical and municipal SARS-CoV-2-infected waste is a big challenge not only for the world of medicine but also for other environmental scientists managing water resources. Increasing numbers of hospitals, clinics and other medical institutions are generating massive amounts of medical waste which could potential contaminate our water systems. The production of new types of waste that may contain pathogens, such as municipal solid waste from households with people in isolation, people who have tested positive for the virus or people in mandatory quarantine or discarded masks and gloves mixed with normal household waste, requires extraordinary measures for the protection of the professionals involved in the collection and disposal (Carducci et al., 2013), as well as the environmental conditions at the disposal sites to ensure that it does not contaminate our groundwater aquifers through leaching. It also raises issues on the sorting and separation of materials from municipal solid waste during these times and the recycling of products that might have originated from household materials contaminated with the virus. The amount of municipal solid waste has also significantly increased lately due to the high demand and storage of food products that eventually degrade. Municipal solid waste contaminated with SARS-CoV-2 should be treated in the same way as regular Medical waste to avoid contaminating our water resources. Presently, two processes are usually adopted for Medical waste destruction (e.g. Italian Parliament, 1997; MEEC, 2020): (a) high-temperature steam sterilisation and landfilling after crushing (MEEC, 2006) and (b) incineration and landfilling of the resulting fly and bottom ash (MEEC, 2003).

Incineration is the most technically and economically feasible option, which is applicable to all types of Medical waste, with a significant quantity reduction (Makarichi et al., 2018; Windfeld and Brooks, 2015). This method has been widely applied in developed countries and will be the mainstream method for dealing with Medical waste in developing countries in the future (Fang et al., 2020). However, in the current situation of the global pandemic, the question remains whether enough Medical waste- or Municipal solid waste-incineration plants exist in each country with a sufficient capacity to process all contaminated waste. In most developing countries, the designed capacity of Municipal solid waste-incineration plants might prove to be insufficient exposing both surface and groundwater resources to the danger of contamination with the deadly SARS-CoV-2 virus. The current emergency circumstances could lead to inappropriate methods in waste storage and disposal, thus resulting in environmental and public health threats of water resources degradation. With most of the countries having insufficient Medical solid waste disposal installations, what is going to happen if waste contaminated with SARS-CoV-2 is added, originating from households with members who tested positive and are quarantined? These questions have further increased the uncertainty and challenges in overcoming the pandemic and the dangers paused to our water resources. A potential solution may be to use existing industrial facilities for hazardous waste by modifying them and increasing the sanitary standards of their operation (Vaverkova et al., 2019).

In many countries, it has been decided that the waste companies determine the method or place for storing, collecting and disposing of such waste, at the same time taking measures to minimise the risk not only to workers who manage waste but also to other citizens and the general environment. These are just some of the questions that scientists in the field of waste management will have to deal with in the near future. Although medical waste after sterilisation and incineration no longer poses health threats, as the infectivity, perniciousness and vulnerability are eliminated, its disposal and recycling during this pandemic is challenging due to the following reasons: (1) Need for managing a large volume of medical waste in the short term. A rapid increase in medical waste production by as much as six times that of under normal conditions has been observed in China, Poland and the Czech Republic. In Italy, temporary disposal areas have been authorised to cope with the emergency and specific guidelines have been issued to manage medically contaminated waste into existing landfills (medical waste must be inserted into big bags, deposited in specific zones of the landfill and covered daily with a layer of soil with an adequate thickness to avoid dispersion in the air). (2) Increased ecological concern on the landfill waste mass. During the pandemic, the type and composition of municipal solid waste have changed and medical waste accounts for a greater proportion of the disposed mass. Due to these changes, the potential impact on the microecology inside the landfills and on the waste degradation process should be considered. Furthermore, the service life and performance of the containment lining system should be re-evaluated. (3) Random disposal of medical waste by the public, although masks and gloves used at hospitals can be collected and managed using proper protocols, it is highly improbable that when disposed by the public at random locations, they could be dealt with similarly. Hence, the presence of these materials in municipal solid waste could lead to a substantial change in the composition of municipal solid waste, particularly in plastic fractions that may end up in material-recycling facilities, composting yards and landfills. It would be prudent to conduct socio-economic analyses on the recycling of these fractions by adopting proper disinfecting schemes. (4) Need for recycling fly and bottom ash. In China, incineration in cement kilns is explored as an option for treating medical waste by using a temperature higher than 1350°C (Wang et al., 2018). The medical waste, which is part of the raw materials, is first calcined to make clinker, adjusted by using gypsum and pulverised into grains smaller than 50 mm to form ordinary Portland cement. In the cement industry, the stability and component variability are strictly controlled, and therefore, the consumption of medical waste is limited. However, to address the current emergency, a possible innovation could be to use clinker with more medical waste as a binder for soil modification/ stabilisation applications in order to consume large volumes of medical waste and avoid contaminating our water sources.

Reduced waste recycling

The world's water resources could face serious risks resulting from the suspension of waste recycling. Waste recycling has always been a major environmental problem of interest to all countries (Liu et al., 2020), in relation to water resources management. Recycling is a common and effective way to prevent pollution, save energy, and conserve natural resources (Ma et al., 2019). As a result of the pandemic, many countries around the world have stopped recycling programs in some of their cities, citing the risk of COVID-19 spreading in recycling centers. Domestic and hospital waste has rapidly increased due to the difficulty of satisfactory solid and liquid waste management (Platon et al., 2020). In the case of domestic waste, food delivery containers have increased drastically. Only a small part of the plastic waste is being recycled, while the rest goes to landfills or is thrown into the environment (Klemes et al., 2020), endangering our water resources. In some countries, the industry has seized the opportunity to repeal disposable bag bans, even though single-use plastic can still harbor viruses and bacteria. Reduced waste recycling in most parts of the world will negatively affect water resources management as some of these waste may end up polluting our water bodies.

Entry of SARS-CoV-2 into water systems

Sars-CoV-2 can enter the soil and water bodies by a range of pathways originating from solid and liquid waste by infected people (Xu et al., 2020). Leaking water and sewerage networks, as a result of prolonged underinvestment in maintenance, upgrade and modernization can lead to cross-contamination of soil and water bodies endangering the public health. The fate of transport and interaction of Sars-CoV-2, with surface water- groundwater- soil needs to be investigated further. In some parts of the world, faeces constitute an important organic fertiliser that is poured onto farmland to promote crop growth. In rainy days, virus-contaminated run-off may enter surface waters or the groundwater by infiltration, causing their contamination. The appearance of Sars-CoV-2 in wells, streams, rivers and lakes will likely be more prevalent in developing countries and poor rural areas of Asia, Africa and South America where sewerage systems are either rudimentary, ageing or non-existent (WHO and UNICEF, 2019).

Various guidelines for the disposal of pathogen-contaminated substances have been developed internationally (e.g. CDPH, 2020; WHO, 2005). For instance, if leakage of pathogen-laden waste water occurs, contaminated groundwater should be remediated immediately. This is critical for rural areas where groundwater is the only source for drinking water and where there may be no controls on water treatment or quality. In such areas, a systematic disposal approach for contaminated substances that is aimed at isolating them from the hydrologic cycle, such as disposing downstream of water resources, locating appropriate geologic formations for disposal and minimising leakage of infected leachate is recommended.

There have not been any studies, to date, that reported infection from the Sars-CoV-2 arising from water bodies (eg. bathing waters). The US CDC (2020) has stated that standard disinfection methods used in municipal water-treatment plants (WTPs) should be sufficient to inactivate the virus. The CDC (2020) has also mentioned that recreational waters in swimming pools, hot tubs and spas should pose no risk to public health if proper operation and maintenance are maintained. International standards for water chlorination recommend both a specific concentration and a contact time (Ct), the time needed for chlorine to act so that pathogens are killed SDWF (2017). For drinking water, this is at least 15 mg min/l (i.e. exposure of 1 litre of water to 1 mg of free chlorine for at least 15 min). For swimming pools, 'current recommendations/best practice' stipulates a free chlorine residual of at least 1.0 mg/l (depending on the pool type and disinfectant used) (HPSC, 2020). Higher doses are mandated in the UK for spa pools with free chlorine at 5 mg/l before emptying them and 50 mg/l for at least 1 h on refilling them (PWTAG, 2016, 2020). International bodies have relied on experience dealing with other viruses, such as Sars and Mers, which belong to the same coronavirus family as Sars-CoV-2, in order to analyse the risks posed by the new virus (HPSC, 2020; PWTAG, 2020; WEF, 2020; WHO and UNICEF, 2020). Despite reassurances about the effect of disinfection in swimming pools, the need for social distancing and the seriousness of the risk have led many countries to issue orders for the closure of swimming pools and other recreational water bodies (PWTAG, 2020).

Disposal of disinfectants and disinfectant by-products

There exists a great risk for contamination of surface and groundwater resources by disinfectants and disinfection by-products used during the Covid-19 pandemic. The Covid-19 pandemic has changed drastically the extent of disinfectant use. This has expanded beyond medical settings with much higher hygienic standards currently required in everyday activities. Some countries, such as Italy, South Korea, the UAE and China, have imposed night curfews in order to clean the streets in major cities with a weak disinfectant solution. The USEPA (2020) has listed 392 disinfectant products (List N) that are effective against Sars-CoV-2. These disinfectants can be broadly divided into alcohol, bleach, hydrogen peroxide and quaternary ammonium compounds. Most of the disinfectants used in medical centres are sodium hypochlorite-based (ESR, 2015; Rutala and Weber, 1997). During the Covid-19 pandemic, heavy usage of these disinfectant products was also done in households. Thus, the percentage of waste that would contain traces of sodium hypochlorite is expected to increase during the pandemic, resulting in this chemical becoming part of the landfill leachate. In addition, the practice to spray outdoor public spaces, including roads, schools and buildings that had hosted infected persons, has directly inserted disinfectants into the storm drainage systems of many cities, thus discharging them into rivers, streams and coastal waters.

Rook (1974) found that hypochlorous acid is formed when sodium hypochlorite is added to water, and in the presence of bromine, hypobromous acid is formed. These two acids react with natural organic matter to produce many water disinfection by-products, including the four primary trihalomethanes (THMs), which are chloroform, bromodichloromethane, dibromochloromethane and bromoform, referred to as total THMs (TTHMs). Medeiros et al. (2019) reviewed the toxicological aspects of THMs and concluded that they pose potential genotoxic and carcinogenic health risks, particularly for the liver and kidney as they are introduced into our water systems. TTHMs are limited to 80 parts per billion, or 0.080 mg/l, in treated drinking water in the USA (USEPA, 2010). The Australian Drinking Water Guidelines (ADWG, 2004) recommends that THM levels in drinking water not exceed 0.25 mg/l.

The presence of organic matter and hypochlorite in landfill leachate could trigger the formation of THM. This could be troubling, particularly for landfills that have not been designed with leachate collection systems (Li and Deng, 2012), as they are likely to end up into our water systems. Stuart et al. (2001) investigated the potential for THM formation in aquifers contaminated by leaking landfills in Mexico, Jordan and Thailand and detected THM concentrations up to 4.551 mg/l at several monitoring wells of the study sites. The injection of disinfectants into the storm drainage systems of cities practicing public space disinfection have severe effect on water resources where these systems are discharging.

SARS-CoV-2 in Sewers and Waste water treatment plants (WWTPs)

Although SARS-CoVs are primarily respiratory viruses, SARS-CoV-2 may infect and replicate in the gastrointestinal tract (Zhang, H. et al. 2020). Additionally, it has been observed that SARS-CoV-2 enters the wastewater system via human excretions (that is, stool and urine) (Medema, G, et, al 2020; Randazzo, W. et al. 2020). The frequency of gastrointestinal disease manifestations, including diarrhoea and vomiting, ranges between 2% to 80% of confirmed patients (Cheung, K. S. et al. 2020). SARS-CoV-2 RNA is often present in stool after respiratory infection resolves and respiratory samples are found to be negative (Xiao, F. et al. 2020). Greywater (that is, water discharged from sinks, showers and drains) is not expected to be a major SARS-CoV-2 transmission vehicle despite containing body fluids such as saliva and sputum with potentially high viral concentrations (Wang, W. et al. 2020). Low virus concentration is expected since greywater often contains detergents, soaps and other disinfectants, to which SARS-CoV-2 is sensitive (Chin, A. W. H. et al. 2020).

Under numerous environmental conditions, virions of SARS-CoVs and other enveloped viruses remain infective for several days. Factors that were found to affect SARS-CoVs infectivity in water and wastewater include temperature, organic content and solution pH (Chin, A. W. H. et al. 2020). However, the way this translates into risk of infection is yet unknown, especially since human activities and water exposure differ across seasons and regions. Temperature is an important variable for survival of virions in general and SARS-CoVs in particular. Longer retention of SARS-CoVs infectivity has been observed at lower temperatures (for example, 14 days at 4 °C versus two days at 25 °C in wastewater) (Wang, X.-W. et al. 2005). This implies that in cold seasons and temperate climate zones, the environmental survival of SARS-CoV-2 may be increased. Temperatures above 56 °C reliably inactivate SARS-CoV-1 and SARS-CoV-2 after 90 minutes and 30 minutes, respectively, most likely due to denaturation of proteins and lipid bilayers (Chin, A. W. H. et al. 2020). Organic matter at increasing concentration was reported to reduce the survival time of spiked CoVs in various water samples (for example, ten days in lake water versus two days in raw wastewater). This may be due to the presence of antagonist bacteria that can inactivate the viruses via extracellular enzymatic activity (Casanova, L., et. al. 2009; Gundy,

P. et. al. 2009). Differently, organic matter in the context of wastewater treatment can non-specifically adsorb to the envelope of SARS-CoV virions, protecting them from oxidative damage, chlorination, ultraviolet (UV) radiation and protozoan or metazoan predation (Gundy, P. et. al. 2009).

In large municipalities, the size of the population connected to the sewer system has a direct impact on the concentration of SARS-CoVs in wastewater and thus the potential for dissemination. Extensive sewer systems in large cities effectively mix wastewater from large areas, resulting in a rather homogenous viral dispersion, and thus lower concentration. However, larger populations inherently have greater likelihood of virus importation, and COVID-19 outbreaks in large population centres naturally produce high virus concentrations that increase transmission risk (Bettencourt, L. et. al. 2007; Yang, S. et al. 2017). Survival time of SARS-CoVs in wastewater is sufficiently long for infective viruses to reach WWTPs and to be further disseminated by several transmission pathways. SARS-CoVs, similarly to other microbial pathogens, can reach natural water bodies used for recreation such as ponds, rivers and lakes via leakage or combined sewer overflows during storm events. The high infectivity of SARS-CoV-2 could lead to transmission of COVID-19 in such environments. Collecting data from central sewer systems in addition to individual testing can provide real-time information on the distribution of SARS-CoV-2 in related communities at reduced costs relative to personal testing. Moreover, this information can be used as an early warning signal for COVID-19 outbreaks in specific communities with pre- and asymptomatic infected individuals (Lodder & de Roda Husman, 2020; Peccia, J. et al. 2020).

These early signs of outbreak can be detected as development of SARS-CoV-2 concentration in wastewater precedes changes in confirmed COVID-19 cases by at least several days. Wastewater monitoring is particularly useful to provide an early indication of re-emergence of SARS-CoV-2 in communities that contained an initial outbreak and subsequently relaxed containment measures. This information provides the ability to reinstate containment measures and allocate healthcare resources before COVID-19 infections become highly prevalent in specific communities. The approach of relaxing containment measures and reopening economies with ongoing community surveillance could be a cost-effective means for pandemic containment. Low-income regions often lack wastewater sanitation, with partial to no sewer systems. Over 0.5 billion people still practice open defaecation, while another 3.5 billion people use unsafe sanitation (WHO/UNICEF, 2019).

These circumstances may facilitate transmission of viral diseases such as SARS-CoV-2 via the incidental faecal–oral route, as people are likely to come in contact with infected waste or wastewater. Unsafe sanitation is often combined with inadequate drinking water infrastructure (for example, exposed sewer systems that contaminate freshwater sources), and lack of basic hygiene services such as clean water and soap for hand washing (WHO/UNICEF, 2019). The spread of the pandemic in low-income countries is likely to be further accelerated by high population density in cities together with limited implementation of COVID-19 control measures. Additionally, tropical and/or monsoonal weather with large volumes of rainwater flushing streets further increases viral contamination of water bodies. It’s most likely that the COVID-19 pandemic will hit hardest the 4 billion people who lack access to safe sanitation, frequently come in direct contact with faecally contaminated water and consume crops irrigated with contaminated wastewater (WHO, 2020 c).

SARS-CoVs may be disseminated into surface and groundwater resources during an outbreak due to leaking sewers or insufficient removal following wastewater treatment. Leakage of wastewater from septic tanks, pipe failure or lack of proper infrastructure can result in direct discharge of SARS-CoVs into receiving water bodies (for example, streams, rivers, ponds, estuaries, lakes and groundwater). Additionally, treated wastewater such as secondary effluent that is discharged may also carry viruses into the environment (Qiu, Y. et al. 2015). Rainfall events can increase virus concentrations in natural water systems via combined sewer overflows or failure of wastewater infrastructure, which raises the probability of SARS-CoVs dissemination. Based on the size of SARS-CoV-2 (~100 nm) as well as the relatively long survival time in water and on surfaces (van Doremalen, et al. 2020), SARS-CoV-2 could potentially travel considerable distances in the subsurface leading to contamination of aquifers used as freshwater sources for potable use. However, a recent study indicated that many enteric viruses are completely removed from secondary effluent during infiltration through a 30–40-m-thick vadose zone, leading to zero virus counts in the monitored groundwater wells (Weisbrod, et al. 2013). This indicates that long infiltration times drastically reduce the risk of groundwater contamination of viruses, including SARS-CoV-2.

In wastewater treatment plants (WWTPs), virions can potentially be removed through physical, biological and chemical processes. Wastewater first undergoes primary treatment where removal of viruses by sedimentation alone is low (Hurst & Gerba, 1989; Clarke, et al, 1961). Secondary (biological) treatment combines aeration tanks with secondary sedimentation to retain the activated sludge. Virus sorption to organic particulates and removal by settling is thought to play an essential role in these secondary treatment steps (Clarke, et al, 1961). Treatment approaches that maximize retention and removal of solids (for example, membrane bioreactors) have been suggested as a particularly efficacious means to remove viral loads from wastewater (Chaudhry, et al, 2015). Although no specific data for SARS-CoV-2 are yet available, enveloped viruses are more likely to be removed together with particles than non-enveloped viruses (Ye, et al, 2016). Additionally, extracellular enzymes such as hydrolases and proteases present in the concentrated bacterial consortia characteristic of secondary bioreactors are also likely to inactivate SARS-CoVs, similarly to other viruses (Ye, et al, 2016). Concentrating SARS-CoVs in the sludge may pose the subsequent problem of sludge treatment and disposal. Based on the fate of non-enveloped viruses, treatment of sludge by thermophilic digestion, lime addition, drying and composting is most promising for SARS-CoVs inactivation. Disinfection of treated wastewater may currently be the most important step to ensure reliable SARS-CoV-2 inactivation, however, while the mechanisms are unclear, enveloped viruses like SARS-CoVs tend to be more susceptible to chlorine-based disinfectants than non-enveloped viruses (Geller, et al, 2012). Although not tested in real wastewater, enveloped viruses such as SARS-CoV-2 are often found covered in organic material that provides a physical barrier against disinfection (Geller, et al, 2012). Hence, it is likely that in a complex medium rich in organic matter such as secondary effluent, SARS-CoV-2 would be less sensitive to disinfectants. In addition, chemical disinfectants are scavenged by organic matter and nitrogen-containing compounds in secondary effluent, resulting in lower concentration of active chlorine. Consequently, infective enteric viruses have been detected even in disinfected secondary effluent. During a pandemic outbreak, when viral loads in raw wastewater would be higher than normal, insufficient viral removal (particularly if disinfectant doses are not increased) may result in viral transmission via reuse. Many industrialized countries apply tertiary treatment (that is, advanced particle removal and disinfection) before wastewater reuse. Tertiary treatment can include sand filtration, managed aquifer recharge, UV radiation, advanced oxidation processes (AOP) and/or membrane technologies to ensure enhanced removal of microbial pathogens.

CONCLUSION

COVID-19 is spreading rapidly all over the world and is not only a health problem, but has also affected the world economy and the environment at large. The consequences of lockdowns have been remarkable, as pollution levels have dropped significantly, eg, greenhouse gas emissions, nitrogen dioxide, black carbon and water pollution have decreased drastically. On the other hand, COVID-19 is also having adverse consequences on the environment and water resources management due to the large amounts of domestic and medical waste generated and the lack of initiatives to recycle medical waste in fear of the risk to spread COVID-19 to the people associated with recycling. While the pros and cons of COVID-19 on the environment and water resources management are evident in the literature, the environment or climate has also had a significant influence on COVID-19 transmissions and mortality. Several studies have reported a significant correlation between climate indicators such as temperature, due point, humidity, wind speed, rainfall and COVID-19 transmissions and fatality. Therefore, COVID-19 can influence the environmental factors and vice versa. In developing countries with large numbers of people living in rural areas, peri-urban and informal settlements where they depend heavily on surface and groundwater resources for their domestic water supply, the risk of contracting COVID-19 through SARS-CoV-2 contaminated water from wastewater systems is very high. Medical waste, waste from isolation and quarantine centres, contaminated surface and groundwater sources, faecal-oral transmission, and contaminated sewage are identified as potential sources and routes of SARS-CoV-2 transmission in water systems.

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