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# Effects of COVID-19 on the availability of clean water and sanitation

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## 1. Importance of water for health

Water is required for drinking, cooking, personal hygiene, washing, cleaning, agriculture, sanitation, etc.<sup>1</sup> The international human rights law states that it is the right of all to have access to adequate water and sanitation. It includes access to safe, affordable, and sufficient water supply as well as to appropriate sanitation facilities. This is vital to ensure humans survival, prevent death due to dehydration, and reduce diseases related to water, sanitation, and hygiene (WASH).<sup>2</sup> Supplying water means treating raw water and distributing it to the customers. Sanitation means collecting and treating wastewater to become safe products that can be discharged to the environment or used for other purposes.<sup>3</sup> Hygiene includes water (such as ensuring the safety of water supplies), personal, domestic, and environmental hygiene.<sup>4</sup>

Inadequate sanitation, limited water supplies, and poor hygiene can contribute to the spread of diarrheal and infectious diseases. Most public health problems, mainly in crises, occur due to inadequate quality and quantity of water.<sup>2</sup> Infectious diseases can be either transmitted by direct contact between the community members or from the environment (contamination of water, food, soil, or from insects). Four water-related transmission routes lead to the spread of diseases<sup>5</sup>:

- (a) Water-borne diseases: caused by ingesting polluted water containing pathogens (e.g., diarrheal diseases, cholera, typhoid).
- (b) Water-washed diseases: caused by inadequate personal hygiene due to lack or scarcity of water (e.g., scabies, trachoma, skin infections).

- (c) Water-based diseases: caused by the intermediate host that lives in water and carries the pathogenic agent (e.g., schistosomiasis).
- (d) Water-related vector-borne diseases: caused by vectors of communicable diseases that develop in or near water (e.g., malaria, yellow fever, dengue fever).

In addition, diseases may occur due to a combination of these causes. For instance, amebiasis is caused by inadequate personal hygiene and polluted water.

The water crisis is defined as “a significant decline in the available quality and quantity of freshwater, resulting in harmful effects on human health and economic activity.” According to the World Economic Forum, the water crisis is the number five global risk in terms of impact on society. Water scarcity affects a quarter of the world’s population, which is expected to worsen with time.<sup>6</sup> Today, 785 million people (1 in 9), 2 billion people (1 in 3), and 3 billion people (2 in 5) globally lack access to safe water, adequate sanitation, and soap and water for handwashing at home, respectively.<sup>7</sup> Furthermore, the United Nations states that nearly 22% of the healthcare facilities globally do not have access to the required water and sanitation services.<sup>3</sup> The water crisis is also a health crisis. WASH-related diseases cause about 1 million deaths annually.<sup>7</sup> In European countries, 31 and 48 million people do not have access to basic sanitation and piped water, respectively, and the unsafe water supply is leading to 14 deaths daily.<sup>8</sup> According to World Health Organization (WHO), poor water and sanitation services accounted for 829,000 deaths due to diarrheal diseases in 2016, equal to 1.9% of the global disease burden.<sup>3</sup> Also, a child dies from a water-related disease every 2 min.<sup>7</sup> More than 90,000 deaths and 2.8 million cases of cholera are reported each year. If untreated, patients die from dehydration within hours. However, with treatment, the case fatality rate can be decreased to less than 1%.<sup>9</sup> Moreover, global warming, urbanization, the rapid growth of megacities, more people living in areas with water stress, and aging infrastructure are major problems that the water sector is facing worldwide.<sup>3</sup> Sometimes, natural disasters further worsen the situation as they result in biological or chemical contamination of water and food, disruption of water supply, damage of the water sources and wastewater treatment services, and electricity cut off, which interrupts pumping water. Hence, an outbreak of water and sanitation-related diseases and a nutrition emergency might occur some weeks or months later after a disaster happens. Climate change is exacerbating the situation. It is leading to more floods and longer droughts. The latter dries up the springs, and floods pollute the water sources.<sup>10</sup>

Knowing that many outbreaks can be prevented, Water, Sanitation, and Hygiene (WASH) interventions play an important role in reducing the burden of these diseases.<sup>9</sup> Pathogens can infect humans through different pathways such as food, flies, fingers, fluid, and feces. In order to reduce public health risks, WASH programs create barriers along these main pathways.<sup>2</sup> There are three main components of WASH interventions in outbreak response: (a) Water: increase its quantity and quality; (b) Sanitation: isolate feces from the environment, assure appropriate feces management, lessen open defecation, and minimize exposure to infectious waste; and (c) Hygiene: promote awareness, distribute hygiene kits, and ensure environmental hygiene.<sup>9</sup> Handwashing with soap mitigates and controls the spread of a wide spectrum of communicable diseases (such as respiratory infections and gastrointestinal diseases). Previous studies ensured that the global burden of disease could be reduced by promoting hand hygiene and is considered a cost-effective measure. In addition, personal hygiene reduces the effects of Severe Acute Respiratory Syndrome (SARS) and is highly recommended to deal with the risk of influenza pandemics.<sup>11</sup>

To have a healthy community, it is critical to promote hygiene practices, supply safe drinking water, provide sanitation facilities, and reduce environmental health risks.<sup>2,12</sup> Key components for strengthening communities before and during an emergency are continuous public education about household water treatment, food hygiene, hand washing, waste disposal, and latrines usage. The top public health priorities in emergencies are (a) having access to healthcare, shelter, food, water supplies, and sanitation facilities; (b) controlling communicable diseases; and (c) having public health surveillance in place.<sup>10</sup>

This chapter aims to discuss the effects of COVID-19 on the water and sanitation sectors. It highlights the challenges that SARS-Cov-2 posed to these sectors by giving examples from different countries and state the related lessons learned.



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## **2. Effect of COVID-19 on water**

### **2.1 Characteristics of SARS-CoV-2**

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes COVID-19, can be transmitted from human to human via direct contact with infected person/surfaces and infective respiratory droplets.<sup>13</sup> To protect the human health during the COVID-19 outbreak, like in any other infectious disease outbreak, appropriate WASH conditions

should be provided.<sup>14</sup> According to the WHO, hand hygiene at the right time and correctly using soap and water or alcohol-based hand rub is one of the preventive measures against SARS-CoV-2.<sup>13,15</sup> Soap can destroy the lipid bilayer surrounding SARS-CoV-2, and the water removes the remaining inactivated virus.<sup>16</sup> Therefore the spread of COVID-19 is influenced by water availability and accessibility.<sup>17</sup>

SARS-COV-2 is an enveloped virus consisting of a fragile external membrane that can become quickly inactive, since it is less stable and very sensitive to oxidants than viruses with water-based transmission (such as rotavirus, norovirus, adenoviruses, and hepatitis A virus).<sup>15</sup> Enveloped viruses are known to be less stable in the environment than nonenveloped human enteric viruses (such as rotavirus, adenovirus, and hepatitis A). The virus can be easily inactivated by chlorine, heat, ethanol, ultraviolet (UV) rays,<sup>18</sup> low or high pH, and sunlight.<sup>13</sup> The presence of organic matter in the water increases the virus's survival.<sup>19</sup> There is no evidence about the persistence of SARS-CoV-2 in treated drinking water, although its presence in untreated drinking water is possible. According to the current evidence, the fecal-oral transmission pathway, i.e., SARS-CoV-2 transmission from the feces, seems to be low.<sup>13</sup>

## 2.2 Vulnerabilities

COVID-19 hit the vulnerable the most. Those who rely on water tankers, private vendors, water points, and toilets in the community will be more vulnerable than others. The high cost of water and waiting for hours to collect water where physical distancing is not feasible can further increase the vulnerability. Also, having limited household budgets might lead some families to consider hand sanitizer and soap a burden and not a priority.<sup>20</sup>

It is very challenging to contain the virus where there is lack of reliable and good quality WASH services, which is the case in many underdeveloped and developing countries.<sup>3</sup> These countries have limited wastewater treatment capacities, and untreated wastewater is usually directly discharged into the water bodies. India, Vietnam, Pakistan, Philippines, and Indonesia treat only 38%, 10%, 8%, 4%, and 1% of their wastewater, respectively. More than 85%, 80%, and 50% of households in sub-Saharan Africa, Asia, and Latin America are not connected to the sewerage network. In addition, if the wastewater treatment facilities are present, they often do not meet the required national standards due to unsafe management leading to environmental contamination. In many areas, surface or groundwater is directly

used (without treatment) by households for daily activities, posing a public health risk. Slums and informal settlements are deprived of their basic needs (clean water, drainage, waste collection, toilets, and sewers) that foster the spread of the diseases.<sup>19</sup> For example, in India, the sewage treatment capacity is very limited such that only 38% of the generated sewage is treated. This means that more than 38,000 million liters of untreated sewage is directly discharged into the rivers daily. The rivers are also polluted by industrial effluents.<sup>15</sup> In the Indian urban areas, about 70% of the sewage goes directly to the water bodies without being treated, and the remaining treated sewage water is used in irrigation.<sup>15</sup> In Brazil, it was reported that the COVID-19 cases and deaths were in municipalities having very limited access to safe water or sewerage system.<sup>21</sup>

COVID-19 pandemic highlighted the importance of providing safe water, sanitation, and hygiene for all to protect their health. Although handwashing seems to be a simple recommendation to prevent being infected by SARS-COV-2, it is very complicated in regions with water scarcity. Eighteen out of 22 Arab countries suffer from water scarcity.<sup>22</sup> 1700 m<sup>3</sup>/person/year is the threshold of renewable water. Countries whose annual renewable water supplies are between 1000 and 1700 m<sup>3</sup>/person/year, below 1000 m<sup>3</sup>/person/year, or below 500 m<sup>3</sup>/person/year are considered to be experiencing water stress, water scarcity, and absolute scarcity, respectively.<sup>22,23</sup> Annually in the Arab countries, more than 362 million people have access to less than 1000 cubic meters of freshwater per individual. Knowing the importance of hand hygiene during the pandemic, the water demand is expected to increase by 9 to 12 L per person daily. In this region, more than 74 million people are more susceptible to get infected by COVID-19, because they do not have access to basic handwashing facilities. Seventy million people have interrupted water supply in 10 Arab countries. The Arab region must spend approximately \$150–250 million each month to meet the increased domestic water demand. Furthermore, over 87 million people do not have access to drinking water through taps. Some purchase drinking water from private vendors, while others cannot afford this option and have to collect water from public sources (wells and standpipes), which poses a risk of COVID-19 transmission. The latter mainly occurs in informal settlements where they are not connected to water supply networks. Curfews and mobility restrictions can worsen the situation since these people will not be able to access the standpipes, and delivering water through tanker trucks might be interrupted. About 26 million refugees and internally displaced persons lack adequate WASH services, making them vulnerable to

COVID-19. Sometimes water supply is intentionally interrupted because of political and military reasons. About 1.8 million Palestinians do not have access to their water resources and need WASH services. In Gaza Strip, the quantity and quality of water are very limited, and only 1 out of 10 has access to safe water.<sup>22</sup> It is important to note that due to the economic crisis, increased unemployment rate, and limited financial resources, the default on water bills will be very high.<sup>22,24</sup> Consequently, fewer resources will be available for operating, managing, and conducting repairs in the water sector.<sup>22</sup>

The sources of water bodies' contamination include open defecation by an infected person, infected wastes, infected sewage, untreated wastewater, and infected personal protective equipment (PPE).<sup>19</sup> Excessive usage of disinfectants and disinfection by-products further deteriorate the quality and safety of the water. Noteworthy, more antiviral drugs are being used to treat patients, and when its residues are discharged into the wastewater then to the water bodies, it will have a detrimental effect on the ecosystem. The demand for PPE has increased since the beginning of the pandemic; however, their safe disposal is challenging. It will be dangerous to enter the water bodies since plastics can be transferred to microplastics, an emerging pollutant. Also, it is predicted that over 1.56 billion masks could end up in oceans in 2020, posing a threat to the ecosystem.<sup>25</sup>

COVID-19 exacerbated the impact of drought and water shortage in countries that are already experiencing climate variation and decrease in rainfall like Ireland, the United Kingdom, Turkey, Ethiopia, Kenya, Syria, Poland, Romania, Kosovo, and India.<sup>8</sup>

### 2.3 COVID-19 and water availability

Overusing water during handwashing and keeping the tap on will pose excess pressure on the water sector. A study in Bangladesh measured the consumption of water per person while handwashing. It showed that keeping the tap on while handwashing led to the overuse of 1.7L of water per handwash and 14.9L of water per day. During the pandemic, hand washing while keeping the tap on led to 13-fold overuse of water in Bangladesh. Compared to the prepandemic situation, each participant used 12.8 times more water per day during the pandemic. It was concluded that keeping the tap on while handwashing will account for 1179% of water loss during this public health emergency.<sup>26</sup>

In low- and middle-income countries, where water scarcity is a critical problem and more than a billion live in informal settlements, people might

prioritize using water for activities other than hand hygiene. Some households tend to store large quantities of water, which leads to viral and bacterial illnesses if it was not properly stored. Water sharing between neighbors might increase to cope with the situation, thus increasing the risk of getting infected due to physical contact. Some people who do not have enough time to wait for hours to collect water or for other reasons might use water from nearby surface water or water tanker with low quality and high prices. Some might seek another place to live where water is more available, increasing the risk of COVID-19 transmission to the new destination.<sup>16</sup>

As this pandemic evolves worldwide, some countries might increase local food production since food-producing countries reduced their food exports. In this way, the already scarce water resources will shift toward the agriculture sector. As a result, more water will be pumped from surface and groundwater resources to meet the demand of the domestic and agriculture sectors leading to water stress.<sup>22</sup> Thus water insecurity will contribute to food insecurity.<sup>16</sup>

## 2.4 Effect of COVID-19 lockdown on water quantity and quality

Locking down cities and shutting down businesses increased the domestic water demand and decreased the non-domestic (i.e., industrial, commercial, public, and institutional) demand.<sup>24</sup> Domestic water refers to water provided for houses and apartments. The industrial category refers to factories and industrial parks. The commercial category includes malls, stores, restaurants, hotels, and others. General category means healthcare and governmental facilities, schools, and universities.<sup>27</sup> In a survey by Global Water Leaders Group, they estimated an average of 27% decrease in water demand by industries due to the pandemic. Notably, many governments excluded the employees in the water sector from movement restrictions policies to maintain service continuity. Nevertheless, disruptions in logistics and supply chains were reported.<sup>3</sup>

Lockdown contributed to the increased domestic water demand since people had to stay home, and handwashing is considered one of the most important measures to prevent infection by the coronavirus.<sup>15</sup> For example, some municipalities in India (e.g., Kozhikode and Ahmedabad) reported up to 25% increase in domestic water usage. Similar results were reported in Joinville city in Brazil, where residential buildings consumed more water than the public buildings and industries (comparing periods before and after the lockdown).<sup>15</sup> This might be due to excess water flow from the tap while handwashing.<sup>26</sup>



The effect of change in water demand depends on the relative proportion of domestic and nondomestic water use and how much each nondomestic sector contributes to the economy, which usually varies between countries. Concerning nondomestic water demand, some sectors were more affected than others.<sup>24</sup> For the majority of the water utilities, there was a drop in the revenues due to a decrease in the total water use<sup>24</sup> (mainly by industries and commercial centers<sup>3</sup>). The change in water demand affected the expenditure and revenue of utilities, water bills, water quality in the buildings, and conditions for using water and wastewater. It is important to note that these effects are short term, and after few months, in some areas, the water demand will go back to the normal conditions (pre-COVID-19 levels).<sup>24</sup>

In the Malaysian river, the water quality index had improved during the lockdown.<sup>28</sup> In India, during the COVID-19 lockdown, many industries were closed from March to September 2020, which led to the short-term improvement of the water quality and quantity in many rivers.<sup>15</sup> The transformation in water quality is expected to go back to its normal condition after businesses reopen.<sup>29</sup> Also, in the same period, the excess rainfall increased the discharge that increased the volume of the water flow in rivers and increased the dilution of the pollutants.<sup>15,30</sup> However, no significant water quality improvement was reported in some rivers where most of the pollution comes from domestic sewage rather than industrial effluents. This ensures the importance of treating the industrial and domestic wastewater before discharging it to the rivers.<sup>15</sup> Moreover, industries located near rivers should abide by the environmental guidelines.<sup>31</sup>

Suspending some agricultural activities during the lockdown led to less water used in irrigation and an increase in the average river discharge and water quantity in reservoirs. For example, in the first 3 months of lockdown in India, the status of the stored water in 123 reservoirs was 159% more than the last 10 years' average storage in the same duration.<sup>15</sup>

During the lockdown, electricity demand in some countries decreased, so less water was consumed for electricity generation. Therefore to reduce the pressure on the water resources, it will be better to shift toward less water-intensive technology for generating electricity.<sup>32</sup>

During COVID-19 lockdown, many private and public buildings will close for a few weeks or months. This means that there will be limited or no water flow in these premises, leading to water stagnation in the building plumbing. Thus the quality of the water will decrease as mold, Legionella bacteria (that causes Legionnaires' disease), or microbial pathogens grow because of corrosion, chlorine decay, or harmful metals leaching from the

**Table 1** Change in domestic and nondomestic water demand during COVID-19 lockdown.

City/country	Increase in domestic water demand (%)	Decrease in nondomestic water demand (%)	References
Portsmouth, England	15%	17%	24
San Francisco, California	10%	32%	24
Kozhikode and Ahmedabad, India	25%	–	15
Joinville, Brazil	11%	53%, 42%, and 30% in the industrial, commercial, and public categories, respectively	27
Ireland	20%	–	8

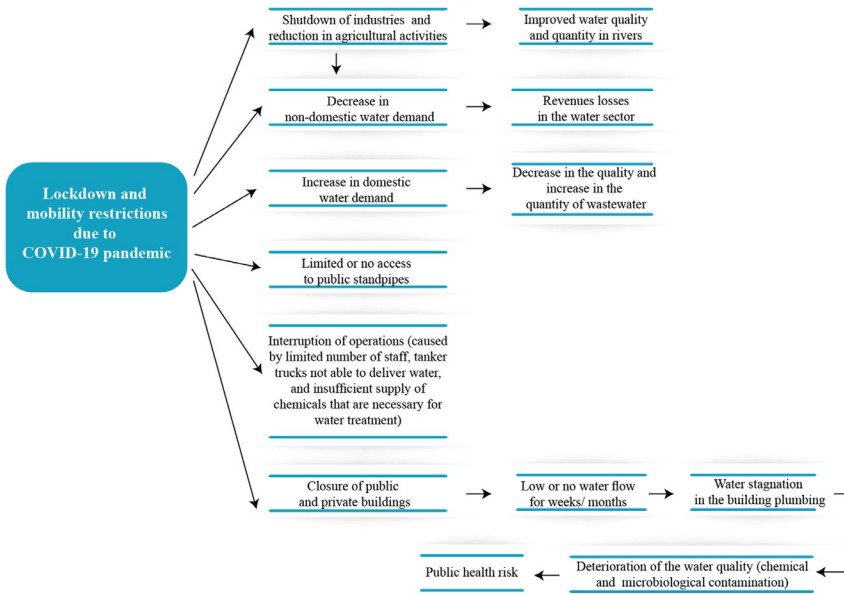
pipes. When premises open again, the deterioration of water quality due to chemical and microbiological contaminants will pose public health risk.<sup>13,24,25</sup> Several measures can be undertaken to minimize the risks within these premises before reoccupancy, including testing the water quality to ensure that it meets the national standards.<sup>13,24</sup>

Table 1 presents the change in demand for domestic and nondomestic water in some cities during the lockdown, and Fig. 1 summarizes the effect of COVID-19 lockdown on water.

## 2.5 COVID-19 and water bills

Major revenue loss is predicted in the water supply chain. During the pandemic, governments took different measures to ensure water services continuity among low-income customers and vulnerable groups. It included, but is not limited to, suspending meter reading and invoicing, moratoriums on cutting off water services, postponing or exempting paying bills, or donating water tanks. All these measures contributed to revenue losses in the water sector. Global Water Leaders Group expects an average of 15% revenue reduction in water and wastewater utilities.<sup>3</sup>

Moratoriums are not a sustainable option, and many water utilities cannot financially afford them. After a short period of time when lifting moratoriums, plans should be in place to prevent the vulnerable members from being disconnected from water. Therefore water utilities can eliminate late



**Fig. 1** Effect of COVID-19 lockdown on water.<sup>3,8,13,15,17,22,24,25,28</sup>

fees and expand repayment options to ease the burden on those facing financial hardships.<sup>33</sup>

Some utilities benefit from the revenue that is gained by selling water to businesses in order to subsidize the household water cost. However, this was greatly impacted in the pandemic, affecting the ability to continue providing affordable water for consumers.<sup>24</sup>

After COVID-19 spread worldwide, all countries introduced new policies to respond to this pandemic; however, little attention was given to the water sector. Only 11 out of 27 European countries implemented short-term policy interventions regarding the water sector, focusing mainly on the payment of water bills. Thus there was absence of major intervention and change in the water sector. This sector faced interruption in operations due to labor cost, absenteeism, inability to buy PPE for all the workers, and shortage of chemicals necessary for treating water.<sup>8</sup>



### 3. Effect of COVID-19 on sanitation

Abdominal pain, vomiting, and diarrhea are among the gastrointestinal symptoms of SARS-CoV-2.<sup>34</sup> SARS-CoV-2 is excreted via the

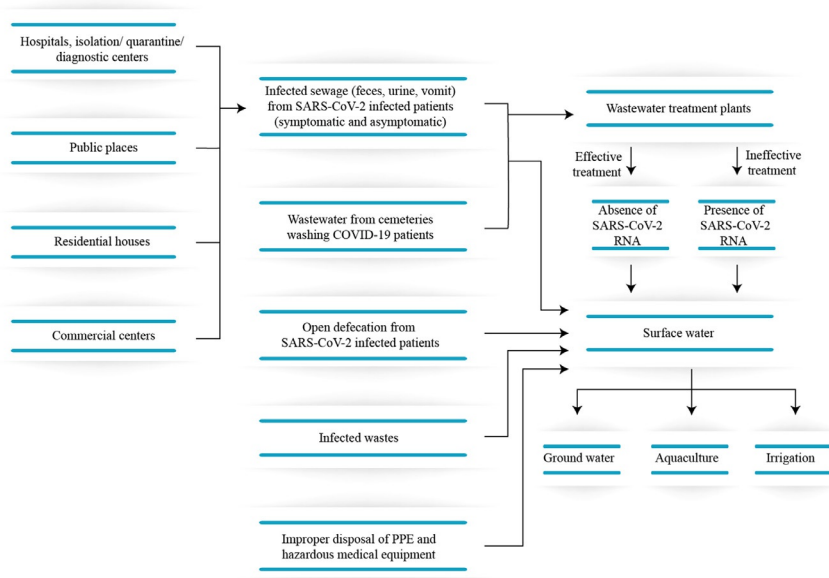
gastrointestinal tract of COVID-19 patients into the wastewater.<sup>18,35</sup> It can be present in an infected person's feces, urine, or vomit.<sup>25,36</sup> Even after the nasopharyngeal samples tested negative for COVID-19-infected patients, SARS-CoV-2 RNA was still detected in their feces for days, suggesting that the virus might be replicating in the gastrointestinal tract.<sup>35</sup> SARS-CoV-2 was detected in raw (untreated) wastewater in Netherlands, Italy, the United States of America, France, Australia, Spain,<sup>35,37</sup> and Iran.<sup>18</sup> In addition, a study done in Iran reported the presence of SARS-CoV-2 RNA in raw and treated wastewater.<sup>18</sup>

One of the pathways of SARS-CoV transmission was fecal-oral, and SARS-CoV-2 is genetically similar to it.<sup>19</sup> SARS-CoV-2 RNA was detected in fecal and urine samples in several studies. These samples were either collected from wastewaters of the affected community or directly from COVID-19 patients. For these reasons, SARS-CoV-2 might be transmitted via the fecal-oral route. Although there is no reported case of fecal-oral transmission of COVID-19, studies show that it is possible mainly in areas with poor wastewater management.<sup>18,19,35</sup> The pandemic hotspots were identified in crowded areas (i.e., large population density and informal settlements), mainly with limited waste management and sanitation services like in Cairo and Mumbai.<sup>3</sup> It is important to point out that the majority of the studies about detecting SARS-CoV-2 in wastewater were conducted in developed countries.<sup>19</sup>

Viral RNA was also detected in Monterrey's surface water and groundwater samples during a SARS-CoV-2 peak phase. Leaked sewage system or contaminated surface water by sewage might be the possible routes that led to the groundwater contamination.<sup>38</sup> Fig. 2 summarizes the possible sources of surface water contamination with SARS-CoV-2.

Several factors determine the degree to which the coronavirus remains infectious in wastewater, including how long it stays in the water, treatment type, and environmental conditions. According to WHO, the human coronaviruses can live for only 2 days in the hospital wastewater (at approximately 20°C) or dechlorinated water.<sup>15</sup> Another study ensured that SARS-CoV-2 could survive in untreated wastewater for a few hours to days, posing public health risks through aerosolized wastewater or water-borne transmission.<sup>18</sup>

An increase in the water demand means consumption of more water with soap or disinfectants, which in return decreases the quality and increases the quantity of wastewater. Thus it requires additional costs to increase capacities for the drainage structures and treatment facilities to safely collect



**Fig. 2** Possible sources of surface water contamination with SARS-CoV-2.<sup>13,18,19,22,25,29,35,36,38,39</sup>

and treat the large quantity of wastewater before being discharged and reused.<sup>17,22</sup> This is challenging in areas with limited wastewater treatment, thus increasing the risk of polluting the surface water that might permeate into the groundwater. The same applies to hazardous medical equipment that is not safely disposed of. Therefore the collected wastewater from areas having COVID-19 patients should be appropriately treated rather than only filtered and discharged into the environment.<sup>22</sup>

One of the studies concluded that using UV for wastewater disinfection is more effective than chlorine. Also, for effective chlorine disinfection, the wastewater treatment plant (WWTP) operators should ensure that the free residual chlorine complies with the international standards at specific conditions.<sup>18</sup>

Available evidence ensures that wastewater monitoring for the virus can help determine the total number of COVID-19 symptomatic and asymptomatic cases in the community.<sup>40</sup> Studies showed a relation between SARS-CoV-2 RNA concentrations in wastewater and the number of reported COVID-19 cases. Also, concentrations of SARS-CoV-2 RNA in wastewater can give information about the COVID-19 cases few days (4 to 7 days) ahead of the results of the COVID-19 clinically confirmed

cases. Environmental surveillance for SARS-CoV-2 was used in several developed countries.<sup>37</sup> Effective surveillance can be applied when populations are connected to WWTPs to identify the infection hotspots.<sup>40</sup> However, this is very challenging where populations are not connected to sewers; rather, they use septic systems, pit toilets,<sup>19,37</sup> or open drains, which is the case in many developing countries.<sup>40</sup> In this situation, testing surface water for sewage contamination is one of the options. Environmental surveillance for SARS-CoV-2 can be used for early warning, detection in areas with limited clinical surveillance capacities and limited access to health facilities, and detection of SARS-CoV-2 from animal sources.<sup>37</sup> Wastewater-based epidemiology (WBE) is an effective surveillance tool for monitoring the virus circulation in the community.<sup>18</sup> It has been applied in several countries and used as an early warning since it can identify the extent of virus spread in the community. The WBE functions by collecting wastewater samples from WWTPs and detecting the presence of viral RNA in order to determine whether the infection rate is increasing or decreasing.<sup>15</sup> Nevertheless, cost-benefit analysis for investing in environmental surveillance versus strengthening WASH and essential surveillance activities should be done, especially in developing countries.<sup>37</sup>

During the pandemic, using treated or untreated wastewater in irrigation will pose public health threat<sup>18</sup> and increase the possibility of foodborne transmission of SARS-CoV-2.<sup>41</sup> To provide reliable data about SARS-CoV-2 transmission, the physical and chemical properties of the wastewater should be studied. Moreover, operation and maintenance standards in WWTPs should be met to prevent the wastewater from contributing to disease transmission.<sup>18</sup> While the wastewater is transported to the WWTP, airborne transmission of SARS-CoV-2 might occur.<sup>19</sup> Aerosolization might occur not only in WWTPs but also in flushing at homes.<sup>40</sup>

WHO recommends sanitation workers to follow standard operating procedures at the workplace that include wearing PPEs, following COVID-19 general mitigation measures, minimizing spills, getting the vaccines for diseases related to sanitation, and self-monitoring for infectious disease symptoms. These people, as well as those promoting hygiene in the community, should be allowed to resume their work during the lockdown and movement restrictions since they are providing extremely important services.<sup>13</sup>

Indeed, wastewater has destroying effects on human health, economy, and ecosystem.<sup>4</sup> Since the excreta from SARS-CoV-2 infected patients might threaten the environment and the public, wastewater should be treated in well-managed WWTPs. Decrease in exposure risk and pathogen

reduction can be only be guaranteed by effective treatment and disinfection of wastewater. Water safety plans should be in place to ensure the safety of the water. Centralized water treatment can decrease the SARS-CoV-2 concentration. In areas lacking centralized water treatment and not connected to safe water pipes, other measures can be applied to destroy the viruses, such as boiling, using ultrafiltration or nanomembrane filters, solar or UV irradiation, and chlorine products with appropriate dose.<sup>13</sup>



#### **4. Sustainable development goal 6 in the context of COVID-19 pandemic**

The impact of COVID-19 on sustainable development goal (SDG) 6 (clean water and sanitation) and the possibility of achieving this goal by 2030 need to be studied in depth.<sup>15</sup> From the positive side, governments are now more than ever aware of the importance of providing clean water for all, and they are trying their best to do so based on the recommendations for combatting the COVID-19 pandemic. Furthermore, this has driven many international organizations to assist less developed countries in increasing water access.<sup>15</sup> The global water demand, before the pandemic, was mainly for the agricultural sector (70%) and other sectors like domestic use and industries (30%). However, the pandemic shifted the water demand and supply patterns for hygiene and protecting human health. Therefore there might be a higher possibility for achieving the SDGs.<sup>15</sup> Also, water directly affects the cities' resilience and sustainability<sup>42</sup> and SDG 11 (sustainable cities and communities) focuses on the importance of having resilient and sustainable cities and human settlements.<sup>43</sup>

On the other side, the Sustainable Development Goals Report 2020 mentions that achieving SDGs is challenging in the COVID-19 pandemic.<sup>44</sup> Knowing that a quarter of the people worldwide do not have a reliable water supply shows that SDG 6 is far from being achieved by 2030.<sup>3</sup> COVID-19 pandemic led to an economic crisis and high rates of unemployment that will affect SDG 1 (no poverty), SDG 2 (Zero Hunger), and SDG 3 (public health) that will definitely affect governments' actions regarding SDG 6.<sup>15</sup> The pandemic will slow down the progress in this goal since water utilities are facing losses in revenues which hinder their ability to do further capital investments. Lower investments in the water sector are expected globally.<sup>3</sup> In some countries, there is a 61% funding gap that hinders them from achieving SDG 6.<sup>45</sup>

In 2021 a report assessing the progress in the Asia-Pacific region regarding SDGs showed that it is far from achieving any of the SDG targets by 2030. The progress regarding Goal 6—clean water and sanitation—is still slow. Water stress is the main obstacle in this region hindering from achieving several targets.<sup>46</sup> In addition, there is a lack of data that can help track the progress in SDG 6 in the European Union.<sup>47</sup>

While meeting the water demands, it is also vital to secure the irrigation. The indirect effect of COVID-19 that countries should be aware of is food insecurity. Due to lockdown and physical distancing protocols, many workers will not be able to participate in harvesting, which might, in the worst scenario, contribute to famine. In this way, SDG 2 will be severely impacted. Thus authorities should ensure the stability of the food system and prevent the disruption of the agricultural supply chain.<sup>42</sup>

COVID-19 deepened the already existing inequalities. SDG 12 (responsible consumption and production) will not be achieved if the human right to water management was not respected and applied. COVID-19 and climate change are threat multipliers that affect the water sector for the dream of having a sustainable world.<sup>42</sup> Good water management is the basis for climate change adaptation and consequently achieving SDG 13 (climate action).<sup>48</sup>

Water is critical for ecosystems, health, eradicating poverty, food security, peace and human rights, and education.<sup>44</sup> Thus responding to the pandemic should pave the way toward the 2030 Agenda.<sup>46</sup> The pandemic is a great chance to build forward better by changing the threats into opportunities to achieve SDG 6 and other SDGs by 2030.<sup>49</sup>



## 5. Lessons learned regarding water and COVID-19

Raising awareness about human health and the environment is the pillar to have a sustainable environment.<sup>31</sup> To prevent and combat future outbreaks, water security has to be strengthened globally. Water security is not only critical for public health but also for food security, economic growth, protecting livelihoods, and increasing resilience to climate change.<sup>20</sup> Water governance, policy-making, and financial investments should be strengthened to increase water sector resilience amid the COVID-19 pandemic, climate change, and freshwater scarcity. No matter what interventions are implemented, COVID-19 recovery will only be shortened if access to clean water and sanitation increases.<sup>8</sup> The SDG 6 Global Acceleration Framework,



coordinated by UN-Water, considers that actions toward achieving SDG 6 are driven by optimizing finance, data and information (to measure progress and do more research), developing capacities (more skilled staff), innovation (use of new technologies), and governance (collaboration and cooperation between countries and different sectors).<sup>50</sup>

Improving and strengthening the water quality monitoring system at the national level by conducting frequent water sampling and having satellite- and ground-based water quality monitoring is needed. These systems are the base for accurate data and conducting detailed analysis about the anthropogenic effects on water quality. The lockdown is considered an opportunity to effectively manage the water resources by monitoring their quality as well as water quantity and biodiversity. The resilience of municipalities in dealing with fluctuating water demands should be assessed. Evaluating the water consumption patterns is indispensable to maintain the water utilities, manage the water requirements, and create policies. To deal with future pandemics, suitable wastewater treatment and surveillance technologies (such as artificial intelligence and the Internet of Things) should be in place to collect comprehensive data, trace the viruses, and determine their threat. Also, there is a need to improve or build infrastructure that connects rural and urban places to WWTPs, upgrade the treatment methods, and use computing techniques for monitoring. It is important to determine the consequences of using water for irrigation and crop production. There is a need to quantify water demand in all sectors, improve safe water supply for all, and strengthen the government capacities to deal with unprecedented events.<sup>15</sup> To manage outbreaks more effectively, having small decentralized WWTPs could be a good option.<sup>40</sup> Moreover, service providers should be able to supply all the chemicals needed to test and treat the water and wastewater to ensure that people are receiving water of high quality.<sup>22</sup> Reusing safely treated wastewater is one of the solutions to cope with water scarcity.<sup>49</sup>

Water and sanitation services should be available for all, including those who cannot afford to pay the water bills. Cutting off the water because of economic problems should be prohibited, and governments and utility operators should reconnect services and set measures such as waiving tariffs to help people.<sup>22</sup> WHO considers that cutting off the water because of inability to pay the bills is not acceptable, and governments should take immediate actions to ensure all have access to water (for example, use tanker trucks or extend pipes for water supplies).<sup>13</sup> To ensure continuity of services,

paying the water bills online and remote technologies should be introduced (since sometimes mobility restrictions delayed collecting bills).<sup>22</sup>

Increasing awareness of water conservation by changing behavior is the basis for sustainable actions. Decreasing water flow in the taps, efficiently using water in the agriculture sector,<sup>22</sup> replacing taps with sensor taps, and changing people's behavior to turn the tap off while handwashing are effective options to mitigate water overuse.<sup>26</sup>

Responding to water changes during the pandemic requires the use of new technologies, demand forecasting systems, and remote monitoring and leak detection systems.<sup>24</sup> Having automated systems that can be remotely controlled will facilitate the operations and lead to efficient response if an unprecedented event occurs. Automated and digitalized industries were able to easily cope with the pandemic's changes, such as social distancing and restrictions.<sup>3</sup> Water utilities should enhance their resilience in order to continue providing water and wastewater services during unexpected events (infrastructure failure, health threats, and extreme climate conditions). Therefore more funding is needed by governments and international organizations to bolster water utility resilience.<sup>24</sup>

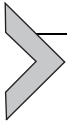
WASH recommendations can also be applied during the pandemic, mainly hand hygiene; safely managing excreta, dead bodies, medical wastes (from COVID-19 patients); frequently cleaning the environment, and applying disinfection practices. Untreated wastewater, including wastewater from healthcare facilities, should not be discharged to be used for producing food and aquaculture. In healthcare facilities, excreta must be considered a biohazard and should be treated based on that.<sup>13</sup> The procedures of disaster and emergency prevention can be utilized to maintain access to good water quality. Public health engineering professionals and other responders play a vital role in managing the impact of the environment on public health.<sup>4</sup>

According to WHO, handwashing facilities should be present everywhere, such as in front of public buildings, toilets, and transport stations, to ensure access for all. These facilities should be functioning and have soaps, not necessarily the antibacterial one since the normal soap is enough to inactivate the enveloped viruses.<sup>13</sup>

Countries should cooperate with one another to share the lessons learned and best practices for safely and sustainably managing the water sector.<sup>22</sup> COVID-19 is an opportunity for countries to cooperate and support one another for shared water resources and other basic water needs. For example,

six countries (over 60 million people) benefit from the Mekong River. Regional water-sharing governance and solidarity are the keys to ensure that no one will be affected and all have access to rivers passing in different countries, mainly in conflict-affected areas.<sup>42</sup> It is critical to prohibit destroying or interrupting water services in conflict-affected areas.<sup>22</sup>

It is the time to ensure good governance, invest in the water sector, build capacities, address the most vulnerable groups, and focus more on research. If we did not increase the resiliency in water and sanitation, we would always be vulnerable to another pandemic.<sup>49</sup>



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## 6. Limitations

Although the pandemic, directly and indirectly, affected the water and wastewater sectors, the extent of the impact is still unclear. There are limited data and monitoring systems to track the water quality in all rivers during lockdowns and movement restrictions.<sup>15</sup> Although many countries already have policies and plans for hygiene, implementing them is hindered due to limited financial and human resources.<sup>52</sup> Available data about hygiene is few and often with poor quality. There is not a standardized definition for hygiene, which is challenging when it comes to reporting or comparing data about hygiene. WHO is willing to develop the hygiene definition. To improve public health, investing in infrastructure should be considered when speaking about hygiene rather than just focusing on handwashing with soap and changing behavior.<sup>51</sup>



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## 7. Conclusion

Water has a pivotal role in combatting COVID-19 and achieving sustainable development. COVID-19 dramatically affected the water sector, and the improper management of water will lead to the spread of this disease. This vicious cycle will only stop if strict measures were set. Investing in the water sector and ensuring all have access to safe water and sanitation is no longer an option; rather, it is fundamental for survival. Fig. 3 summarizes the challenges in finance, research, and water and sanitation services that were highlighted during the pandemic and should be tackled in the future to end up with resilient communities.

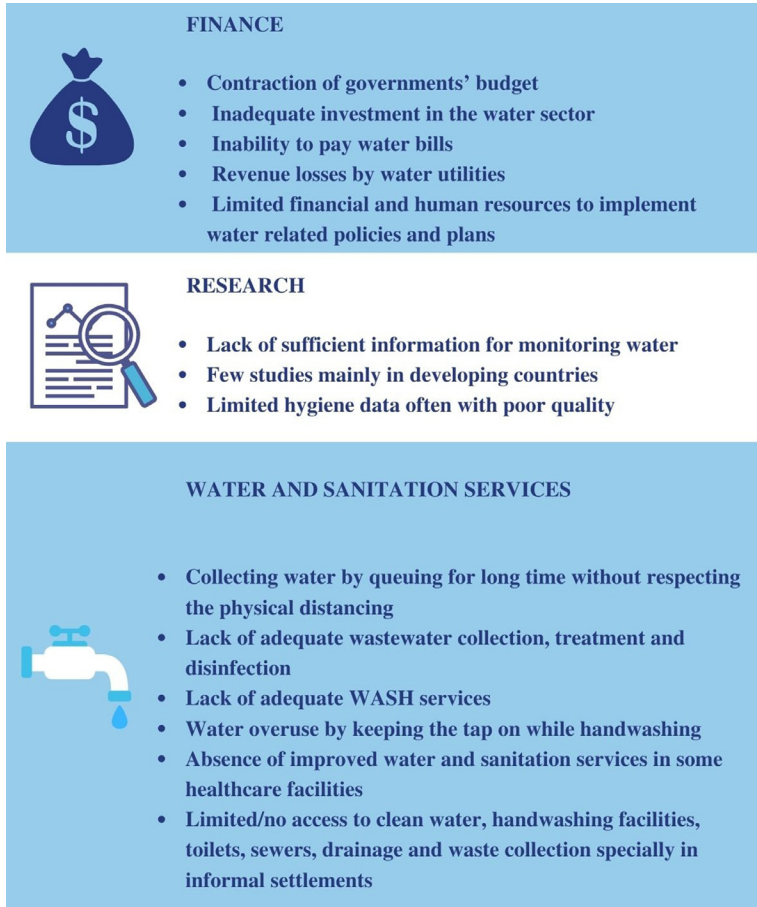


Fig. 3 Challenges highlighted during COVID-19 pandemic.<sup>3,7,8,15,19-22,24,26,49,51</sup>

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