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Review

Effects of the COVID-19 Pandemic on the Urban Water Cycle

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Abstract

The coronavirus disease 2019 (COVID-19) is a global crisis spreading to all countries. This study explains and documents the first-order effects of the new coronavirus on the urban water cycle. Urban water systems play an important role in public health because people rely so heavily on water services. Findings address short- and long-term changes in climate variables; availability and accessibility of clean water to prevent and control the spread of coronavirus in water-scarce cities; shifts in habits, behavior, and lifestyles of people and effects on water demand during lockdowns; and role of wastewater treatment in preventing the spread of coronavirus.

Keywords

COVID-19; water cycle; water demand; water supply; wastewater

1. Introduction

Freshwater availability and accessibility are key factors to prevent epidemics of infectious diseases such as COVID-19 [1-5]. However, on a global basis, about 884 million people lack access to safe water sources and millions more are served by poorly-performing piped systems [6]. The risk of coronavirus outbreaks can multiply in high- and low-income countries alike with limited clean water availability and accessibility [7, 8]. In particular, water-scarce regions face major challenges to control and prevent the spread of COVID-19 [1, 9-12]. Because the COVID-19 pandemic may last for years, improved management of urban water systems is a major challenge for water resource planning and management in urban areas [8, 13-15].

Urban water systems provide engineered methods to provide clean water, treated wastewater service, and stormwater management to aid healthy cities [16, 17]. These systems operate within the urban water cycle, as shown in Figure 1. Cities need effective and sustainable infrastructure and operational systems to manage water through the urban water cycle, and the COVID-19 pandemic is a test to evaluate their effectiveness under stress [12].

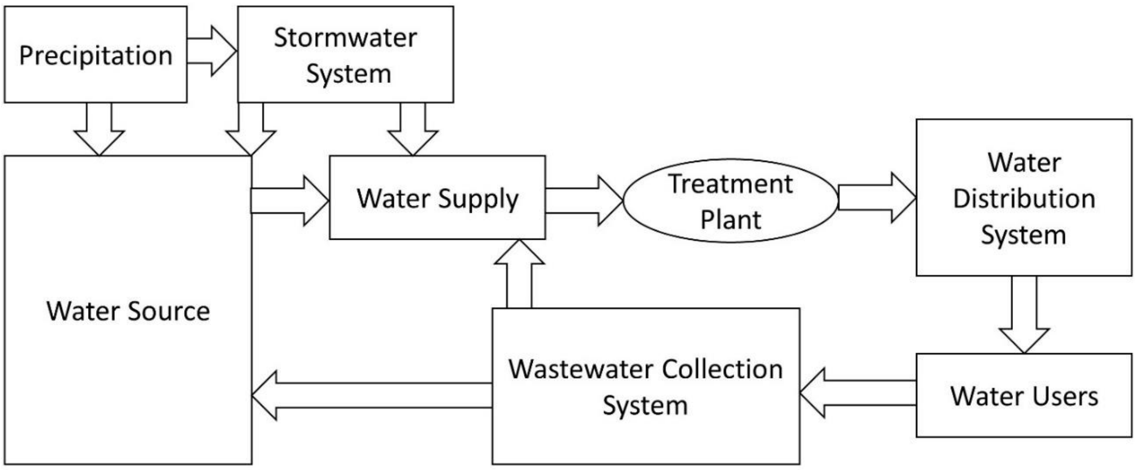

Figure 1 A schematic of urban water cycle.

Water planners and managers must understand the fate of the coronavirus in the urban water cycle. Questions raised are: 1) how do the virus and the COVID-19 pandemic affect the urban water cycle? and 2) how can urban water systems play a role in preventing and controlling COVID-19 disease? To provide deeper understanding, we studied the effects of the COVID-19 pandemic on the urban water cycle. These effects may be positive or negative, depending on their linkages and systemic effects.

The study began with an analysis of climate change on the urban water cycle and continued to the components of the urban water system. The novel contribution of the paper is to consider COVID-19 effects systemically, considering direct and indirect effects and their feedbacks. The objectives of the study are: 1) investigate the relationship between COVID-19 and climate variables as the main factor to influence water supply; 2) characterize the effects of municipal water supply systems on the spreading of coronavirus; 3) assess the impacts of the COVID-19 pandemic on municipal water demand; and 4) evaluate how wastewater systems can affect spreading of COVID-19 disease. The effects of stormwater and recycled water systems are also described. The study is based on a review and integration of relevant recent reports on COVID-19 and urban water systems.

The mutual effects of the COVID-19 pandemic and urban water systems must be addressed to improve insight for the fight against COVID-19. This is especially important, given the massive urbanization that is occurring, especially in low-income countries. Shifts in human lifestyles during the COVID-19 pandemic may upset current patterns in the urban water cycle and create new data and management problems [18]. The findings can improve understanding of future challenges in holistic urban water management.

2. The COVID-19 Pandemic and Climate Change

Climate change is a major driver of the urban water cycle [19, 20] and an influential factor in epidemics [17, 21, 22]. It can contribute to increasing water scarcity [23, 24, 25] and other natural disasters such as floods [26] and forest fires [23] and lead to the consequent rapid spreading of viruses [21, 27-30]. In a study about the relationship between climate change and coronavirus, Hepburn et al. [31] reported that the pandemic may dramatically affect the progress of climate change. The fiscal recovery package may be the most important factor in the long-term effect of the COVID-19 pandemic on climate by decoupling economic growth from Greenhouse gas (GHG) emissions and reducing welfare inequalities [31].

Quéré, et al. [32] explained how climate change mitigation may get advantages from the COVID-19 pandemic by a temporary reduction in daily global CO2 emissions. Although GHG emissions have been estimated to drop to the lowest rate since World War II due to the COVID-19 lockdown [33, 34], a short-term decrease in GHG emissions may only have minor long-term effects on climate [32].

Bhat et al. [35] investigated the effects that the COVID-19 pandemic and the consequent lock down posed on the air quality across the major cities of the world and reported that the lockdown led to some positive impacts on environment by decrease in concentrations of particulate matter (PM), NO2 and CO. For example, they found that the Covid-19 pandemic has reduced the NO2 emission by 20-30% in China, Italy, France and Spain, 30% in the United States, 54.3% in Brazil, and 52.68% in India.

Bashir et al. [36] investigated the correlation between the COVID-19 pandemic and climate indicators including average temperature, minimum temperature, maximum temperature, rainfall, average humidity, wind speed, and air quality. They reported that some climate parameters are highly correlated with the COVID-19 epidemic in New York [36]. Lauc et al. [37] also found that the transmission of COVID-19 is more efficient in regions with cold and dry climate conditions. Besides, Rahman et al. [38] assessed the potential impact of a simultaneous strike of climatic hazards and infectious disease outbreaks in Bangladesh and found that the effects of the COVID-19 pandemic can be intensified if there is a climatic hazard such as flood [38].

Botzen et al. [27] investigated how parallels can be drawn between decision-making processes about the COVID-19 pandemic and climate change. They assessed six important risk-related behavioural biases in individual decisions making about climate change and the COVID-19 pandemic and founded that the effects of climate change can be attenuated and mitigated if we implement policies that work with, instead of against.

Although there is some evidence about the relationship between climate parameters and the COVID-19 pandemic, further research is needed to improve understanding of how both climate change and the COVID-19 pandemic may mutually affect one another and have short-term and long-term impacts on the urban water cycle in the future.

3. The Effects of Municipal Water Supply on Spreading of Coronavirus

Among the urban water systems, municipal and industrial water supply has the strongest linkages with people and the economy [39]. The availability of safe and adequate water supplies plays an important role in providing adequate health conditions and preventing the spread of coronavirus [40-44]. Unfortunately, many people around the world cannot access sufficient water supply to wash their hands [45]. Water is especially scarce in many rural communities and peri-urban zones [46] even for the most basic needs [47]. Some 1.5 million deaths have occurred around the world due to limited access to handwashing facilities according to Worldwide statistics for 2017. Nearly 74 million people in the Arab regions, where water is often scarce, are exposed to a higher risk of COVID-19 due to lack of clean water for handwashing [1, 48].

The COVID-19 pandemic does not have an independent and direct impact on municipal water supply, but limited water supply can accelerate coronavirus risk [15, 49]. Limited water supply during the COVID-19 pandemic has affected many counties [50] such as the United Kingdom [51], India [10, 52], Mexico [53], Burkina Faso [54], Zimbabwe [55], South Africa [56], Pakistan [47], Nicaragua [46], and Kenya [57]. Even in a developed country such as the United States, some regions such as the Navajo Nation are facing problems in accessing safe water during the COVID-19 pandemic [58-60]. Another impact is that that the quality of water in rivers has improved after the COIVD-19 lockdown due to the reduction in industrial effluents entering the rivers [33, 61].

4. The Effects of COVID-19 Pandemic on Patterns of Municipal Water Demand

The COVID-19 pandemic affects the spatial and temporal distribution patterns of municipal water demand [42, 62, 63]. Demand for safe residential water has increased due to the COVID-19 pandemic as people stay at home to prevent the spread of the virus [13, 15, 57]. While the pandemic increases residential demand, non-residential water demand has decreased [15, 64]; consequently, the effects of the pandemic on total municipal water demand depend on the ratio of residential and non-residential water use [65].

Stay-at-home and safer-at-home orders in the United States resulted in an approximately 21% increase in residential water use in April than February. New York and Minnesota reported the highest increase in daily water use by 28% and 25%, respectively. California, with the highest population, experienced an 11.5 % increase from February to April [66, 67]. Some larger cities such as Boston, Massachusetts [68], Austin, Texas, and Pittsburgh, Pennsylvania [69] experienced a reduction in total water demand from March to May 2020 [65], while other smaller cities such as Stoneham, and Swampscott, Massachusetts have experienced an increase in total water demand by 16.7% and 12.7%, respectively [67]. However, Feizizadeh et al. [42] reported that the COVID-19 pandemic has posed severe pressure on the urban water system in Tabriz, Iran by increasing the annual water deficit from 18% to about 30% in 2020.

The COVID-19 pandemic may also shift the peak of residential water use [70, 71]. WatEner, [72] compared recorded water data before and during the COVID-19 pandemic for Karlsruhe, Germany during March 2020. They determined that shifting morning peak demands were due to changes in the sleep habits of people. Balaco et al. [62] also reported shifts in residential water use in five cities in Italy by 1-2 hour shifts in the morning peak. They also learned how daily commuters also play an important role in changes in water consumption of commercial regions and college towns [62].

5. The Role of Wastewater in Spreading the COVID-19 Disease

The chance of contamination of municipal water supply by coronavirus is high in regions with high population density and low-capacity sewage treatment facilities [6, 73-75]. Municipal water supply systems may be contaminated by coronavirus because of combined sewer overflow and inadequate wastewater disinfection [6]. The coronavirus may be related to wastewater because some originates in the feces and urine of infected people [76-78]. SARS-CoV-2 can also be inactivated by filtration and disinfection [73, 75, 79, 80].

Besides, the SARS-CoV-2 was not only presented in raw/untreated wastewater, it was also detected in effluent from secondary treatment and sewage sludge as well [74, 80, 81]. However, there are limited studies on the persistence and infectivity of SARS-CoV-2 in water wastewater [74].

SARS-CoV-2 might quickly be inactive compared to other viruses that are able to have water-based transmission [82]. The degree to which the coronavirus can persist in wastewater highly depends on several factors such as resident duration of water, type of treatment, and prevailing environmental conditions [83]. However, the World Health Organization (WHO) reported that the human coronavirus can persist only two days in dechlorinated water and hospital wastewater.

Testing wastewater is an effective method to identify if COVID-19 is present in a community, and can provide early detection before spreading to the number of cases [84, 85]. Tiwari et al. [75] suggested that the COVID-19 pandemic offers an opportunity to include Surveillance of Wastewater for Early Epidemic Prediction (SWEEP) in routine urban water management to put the humankind at front to mitigate such pandemics in the similar situations [86].

Note that as stormwater carries many pollutants, it might be suspected to transmit the COVID-19 virus [73]. However, there is no evidence to date that coronavirus infections can be directly spread by stormwater.

Table 1 provides some quantitative results from previous studies about the effects of the COVID-19 pandemic on components of the urban water cycle including climate, water supply, and water demand. The mutual effects of the COVID-19 pandemic and urban water systems must be addressed to improve insight for the fight against COVID-19. While the COVID-19 pandemic has changed the spatial and temporal patterns of urban water cycle in some regions, problems of availability and accessibility to clean and safe water may prompt the spread of the coronavirus by decreasing clean water availability. Shifts in human lifestyles during the COVID-19 pandemic may upset current patterns in the urban water cycle and create new data and management problems.

Table 1 Examples of quantitative results regarding the effects of COVID-19 on the urban water cycle.

Component of water cycle	Source	Study Area	Findings
Climate	(Bhat et al. [35])	China, Italy, France, and Spain.	20-30% reduction in NO_2 emission.
		United States	30% reduction in NO_2 emission
		Brazil	77.3% reductions in NO, 54.3% in NO_2 and 64.8% in CO concentrations.
		India	51.84% reduction in PM10, 53.11% in PM2.5, 17.97% in SO_2, 52.68% in NO_2, 30.35% in CO, 0.78% in O_3 and 12.33% in NH_3.
	(Le Quéré et al. [32])	Global	17 % reduction in daily global CO_2 emissions. At their peak, emissions in individual countries decreased by –26% on average.
	(Jha et al. [2])	623 pandemic affected districts of India	Strong climate influence on COVID 19 cases was observed in 76.08% of districts.
			Strong climate dependence was detected in 76.08% of districts.
			53.6% of rural districts, 32.1% of urban districts and 53.9% of total population districts were at high risk.
Water Supply	(Feizizadeh et al. [42])	Tabriz, Iran	The annual water deficit increased from 18% to about 30% in 2020.
	(Stoler et al. [50])	23 low- and middle-income countries	45.9% of households were unable to wash their hands. 70.9% of households experienced one or more water-related problems.
	(Muduli et al. [61])	New Delhi, India	55% decline in turbidity was detected during the lockdown.

	(Rezaeitavabe et al. [63])	Iran	15% - 20% reduction of NO_2.
Water Demand	(Rezaeitavabe et al. [63])	Iran	10% - 40% increase in water consumptions.
	(Balacco et al. [62])	Five Apulian towns, Italy	Water consumption starts with 2 hours delay about 10.00 a.m. and lasts until 15.00.
	(Feizizadeh et al. [42])	Tabriz, Iran	The domestic water consumption increased by 17.57% during the year 2020.
	(García et al. [64])	Huelva, Spain	The residential water consumption increased by 15% during the full lockdown and 7.5% during the reopening period. The non-residential water consumption decreased by 38% during full lockdown and 14.5% during the reopening period.
	(Kim et al. [70])	Seoul, Republic of Korea	The hot water demand in the residential sector increased by 8.08–16.41%.
	(Li et al. [66])	California, United States	7.9% decrease in California's urban water use. 11.2% decrease in the commercial, industrial, and institutional sector. 1.4% increase in the residential sector.
	(Lüdtke et al. [71])	Germany	14.3% increase in residential water consumption per day with higher morning and evening demand peaks during the day.

6. Conclusions

The reports cited identify the following four significant impacts of the COVID-19 pandemic on the urban water cycle:

(1) Short term changes in climate variables due to a reduction in GHG emissions during the COVID-19 lockdown are not likely to have long-term impacts on climate change and precipitation. However, the virus-driven fiscal recovery package may have a higher impact on climate conditions if the pandemic lasts for several years

(2) The availability and accessibility of clean water play important roles in preventing and controlling the spread of coronavirus in cities because, without water, people cannot follow sanitation rules. Water-scarce regions with high population density and low clean water availability and accessibility are at a higher risk of COVID-19 disease.

(3) The COVID-19 pandemic led to shifts in habits, behavior, and lifestyles of people and these may shift the distribution and timing of municipal water demand during the lockdown.

(4) Adequate wastewater treatment facilities play an important role in preventing the spread of coronavirus through the feces and urine of infected people. Monitoring wastewater from residential areas and public buildings can provide indications of early signs of the COVID-19 at specific locations.

These findings indicate that conservation and wise water management are key to fighting COVID-19. While bottled water is a temporary solution to mitigate municipal clean water shortage during the COVID-19 pandemic [87], long-term water planning and management should heed lessons from the it to build more sustainable and effective systems.

These long-term responses and investments to support the urban water cycle should focus on water services for poor communities, where vulnerability to infection is high. Investments should support sustainable access and resilient services. These should focus on extending access to services in urban areas where related problems, such as inadequate housing, increase likelihood of infection [21].

The COVID-19 pandemic challenges decision-makers to integrate urban water management into municipal policies and is another reason to promote Integrated Water Resources Management (IWRM) [88]. This should include adequate urban infrastructure to support reliable clean and safe water supply with a holistic approach to stormwater management, water treatment, and water reuse [47].

Note that the COVID-19 pandemic has leaded to a unique and systematic stress test that is beyond single natural-resources sectors and requires to provide a systemization of impact, current responses and long-term perspectives of COVID-19 on water-energy-food nexus [9, 89].

The COVID-19 pandemic may last longer and challenge water managers and city officials to manage its impacts on the urban water cycle. This exploratory study indicates that further research should assess the effects of the pandemic on the urban water cycle and its supporting systems with data, modeling, and quantitative management tools.

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Author Contributions

Conceptualization, H.H.; investigation, H.H.; writing, review and editing, H.H., N.G.

Competing Interests

The authors have declared that no competing interests exist.

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