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The Impact of COVID-19 on the Water Sector: A Review

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This paper provides a literature review of the impact of the COVID-19 spread-prevention measures on the water sectors, including general water network management, water quality and quantity, and wastewater treatment. Fifty-four papers are selected for the analytical review, and the results showed that the pandemic poses both positive and potential long term negative impacts to the water sector. In the short term, the limitations in mobility and industrial activities lead to the water use patterns shifts between especially the industrial and residential sector, and reduction in aquatic pollution discharge. But in the long run, the changes in the industrial development patterns and people's lifestyle caused by the pandemic might also require further adaption and update of the current water networks. Understanding the interactions between the pandemic and water-related aspects is essential to ensure the urban water supply system is resilient in pandemic situations. As a response, this resilience can help to facilitate controlling and mitigating the spreading of the virus.

1. Introduction

The widespread SARS-cov-2 (COVID-19) has been leading to significant changes in various aspects globally, which also caused challenges to immensely human health, and covers almost the whole list of the Sustainable Development Goals (SDGs) (Tortajada and Biswas, 2020). The countermeasures have been taken on a global level against the initial sharp spreading and the continuous waves of the virus. The pandemic and the global reactions against the pandemic have also been posing considerable impacts to the environment and resources (Figure 1). One of the most significant emerging issues being the increased discharge of waste disposals from medical supplies, online shopping packaging waste, and the related energy consumption and environmental issues caused by the waste generation (Elsaid et al., 2021). For example, Klemeš et al. (2020) carried out one of the initial studies discussing the plastic waste and environmental footprints caused by the COVID-19. It is estimated that until March 2020, the plastic waste from medical supplies and packaging increased about 57 % comparing with the beginning of the pandemic. Challenges have also been brought up as these plastics are rarely recycled, and the treatment would also increase the environmental footprints as incineration is still the dominant method for medical waste treatment. The pandemic has also been causing challenges to the energy supply and distribution with as the large-scale and intermittent lockdown. Jiang et al. (2021) discussed the challenges and potentials in energy demand and consumption during the COVID-19. The instability of the energy demand and energy consumption intensity during the pandemic has been one of the major issues for the energy generation and distribution system and requires a more systematic and resilient scheduling scheme in the future.

As another one of the most important environmental elements, water has also been facing new challenges brought by the pandemic. Water scarcity caused by the quantitative shortage and qualitative degradation has been increasingly severe in various regions globally. The influence of the pandemic has been diverse with both positive and negative in the water sector. For example, the limitation on mobility and large-scale lockdown could reduce industrial water consumption and pollution generation, and the lifestyle change could shift the sector water consumption patterns (Li et al., 2021). In addition to the direct impact, the indirect impact, caused by changes in energy consumption patterns, industrial production, international trade, as well as lifestyle would also affect the water sector in the long term. This review provides attempts to provide an overview of the current studies in order to provide insightful information and suggestions to improve water management and reduce the

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water-related environmental footprints. The review aims to remark the importance of the water-related countermeasures and to gain experience in water management during a pandemic.

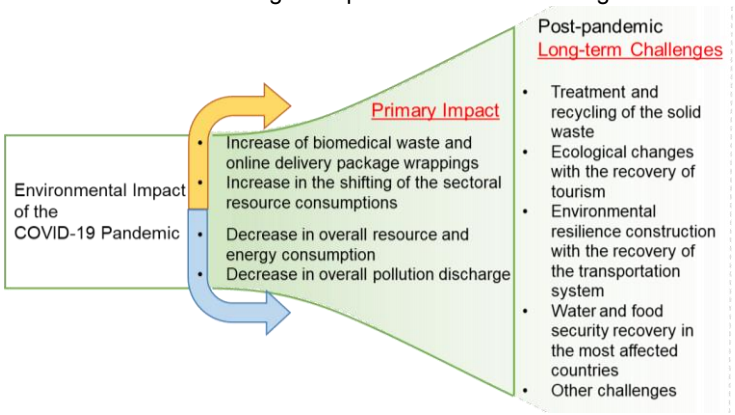

Figure 1: The primary and long-term environmental impacts of the COVID-19 (developed by the authors based on the general review)

2. Review method

This review mainly covers analytical and review studies of the water environmental impact of the COVID-19 on various scales. Searching in Scopus with the Keywords “Water” & “COVID-19” or “SARS-Cov-2”, with the time period from 2019 to 2021, 1,495 documents are found. As the review aims to investigate the environmental impact of the pandemic, subject areas such as “Medicine”, “Pharmacology, Toxicology and Pharmaceutics”, “Immunology and Microbiology”, “Biochemistry, Genetics and Molecular Biology” etc. are excluded. Document types are limited to Article and Review published in English, 415 documents are found. To select the articles under the aimed scope, a screening selection is then carried out by reading the articles title, keywords, and abstract, and a final 54 articles remained for this review. Among the selected articles, 33 are original research and 21 are review and overview articles, 21 were published in 2020 and 33 were published (or article in press) in 2021. The analytical review has been presented in the following sections.

3. Literature review

The bibliography characteristics, i.e. in this study, the number of authors by countries are analysed together with the COVID-19 infection cases. Then, the research scopes, research scale, as well as the research methods used in the selected 54 papers are analysed and discussed.

3.1 Bibliography characteristics

Figure 2 presents the number of authors by countries with the comparisons of the ranking of the countries by the total number of infected cases until 21 May 2021 (Worldometers, 2021). The authors of the selected 54 articles are from a total of 114 countries. Figure 2 shows the 20 countries with at least two authors.

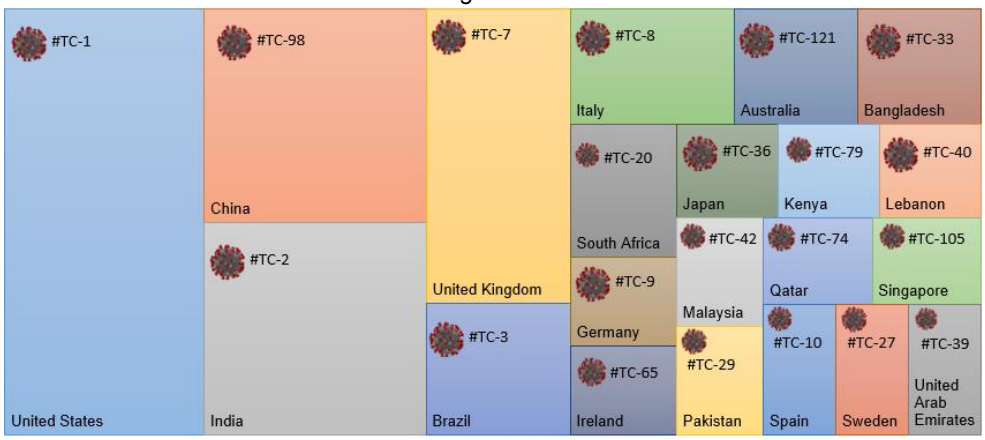

Figure 2: Number of authors by countries and the rank of total cases (#TC-) infected with COVID-19 (ranking data from Worldometers, accessed 21.5.2021)

It showed that the number of publications investigating the impact of COVID-19 on the water sector has a considerable correlation with the infected case numbers. Within the top 10 countries with the most contribution to water impact of COVID-19 studies (18 authors), seven of which are within the top 10 countries with the most number of total infected cases. For example, most of the publications under the topic of the impact of COVID-19 on the water sectors comes from the United States, which is ranking the No. 1 by total infected cases. India and the United Kingdom (UK) ranks No. 2 and No. 7 by total cases, with the number of contributing authors of 10 and 9. Following is Brazil and Italy, each with four contributing authors and ranks within the top 10 by total infected cases. Other countries with less number of contributing authors also rank lower with total infected cases. China is an exceptional case with a lower ranking in total infected cases, but a higher number of contributing authors (10), which is possibly due to that China is one of the countries where experienced a serious hit by the coronavirus, and the total number of academic researchers in China. In the selected 54 articles, no contributing authors are from France, Turkey, and the Russian Federation (Russia), which are ranking No. 4, 5, and 6 by total infected cases.
Overall, the contributing authors to the selected publications show a considerable positive correlation with the total number of infected cases. This indicates that COVID-19 did affect the water sectors to a remarkable extent, and academia has been making an effort to investigate these impacts to search for solutions.

3.2 Research trend in scope, scale and methods

After the analysis of bibliographical features, the authors carefully studied the abstracts and full texts of the selected 54 articles and analysed and discussed the detailed research scopes, sub-scopes, research scale of these studies (Figure 3).

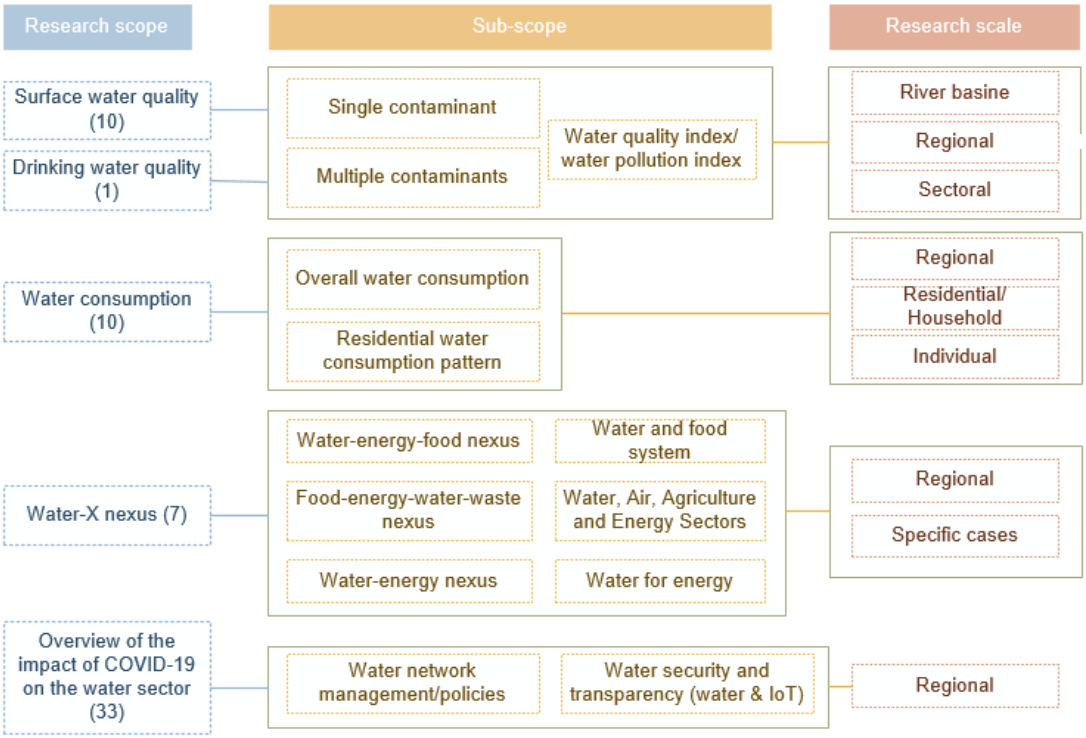

Figure 3: Trend of research scope and scales of the reviewed article (Note: the number in brackets is the number of articles, the numbers may overlap among different scopes)

Among the selected articles, 13 are reviews, 8 are overviews, and 33 are original research. Five major research scopes have been identified, including the COVID-19's impact on surface water quality, residential water quality, water consumption (quantity), water-related nexus, and the general overviews of the impacts of the pandemic on the water sectors. Within original research studies, most of the studies (8 articles) are investigating the surface water quality changes during the pandemic lockdown. In terms of research scale, these studies vary from individual, specific case, residential/household, sectoral, river basin, to large scale regional studies.
Some of these studies cover single contaminant, such as chlorine (García-Ávila et al., 2021), dissolved organic nitrogen (DON) (Wang et al., 2021), and suspended particulate matter (Yunus et al., 2020). More studies consider certain multiple types of contaminants or using the water quality indicators such as Water Quality Index

(WOI) or Water Pollution Index (WPI). For example, Cecchi (2021) investigated the COVID-19 lockdown impact on microplastics and mass tourism-related pollutants (such as Volatile organic compound, VOC) in Venice lagoon water. Their results showed that 17 types of VOC contaminants became not detectable, and the amount of many other contaminants also dropped after the lockdown period (since March 2020), and the lockdown restrictions also lead to a sharp drop of seawater contaminants. Pant et al. (2021) analysed the surface water quality of a river basin in Nepal, considering multiple water quality parameters, including the water temperature, pH, electrical conductivity, total dissolved solids, dissolved oxygen (DO), major ions, total hardness, biological oxygen demand (BOD), and chemical oxygen demand (COD), etc. The results showed that with limiting anthropic activities, the water quality in the Bagmati river basin had experienced a remarkable recovery during the lockdown. Similar remarks have also been concluded by other surface water quality studies using WQI or WPI. Najah et al. (2021) determined the impact of the lockdown on the WQI of selected rivers in Malaysia, and the major observations showed that noticeable enhancements of varying degrees in the WQI in the two investigated rivers. There is a significant increase in the WQI Class I (cleanest), from 24 % in February 2020 to 94 % during the lockdown month of March 2020 in Putrajaya Lake. According to Patel et al. (2020), the WQI of Delhi has a significant increase of 37 % during the lockdown. The water pollution parameters also declined notably within most river stretches, and the partial/non-operational status of most industries during the lockdown also enabled a significant reduction in effluent loads in the studied river. Apart from surface water qualities, the quality of residential water supply/discharge has also been discussed as it's closely related to human health. Quinete and Hauser-Davis (2021) presented an analytical review on the pollutants in drinking water, such as metals, plastic components, plasticisers, per- and polyfluoroalkyl substances, and pointed out that these pollutants might potentially exacerbate the COVID-19 infection symptoms.

The large-scale lockdown limits human mobility, industrial production, and international trades, and precipitate the emerging development of e-commerce. These changes have been reshaping the water demand and consumption patterns. Washing hands has become one of the new habits since the pandemic. Sayeed et al. (2021) carried out a web-based survey tool with 1,980 participants and an experiment on 126 participants to estimate the overuse of water during hand scrubbing while the tap is on. The results showed that 80 % of the participants washed their hands regularly after returning home from outside, and 57.3 % of participants keep the tap on throughout the handwashing process. It is estimated that for the participant who kept his tap on throughout the handwashing process, overused approximately 1.7 L of water per hand wash (14.9 L of water per day). Home office has also become a common approach to practice isolation. Abu-Bakar et al. (2021) claimed that the lifestyle changes had led household water consumption to an all-time high in the south and east regions of England, and another major finding is that households' internal leakage constitutes about 10 % of the total network water consumption, which requires extra attention. Another study (Li et al., 2021) estimated since the pandemic, the urban water use in California's dropped by 7.9 %, which was largely attributed to an 11.2 % decrease in the commercial, industrial, and institutional sector that more than offset a 1.4 % increase in the residential sector.

Water-related nexus has also been investigated to provide a systematic perspective of the environmental impacts of the pandemic. Al-Saidi and Hussein (2021) presented a holistic assessment of the implications of COVID-19 on the water-energy-food (WEF) nexus, and concluded that the increased medicalization and hygienation requires more water and waste treatment and embedded energy consumption, and the relocalisation of production might to increase tendencies for local food production and increase the agricultural water and energy demand. In addition, the fluctuations in water demand can also cause uncertainties to the water-energy nexus, such as water for cooling or energy for water production, etc. As a specific case, Yan et al. (2021) proposed and determined the performance of a localized steam sterilization applications with the air source heat pump and water vapour compressor during the COVID-19 pandemic. Roidt et al. (2020) investigated the changes in the water footprint and virtual water trade of thermal power generation in Europe. It is estimated that compared with the average of the past four years, the consumptive water footprint of thermal power plant operations in Europe decreased by 1.77 Mm^3/d during the COVID-19 lockdowns. The electricity demand/consumption reduction accounts for 16 % of the total decrease. Due to the reduction of international trade, the electricity-related virtual water import in Italy reduced by 70,700 m^3/d, and Germany and France slightly reduced their domestic water footprint of electricity but increased their virtual water imports.

Overall, the large-scale behaviour and technological changes have been reshaping the water-energy-food nexus, and the interlinkages with GHG emissions, waste management, etc. It is critical to note that the transition toward less water-intensive power generation technologies should be the major direction before and after the lockdown. Other research topics such as water reliability (Parsa, 2021), water transparency (Braga et al., 2020), the digitalisation of water networks (Poch et al., 2020), as well as the integration of water network with the Internet of Things (IoT) during the pandemic have also been discussed. These studies point out an important direction for the future development of smart water systems in the post-pandemic period.

3.3 Classification of the impacts

This section summarises the identified primary impacts of the COVID-19 on the water sector and discusses the potential long-term impacts of the pandemic, which has not been well addressed in the existing studies

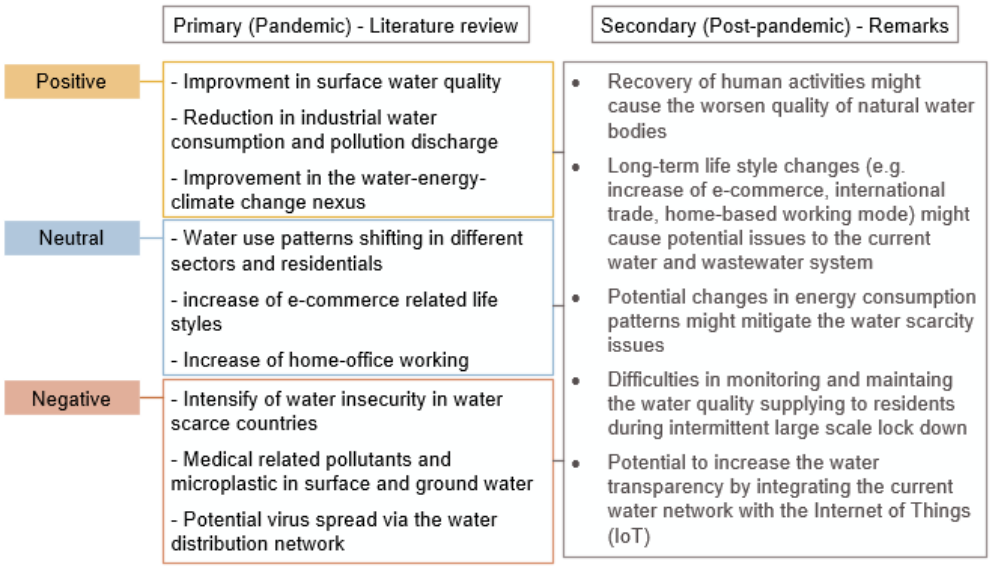

Figure 4: primary and long-term impacts of the COVID-19 pandemic on the water sector

Figure 4 shows the primary and long-term impacts of the COVID-19 pandemic on the water sector. Various studies have claimed the positive impact of the pandemic on the water sector, the major one being the improvement in surface water quality due to the reduction of anthropic activities during the lockdown. Another positive impact is that the periodical/long-term non-operation of some industries reduced the pollutant discharge to not only water but also air. The pollution reduction also elevates the water-energy-climate change nexus. Medical waste and related micro-plastic pollutants pose challenges to drinking water treatment. When not treated properly, water can be easily a medium for virus spreading.

Some impacts, such as the changes in water use pattern shifting, the increase of e-commerce and related lifestyle and home-office working, do not have an obvious positive or negative impact on the water sector, but these impacts may be revealed in the post-pandemic era. This study also remarks the potential long-term (secondary) impacts of the pandemic on the water sector. Firstly, with the relaxation of COVID-19 restrictions, people are eager to return to the previous lifestyle and industries to recover the production, which means the mobility and traffic is possible to increase sharply. This might cause the worse of surface water quality due to tourism and industrial discharges. Some changes caused by the pandemic might become the “new normal”, such the emerging development of e-commerce in Eastern and Central Europe. With food and grocery delivery services and home-office as the typical examples, these changes might cause potential issues in water supply and wastewater treatment. The issues arising in the water sector might also pose challenges to the water-related nexuses. On top of these challenges, new potentials are the promotion of digitalisation of the water sectors, and the integration of water with IoT. These potential future development directions could enable the systematic monitoring of the water quality and quantity and facilitate smart water management.

4. Conclusions

This study provides a review of the studies investigating the impact of the COVID-19 pandemic on the water sectors. Based on the literature collected by keyword searching, a strict selection based on abstract and full-text reading remains 54 articles for detailed review and analysis. The major conclusions of the review are: i) There is a positive correlation between the number of total cases and the number of contributing authors of the selected water-COVID-19 studies; ii) Surface water quality is the most studied impact of the pandemic, and a positive impact has been posed on the betterment of surface water qualities and the water-related nexus; iii) Water consumption pattern shifts in different sectors. Implications for future studies include i) the follow-up investigation of the post-pandemic impact on the water sectors, ii) improvement of digitalisation of the water sectors, and iii) increase of the integration with the Internet of Things by constructing smart water network.

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