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Indirect effects of Covid-19 on water quality

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A B S T R A C T

The provision of safe water and functioning waste management play key roles in preventing and combating disease outbreaks such as the Covid-19 pandemic. Good water quality is needed for effective hygiene measures like washing hands as well as for lowering pathogen transmission. Almost all over the world, especially in developing countries, water is vulnerable and at high risk and surging insecurity with time. Effective water management, sanitation, and hygiene help to protect lives during the global COVID-19 pandemic. While sanitation and hygiene also disturb the quality and increase water consumption per capita to 40% comparatively and wastewater production in many developing countries. This rapid increase in water consumption puts direct pressure on water reservoirs and inadequate management of wastewater is also a serious threat to waterways, nowadays. Similarly, the quality of water bodies is significantly affected by the COVID-19 pandemic, but the risk of transmission of COVID-19 through sewage systems is recorded as low. Hence, the current review paper aims to highlight the main concerns directly linked with the frequent usage of detergents/soaps and alcohol-based hand sanitizers on water quality and the post-pandemic handwashing habits to overcome the COVID-19 spread also threatening the water reserve reservoirs via water high consumption along with more wastewater production with less water reuse efficiency and collectively the pressure on drinking water facilities. This review also focuses on the indirect influence of COVID-19 on water quality through technical interventions among COVID-19, water pollution; soaps/detergents, and hand sanitizer and the complete water management plan for water security and safety from policymakers to end users after the viral revolution briefly.

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1. Introduction

Water quality is a major challenge for humankind in the twenty-first century. On one hand, water is viewed as the most fundamental of natural resources that is imperative for human existence, while on another hand, human activities present serious dangers to freshwater systems around the globe (Ebenstein, 2012). Presently, anthropogenic contamination of freshwater is a great concern for the world (Mallin, 2000; Rashid et al., 2013). The unnecessary utilization of water for different activities like industrialization and urbanization amplifies human access to water but frequently hinders access to drinking water, with conceivably serious but un-quantified costs (Britto et al., 2019).

The water quality concerns for under-developed countries are aggravated due to unplanned and vigorous urbanization. The unorganized development of major urban areas has huge pressure on groundwater. This causes unsanitary conditions which undermine the health of urban inhabitants (Rahman et al., 2018). Although the
water quality is disturbed by several reasons, however, water shortage, pollution brought about by the utilization pattern and the absence of effective wastewater treatment systems are viewed as the fundamental driver of water pollution. As per United Nations proposals, the subsequent twenty years will bring serious challenges to water quality as well as quantity, especially in South Asian countries (Villholth, 2006). Different reports on a global level concluded that the water quality of urban areas specifically highly intense areas has serious consequences for living healthy. The negative effects of contaminated water on health are generally recognized nowadays (Ashraf et al., 2010; Khan et al., 2013; Machdar et al., 2013). As stated by the WHO database, water-borne illnesses are at the top in the overall communicable disease episodes (Brown and Murray, 2013).

Water pollutants occur due to two main sources i.e point or dispersed sources. A point source pollutant is due to a single and identifiable source, for example, an out-fall pipe or sewage discharge. Dispersed sources are wide, un-confined areas from which pollutants enter a waterway. Surface run-off from ranches is a dispersed source of contamination, adding manures, herbicides/pesticides, and sediments into nearby streams. Metropolitan water waste may convey sand and other lumpy materials, oil deposits from autos, and road synthetic compounds are considered dispersed source because it joins the neighboring lakes and rivers at various points. It is easier to control point source pollution than dispersed because the source of point pollutants is known where treatment protocols can be installed to avoid causing pollution. Such control measures are not generally applicable to dispersed source pollution. General water pollutant types include plant nutrients, pathogenic organisms, oxygen-demanding squanders, inorganic chemicals, synthetic organic chemicals, sediments, microplastics, radioactive substances, heat, and oil.

Hand washing is regularly viewed as a significant factor to prevent contact transmission of microbes and fecal-oral (Boyce and Pittet, 2002). Hand hygiene is a significant helpful practice and it has been perceived to be an advantageous, successful, and practical method for forestalling contagious diseases (Tao et al., 2013). Throughout the COVID-19 outbreak, continuous handwashing with a cleanser was considered quite possible and the best activity to decrease the infection spread (Organization, 2019). UNICEF and WHO also suggested switching the faucet/tap off while at the same time washing hands with a cleanser and scouring for at least 20 seconds to forestall the water loss (Park et al., 2010). The 2014–16 Ebola outbreak in West Africa also increased the demand for clean water for treatment and prevention. Keeping in view the COVID-19 outbreak, the practice of handwashing increased many times as compared to routine practice before the pandemic. During this COVID-19 outbreak, 20 to 30% of tap water used increased for handwashing in India (Rohilla, 2020). Similarly, Jordan Water Sector officially mentioned that the 40% water demand increased after the lockdown with the strict order to stay at home because handwashing activities suddenly enhanced the water used (Cheval et al., 2020). A sum of 80% of the members washed their hands routinely after getting back from outside. About 57.27% of members for the most part did not turn off their tap when washing their hands. A single member, who keeps his tap on all through the handwashing cycle, squandered roughly 1.7 L of water per handwash and 14.9 L of water every day. Handwashing increased thirteen-fold in freshwater locals during this pandemic.

The circular water economy is the business model that aims to reuse non-conventional water as an alternative water source for various purposes, while extracting valuable resources from non-conventional water to realize sustainable production and consumption (Fig. 1) (Pieroni et al., 2021). From the perspective of integrated water resource management, the beneficial reuse of non-conventional water deserves attention as a route toward sustainable water supply (Hussain et al., 2019). Non-conventional water (as shown in Fig. 2) comes from seawater, stormwater, agricultural drainage, thermolectric cooling water, hydraulic fracturing water, industrial processed (waste) water, domestic wastewater, and commercial discharges (e.g., hot spring discharge). The massive amount of non-conventional water provides a promising opportunity to meet the demand for water as we head toward a new era of urbanization. Several countries have started to reuse treated wastewater for crop growing, especially in those areas facing severe water shortages, such as Egypt (El-Kady and El-Shibini, 2001), Jordan (Abu-Sharar et al., 2003), Tunisia (Haddaoui et al., 2017), Turkey (Kanber et al., 2005), and Saudi Arabia (Qadir et al., 2007).

Already, the water restores are under pressure due to the blind use of water which ultimately increased the water demand. Handwashing is one of the imperative civic health measures to forestall the COVID-19 pandemic from the spread. However, loss of water from extreme handwashing may squeeze the generally over-stretched groundwater resources and family units’ financial well-being. Additionally, the present circumstance of COVID-19 deteriorating and drying the water reservoir exponentially. Thus, excess water loss during the washing of hands during the pandemic of COVID-19 is a new hot issue, but no such evaluation studies, reports, or data are available that evaluate the relationship between loss of water during washing hands. Therefore, this investigation was planned to evaluate the loss of water during handwashing amid the COVID-19 pandemic with an accentuation on the misuse of groundwater from fundamental cleanliness activities at a homegrown scale. Thus, this study deliberates on the indirect effect of COVID-19 outbursts on water losses due to the specified practices of handwashing. Secondly, the main focus of the current study is the post-pandemic responses and environmental changes, which ultimately affected the personnel habits and proceedings after the COVID-19 pandemic so this article will critically address the unpredicted outcomes (i.e., high wastewater production, the wastewater composition, and limited natural reserves of water) along with their management practices from producer to policymakers and end users level.

1.1. Impact of adequate quality water on the COVID-19 pandemic

To suppress and quell the spread of pandemics, Covid-19, a standard and continuous supply of satisfactory water quality is indispensable. Despite the fact, that water quality has rapidly deteriorated at the anticipated rate. A tremendous increase in water pollution has been noticed in all waterways in Latin America, Africa, and Asia. The reasons behind the excessive contamination of both surface as well as groundwater are industrial wastes discharges, sewerage, agrochemicals, and human wastes. Because of excessive pollution human has lost many valuable freshwater resources most importantly the Nairobi River in Kenya. Studies have revealed that maximum pollution is caused by developing countries due to their high financial growth, industrialization, populace development, and poor wastewater administration system (WWAP, 2017). Climate change also adversely affects water quality in many ways. Besides that, the management of solid wastes is an important issue in developing countries. A study revealed that only 40% to 50% of waste is collected across South Africa (Grau Satorras, 2017). The uncontrolled dumping sites and poor management of solid wastes are posing some serious biohazard dangers. These
solid wastes hinder the wastewater treatment services and the self-refining capability of freshwater resources (WWAP, 2017). Proper attention should be paid to evaluating the impact of pharmaceutical and other medical wastes on water resources. Lack of access to infrastructure and poor sanitation services negatively affect public well-being (Rodriguez et al., 2020). Poor administration and management of sanitation services result in pollution of surface as well as groundwater (Satterthwaite et al., 2019). Similarly, a surge is also highly reported in waterways contamination after the COVID-19 pandemic in terms of patient treatments and safety measures of handwashing practices, which directly changes the nature of water pollution and threatens the biosafety hazards to these waterways. (So, we are attempting to be aware of the main causes and their management through this article).

1.2. Reduction of COVID-19 severity through affordable access to WASH

Finance is a significant task for spreading admittance to services, between 2015 and 2030, approximately US$114 billion will be needed each year to achieve the WASH access of SDG 6. In the long-standing, urban areas ought to stretch out access to dependable and inexpensive piped water to the plot or home, with temporary measures including support-expanded entrances to controlled booths and water points. Stretching out admittance to piped water includes addressing reasons for the discontinuous supply of water, different methodologies to make water progressively moderate with unique contemplations for low-pay patrons, and supporting the promotion of casual settlement (Mitlin et al., 2019). It will also include planning information, increased maintenance investment, water infrastructure, and good authority. Short-term measures for example low-pay patron upload units can upsurge admittance to the outdoor plot or home. Digital devices, for example, smart meters can assist to uphold service delivery and guarantee sustainable water admittance for patrons. The volume of buildings and use of digital equipment usage can upsurge the maintainability of service delivery administrations that frequently have issues with non-revenue water, cost retrieval, and low revenue collection.

1.3. Water plays a major role in the prevention and pandemic suppression

The delivery of hygienic, safe water and sanitation conditions is fundamental to ensuring human well-being in the course of all contagious disease outbursts, including Covid-19 outbursts (Organization, 2019). On the other hand, across emerging countries admittance to WASH is imperfect. For instance, three billion individuals lack essential facilities for handwashing (Organization, 2019). This makes several difficulties for fighting Covid-19 passing on and forestalling/smothering forthcoming possible pandemics. Underdeveloped water supply and waste management systems are some of the important factors that contributed to the spread of the Ebola epidemic in 2013–16 and are recognized as the primary factor which cause a huge number of deaths during the outbreak (Kalra et al., 2014). Living in temporary settlements, the poorest and marginalized could be predominantly susceptible as they frequently depend on collective water points and lavatories, private merchants, and water tankers. Large water expenses and constrained access could forbid liberal utilization of H2O for hand-washing, whereas expecting to venture out from the home to get mutual facilities and lining for access in closeness to others makes social distancing and self-isolation hard to execute (Ezeh et al., 2020). It also makes lockdowns unfeasible. Constrained family financial plans may also imply that buying a cleanser or hand sanitizer is not a family unit need. Mid-term measures should be adopted to track the rapid WASH response to enhance water safety. The rapid water-related reactions to the Covid-19 pandemic have focused on the establishment of universal handwashing stations in temporary shelters. Donor programs, for example, a campaign of DFID with Unilever's goals of reaching $1 billion through hand-washing crusades and soap; in collaboration with government and water companies to connect household units with water supplies system, and guaranteeing chemicals supplies of water treatment; and, scaling up access to WASH in medicinal services settings. Planning for future pandemics will require economical supplies of satisfactory quality water. This will include supporting supply, storage, and treatment solutions, and management of robust water along with expanding moderate and feasible access to WASH. There are massive consequences for public health if we don't discourse evenhanded water access (Elambo et al., 2020). Access to WASH should be situated in the more extensive setting of expanding, possibly contending, water requests from various parts because of the scope of climate change and human drivers. Inquiries of where water is going to originate from to help public health, how it ought to be figured out, how to guarantee maintainable supplies and sufficient quality, and how to make it moderate, should be addressed critically.
1.4. Survival time of different coronavirus strains in water and other mediums

The water treatment system of surface, as well as groundwater, has severe chances of getting contaminated with SARS-CoV-2 from the discharge of sewerage water or improper disinfection at the wastewater treatment system of the excretion from an already infected person nearby. The facial-oral or waterborne dissemination of viruses is a challenging issue that is increasingly reported in areas with poor sanitation systems and where people have very rare excess to good quality water (Yeo et al., 2020). Furthermore, it has been reported that 4.2 billion people worldwide lack a proper sanitation system, approximately 884 million people have no access to fresh water and 1.8 billion people are using faecal contaminated water for drinking purposes, which can be a huge risk to upsurge the COVID-19 outbreak more severe shortly (Naidoo, 2020). However, there is no such evidence of the dissemination of novel coronavirus through drinking water. It can be said that with proper precautions the risk of dissemination of coronavirus through drinking water is low (Bhowmick et al., 2020). Different researchers have investigated the survival time of different surrogates of coronaviruses. They revealed that they may survive and remain infectious in contaminated water for weeks (Rabenau et al., 2005). Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV) remains infectious in sputum, serum, and faecal samples for more than 4 days and not for not less than 3 days in urine (Duan et al., 2003). Wang et al., 2005 found that SARS-CoV can survive in dechlorinated tap water (DTW), hospital water (HW), and sewage (DW) for 2 days. While in faecal matter, PBS and urine for 3, 14, and 17 days at 20 °C respectively. The survival time and temperature of other CoV strains such as transmissible gastroenteritis virus (TGEV), feline infectious peritonitis virus (FIPV), severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), mouse hepatitis virus (MHV), and human coronavirus (HCV) is represented in Table 1. These findings clarify the importance of incubation time and temperature in minimizing or inactivation of viruses in water distribution systems. The data in Table 1 is corroborated with the previous research conducted on the survival time of viruses in the aqueous medium. Therefore, the transmission of airborne viruses in the long term and survival of the virus in an aqueous medium could be a serious risk of spreading the Covid-19 outbreak if not properly managed.

1.5. Importance of wastewater analysis during COVID-19 lockdown

COVID-19 belongs to a virus pathogenic family name Coronavirus (CoVs) which causes different kinds of viral diseases in humans and animals which are associated with respiratory diseases (Channappanavar and Perlman, 2017). However, the novel Coronavirus named COVID-19 emerged in early 2020 is considered a severe acute type of CoVs.

Monitoring of wastewater has been considered a successful approach to identify human activities such as the regional consumption demand by humans increased during the outbreak for a healthy community. For instance, the request for pure water augmented in course of the Ebola 2014 outburst in West Africa. Improved requests for household water and H₂O for human services settings could cause trade-offs both upstream (in contending requests for provisions from agriculture and other zones) and downstream (in the production of wastewater) (Ezeh et al., 2020). Redirecting H₂O from farming for usage in metropolises could impact the production of food, whereas keeping up water for farming could imply that urban areas do not have satisfactory supplies to battle outbursts. This situation would happen in a setting where interest in H₂O is now becoming because of drivers including populace development, urbanization, and varying patterns of consumption. Worldwide interest in water is expanding at a rate of 1% yearly also will keep on developing altogether, the largest use of water is in agriculture production (WWAP, 2017). Water reservoirs in Africa including a large number of water channels are squeezing due to both deforestation and climate change with suggestions for both quality and supply of water (Cooper, 2020). Climate change is modifying the worldwide water cycle bringing about expanded fluctuation and affecting the availability of water. This incorporates a varying pattern of rainfall, faster melting in glaciers, varying flow of the river, and anticipated increments in both water shortage and water pressure (Smith et al., 2014).

2. Strategies to improve the water status during pandemics

2.1. Adequate water availability

Fighting and handling epidemics need H₂O, globally water consumption demand by humans increased during the outbreak for a healthy community. For instance, the request for pure water augmented in course of the Ebola 2014 outburst in West Africa. Improved requests for household water and H₂O for human services settings could cause trade-offs both upstream (in contending requests for provisions from agriculture and other zones) and downstream (in the production of wastewater) (Ezeh et al., 2020). Redirecting H₂O from farming for usage in metropolises could impact the production of food, whereas keeping up water for farming could imply that urban areas do not have satisfactory supplies to battle outbursts. This situation would happen in a setting where interest in H₂O is now becoming because of drivers including populace development, urbanization, and varying patterns of consumption. Worldwide interest in water is expanding at a rate of 1% yearly also will keep on developing altogether, the largest use of water is in agriculture production (WWAP, 2017). Water reservoirs in Africa including a large number of water channels are squeezing due to both deforestation and climate change with suggestions for both quality and supply of water (Cooper, 2020). Climate change is modifying the worldwide water cycle bringing about expanded fluctuation and affecting the availability of water. This incorporates a varying pattern of rainfall, faster melting in glaciers, varying flow of the river, and anticipated increments in both water shortage and water pressure (Smith et al., 2014).

2.2. Nature-based solutions (NBS)

NBS could enhance the supply and storage of H₂O by expanding the availability of water for a variety of human activities. The use of natural procedures or NBS treatment of water increases the security and safety of the water. Securing, restoring, and upgrading natural procedures in both artificial and natural ecosystems would expand the amount of available H₂O (WWAP, 2017). For instance, increasing wetlands, reestablishment of forests and coastal mangroves, water-shed reclamation, conservation of forests, and upgrading groundwater reservoirs ensure water security. According to a report, a preliminary examination of the Maas Forest complex (a water tower) in Kenya between 2012 and 2016 found that the forests provide clean water and filtered water through waterways from agrarian land, along withreviving the aquifer water level which meets the safety of fresh water (Jacobs et al., 2016). Serious activities in ecosystems influence hydrology, for instance, trees can upsurge or reduce the recharge of groundwater contingent upon their size type, age, location, and density (WWAP,
Table 1

| Coronavirus | Drinking water/tap water | Natural water body | Sewage/wastewater | Regent grade water | Serum | Sputum | Seawater | Urine | References |
|-------------|--------------------------|--------------------|-------------------|-------------------|-------|--------|----------|-------|-------------|
| TGEV        | NA                       | ~13 days (at 25°C, T99) | ~10 days (at 23°C, T99.9) | ~56 days (at 4°C, T99.9) | NA    | NA     | NA       | NA    | (Casanova et al., 2009) |
| MHV         | ~25 days (at 25°C, T99); 7 days (at 25°C, T99.9) | 10 days (at 25°C, T99) | 2–3 days (at 23°C, T99.9) | 2 days (at 18°C, T99.9); 10 days (at 4°C, T99.9) | NA    | NA     | NA       | NA    | (Casanova et al., 2009) |
| HCoV        | NA                       | ~13 days (at 37°C, T99.9); 2–3 days (at 23°C, T99.9) | 2 days (at 37°C, T99.9); 10 days (at 4°C, T99.9) | ~56 days (at 4°C, T99.9) | NA    | NA     | NA       | NA    | (Casanova et al., 2009) |
| SARS-COV    | ~56 days (at 4°C, T99.9) | 10 days (at 4°C, T99.9) | 3 days (at 4°C, T99.9) | ~56 days (at 4°C, T99.9) | NA    | NA     | NA       | NA    | (Casanova et al., 2009) |
| SAR-CoV-2   | ~56 days (at 4°C, T99.9) | ~56 days (at 4°C, T99.9) | ~56 days (at 4°C, T99.9) | ~56 days (at 4°C, T99.9) | NA    | NA     | NA       | NA    | (Casanova et al., 2009) |

References:
- (Casanova et al., 2009)
- (Gundy et al., 2009; Wang et al., 2005)
- (Everard et al., 2021)
- (Hoekstra, 2016)
- (WWAP, 2017)

2.3. Protection and restoration watersheds

Protection and restoration of the watershed through upgraded management of land can upsurge water security of urban and rural communities. The resilience of urban water frequently relies upon the upstream of watersheds which are already under pressure from the native public community (Cooper, 2020). Human activities including land usage change and deforestation can contrarily influence the quality and quantity of water downstream. This can promptly intensify urban flooding, decreased the availability of good quality water for urban communities, and increased the demand and treatment costs for city water (WWAP, 2017). Therefore, the protection and restoration of wetlands during the days of the pandemic are important to ensure water security in the country.

2.4. Combining green and gray infrastructure

The combination of green and grey infrastructure may ensure the supply and storage, produce vigorous services and enhance the system performance. For example, the life of reservoirs increases with the application of the green framework to manage corrosion, (Everard et al., 2021). Green infrastructure strategically exalts or reestablish the components of a natural framework such as agricultural land, riparian, woodland, and floodplain zones (Browder et al., 2019). Application of grey and green infrastructure perceives that enhance the performance of ecological systems and watersheds that are influenced by the water qualities. Green infrastructure could be implanted in rural as well as urban zones. In urban regions, green infrastructure such as botanical gardens would reduce the possibility of flooding and ultimately enhance water quality. Sand dams and other water-storing approaches help in increased water supply, enhance living standards, and minimize the possibility of conflict occurrence among clients (Mekonnen and Hoekstra, 2016).

2.5. Groundwater

The proper management of groundwater also reduces water hazards and enhances water protection. Strategies such as proper management of soil to inspect the percolation and storage of rainwater can be used in the time of need (WWAP, 2017). The cautious management of ground, as well as surface water, would magnify the ability to cope with drought and water shortage. Managed aquifer recharge (MAR) is executed in Nambia to curb drought, and climate change and control the urban water supply (Murray et al., 2018). In India, the Underground Taming of Floods for Irrigation (UTFI) program was launched to maintain the groundwater table by harvesting water in the wet season minimizing the impact of floods and storing water from catchments which mitigates the effect of drought the recharged groundwater table is then used for a vast range of necessities including irrigation. This program was enrolled with Mahatma Gandhi Rural Employment Scheme which attracts the local communities to take interest and were compensated (Haupt and Lerch, 2018). Groundwater is a large valuable asset, however, excessive misuse and exhaustion have brought this valuable asset under high pressure. For example,
Lahore, the 2 most populous city in Pakistan, totally depends on groundwater. The exhaustive approach toward groundwater with almost negligible reviving of groundwater has brought the groundwater table under tremendous pressure, which is declining up to one meter per annum this will, ultimately, cause saline water interruption more quickly (Cooper, 2018). The establishment of a proper database that shall keep a record of groundwater accessibility and exhaustion is the need of the hour (Grau Satorras, 2017). A valid record of groundwater provides the basis for making decisions and carrying discussions about the availability of water and warily managing the use of available water distribution among different sectors.

2.6. Wastewater

The treatment of wastewater for reuse can be an extra source of available water, while the recuperation of resources from treating the wastewater may contribute to the cleanliness frameworks and enhance the utilities of water (Raza, 2021). In developing countries, cities are developing into a more modern form with centering different approaches for further improvements to minimize the injudicious use of the already available resources while focusing on the recuperation of resources (Syed, 2022). Different valuable resources such as reusable water, nutrients, and energy can be generated from wastewater. These can also be a source of generating revenues which can be used to uphill the activities. Accepting circular principles of economy in the treatment of wastewater can help shift from an expensive approach to a self-continuing approach and enhance the economy. These services might be run properly, well-structured, and planned, and must function proficiently to achieve the goal. Shifting from an isolated approach to treating wastewater such as one treatment plant for every region to a vast management strategy such as a covering river basin approach could be a rapidly progressively feasible and tough framework. Reusing wastewater with no proper treatment approaches results in serious health and ecological issues (Rodriguez et al., 2020). Reusing treated wastewater can be helpful to mitigate the rivalry among the water usage zones by providing them with extra water.

2.7. Urban sanitation and sewers

Sanitation services should be made inexpensive and should be brought within the reach of the common man for the well-being of the community. Proper sanitation demands expenses that are not within the reach of below-average class families. A simple lavatory and a septic tank can cost 50 to 70% of a below-average family's total monthly income. A proper focus should be paid to subsidizing the expenses of sanitation for poor families. Subsidizing the public sewer connections and subsidizing the expenses of proper management of cleanliness, transporting and safe disposal of solid wastes, and proper treatment and reuse system for the wastewater (Satterthwaite et al., 2019). The new trends in sanitation infrastructure such as waterless lavatories and container-centered cleanliness services should be considered. In rural areas of Thekwini municipality, South Africa, where more than 85,000 urine diversion dry toilets (UDDTs) have been installed, where the masses have poor socio-economic conditions the majority of them cannot afford a private septic tank and were not connected to the sewerage system (Mkhize et al., 2017). The container-based sanitation (CBS) services can be a better option for both families and public lavatories, service supplier provides a latrine with an extra compartment that can be transported from one place to another securely (Bank, 2019). In urban areas where not enough space in streets to construct proper sanitation and sewerage systems, CBS services can be adopted as an effective and secure means of sanitation. Administrative authorities in urban areas should look for modern ways of sanitation and abandon practices like pit toilets and dumping human wastes in nearby streams to avoid public health risks. Enhancing the administrative capacity of feeble administrative services in urban communities to guarantee proper sanitation and sewerage services. The whole chain of sanitation must be solid, properly covered, and reasonable. A massive sewerage system should be constructed which must be within the reach of family units, and public and open latrines linked to the main system. Sanitation services on a community or city basis require a continuous supply of water and capital investment to work properly (Satterthwaite et al., 2019). Broaden sewerage systems and developing wastewater treatment plants guarantee adequate cleanliness citywide particularly in casual settlements (Bank, 2019); simplified sewerage system which is within reach of more people might be more efficient in densely populated areas (Manga et al., 2020). As the effect of climate change in terms of water, scarcity is to be felt worldwide there for grey infrastructure solutions for sanitation and wastewater treatment problems have been boasted in developing countries by different financing institutes.

3. Water resources management

Efficient water management is the key to expanding water safety and security. The explanation above can improve the quality and can upsurge the quantity of water. of accessible water, yet management of good water resources is vital to guaranteeing sustainability and strength.

3.1. Climate resilient water management

It is a coordinated way to deal with building strength for the water-related executive to discourse the small and extensive haul effects of the changing climate by offsetting strength with adaptability (Smith et al., 2019). As there is a vulnerability about forthcoming water resource accessibility because of the impacts of climate change, the most ideal alternatives for the management of water should be strong (perform well over a scope of potential prospects) and adaptable (hold the capacity to react to sudden climate stuns and stressors and long-haul vulnerability). Infrastructure and Institutions Establishments and foundations should be coordinated to a moving climate and an indefinite water cycle. Grey substructure solutions are an extensive haul project and can padlock countries into ineffective and unmaintainable solutions as water accessibility and probability change. For instance, there is a developing climate incongruity between a non-static climate and the design parameters of Zambia’s Kariba Dam, subsequently, the dam just creates power for a couple of hours out of every day with financial ramifications for both Zimbabwe and Zambia (Smith et al., 2019). Planning, investments, water resources agreements, regulations, and grey substructure have been planned to utilize supposition of stationarity (that previous water accessibility and pattern of weather can foresee the future), Climate change is subverting this presumption making it difficult for leaders, organizers, and supervisors who can't recognize the probability of broadly different situations and select suitable solutions (Matthews et al.,
Resilience relies upon the demonstration of engineered framework and occupations of ecosystems, in addition to decisions and institutions made in the vicinity and at more significant levels (Smith et al., 2019). Instances of new methodologies, tools, and solutions include:

- World Bank and CRIDA’s Decision Tree Framework uphold the management of climate-resilient water by observing a specific framework, understanding how it works, and thinking about both grey substructure and NBS mutually including source water flexibility (Matthews et al., 2019).

- China’s sponge cities join the engineering of urban storm H2O adaptable ways to deal with utilizing the green spaces to support streams of water during outrageous occasions (Smith et al., 2019). In Rwanda the water source protection: wetlands debasement upstream of 2 hydro-power plants in the Rugezi River intensified the impacts of a mellow dry spell in 2002, decreasing the flow of the river and power generation sparking a temporary crisis. Reactions involved the re-establishment of wetlands; lawmaking to secure national resources of water and to guarantee dispossessed ranchers had to access to ploughing fields in less delicate areas (this decreased burden on national riparian and wetlands sectors); and, diversification of energy away from an over-reliance on hydropower and expanded hydro-power generation away from a solitary sink (Matthews et al., 2019).

- In Zimbabwe, the lower Save Catchment, the DFID-supported Climate Resilient Infrastructure Development Facility (CRIDF) created water reflection, irrigation, and pumping setup in two rustic communities to upsecure supply of food, expand river health, and enhance admittance to WASH. In reaction to poor harvests because of a varying pattern of rainfall, agriculturalists had moved the farm to riverbanks, contrarily affecting the health of the river. In sequence, the communities partially depend on the river for drinking H2O. The project also involved sexual orientation comprehensive network management advisory groups and an agreement-cultivating course of action, which assisted to upsecure some family earnings. One of the irrigation plans is sun oriented, which adds to the strength, as there are no power expenses. Likewise, with numerous rural plans, there is a concern about continuous activity and upkeep: in Zimbabwe setting the financial circumstance implies sourc- ing parts can be troublesome.

### 3.2. Governance

Governance of good water is expected to guarantee a satisfactory supply of suitable quality H2O to battle and forestall forthcoming pandemics. At the same time, in all actuality water administration is frequently divided. Interventions could incorporate reinforcing strategies and institutional and administrative structures. For instance, a typical boundary across the board for the appropriation of the green framework, is the absence of empowering laws, policies, and code of practice (Ezeh et al., 2020). Lawmaking in Peru needs utilities of water to reserve income for H2O preservation and fighting climate change, with procedures measured in their process of planning and budgeting. In light of Covid-19, policy reactions are requiring that discourse procedures measured in their process of planning and budgeting. Frail frameworks, including budgetary frameworks to help administration conveyance, furthermore, feeble institutes are the main difficulties in expanding admittance to WASH (Water, 2019). For instance, just twelve percent of 115 countries and regions overviewed for the WHO, the United Nation’s worldwide examination and appraisal of cleanliness and drinking H2O detailed that urban drinking H2O observation was completed at a hundred percent of the necessary recurrence. Many countries revealed that they are looking to make WASH service moderate through strategy measures and money-related plans, generally for urban water supply. Notwithstanding, frameworks to screen and account for these measures are generally set up, showing that the degree of execution is deficient (Water, 2019).

Solid formal and informal institutes and human resources are significant for good H2O administration. The absence of capability and human resources, overall territories including agribusiness, hazard the executives, waste-water, and cleanliness, are compelling water resource improvement and administration across areas including South and Southeast Asia and sub-Saharan Africa (Schrecongost et al., 2020). For instance, the provinces of Pakistan such as KPK and Punjab, the institutes answerable for provincial drinking H2O, urban H2O, and cleanliness need competent human resources and the ability to oversee and grow water (Pahl-Wostl et al., 2020). Long-haul support for information and volume improvement is required as it takes a very long time to reinforce institutional capability with a unit of experienced, what’s more, viable experts and specialists (Nishra et al., 2020).

### 3.4. Move beyond sectoral thinking

Moving beyond sectoral thinking which perceives resources of WASH, water, and community health as to a great extent separate areas will assist nations in preparing for future dangers (Ashford et al., 2020). The COVID-19 outbreak demonstrates that WASH exercises ought to be considered a vital civic health intervention, while management of water resources upstream is fundamental for urban H2O supply (Smith and Judd, 2020). Understanding the connections between these parts and separating siloes will expand cognizance also, plan facilitated reactions to get ready for future pandemics. This will likewise include assessing any transboundary perspectives as water resources frequently cross national fringes (Azorín, 2020).

### 3.5. Data and information

A shortage of data can present difficulties for the administration of water predominantly in a setting of climate change, H2O scarcity and stress, rapid urbanization, and population growth. For instance, data is expected to screen growth and to grasp service suppliers. Notwithstanding, numerous countries do not have monetary, human, and institutional resources to secure and scrutinize data to help services (Song, 2021). Casual settlements represent a data challenge as there is frequently no solid data about the number of individuals who live inside them or their entrance to administrations (Cooper, 2020). The advancement of instruments, for example, water accounting can assist policymakers, organizers,
also administrators to comprehend and resolve water issues. Characterized as the precise quantitative evaluation of patterns and status in H₂O supply, request, accessibility, delivery, and usage in specified spaces, H₂O accounting improves comprehension of intermediate and lengthy haul changes sought after overall water clients and notify decisions of water management (Hemming and Macneill, 2020).

Rapid urbanization is intensifying the management of H₂O challenges for huge urban areas across most locales. Urban H₂O accounting, consolidating information from a series of sources including hydro-logical displaying, field estimations also, and remote detecting can increase comprehension of the urban H₂O cycle and can assist to address challenges of urban water (Lincoln Lenderking et al., 2020). This contains measuring the quantity of water inflowing and leaving a city, evaluating the influence of green infrastructure, and augmenting urban precipitation harvesting methods.

Human has direct interaction with the environment, any damage to the environment directly/indirectly impact living things, especially human health, and most pandemics has inevitable environmental consequences. In this review, we point out that this COVID-19 pandemic opens uncommon options for the research community to reassess the effect of human society development, and absolutely, constant nature feedback before and after COVID-19 pandemic scenarios.

Let we can hope that this pandemic has given us valuable lessons and we should have to learn from it which will be worked as a reference for ethical, proper, and timely actions in near future.

4. Conclusion

Water bodies are significantly impacted by COVID-19, especially during the strict days of lockdown. The negative impacts of COVID-19 on the water in the world were explained on the based: (a) the impact on water quality and quantity (b) deficiencies that were ignored for water assessment (c) future prospects and recommendations. The magnitude of recovery in water bodies needed an extreme kind of measurement that has been caused during the pandemic by society. This review study pays attention to the entry of sewage water containing sanitizer, detergents, and liquid medicine contaminations into the water used for drinking, irrigation, and other uses. Furthermore, the discussion of the paper highlights (a) the indirect effect of the COVID-19 pandemic on water quality and its role in water contamination, (b) evaluate the methods to recover, and (c) the protection of water bodies. Studies showed that the water quality improved during the days of COVID-19 in different countries due to the result of the lockdown. Some research studies and knowledge also pointed out that no persistent indication of viral disease sources like SARS-COV-2 was recorded in the water. However, some studies after the COVID-19 pandemic confirmed the presence of RNA fragments of SARS-COV-2 in wastewater. Several studies are available which suggest that many diseases and viruses are transmitted through feces. According to SDGs goals, it is important to monitor the wastewater during the peak days of any viral disease to prevent the risk of the disease of virus transfer through water. This study also emphasized that there is a need (a) necessary to monitor the entry of polluted water into major reservoirs of water like canals, rivers, or ponds to reduce the potential of viral diseases risk (b) should be processed through chemical, physical or biological treatment before (c) need to strengthening the facility to collect and process the water data, (d) create a comprehensive dataset for immediate analysis for surrogate data (e) to develop a preditory model for future risks assessment, (f) SDGs goals also need to reassess as a result of the pandemic disruption.

The recorded data and estimation during the time of lockdown may work as a base for different estimations in the water sector such as wastewater discharges, water consumption, water treatment, groundwater digging, and estimation of future impacts on water sectors due to the natural and anthropogenic outbreak. Application of advanced technologies like artificial intelligence, internet data, and remote sensing would ameliorate management strategies for extensive monitoring as well as the modeling of a system to go with the research activities. Thus it is necessary to take water action and considered it an eminent issue of health and the environment. This critical discussion was carried out using comprehensive studies data available on the Internet related to the objective of the study, we strongly believe that this study’s suggestions are valuable to the developing world when supported through quantitative analysis with related data.

References

Abu-Sharar, T.M., Hussein, I.A., Al-Jayyousi, O.R., 2003. The use of treated sewage for irrigation in Jordan: opportunities and constraints. Water Environ. J. 17 (4), 232–238.

Ahmed, W., Angel, N., Edson, J., Bibby, K., Bivins, A., O’Brien, J.W., Choi, P.M., Kiratima, M., Simpson, S.L., Li, J., 2020. First confirmed detection of SARS-COV-2 in untreated wastewater in Australia: a proof of concept for the wastewater surveillance of COVID-19 in the community. Sci. Total Environ. 728, 138764.

Ashford, N.A., Hall, R.P., Arango-Quiroga, J., Metaxas, K.A., Showalter, A.L., 2020. Addressing inequality: the first step beyond COVID-19 and Towards Sustainability. Sustain. 12, 5404.

Ashraf, M.A., Maah, M.J., Yusoff, I., Mehmood, K., 2010. Effects of polluted water irrigation on environment and health of people in Jamber, District Kasur. Pakistan. Int. J. basic appl. sci. 10, 37–57.

Azorín, C., 2020. Beyond COVID-19 supernova. Is another education coming? J. Prof. Cap. Comm. 5, 381–390.

Bhowmick, G.D., Dhar, D., Nath, D., Gangrekar, M.M., Banerjee, R., Das, S., Chatterjee, J., 2020. Coronavirus disease 2019 (COVID-19) outbreak: some serious consequences with urban and rural water cycle. NPJ Clean Water 3 (1), 1–8.

Boye, J.M., Pittet, D., 2002. Guideline for hand hygiene in health-care settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. Am. J. Infect. Control. 30, S1–S46.

Britto, A.L., Maiello, A., Quintril, S., 2019. Water supply system in the Rio de Janeiro Metropolitan Region: open issues, contradictions, and challenges for water access in an emerging megacity. J. Hydrol. 573, 1007–1026.

Brown, L., Murray, V., 2013. Examining the relationship between infectious diseases and flooding in Europe: a systematic literature review and summary of possible public health interventions. Dis. Health. 1, 117–127.

Browder, C., Ormvent, S., Rebberger Bescos, L., Gartner, T., Lange, G.M., 2019. Integrating green and gray. World Bank and World Resources Institute, Washington, DC.

Casanova, L., Rutala, W.A., Weber, D.J., Sobsey, M.D., 2009. Survival of surrogate coronaviruses in water. Water Res. 43 (7), 1893–1898.

Channappanavar, R., Perlman, S., 2017. Pathogenic human coronavirus infections: causes and consequences of cytokine storm and immunopathology. Seminars in immunopathology, vol. 39. Springer, pp. 529–539.

Cheval, S., Mihai Adamescu, C., Georgiadis, T., Herrnegger, M., Piticar, A., Legates, D. R., 2020. Observed and Potential Impacts of the COVID-19 Pandemic on the Environment. Int. J. Environ. Res. 17, 4140.

Choi, P.M., Tschirke, B.J., Donner, E., O’Brien, J.W., Grant, S.C., Kasern, S.L., Mackie, R., O’Malley, E., Croisie, N.D., Thomas, K.V., 2018. Wastewater-based epidemiology biomarkers: past, present and future. Trends Analyt Chem. 105, 453–469.

Cooper, R., 2020.Nature-based Solutions and Water Security. Cooper, R., 2018. Water, sanitation and hygiene services in Pakistan. Damania, R., Desbureaux, S., Rodella, A.-S., Russ, J., Zaveri, E. 2019. Water quality and its determinants.
Wurtzer, S., Marechal, V., Mouchel, J.-M., Moulin, L., 2020. Time course quantitative detection of SARS-CoV-2 in Parisian wastewaters correlates with COVID-19 confirmed cases. MedRxiv.

WWAP, U., 2017. WWAP (United Nations World Water Assessment Programme). Unesco, Paris.

Yeo, C., Kaushal, S., Yeo, D., 2020. Enteric involvement of coronaviruses: is faecal–oral transmission of SARS-CoV-2 possible? Lancet Gastroen. Hep. 5 (4), 335–337.