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Changes in Global Domestic Water Use Due to Handwashing for Preventing COVID-19: An Assessment

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Abstract: The emergence of COVID-19 has created many unanticipated changes globally, particularly in terms of the availability and use of water resources. This study aims to estimate the potential increase in global domestic water use, exclusively due to the handwashing requirement for COVID-19. To assess the potential increase in domestic water use, this study analyzed population and water use data of 175 countries. Based on WHO guidelines, the additional water required for handwashing per person per day was estimated to be 0.018 m^3 and was integrated with water use and population data for the analysis. These findings reveal that if everyone washes their hands six times a day solely to prevent the spread of coronavirus, global domestic water use and total water use would increase by about 11.96% and 1.25%, respectively. Africa (23.88%), Asia (15.05%), Latin America, and the Caribbean (7.18%) are anticipated to have the most significant increases in domestic water use due to the increased handwashing. This is a concerning phenomenon because these nations are already experiencing water shortages, even before the pandemic. These results may aid these countries in achieving Sustainable Development Goal 6, by guiding stakeholders and decision-makers to take action to address the water resource management challenges posed by the unexpected rise in water use caused by events such as COVID-19.

Keywords: COVID-19; handwashing; global water use; domestic water use; Sustainable Development Goal 6

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1. Introduction

The coronavirus disease (COVID-19), an infectious disease caused by the SARS-CoV-2 virus, was first identified in Wuhan in December 2019. The World Health Organization [1] declared the outbreak a public health emergency of international concern on 30 January 2020, and was later declared a pandemic on 11 March 2020. Since the outbreak was declared a pandemic, people have become very aware of personal hygiene, and many people have been following the ideal number of handwashes per day, which is at least six times a day according to the Centers for Disease Control and Prevention [2,3], the World Health Organization [4], and the United Nations International Children's Emergency Fund [5]. While recognizing that millions of people lack the water required for appropriate hand hygiene, UNICEF has listed behavioral changes and the provision of information as key measures for promoting handwashing during this crisis [6].

Aerosolized droplets, which are produced and discharged during coughing, sneezing, breathing, and also possible airborne transmissions, are the primary routes for the spreading of COVID-19 [7]. The Centers for Disease Control and Prevention [3] suggests that avoiding close contact with people, particularly infected people, wearing face masks that cover the mouth and nose, always covering the mouth and nose during coughing and sneezing, using sanitizers containing at least 60% alcohol, washing hands with soap for at least

20 s, cleaning and disinfecting areas which are touched frequently, and being cautious of symptoms are the possible ways of preventing further exposure and transmission of the coronavirus disease. Among them, social distancing and handwashing are of the greatest significance [8].

Appropriate hand hygiene practices are associated with an increase in domestic water use. Washing hands at least six to ten times per day is a fair approach to the prevention of various infections, such as COVID-19 [9]. According to the United Nations (UN) World Water Development Report 2019 [10], a combination of factors such as population growth, socioeconomic development, and changing usage patterns have been responsible for the increase of water use demand by about 1% annually since the 1980s. The coronavirus pandemic has also brought a change in the global water usage pattern due to increased awareness of personal hygiene. A survey conducted in India showed that about 60% of the population is using soap and water to clean their hands within the advised minimum time of 20 s for preventing the coronavirus pandemic [11]. In the same way, millions of people around the world are following the advice of health experts to wash their hands frequently, as the coronavirus disease is posing a threat to life by spreading worldwide [12].

However, this new trend of frequent handwashing was not a common practice before the coronavirus pandemic. For example, a study conducted in Hong Kong reveals that the majority (>60%) of the respondents wash their hands after touching food/cooking, after touching living animals, after defecation, when hands are visibly dirty, after being in contact with animal excreta, and after the disposal of waste, for less than 10 s [13]. A similar study in Singapore reveals that the majority (> 60%) of the respondents admitted to washing their hands after defecation, going to the toilet, and before and after attending to a sick person or children, following only four out of the eight steps of handwashing, which are recommended by the Singapore Health Promotion Board [14]. A study conducted in India reveals that the respondents wash their hands five times daily [15]. Moreover, a study conducted in Nigeria reveals that the majority (>60%) of the respondents confirmed washing their hands only after defecation [16]. Therefore, it is difficult to characterize the global handwashing pattern. Kumar et al. [17] analyzed data from 51 nations between 2010 and 2013 to determine the handwashing pattern. They reported discrepancies even amongst geographical regions of the same country.

The current annual growth rate of global water use has been approximately 1% since the 1980s [10]. Due to frequent handwashing during a global pandemic, global water use might increase by more than 1% annually, which may lead to water insufficiency. Water resources are sensitive to climate change and uncertainty in future water demands [18,19]. However, only considering the future climate change-related vulnerabilities, and not including the changes in water use due to unanticipated events like COVID-19-induced human water use behavioral patterns, might lead to an unreliable prediction of future water availability [20]. This uncertain prediction of future water availability is not sustainable, as it may hinder sustainable water resource development due to the unexpected changes in global water use and, hence, it might create massive and unmanageable challenges to achieving water-related Sustainable Development Goals (SDGs). Particularly, the progress of SDG 6, which aims to ensure access to adequate water, sanitation, and hygiene for all by 2030 [21], may be hindered due to the unanticipated increase in global domestic water use.

Researchers have documented an increase in residential water use during the COVID-19 epidemic. Nemati and Tran [22] analyzed data from six water utilities in six states in the United States to conclude that daily water use increased by 3.08% to 13.65% during the stay at home orders, as compared to the same period in 2018 and 2019. Water consumption patterns in 31 municipalities in the Brazilian state of São Paulo were studied by Silva et al. [23]. The authors initially used the Holt–Winters multiplicative approach to make a six-month water usage projection for 2020, which they then compared with actual data from the same time period. The average disparity between expected and actual consumption was found to be 6.23% for homes and 18.59% for businesses. The average daily residential usage went up by 8.44 L per person. Changes in personal hygiene, increased social distance, and

the decline or elimination of less crucial commercial services were deemed to be the root causes of the observed shifts in consumption patterns. In another study conducted during COVID-19, Alvisi et al. [24] examined how the city's lockdown affected its inhabitants. During the lockdown, water usage data was aggregated and evaluated at several different temporal and regional scales, and then compared to the same data from the previous year. Based on these findings, it is clear that there was an 18% increase in water use in this predominantly residential region when the lockdown was in effect. Additionally, it was seen that water consumption was more evenly distributed throughout the day, with less water being consumed in the morning on weekdays.

As an integral part of utility reliability, emergency preparedness is essential. Different utilities have had to deal with significant and unplanned alterations in the timing, size, location, and composition of water and wastewater flows during the epidemic, as noted by Sowby [25]. Water use was increased, peaked at different times, and concentrated in residential areas as a result of people staying at home and becoming more careful about hygiene, among other factors. Water and wastewater utilities must refresh and enhance their disaster preparedness efforts in light of the significant implications of COVID-19 across numerous service sectors [25]. The author acknowledges that there is no need to reconstruct the process because so many resources, including policy guidance and instruments, already exist. Berglund et al. [26] surveyed 27 water utilities all over the world to make similar observations on emergency preparation response plans. Pandemic impacts on water system operations, demand, revenues, system vulnerabilities, and emergency response planning (ERP) were the primary topics of the survey. Twenty-three out of twenty-seven utilities reported modest shifts in demand volumes and patterns, which can influence the maintenance and performance of water infrastructure, and the quality of the water supplied to the public. Many utilities reported plans to incorporate lessons gained into future ERPs, such as pandemic risk management training or annual simulated emergency drills.

Sowby and Lunstad [27] think this is a rare chance to investigate how a pandemic, such as COVID-19, affects the physical world. This, say the authors, is a great opportunity to validate different models and learn more about how reliant infrastructure has changed over time. The authors also noted that the consequences of pandemics are different from those of short-term hazards such as earthquakes, and long-term hazards such as climate change, therefore, study in this area should focus on a time span of one to three years. Furthermore, Berguland et al. [28] made a similar remark. In light of the aforementioned, Kadinski et al. [29] used an agent-based modeling framework to investigate the social dynamics and responses of water customers and utility management in the wake of a contamination event, accounting for both normal and pandemic demand. Using techniques from graph theory, utility manager agents can partition the network into zones at risk of contamination, and zones that have been reclaimed for human use. To foresee what would happen to a contaminated plume in the water distribution system, consumer agents receive real-time updates on the state of individual network nodes, and modify their water consumption accordingly.

The majority of the present literature emphasizes the rise in residential water consumption without focusing specifically on handwashing. The main purpose of this study is to estimate the amount of water consumed around the world as a result of the increased number of handwashes caused by the recent coronavirus pandemic. This study is the first of its kind to estimate the changes in global domestic water use for handwashing due to unanticipated events, such as COVID-19, so that the water authorities around the world could be prepared well in advance to ensure sufficient water supply during emergency situations. COVID-19-related handwashing is the new effect that this study has examined, regardless of any past handwashing practices. This study compared the total annual domestic water use for the year 2017 with the estimated total domestic water use during the COVID-19 (2020) pandemic in 175 countries. Based on these estimated results, the attention of the authorities, scholars, decision-makers, and stakeholders who focus on

water management may be directed toward addressing the increasing water use due to the coronavirus pandemic. In turn, these findings will assist water managers in promoting sustainable water resource management and achieving Sustainable Development Goal 6. SDG targets 6.2 and 6.4, in particular, will be met, as these targets aim to achieve access to adequate and equitable sanitation and hygiene for all, significantly increase water-use efficiency across all sectors, ensure sustainable withdrawals and supply of freshwater to address water scarcity, and significantly reduce the number of people suffering from water scarcity by 2030 [21].

2. Methodology

For this research, water use and population data of 175 countries were collected from FAO AQUASTAT [30] and Worldometer databases [31], respectively. Water use data for 2017 was chosen for this research, as this is the most recent global data available in the FAO AQUASTAT database [30]. Additionally, 2017 represents a pre-pandemic, normal water-use environment. The number of handwashes was determined based on a study [9], which suggests washing hands six to ten times a day for the prevention of infections such as COVID-19. The minimum duration of each handwash was determined based on the information found by the Centers for Disease Control and Prevention [2] and the United Nations International Children's Emergency Fund [5], both of which suggest washing hands for at least 20–30 s. The World Health Organization's guidelines [4,32] were used for determining the duration of handwashing, and data from the Alliance for Water Efficiency [33] was used to calculate the faucet discharge speed. The methodology of this study is presented in Figure 1.

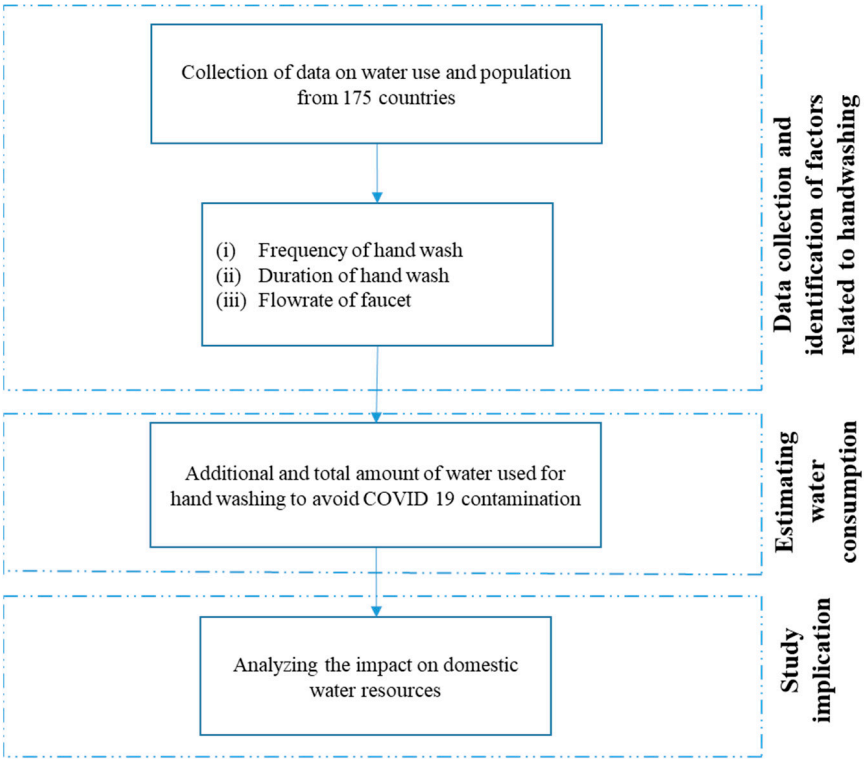

Figure 1. Steps involved in this research.

2.1. Water Requirement and Frequency of Handwashing Solely to Prevent COVID-19

According to the Alliance for Water Efficiency [33], the flow rate of faucets was limited to 0.5 m^3/h (cubic meters per hour) since 1992, following the *USA Energy Policy Act of 1992* [33]. For residential use, the flow rate of bathroom faucets is restricted to between

0.34 m^3/h and 0.11 m^3/h, while the flow rate of kitchen faucets can be 0.5 m^3/h [34]. Handwashing for 15–30 s is best for maximum removal of pathogens [35].

The U.S. Food and Drug Administration's [36] *Model Food Code* recommends washing hands for 20 s. Since the outbreak of the coronavirus disease, the United Nations Children's Fund [5] and Centers for Disease Control and Prevention [2,37] have also advised scrubbing hands with soap for at least 20–30 s. According to the World Health Organization, the entire procedure for washing hands takes about 40–60 s, and includes a total of 10 steps, starting with rinsing hands, applying soap, hand rubbing techniques, once more rinsing hands, and finally wiping the hands with a towel [32].

As the process of drying hands and extensive hand rubbing techniques does not require the faucets or taps to be kept open, all other steps were omitted, keeping only the essential steps of handwashing, i.e., (1) rinsing, (2) scrubbing, and (3) rinsing, which tends to be the behavioral pattern of the majority of people. Therefore, this study assumes six handwashings each day for the sole objective of preventing COVID-19, regardless of previous handwashing habits. In addition, it is assumed that each wash takes 30 s, taking into consideration that the duration for rinsing hands each time is 5 s, and that of scrubbing is 20 s.

As mentioned earlier, the flow rate of the faucet can be anywhere from 0.11 to 0.34 m^3/h (cubic meter per hour). However, for this research, 0.34 m^3/h is selected as the flow rate of the faucet as a factor of safety, so that the maximum possible water use for handwashing could be taken into consideration. Assuming the flow rate to be 0.34 m^3/h for each household, and it takes 30 s per handwash, water use per handwash is [(0.34 m^3/h) × (30 s × 1 h/3600 s)] = 0.003 m^3. Assuming that people currently wash their hands six times a day solely to prevent the coronavirus disease, as recommended by the World Health Organization [4], the total use of water for handwashing by each person per day is approximately 0.018 m^3.

2.2. Change in Water Use Due to Handwashing Solely to Prevent COVID-19

The increase in domestic and total water use was calculated using MS Excel. This allows for easy forecasting of future water usage due to the increased number of handwashes to prevent COVID-19. The results of future domestic and global water use may be recorded and visualized using figures and graphical tools. The data used for the analysis included water use and population statistics of 175 countries obtained from FAO AQUASTAT, as well as the assumed total use of water for handwashing by each person per day, which is approximately 0.018 m^3. The constant value in this evaluation method is 0.018 m^3 (total quantity of water used for handwashing per person per day solely to prevent COVID-19). In contrast, the variables related to population and water use are different for each nation. It should be noted that residential water use for other activities is anticipated to be constant in 2017 and 2020. The excess amounts in domestic and total water uses are primarily due to the population data variable. The higher the population, the greater the necessity of water for handwashes owing to COVID-19 for each country.

A sample process of the calculations for six countries selected by the highest percent of the increase in domestic water use within each region for the years 2017 and 2020 is shown in Table 1.

Table 1. Comparison of domestic and total water use of the countries with the highest % of increase of domestic water within each region in 2017 and 2020 [30,31,38].

Region	Asia	Africa	Europe	Oceania	North America	Latin America and the Caribbean
Sub-Region	South Asia	East Africa	Eastern Europe	Melanesia		South America
Country	Nepal	Somalia	Slovakia	Papua New Guinea	Canada	Bolivia

Table 1. *Cont.*

Region	Asia	Africa	Europe	Oceania	North America	Latin America and the Caribbean
YEAR of data collection	2017	2017	2017	2017	2017	2017
Total water used in year 2017 (in billion m^3)	9.497	3.298	0.5563	0.3921	35.6	2.088
Domestic water used in year 2017 (in billion m^3)	0.1476	0.015	0.2935	0.2235	4.888	0.136
Population (year 2020)	29,136,808	15,893,222	9,459,642	8,947,042	37,742,154	11,673,021
Excess water for handwashing per day per person solely to prevent COVID-19 (in m^3)	0.018	0.018	0.018	0.018	0.018	0.018
Excess water due to excess handwashing per day (in m^3)	524,463	286,078	170,274	161,047	679,359	210,114
Excess water solely due to handwashing in one year (in m^3)	191,428,829	104,418,469	62,149,848	58,782,066	247,965,952	76,691,748
Increase in water use due to handwashing to prevent COVID-19 (in billion m^3)	0.191	0.104	0.062	0.059	0.248	0.077
Probable total water use in the year 2020 (in billion m^3)	9.688	3.402	0.618	0.451	35.848	2.165
Probable domestic water use in the year 2020 (in billion m^3)	0.339	0.119	0.356	0.282	5.136	0.213
Domestic water use increase (in %)	129.69	696.12	21.18	26.30	5.07	56.39
Total water use increase due to handwashing for preventing COVID-19 (in %)	2.02	3.17	11.17	14.99	0.70	3.67

By following the same process, the estimated annual increase in domestic water use for handwashing for preventing the coronavirus pandemic can be calculated for each country of the six regions of the world, i.e., Asia, Africa, Europe, Oceania, Northern America, and Latin America, and The Caribbean [31,38].

The probable total amount of water required due to handwashing per day in a particular country is calculated by Equation (1):

$$The\ total\ amount\ of\ water\left(\frac{m^3}{d}\right) = Population\ of\ the\ country\ in\ the\ year\ 2020 \times 0.018 \quad (1)$$

Excess water due to handwashing in one year is calculated by Equation (2):

$$\begin{aligned} &Excess\ water\ due\ to\ hand\ washing\ in\ one\ year\left(m^3\right) \\ &= amount\ of\ water\ due\ to\ handwashing\ solely\ for\ preventing\ COVID19\ per\ day \times 365 \end{aligned} \quad (2)$$

Total water usage for the year 2020 is calculated by Equation (3):

$$\begin{aligned} &Probable\ total\ water\ use\ in\ 2020\left(m^3\right) \\ &= the\ expected\ increase\ in\ water\ use\ due\ to\ handwashing\ for\ preventing\ COVID19 \\ &+total\ water\ used\ for\ the\ year\ 2017 \end{aligned} \quad (3)$$

Probable domestic water use for the year 2020 is calculated by Equation (4):

$$\begin{aligned} &\text{Probable } domestic\ water\ use\ in\ 2020\left(m^3\right) = \\ &the\ expected\ increase\ in\ water\ use\ due\ to\ handwashing\ for\ preventing\ COVID19+ \\ &domestic\ water\ used\ for\ other\ activities\ in\ the\ year\ 2017 \end{aligned} \quad (4)$$

The estimated percentage increase in domestic water use due to handwashing for COVID-19 is calculated by Equation (5):

$$\begin{aligned} &\textit{The estimated increase of domestic water use}(\%) \\ &= \frac{\textit{Domestic water used in year } 2020 - \textit{Domestic water used in year } 2017}{\textit{Domestic water used in year } 2017} \times 100 \end{aligned} \quad (5)$$

where, water use is billion m^3

The estimated increase in total water use due to handwashing for COVID-19 is calculated by Equation (6):

$$\begin{aligned} &\textit{The estimated increase of total water use}(\%) \\ &= \frac{\textit{Total water used in the year } 2020 - \textit{Total water used in the year } 2017}{\textit{Total water used in the year } 2017} \times 100 \end{aligned} \quad (6)$$

where, water use is billion m^3.

Terms such as water stress and water scarcity are used throughout the paper, so it is important to define them. According to the United Nations Department of Economic and Social Affairs, water stress is defined as when an individual of a particular area has access to less than 1700 m^3 of annual water resources; water scarcity is defined as when an individual of a particular area has access to less than 1000 m^3 of annual water, and when access to water resources is less than 500 m^3, it is termed as "absolute scarcity" [21].

3. Results

Hand hygiene practices have increased significantly since the coronavirus pandemic spread across the globe [22–24]. This study estimated the increase in domestic water use due to increased handwashing during the pandemic for the population living in 175 nations situated in six regions across the world. Based on each country's reported population, the probable domestic water use and total annual water use for the COVID-19 (2020) pandemic period have been computed. Tables 2–5, A1 and A2 provide the annual domestic water use pre-pandemic (2017) and during COVID-19 (2020) for different sub-regions of the six global regions.

Table 2. Comparison of domestic and total annual water use in 2017 and 2020 (during COVID-19) for sub-regions of Asia [30,31,38].

Region	Sub-Region	Domestic Water Use in the Year 2017 (in Billion m^3)	Increase in Water Use Due to Handwashing for COVID-19 (in Billion m^3)	Probable Domestic Water Use in the Year 2020 (in Billion m^3)	Total Water Use in the Year 2017 (in Billion m^3)	Probable Total Water Use in the Year 2020 Due to COVID-19 (in Billion m^3)	% of the Increase in Total Water Use Due to COVID-19	% of the Increase in Domestic Water use Due to COVID-19
Asia	Central Asia	6.38	0.49	6.87	130.45	130.94	0.37	7.65
	East Asia	102.43	10.82	119.82	715.75	726.57	1.51	16.97
	Western Asia	17.48	1.84	19.32	173.00	174.83	1.06	10.51
	South Asia	76.63	12.75	89.38	1116.73	1129.48	1.14	16.64
	South Eastern Asia	41.67	4.35	46.02	504.24	508.60	0.86	10.44
	Total	244.59	30.24	281.40	2640.17	2670.41	1.15	15.05

Table 3. Comparison of domestic and total annual water use in 2017 and 2020 (during COVID-19) for sub-regions of Africa [30,31,38].

Region	Sub-Region	Domestic Water Use in the Year 2017 (in Billion m^3)	Increase in Water Use Due to Handwashing for COVID-19 (in Billion m^3)	Probable Domestic Water Use the Year 2020 (in Billion m^3)	Total Water Use in the Year 2017 (in Billion m^3)	Probable Total Water Use in the Year 2020 Due to COVID-19 (Billion m^3)	% of the Increase in Total Water Use Due to COVID-19	% of the Increase in Domestic Water Use Due to COVID-19
Africa	North Africa	17.20	1.61	18.81	136.03	137.64	1.19	9.38
	East Africa	4.48	2.92	7.40	47.36	50.28	6.16	65.13
	Central Africa	0.91	0.59	1.50	3.04	3.63	19.47	65.07
	West Africa	6.93	2.47	9.40	26.97	29.44	9.15	35.58
	South Africa	4.12	0.44	4.57	20.97	21.42	2.11	10.75
	Total	33.65	8.03	41.68	234.37	242.40	3.43	23.88

Table 4. Comparison of domestic and total annual water use in 2017 and 2020 (during COVID-19) for sub-regions of Europe [30,31,38].

Region	Sub-Region	Domestic Water Use in the Year 2017 (in Billion m^3)	Increase in Water Use Due to Handwashing for COVID-19 (in Billion m^3)	Probable Domestic Water Use the Year 2020 (in Billion m^3)	Total Water Use in the Year 2017 (in Billion m^3)	Probable Total Water Use in the Year 2020 Due to COVID-19 (in Billion m^3)	% of the Increase in Total Water Use Due to COVID-19	% of the Increase in Domestic Water Use Due to COVID-19
Europe	Eastern Europe	26.27	1.95	28.22	105.03	106.98	1.86	7.43
	Northern Europe	9.73	0.70	10.43	19.46	20.15	3.58	7.15
	Southern Europe	19.26	0.98	20.24	97.33	98.31	1.00	5.08
	Western Europe	13.26	1.29	14.55	76.23	77.52	1.69	9.72
	Total	68.53	4.91	73.44	298.05	302.96	1.65	7.17

Table 5. Comparison of domestic and total annual water use in 2017 and 2020 (during COVID-19) for sub-regions of Latin America and the Caribbean [30,31,38].

Region	Sub-Region	Domestic Water Use in the Year 2017 (in Billion m^3)	Increase in Water Use Due to Handwashing for COVID-19 (in Billion m^3)	Probable Domestic Water Use the Year 2020 (in Billion m^3)	Total Water Use in the Year 2017 (in Billion m^3)	Probable Total Water Use in the Year 2020 Due to COVID-19 (in Billion m^3)	% of the Increase in Total Water Use Due to COVID-19	% of the Increase in Domestic Water Use Due to COVID-19
Latin America and the Caribbean	Caribbean	4.00	0.27	4.28	22.68	22.96	1.21	6.83
	Central America	17.56	1.18	18.74	100.94	102.12	1.17	6.72
	South America	37.58	2.79	40.37	211.37	214.16	1.32	7.43
	Total	59.15	4.25	63.39	334.99	339.24	1.27	7.18

The domestic water use changes before the pandemic (i.e., in 2017) and during COVID-19 (2020) presented in the abovementioned tables indicate that, due to the increased amount of handwashing for preventing the transmission of the coronavirus disease, the domestic water use is expected to increase by approximately 11.96% compared to the base year of 2017. Moreover, it is predicted that global total water use is expected to increase by around 1.25% compared to the year 2017. Likewise, the data from each of the six world regions, namely, Asia, Africa, Europe, Oceania, Northern America, Latin America, and The Caribbean, were thoroughly analyzed to determine the potential increase of domestic water use to prevent the spreading of the coronavirus disease. Region-wise key findings of this research are summarized in the following sections.

3.1. Asia

Asia is divided into five sub-regions, i.e., Central Asia, East Asia, Western Asia, South Asia, and South Eastern Asia [31]. Among the five Asian sub-regions, East Asia withdrew the highest amount of water for domestic purposes in 2017 (102.43 billion m^3), and also during the coronavirus pandemic (2020) (119.82 billion m^3) (see Table 2). Even though East Asia is leading in terms of domestic water withdrawals, South Asia represents the highest total water withdrawals in 2017 (1116.73 billion m^3) and during the coronavirus pandemic (2020) (1129.48 billion m^3). The expected domestic water use in South Asia during the COVID-19 (2020) pandemic is 89.38 billion m^3 (Table 2), with a 95% confidence interval (CI) of 9.93 ± 13.74 (Figure A1, Table A3). The 95% CI shows the upper and lower limit of water use (mean ± margin of error) with a 95% probability. The CIs for other regions are also presented in Figure A1. At the country level, the expected increase in domestic water use is highest in China (9.456 billion m^3), followed by India (9.057 billion m^3) and Indonesia (1.797 billion m^3). These three countries belong to East Asia (CI: 22.65 ± 32.93), South Asia (CI: 9.93 ± 13.74), and South East Asia (CI: 5.11 ± 5.38), respectively. Yemen, Jordan, Palestine, the Maldives, and Cambodia are expected to experience an increase in total water use by more than 5% for maintaining the standards of hand hygiene to prevent the spreading of the coronavirus disease. In the Maldives, the total water use is expected to increase by 60.19%, exceeding all other Asian countries.

In the Asia region, Nepal is expected to have the highest percentage of domestic water use increase (129.69%), followed by Afghanistan (125.74%) and Cambodia (112.09%). In six Asian nations—Yemen, Nepal, the Maldives, Afghanistan, Vietnam, and Cambodia—it is anticipated that domestic water use will increase by more than 50% as a result of the coronavirus pandemic (2020). Out of these six countries, one country is located in Western Asia (CI: 1.07 $\pm$ 0.73), three countries are in South Asia (CI: 9.93 $\pm$ 13.74), and two countries are in South Eastern Asia (CI: 5.11 $\pm$ 5.38). Many countries in Asia, in particular in Western Asia, were experiencing water scarcity long before the coronavirus pandemic; this sudden increase in water use during the ongoing pandemic will create enormous water management challenges in the region [39,40].

In South Asia, total water withdrawal in India is expected to be highest during the COVID-19 pandemic (2020). Three countries in South Asia are predicted to experience an increase in domestic water use by more than 50%, i.e., Nepal (129.69%), followed by Afghanistan (125.74%) and the Maldives (63.42%). This is quite alarming, as in South Asia pressure on water resources is rapidly increasing, which may lead to future challenges in meeting domestic water use. Even before the outbreak of the coronavirus disease, Rasul [41] predicted water use in South Asia would increase by 55% in 2030 in comparison to 2005. In this context, it is important to note that in many disadvantaged countries, water shortage is not just caused by a lack of physical resources. The problem is caused by economic difficulties, pollution, inadequate management, or a lack of technological resources. Unfortunately, unless these variables are addressed in accordance with SDG 6, the rising demand for disease prevention will not be met by greater supply and use.

According to Sustainable Development Goal (SDG) 6, access to adequate water, sanitation, and hygiene should be ensured for everyone [21]. SDG target 6.4 aims to increase the efficiency of water utilization to address water scarcity [21]. Access to water, sanitation, and hygiene should be recognized as a prerequisite for improving the quality of life of the people living in Asia. Hence, the excess water use due to ensuring compliance with hand hygiene practices for preventing transmission of the coronavirus disease should be taken into serious consideration for ensuring sustainable water resource management in South Asia.

3.2. Africa

The Africa region consists of four sub-regions, i.e., North Africa, East Africa, Central Africa, and West Africa [31]. Among the four sub-regions of Africa, North Africa is expected to experience the highest amount of water withdrawal for domestic use (18.81 billion m^3) (see Table 3). East Africa is predicted to have the highest volume of annual domestic water use increase (2.92 billion m^3) due to increased handwashing requirements during the coronavirus pandemic (2020). At the country level, the expected increase in domestic water use is highest in Nigeria (1.354 billion m^3), followed by Ethiopia (0.755 billion m^3) and Egypt (0.672 billion m^3).

Among the four sub-regions of Africa, East Africa is expected to experience the highest percentage increase in domestic water use, which is around 65.13%, followed by 65.07% in Central Africa (see Table 3).

In the Africa region, total water use is predicted to increase by more than 20% in fourteen countries, i.e., Burundi, Comoros, Djibouti, Rwanda, Uganda, Angola, Central African Republic, Congo, Equatorial Guinea, Benin, Liberia, Sierra Leone, Togo, and Lesotho. Out of these fourteen countries, five countries are located in East Africa, four countries are in Central Africa, four countries are in West Africa, and one country is in Southern Africa. Comoros is expected to experience the highest percentage of total water use increase, which is 57.13%, followed by Uganda (47.18%) and Equatorial Guinea (46.55%).

In twenty-five African countries, the expected percentage increase of domestic water use is more than 50%, i.e., Tunisia, Burundi, Comoros, Eritrea, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Somalia, Tanzania, Uganda, Angola, Cameroon, Central African Republic, Chad, Congo, Equatorial Guinea, Benin, Cabo Verde, Ghana, Mali, Niger, Senegal,

and Lesotho. Out of these twenty-five countries, one country is located in North Africa, eleven countries are in East Africa, six countries are in Central Africa, six countries are in West Africa, and one country is in South Africa. Among all the countries in Africa, Somalia is expected to experience the highest percentage of domestic water use increase which, is 696.12%, followed by Burundi (181.26%) and Mali (124.34%).

SDG target 6.2 aims to achieve access to equitable and adequate sanitation and hygiene facilities for all by 2030 [21]. Currently, many countries in Africa do not have access to water and sanitation facilities. For example, in three East African countries, namely, Uganda, Tanzania, and Kenya, 42 million people do not have access to safe water supplies, and 13 million people do not have access to safe sanitation facilities [42]. In Nigeria, most of the freshwater sources are contaminated and more than half of the population is experiencing water insufficiency [43].

It should be kept in mind that the region was facing a water crisis, even before the outbreak of the coronavirus disease. Ensuring availability of the excess water required for hand hygiene during the pandemic creates a massive water management challenge in the region that will seriously hinder the achievement of SDG 6, and in particular SDG target 6.2.

3.3. Europe

The Europe region consists of four sub-regions, i.e., Eastern Europe, Northern Europe, Southern Europe, and Western Europe [22]. Among the four sub-regions of Europe, Eastern Europe is expected to have the highest amount of total annual water use (106.98 billion m^3) and domestic water use (28.22 billion m^3). Out of all the countries in Europe, Russia is predicted to experience the highest volumes of domestic water use (18.67 billion m^3), as well as total water use (65.37 billion m^3), out of which, the COVID-19-related handwashing water requirement is predicted to be around 0.96 billion m^3.

Domestic water use is predicted to increase by more than 10% in thirteen European countries, i.e., Belarus, Czech Republic, Hungary, Poland, Moldova, Romania, Slovakia, Ukraine, Estonia, Latvia, Lithuania, Belgium, and Germany. Out of these thirteen countries, eight countries are located in Eastern Europe, four countries are in Northern Europe, and one country is in Western Europe. The estimated increase in domestic water use due to handwashing is expected to be highest in Slovakia (21.18%), followed by Moldova (17.91%) and Estonia (14.67%). Slovakia, Denmark, Latvia, Lithuania, the United Kingdom, Luxembourg, and Monaco are predicted to experience a total water use increase of more than 5% annually.

Around 11% of the population of Europe is currently experiencing water scarcity [44]. SDG target 6.2 aims to provide access to sanitation and hygiene facilities for all, and SDG target 6.4 aims to ensure sustainable withdrawals and supply of freshwater to address water scarcity, and to substantially reduce the number of people suffering from water scarcity by 2030 [21]. The prevalence of water insufficiency in Europe hinders the development of both SDG targets 6.2 and 6.4. Hence, it is of utmost importance for water managers to address the unanticipated increase in domestic water use during the ongoing pandemic. Without a sustainable water resource management policy to address the sudden increase in water use due to unanticipated events, such as the coronavirus pandemic, it will be almost impossible to achieve SDG 6, in particular targets 6.2 and 6.4, in Europe and the world.

3.4. Oceania

The Oceania region consists of two sub-regions, i.e., Australia and New Zealand, and Melanesia [22]. Domestic water use increase due to handwashing during the coronavirus pandemic is expected to be 4.74% and 25.99% in the Australia and New Zealand, and Melanesia sub-regions, respectively (Table A1). Among the two sub-regions of Oceania, the Australia and New Zealand sub-region is predicted to have the highest amount of total annual water use (21.95 billion m^3) and annual domestic water use (4.4 billion m^3) during COVID-19 (2020) (Table A1). Australia is expected to have the highest total water use (16.298 billion m^3) and domestic water use (3.56 billion m^3). Papua New Guinea is

expected to experience a 26.30% increase in domestic water use, which is highest in the Oceania region, followed by Fiji (23.28%). It is also observed that the increase in domestic water use due to handwashing is expected to be less than 5% in Australia (4.94%) and New Zealand (3.91%).

Countries in the Oceania region have their water challenges. Currently, Australia may have adequate water resources to meet the population's supply and demand, but as river flows are expected to decrease by 10–25% over the next 10 years, it may face difficulties in meeting the demands of the growing population due to various environmental drawbacks and increasing uses for COVID-19-related hand hygiene requirements [45]. Water withdrawals in Australia and Oceania increased by approximately 30 times between 1900 and 1995, and due to factors such as population growth and industrialization, it is predicted that withdrawals would increase by roughly 39% by 2025 [46]. In Oceania, water supply potential is among the lowest in Tokelau, Tuvalu, and Kiribati due to various challenges, e.g., population expansion, watershed degradation, and saltwater incursion from rising sea levels [47,48]. In Papua New Guinea, ensuring accessibility to reliable water sources near the residences is considered a major water resources management challenge, as women have to walk very long distances to collect water for domestic water use [49]. SDG target 6.2 aims to achieve universal adequate and equitable access to sanitation and hygiene, and fulfill the needs of women and girls in a vulnerable situation; SDG target 6.b aims to assist and encourage the participation of the people for the improved sanitation and hygiene of SDG 6 [21]. As a result, efforts should be made to ensure that appropriate water supplies and hygiene facilities are accessible at all times, even during the pandemic.

The policymakers of the Oceania region should consider formulating a sustainable water management approach that is resilient enough to meet the increasing water use due to unanticipated, events such as the coronavirus pandemic, for ensuring adequate and equitable sanitation and hygiene for all, otherwise, meeting SDG 6 in the region might be extremely difficult.

3.5. Northern America

The Northern America region consists of two countries, i.e., the USA and Canada [31]. In the USA and Canada, domestic water use is expected to increase by 3.72% and 5.07%, respectively, due to handwashing during the coronavirus pandemic (Table A2). Compared to the other five regions of the world, Northern America is in a better position to tackle the water resource challenges due to the increase in water use during the pandemic. In another estimate, Nemati and Tran [22] showed a higher rate of increase in water use during the stay-at-home condition during the pandemic, which is in the range of 3.08–13.65%. According to the authors, this rise was due to frequent handwashing to minimize bacterial contamination, eating at home because many were closed and people avoided eating out, and many other activities that took place at home due to limited mobility.

However, it is important to note that overuse of water resources [50], climate variability [51], and salinity [52] contribute to the water stress in some states of the United States. Global warming and man-made alterations to the available water resources have reduced the flow of rivers in the western prairie provinces of Canada, resulting in water scarcity [53]. In this context, we would like to emphasize that wealthy nations have the technological tools and the financial resources to transfer water, produce freshwater from saltwater, and purify polluted water for reuse. Therefore, they may not experience an increase in withdrawal pressure in cases of frequent handwashing.

SDG target 6.4 calls for ensuring sustainable freshwater withdrawals and supply, as well as addressing water, and SDG target 6.6 aims to protect and restore the fresh water-related ecosystems. Considering the looming water stress and deterioration of existing water bodies, Northern America should focus on developing a sustainable water resources management mechanism that can address the challenges to achieve SDG 6, and also to meet the sudden increase of water use due to unanticipated events, such as the coronavirus pandemic.

3.6. Latin America and the Caribbean

Latin America and the Caribbean consist of three sub-regions, i.e., the Caribbean, Central America, and South America [31]. Among the three sub-regions, South America is predicted to experience the highest percentage increase in domestic water use due to handwashing for COVID-19 (7.43%), followed by the Caribbean (6.83%) and Central America (6.72%) (Table 5). The increase in domestic water use during the pandemic is estimated to be highest in Brazil (1.397 billion m^3), followed by Mexico (0.847 billion m^3) and Argentina (0.297 billion m^3). Bolivia is predicted to have the highest percentage increase in domestic water use (56.39%), followed by Belize (22.92%) and Honduras (20.66%). Seven countries are expected to experience domestic water use increase by more than 10%, i.e., Haiti, Jamaica, Belize, Guatemala, Honduras, Nicaragua, and Bolivia. Of these seven countries, two countries are located in the Caribbean, four countries are in Central America, and one country is in South America.

Water conflicts due to the mismanagement of water resources and water scarcity are already visible in some parts of the region. For example, in Mexico, 90 million people face the adverse consequences of severe water scarcity throughout the year [54]. In a few countries of the region, most notably in Brazil, the COVID-19-related deaths are among the highest in the world [31]. Some Asian [55], African [42], European [56], Oceanian [49], and Latin American and Caribbean [57] countries lack access to sanitation and hygiene facilities, owing to the absence of clean water sources. Water shortage is evident in the majority of Asian [19,40,41], African [58], European [54], some Oceanian [45], Northern American, [53] Latin American, and Caribbean [54] countries. As the region is severely affected by the coronavirus disease, the countries in the region should do their best to provide access to adequate and equitable water, sanitation, and hygiene for all by increasing water use efficiency, and ensuring sustainable withdrawals and supply of freshwater to address water scarcity, and substantially reducing the number of people suffering from water scarcity in line with targets 6.2 and 6.4 of SDG 6 [21].

As water quality and overuse are major concerns for some Asian [40,59], African [60], Northern American [50], and Latin American and Caribbean [54] countries, freshwater resources should be protected and restored to prevent depletion, as stated in SDG 6 target 6.6. Following SDG goal 6.6b, local community cooperation to enhance water supply and sanitation management should be encouraged in Asia [55], Africa [42], Europe [56], Oceania [49], and Latin America and the Caribbean [57]. The countries in Latin America and the Caribbean should be prepared to cope and adapt to the sudden increase in water use due to unforeseen natural events, such as COVID-19. Otherwise, the countries in the region will face challenging situations which will lead to the suffering of the people residing in the region.

4. Discussion

The result of this research reveals that domestic water use is expected to increase by approximately 11.96% globally due to the increased number of handwashes to prevent transmission of the coronavirus disease. It is estimated that Asia will account for a 65.78% increase in the total global water use due to handwashing for COVID-19 (2020), followed by Northern America (11.88%), Latin America and the Caribbean (8.36%), Europe (7.46%), Africa (5.97%), and Oceania (0.55%) (Figure 2).

The highest water withdrawals among the sub-regions of six regions i.e., Asia, Africa, Europe, Oceania, Northern America, and Latin America and the Caribbean, have been presented in Figure 3. Analysis of the data reveals that the increase in domestic water use during the coronavirus pandemic (2020) is expected to be highest in South Asia, and lowest in Australia and New Zealand. This drastic difference between the two regions is because of the huge population gap.

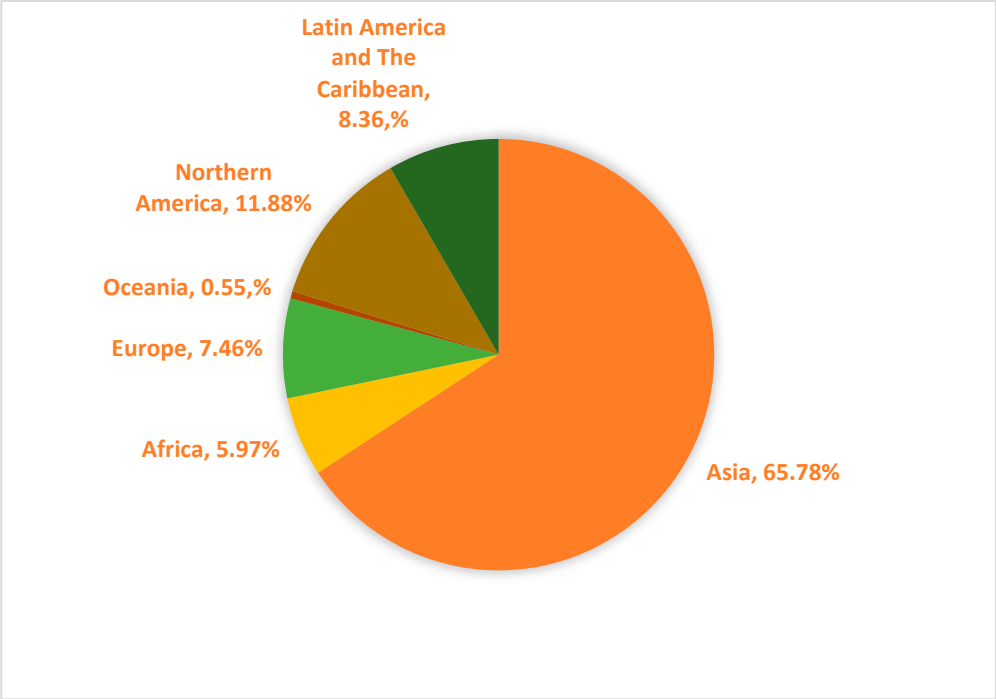

Figure 2. Regional contribution to global water use increase due to hand hygiene for COVID-19 (redrawn from [30,31,38]).

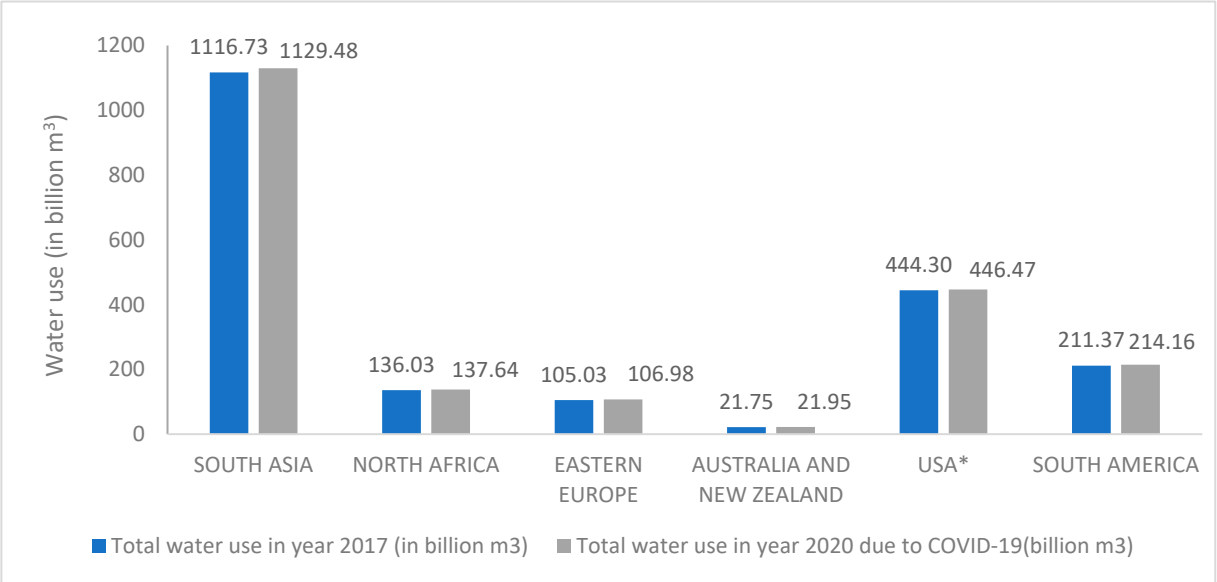

Figure 3. Highest total water use by sub-region in 2017 and 2020 (during the COVID-19) (redrawn from [30,31,38]) [* USA represents the "country" achieving the highest water use for Northern America, as no collective data for sub-region was present].

Africa (23.88%), Asia (15.05%), and Latin America and the Caribbean (7.18%) are predicted to have the highest percentage of increase in domestic water use due to hand hygiene practices during the coronavirus pandemic (2020). This is an alarming trend, as these regions were facing water shortages even before the pandemic. The countries located in Central Africa and West Africa are known for having access to an ample number of freshwater sources [61]. The rest of the sub-regions, i.e., Southern Africa, East Africa, and North Africa, lack the essential water resources required for survival [62]. Moreover, less than 5% of the population residing in Liberia, Lesotho, the Democratic Republic of Congo,

and Rwanda have access to available hand hygiene facilities [63]. In Asia, around half a billion people in India (180 million), Pakistan (73 million), and Yemen (18 million) were facing water scarcity throughout the year [54]. Some areas covered in Western Asia, South Asia, and East Asia are in absolute water scarcity, as water withdrawals per person are less than 500 m^3 annually [64]. In Latin America, 100 million people do not have access to proper sanitation facilities, and 60% of rural people lack basic sanitation facilities [65]. Problems such as water contamination, declining water tables, reduced water flows due to changes in hydrological patterns, etc., are evident in various cities in Brazil, Mexico, Argentina, Chile, Colombia, and Venezuela [66].

Even though these regions are more prone to water insufficiencies, the rest of the regions should not be overlooked. Europe (7.17%), Oceania (5.93%), and Northern America (3.83) are also subject to an increase in domestic water use to prevent transmission of the coronavirus disease. It is a matter of concern that vast areas of Eastern Europe have less than 1000 m^3 per capita per year of available freshwater [64], which falls into the category of water scarcity. Around 30 million people living in Europe do not have access to basic sanitation facilities [1]. Sivakumar [46] found that even though Oceania has the highest amount of available freshwater resources (83.8 $\times$ 103 m^3/year per capita), the water availability varies among different countries. For example, in Australia, the water availability is only 19.7 $\times$ 103 m^3/year per capita [46]. In Papua New Guinea (a country in Oceania), only 57% of urban people and 13% of rural people have access to basic sanitation facilities [5]. In addition, some of the large cities in the United States of America are starting to experience water scarcity and, at the same time, water uses are also increasing [67]. Consequently, the pressure on local and regional water resources is also continuously rising [67].

These increases in domestic water use to ensure hand hygiene compliance during the coronavirus pandemic can add to the already existing water shortages, which were present long before the appearance of the pandemic. Currently, around 4 billion people live under conditions of water scarcity for at least one month of the year, of which the majority are living in India (1 billion), China (0.9 billion), Bangladesh (130 million), the USA (130 million), Pakistan (120 million), Nigeria (110 million), and Mexico (90 million) [54]. Among the countries mentioned above, India, China, Bangladesh, and Nigeria are expected to experience an increase in domestic water use by approximately 16.19%, 11.91%, 30.06%, and 27.09%, respectively. In the USA, Pakistan, and Mexico, the predicted percentage increases in domestic water use are 3.72%, 15.04%, and 5.95%, respectively. This sudden additional water use due to the coronavirus pandemic will exacerbate the water management situation in countries which are already experiencing water scarcity.

Table 6 and Figure 4 show the changes in total water use and domestic water use in six regions of the world before (2017) and during (2020) the coronavirus pandemic period [30,31,38].

Table 6. Changes in total water use and domestic water use in 2017 and 2020 (during COVID-19) for six regions of the world [30,31,38].

Region	Domestic Water Use in the Year 2017 (in Billion m^3)	Increase in Water Use Due to Handwashing for COVID-19 (in Billion m^3)	Probable Domestic Water Use the Year 2020 (in Billion m^3)	Total Water Use in the Year 2017 (in Billion m^3)	Probable Total Water Use in the Year 2020 Due to COVID-19 (in Billion m^3)	% of the Increase in Total Water Use Due to COVID-19	% of the Increase in Domestic Water Use Due to COVID-19
Asia	244.59	30.24	274.83	2640.17	2670.41	1.15	15.05
Africa	33.65	8.03	41.68	234.37	242.4	3.43	23.88
Europe	68.53	4.91	73.44	298.05	302.96	1.65	7.17
Oceania	4.45	0.26	4.71	22.23	22.49	1.19	5.93
Northern America	63.28	2.42	65.7	479.9	482.32	0.5	3.83
Latin America and the Caribbean	59.15	4.25	63.39	334.99	339.24	1.27	7.18
Total	473.65	50.11	530.32	4009.71	4059.82	1.25	11.96

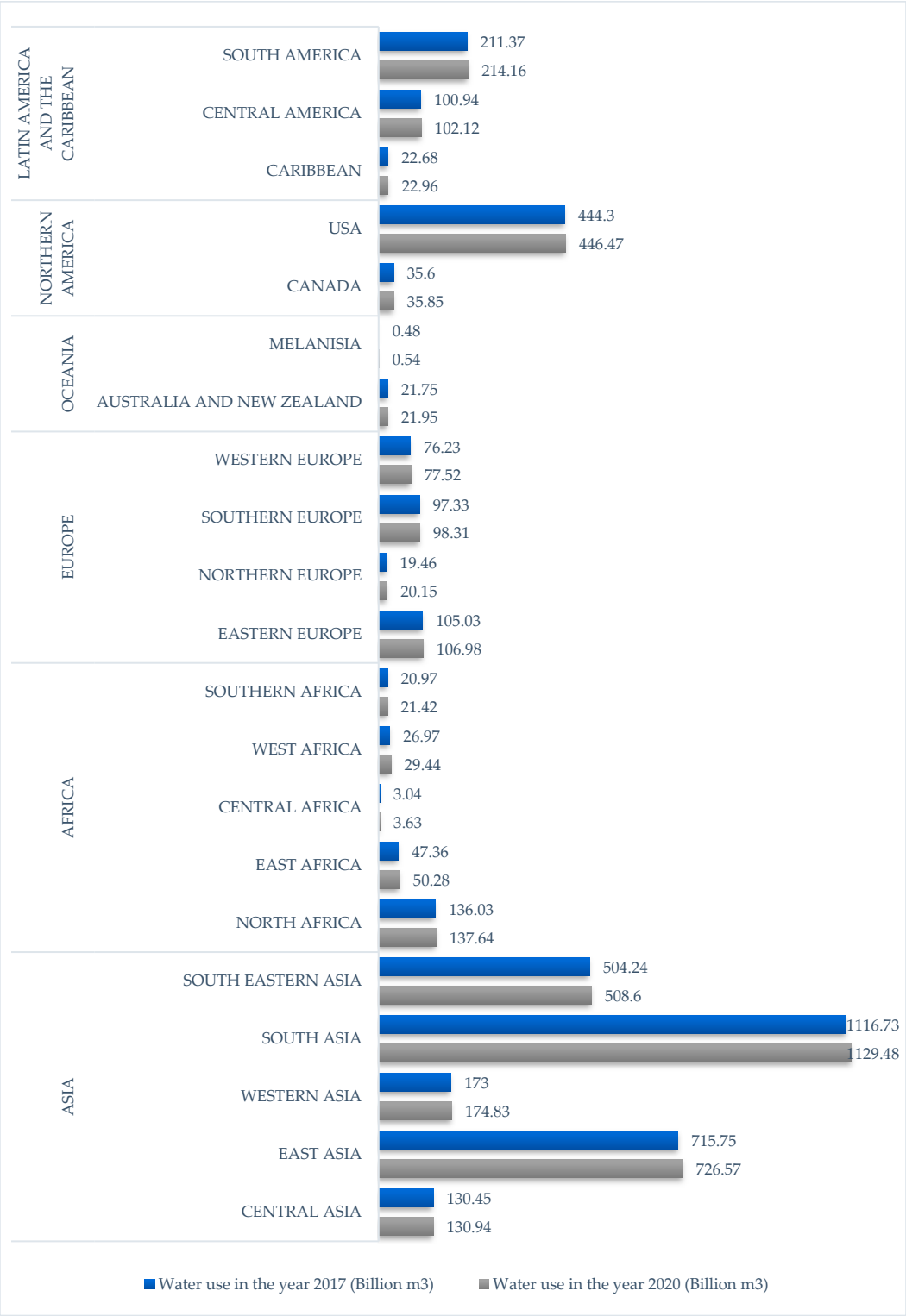

Figure 4. Total water use in 2017 and 2020 (during COVID-19) by regions and sub-regions (redrawn from [30,31,38]).

Policy Implication and Significance of the Study

The current annual growth rate of global water use has been approximately 1% since the 1980s [10]. However, this study shows that world water use patterns have changed dramatically due to COVID-19. While in the short term, domestic water uses have increased dramatically due to awareness of personal hygiene, in the long-term, COVID-19 necessitates

significant changes in the management of water resources at a local, national, regional, and global scale. The objective of sustainable global water management should be that water should be available for all uses and users and be of appropriate quality, even with the increase in demand.

History has shown us that people rarely draw lessons from the past. For example, during the 1918 Spanish Flu pandemic, that claimed 50 million lives, newspapers were filled with advertisements with advice given to the public to wash their hands regularly [68]. However, after 100 years of the last global pandemic, our water organizations and authorities still do not have any contingency plan to ensure quality water to meet the increasing water use requirements due to the additional handwashing and other related requirements during unanticipated events, such as COVID-19 or the 1918 Spanish Flu. The results of this study will help decision makers, water professionals, water managers, scholars, and other stakeholders to understand the importance of taking appropriate measures to meet the sudden changes in water use and related water management challenges during unanticipated events.

This is important, as otherwise, we might forget the suffering and deaths of people after the pandemic is over, as it happened after the 1918 Spanish Flu pandemic, and history will keep repeating itself again and again. It is high time for the local, national, regional, and global water stakeholders and authorities to work together to have a plan of action, so that people are better prepared to achieve Sustainable Development Goal 6, that is to ensure access to water and sanitation for all, with a special focus on targets 6.1 and 6.2.

During the current COVID-19 pandemic, the world was fortunate enough to be financially able to lockdown the entire country for a significant period of time. As a result, during that time, industrial and commercial water usage were drastically reduced, and water authorities did not experience any significant water shortages due to increased domestic water use. However, if, during any future unanticipated and sudden global pandemic, we fail to afford any lockdown globally for an extended period and need to expose our population to their workplaces to ensure enough food and the basic needs of the societies are met, we must provide them with an adequate water supply to meet the increased water requirements to stop spreading the viruses while, at the same time, making sure that the world economic cycles are functioning properly.

Through this study, we want to underline the significance of understanding the requirement for proper management strategies, along with a contingency plan to meet any unexpected increases in global water usage due to unanticipated events.

5. Conclusions

The findings of this research reveal that global domestic and total water use increased by approximately 11.96% and 1.25%, respectively, due to handwashing for preventing the COVID-19 pandemic. The key results of this research have been summarized in Table 6 and Figure 4. To deal with this substantial rise in water use, immediate measures should be taken to provide water availability in areas facing water stress and scarcity. The majority of such areas are in Africa and Asia, where water has been scarce since 1900 [69].

The unexpected surge in global domestic water use to ensure proper hand hygiene during the coronavirus pandemic would pose enormous difficulties in achieving Sustainable Development Goal 6 worldwide [70,71]. According to UN resolution 64/292 and General Comment No. 15 of the UN Committee on Economic, Social, and Cultural Rights, access to clean drinking water and sanitation is recognized as a human right [72].

The achievement of SDG 6 is vital for all countries located in the world's six regions to provide access to adequate and effectively managed water resources, sanitation, and hygiene for all. However, this goal is yet to be fully achieved throughout the world. To address the water scarcity and meet the increasing water use required for appropriate hand hygiene during the ongoing coronavirus pandemic, the countries must emphasize achieving SDG targets 6.2 and 6.4. These targets aim to ensure access to adequate sanitation and hygiene for all, and to increase water use efficiency and ensure sustainable water

withdrawals and supply of freshwater, and substantially reduce the number of people suffering from water scarcity. Since water quality and overuse are major concerns for certain countries, freshwater resources should be protected and restored to prevent depletion, in line with target 6.6 of SDG 6. To achieve SDG 6, forward-looking sustainable water resources management policies should be developed and implemented to ensure universal access to water, sanitation, and hygiene.

This study does have certain limitations. To begin, the assessment was conducted by taking into account the same handwashing habit and method for each country's population, e.g., faucets and flow rate, without taking into account the diverse physical, environmental, economic, social, cultural, and health conditions in individual countries. The impact of environmental and socio-cultural dynamics, and the impact of cultural groups on the domestic water use during COVID-19 is reported by some researchers [73–75]. Consumption of water is affected by a variety of environmental conditions, including rainfall, temperature, and rates of evaporation. In order to keep the outside landscaping in areas with high temperatures and minimal rainfall looking nice, more water will need to be used. Even within the same hydrologic region or the same water supply district, these characteristics can vary a great deal, which has a substantial impact on the amount of water that is required to keep landscapes in good condition [76,77]. Secondly, the study calculated the potential increase in water use during the pandemic based on population and, as a result, assumed that all individuals throughout the world have access to appropriate hand hygiene facilities. However, it is important to note that many people in the regions do not have access to adequate safe water, sanitation, and hand hygiene facilities. Existing hygiene habits will greatly influence the increase in handwashing [73]. Furthermore, in order to acquire more accurate findings, it is necessary to objectively assess the behavioral patterns of water usage in each country. This may be accomplished by gathering comprehensive information and data that will enable the global water community to develop adequate response strategies to deal with the increased water use caused by the required hand hygiene measures during the coronavirus pandemic. It is likely that with the decline of the pandemic, the amount of water used for handwashing decreased. Similar observations were reported by Nemati and Tran [22] and other researchers [78,79], who observed that domestic water consumption decreased significantly when the regulation of stay-at-home was removed. However, certain "frontline" professionals (including doctors, nurses, firefighters, and emergency response staff) would consume the same amount of water during the pandemic and pre-pandemic periods.

The results of this research will help decision-makers, water professionals, scholars, water managers, and all relevant stakeholders around the world to appreciate the overwhelming water management challenges due to the handwashing requirements during the coronavirus pandemic, and prepare themselves to face and overcome those challenges in a sustainable way, and to contribute towards achieving Sustainable Development Goal 6. The coronavirus pandemic taught the world once again that "if there is no water, there is no life" and, hence, the global water community must act wisely to take all necessary measures to meet the sudden increase of global domestic water use during unanticipated events, such as the ongoing COVID-19 pandemic, and achieve Sustainable Development Goal 6.

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Data Availability Statement: The datasets analyzed during the current study are available in the FAO AQUASTAT [https://www.fao.org/aquastat/en/] and Worldometer [https://www.worldometers.info/world-population/population-by-country/] (accessed on 14 March 2023) repositories.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Comparison of domestic and total annual water use in 2017 and 2020 (during COVID-19) for sub-regions of Oceania [30,31,38].

Region	Sub-Region	Domestic Water Use in the Year 2017 (in Billion m^3)	Increase in Water Use Due to Handwashing for COVID-19 (in Billion m^3)	Probable Domestic Water Use in the Year 2020 (in Billion m^3)	Total Water Use in the Year 2017 (in Billion m^3)	Probable Total Water Use in the Year 2020 Due to COVID-19 (in Billion m^3)	% of the Increase in Total Water Use Due to COVID-19	% of the Increase in Domestic Water Use Due to COVID-19
Oceania	Australia and New Zealand	4.20	0.20	4.40	21.75	21.95	0.92	4.74
	Melanesia	0.25	0.06	0.31	0.48	0.54	13.56	25.99
	Total	4.45	0.26	4.71	22.23	22.49	1.19	5.93

Table A2. Comparison of domestic and total annual water use of in 2017 and 2020 (during COVID-19) for countries of Northern America [30,31,38].

Region	Sub-Region	Domestic Water Use in the Year 2017 (in Billion m^3)	Increase in Water Use Due to Handwashing for COVID-19 (in Billion m^3)	Probable Domestic Water Use the Year 2020 (in Billion m^3)	Total Water Use in the Year 2017 (in Billion m^3)	Probable Total Water Use in the Year 2020 Due to COVID-19 (in Billion m^3)	% of the Increase in Total Water Use Due to COVID-19	% of the Increase in Domestic Water Use Due to COVID-19
North America	Canada	4.89	0.25	5.14	35.60	35.85	0.70	5.07
	USA	58.39	2.17	60.56	444.30	446.47	0.49	3.72
	Total	63.28	2.42	65.70	479.90	482.32	0.50	3.83

Table A3. CI calculated for different sub-regions for total water use in 2017 and 2020.

SUB-REGION	Countries	CI for Total Water Use in 2017 (Mean ± Margin of Error)	CI for Total Water Use in 2020 (Mean ± Margin of Error)
Central Asia	Uzbekistan, Kazakhstan, Tajikistan, Kyrgyzstan, Turkmenistan	26.09 ± 17.72	26.19 ± 17.78
East Asia	China, Japan, South Korea, North Korea, Mongolia	143.15 ± 224.63	145.31 ± 228.21
Western Asia	Turkey, Iraq, Saudi Arabia, Syria, Yemen, Azerbaijan, UAE, Israel, Jordan, Palestine, Lebanon, Kuwait, Oman, Georgia, Qatar, Armenia, Bahrain, Cyprus	9.61 ± 7.39	9.71 ± 7.44
South Asia	Bangladesh, India, Iran, Pakistan, Nepal, Bhutan, Maldives, Afghanistan, Sri Lanka	124.08 ± 160.84	125.49 ± 162.72
South Eastern Asia	Malaysia, Indonesia, Vietnam, Thailand, Myanmar, Philippines, Cambodia, Laos	56.02 ± 46.84	56.51 ± 47.19
North Africa	Algeria, Egypt, Sudan, Tunisia, Morocco, Libya, Burundi, Comoros, Djibouti, Eritrea, Ethiopia	22.67 ± 22.41	22.94 ± 22.58
East Africa	Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Seychelles, Somalia, South Sudan, United Republic of Tanzania, Uganda, Zambia, Zimbabwe	2.63 ± 1.75	2.792 ± 1.80

Table A3. *Cont.*

SUB-REGION	Countries	CI for Total Water Use in 2017 (Mean ± Margin of Error)	CI for Total Water Use in 2020 (Mean ± Margin of Error)
Central Africa	Angola, Cameroon, Central African Republic, Chad, Congo, Equatorial Guinea, Gabon, Sao Tome and Principe	0.38 ± 0.30	0.455 ± 0.35
West Africa	Benin, Burkina Faso, Cabo Verde, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo	1.79 ± 1.64	1.96 ± 1.79
Southern Africa	Botswana, Eswatini, Lesotho, Namibia, South Africa	4.19 ± 7.44	4.28 ± 7.59
Eastern Europe	Belarus, Bulgaria, Czech Republic, Hungary, Poland, Republic of Moldova, Romania, Russia, Slovakia, Ukraine	10.50 ± 11.93	10.69 ± 12.10
Northern Europe	Denmark, Estonia, Finland, Iceland, Ireland, Latvia, Lithuania, Norway, Sweden, UK	1.95 ± 1.52	2.01 ± 1.59
Southern Europe	Albania, Croatia, Greece, Italy, Malta, Montenegro, North Macedonia, Portugal, Serbia, Slovenia, Spain	8.85 ± 7.39	8.93 ± 7.47
Western Europe	Austria, Belgium, France, Germany, Luxembourg, Monaco, The Netherlands, Switzerland	9.53 ± 7.67	9.69 ± 7.81
Australia And New Zealand	Australia, New Zealand	10.88 ± 11.1	10.985 ± 11.25
Melanesia	Fiji, Papua New Guinea	0.24 ± 0.30	0.275 ± 0.35
USA	Canada, USA	239.95 ± 400.52	241.16 ± 402.41
Caribbean	Antigua and Barbuda, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Haiti, Jamaica, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Trinidad and Tobago	1.89 ± 1.73	1.91 ± 1.74
Central America	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama	12.61 ± 21.07	12.77 ± 21.27
South America	Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela	17.61 ± 11.26	17.85 ± 11.45

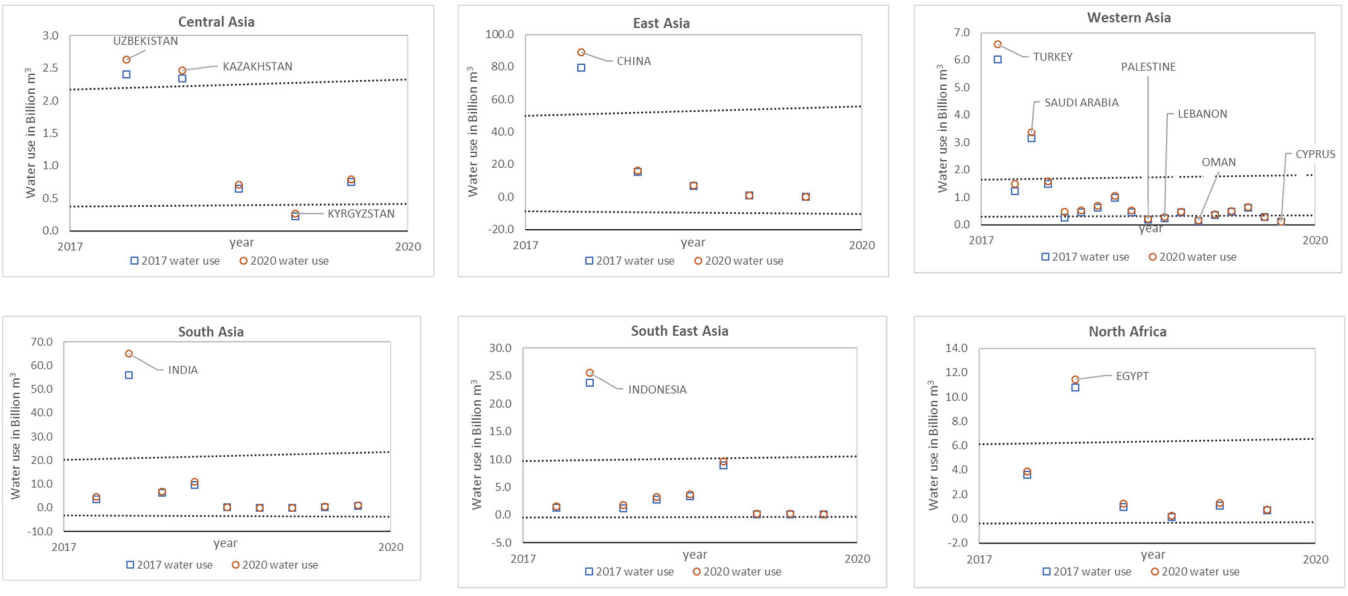

Figure A1. *Cont.*

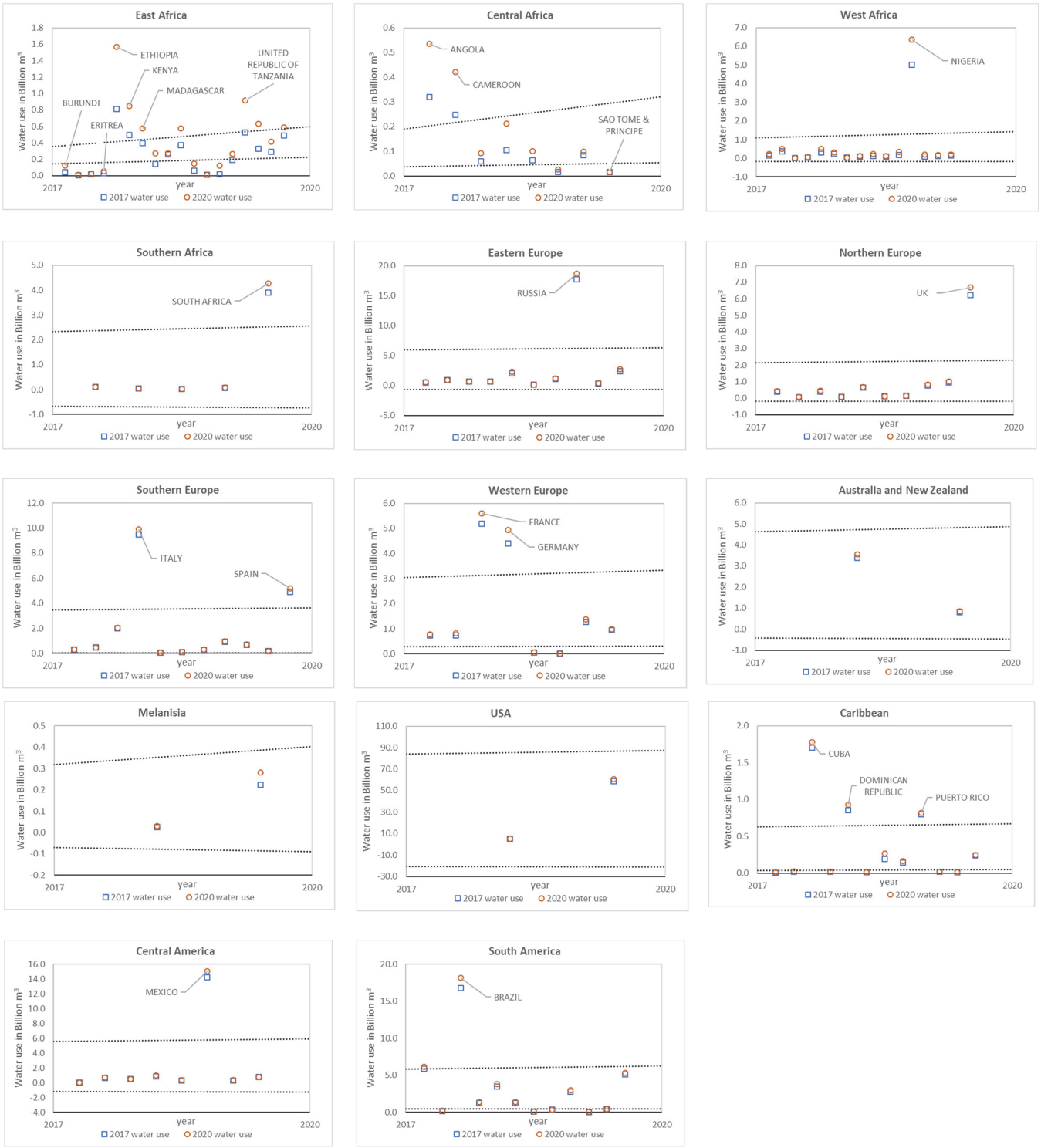

Figure A1. Status of 95% CI of domestic water use for countries under sub-regions, calculated as $\bar{x} \pm Z\frac{S}{\sqrt{n}}$, where, $\bar{x}$ is sample mean; Z is Z-score (1.959964 for 95% CI), S is standard deviation and n is sample size. The above and below dotted lines in the figures show the upper and lower limit of the CI, respectively, for a region, calculated between years 2017 and 2020.

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