Water consumption changes during and after COVID-19 in Ghana

Peace Korshiwor Amoatey[1*], Godwin King-Nyamador[2], Micheal Martey[3], Maxwell Kusi-Akosah[4], Cynthia Naa Adoley Acquaye[5], and Wonder Nutsugah[6]

[1]Department of Agricultural Engineering, University of Ghana, Legon
[2]Institute for Environment and Sanitation Studies (IESS), University of Ghana, Legon
[3]Ghana Institute of Management and Public Administration, GIMPA, Achimota.
[4]Ghana Water Company Limited, Accra
[5]Department of Built Environment, University of Environment and Sustainable Development (UESD), Somanya, Ghana
[6]Department of Public Administration, UGBS, University of Ghana, Legon

***Corresponding Author:** pkamoatey@ug.edu.gh

ABSTRACT

Maintenance of good hygiene practices are encouraged in the outbreak of infectious diseases like COVID-19 and therefore, water consumption is expected to increase. There is evidence that across the globe, water consumption increased as a result of hygiene practices as people stayed at home during the pandemic, blending work, study and other daily activities. To adequately tackle the infection rate, the government of Ghana announced "free water" for all policy. This study seeks to investigate whether the pandemic and subsequent policy in 2020 has influenced water consumption over the last 2 years. The study employed descriptive statistics and Interrupted Time Series Analysis (ITSA) on monthly water consumption data from 2018 to 2022. 60 data points consisting of 27 pre and 33 post-interruption data points were used to allow the model to measure the trend before the intervention (policy) and the immediate impact of the intervention. On the average, consumption in terms of volumes increased by about 30%, and ITSA showed a significant immediate impact and increasing trend on monthly water use. The findings of the study have implications on further research, engineering practice, policy and its implementation to help in preparation for future pandemics.

Keywords: Covid-19, Interrupted Time Series Analysis (ITSA), Intervention, lockdown, water consumption

1.0 BACKGROUND

With the outbreak of any viral respiratory disease, the World Health Organisation (WHO) usually announces and encourages the washing of hands as a preventive measure. Brauer, Zhao, Bennitt and Stanaway (2020) indicated that systematic reviews have shown the effectiveness of handwashing in reducing the transmission of respiratory disease-causing viruses. For example, evidence suggests that a handwashing session with 0.2 litres is sufficient to keep one safe from being exposed to viral infection

(Mattioli et al., 2014). It has been observed that in the event of epidemics and pandemics such as Cholera, Ebola among others, water consumption generally increases. This is because an important way of preserving human lives during infectious disease outbreaks includes supply of safe drinking water, good hygiene and adequate sanitation practices (Kalra et al., 2014; WHO, 2015, 2020). This explains the reason for the all-time high increase in water consumption during the total and partial lockdown that resulted from the deadly Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV2) pandemic. Children were out of school and most workers were working from home leading to an increase in domestic water demand. Activities such as the drinking of water and flushing of toilets significantly increased in homes and diminished at the various places of work, and in schools.

Drinking lots of water and washing hands under running water became a mantra for both the young and old. Behavioural changes in personal hygiene were confirmed with increased frequency in handwashing and showering upon their return, after they had gone shopping for groceries or attended to anything outside their homes. Activities such as the washing of clothes and disinfection of surfaces such as tables, may have also contributed to increased daily water volumes consumed at home. With the lockdowns, time spent doing housework increased, leisure increased and the amount of gardening might have increased as well (Campos et al., 2021; Del Boca et al., 2020; Kalbusch et al., 2020; Nemati, 2020). On the other hand, some industries had to shut down or reduce production as a result, thus, industrial and institutional consumption was expected to decrease. Significant changes in the global consumption of water influenced continuity of water supply in terms of quantity and quality of services to customers (International Water Association, 2020). The World Health Organisation (WHO, 2020) and Kalbusch et al. (2020) reported that the pandemic caused a surge in the quantities of water consumed in health facilities due to continuous cleaning of equipment and facilities as well as in the treatment of patients. Therefore, hospitals were most likely the only non-residential use with increased consumption. With these developments, the International Water Association (IWA, 2020) reported that changes in consumption patterns had increased during the day as people worked from their homes. A general decrease in pre-pandemic weekday morning peaks was observed in many countries. Morning peaks were reported to have been delayed by one to two hours and were also observed during weekdays (Abu-Bakar et al., 2021; Balacco et al., 2020; Lüdtke et al., 2021). Aquatech (2020) confirmed that the city of Karlsruhe, Germany observed water consumption changes over a period.

Kalbusch et al. (2020) reported a similar situation in Joinville, Southern Brazil; the study revealed that there was an 11% increase in the water consumption in the residential category whereas there was a significant decrease in the quantity of water consumed in the public. Lüdtke et al. (2021) reported a 14.3% increase in consumption in northern Germany during the first wave of the pandemic while an 18% increase was observed in Rovigo, Italy (Alvisi et al., 2021). In England and Wales, a 35% increase in peak daily consumption was observed in certain regions during the lockdown (Abu-Bakar et al., 2021; Alda-Vidal et al., 2020; Marshallsay, 2020). Similarly in Portsmouth in England, there was a 15% increase in water demands (Portsmouth Water, 2020) while Eastman et al. (2020) reported a 14% increase in a water utility in Arizona, USA. Likewise, residential demand in San Francisco, California increased by 10% (Cooley et al., 2020). Birişçi and Öz (2021) reported a 20% increase in residential consumption in Bursa, Turkey. Almulhim and Aina, (2022) reported a whopping 50% increase in water use in the Dammam Metropolitan Area, Saudi Arabia. Sayeed et al. (2021) reported water usage in Bangladesh to have been 1.7 L in excess of the norm due to handwashing practices. Although not much statistics is documented for African countries, Niasse and Varis (2020) confirmed that COVID-19 has led to an increase in domestic water demand in African countries like Nigeria and Rwanda who are already suffering from water insecurity. There have been a number of studies that sought to examine how COVID-19 spreads, its effect on human activities and possible ways of mitigating it.

Other studies have equally assessed the impact of lockdown and its possible effect on the quality of water as well as the quality of air (Mahato et al., 2020; Muhammad et al., 2020; Yunus et al., 2020). Furthermore, other studies have focussed on the spatio-temporal changes of daily routines (Alda-Vidal et al., 2020). Abu-Bakar et al. (2021) measured households' unique water consumption patterns in England and Cooley et al. (2020) assessed the financial implications for customers and utilities, as well as impacts on water and wastewater operational conditions. These studies have been useful in making predictions in preparation against future pandemics. It is in this light that this study seeks to assess what the situation in Ghana was during and after the pandemic. In Ghana, every citizen was supplied water for free from April 2020 till March 2021 (Dapaah, 2020; Government of Ghana, 2020; Graphic Online, 2020) which led to changes in consumer behaviour as communities which did not have piped water pre-COVID were equally served with water in tankers. Also, when the government withdrew the waiver, a section of the populace pleaded that the government reconsider a further extension of non-payment for water. This led to the government making consumption free for those whose monthly consumption was less than 5 m3 from January to March 2021 (Government of Ghana, 2021; Nyavi, 2021). For forecasting and planning purposes, it is essential to understand the dynamics and adaptations the pandemic has brought on, as well as the factors influencing these dynamics or patterns, hence the need for this study.

It is uncertain how the changes in water consumption have continued 2 years on. Cooley et al. (2020) has emphatically stated for example that, as people continue to work from home, COVID-related impacts on water demand may be short-lived when people return to work. Lüdtke et al. (2021) also posits that the change in practices that might have caused the increase in the observed water consumption may or may not persist into the future. Additionally, Nemati (2020) reports that analysing changes in water use is valuable for water agencies, water managers, and policymakers. The changes affect the operational conditions, revenue, finances and wastewater generated as far as water agencies are concerned. The fact that water was distributed or shared for free might impact residential/domestic consumption as pricing is known to control per-capita water consumption (Amoah, 2020). A direct consequence of such a social intervention during emergencies such as COVID-19, as what happened in Ghana, impacts customers willingness to pay for water, which causes a reduction in revenues for the water utility company and thus creates a vicious circle (Cooper, 2020). This study seeks to investigate whether bulk water consumption changed in Ghana, potential reasons for the change in water use, the dynamics and peculiarities of the change specific to different regions and whether COVID-19 and the "free water" policy significantly influenced these changes.

2.0 METHOD

2.1 General overview of water supply in Ghana

The Ghana Water Company Limited (GWCL) is a fully owned state utility company mandated to supply potable water to all urban communities in Ghana. The average daily production is around 882,000 m3. The current water consumption is predicted to be around 1,100,000 m3 per day making water supply coverage to be about 77% (GWCL, 2023). GWCL has a customer size of about 800,000 of which 86% are metered. The water supply administration in Ghana is organised under 13 regions with Greater Accra and Ashanti Regions having 3 and 2 respectively due to the level of population (customer size) in these regions. There are 90 water treatment plants supplying water to the entire country. Bulk water production volumes, customer size, billing records and revenue collection among others were collected from these 90 plants of the various regions. Bulk monthly water consumption and customer strength records from 2018 to 2022 were obtained from the GWCL for this study. The essence is to understand the situation prior to and during COVID-19. Interrupted Time Series Analysis (ITSA) was conducted taking April 2020 as the start of the intervention since the lockdown and the "free water" policy all took place at the end of March. This imply that the full effect of the interruption will be felt in April. A total of 60 data points, 27 data points pre-interruption and 33 data points post-interruption were used for the ITSA. The purpose of the ITS analysis is to determine whether the water consumption data patttern observed after the outbreak (interruption) varies compared to that observed before the interruption.

2.2 Statistical Analysis: ITSA

One way of assessing whether water consumption behaviour has changed during the outbreak of the recent Coronavirus (COVID-19) pandemic in Ghana is to use the ITSA design to evaluate if there has been an immediate impact and/or decrease or increase in the trend of water use. This was done using the "itsa addon" in stata (Linden, 2015). It is an increasingly popular quasi-experimental design involving the analysis of time series data, like an outcome measured over a time period of a defined population (Hudson et al., 2019). Basically, it refers to a set of measurements taken at equal intervals over a period of time that are interrupted by an intervention. The itsa is a wrapper program that uses the Newey-West method (Newey and West 1987) by default and produces Newey-West standard errors for coefficients estimated by ordinary least-squares regression (Linden, 2015). The standard errors are robust and adjusted for autocorrelation and heteroscedasticity (Dorward et al., 2021; Linden, 2018; Turner et al., 2021). It is very useful in solving complex situations, which is why this study employs the model to evaluate and compare the pre- and post-intervention water used during the COVID-19 pandemic. The method also allows the researcher to specify the number of lags to include in the model. The lag determines the extent to which previous information is relevant in predicting current happenings. The Cumby-Huizinga test for auto-correlation was employed to test for the maximum number of lags. The "itsa" accepts an outcome variable, a time variable for the pre-and post-intervention times, and a dummy variable for pre- and post-intervention and interaction term. The model time variable measures the trend before the intervention, the intervention variable measures the immediate impact of the intervention while the interaction term estimates the difference between the pre-intervention and post-intervention trend (Dorward et al., 2021; Linden, 2015). The model is specified as follows:

$$V_t = \beta_0 + \beta_1 T_t + \beta_2 X_t + \beta_3 T_t X_t + \varepsilon_t$$

where:

V_t is the monthly volume of water used

T_t is the time variable measuring the period from the start of the study

X_t is the interruption variable which is a dummy variable with 1 of interruption period and 0 otherwise

β_0 is the base level

β_1 is the trend before the intervention

β_2 is the immediate impact of the interruption

β_3 is the difference between the pre- and post-interruption trend

ε_t is the error term.

According to Penfold and Zhang (2013), a researcher may use a single time series to describe only the intervention or compare the changes by the intervention at one time point to another time point where there are no interventions introduced, usually referred to as the control.

3.0 RESULTS AND DISCUSSION

A comparison of the monthly bulk consumption data for 2018 - 2022 indicated that there was notable increase in the volume of water per region in 2020 in relation to the previous year 2019 when the pandemic had not occurred. This general increase in consumption in each region for the year 2020 can be observed in Figure 1. In 2021, nearly all regions still recorded a relatively higher consumption than pre-pandemic volumes, though lower than that of 2020, which suggests that people continued to observe the hygiene practices despite returning to their workplaces. However, it can also be seen that in 2022, some regions, except Ashanti South, Western and Central, recorded significantly higher consumption compared to 2021 but lower than 2020.

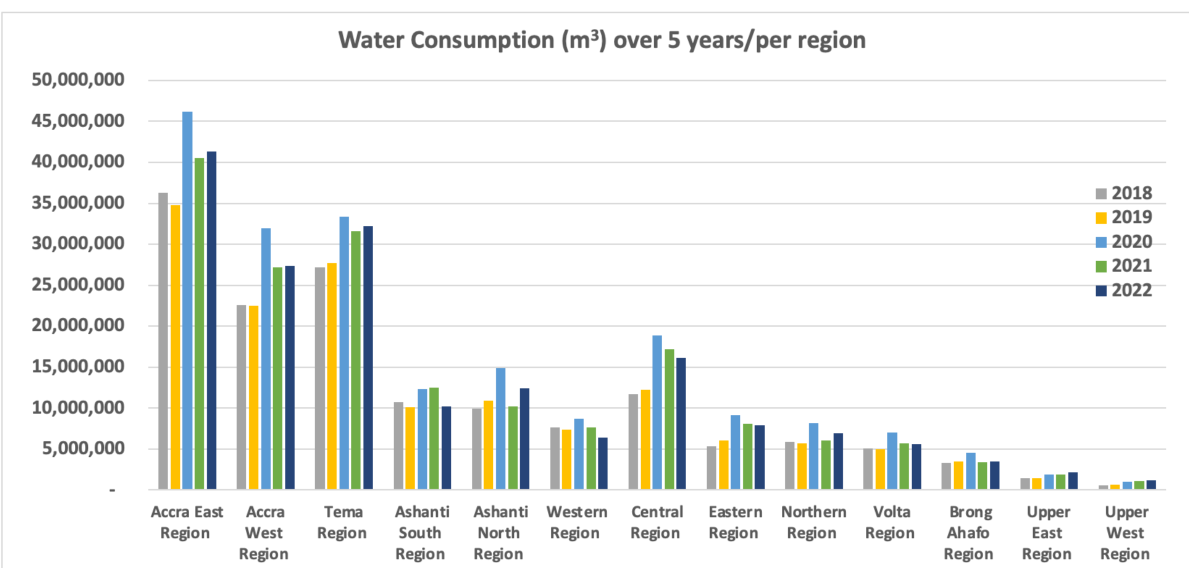

Figure 1: Water consumption per region over 5 years

It can also be seen from Figure 1 that; Accra East recorded the highest increase in water consumption compared to previous years (2018 - 2019). Overall, in 2020, the average national increase in consumption was 34% even though some regions recorded as low as 18% (Western region) and others as high as 67% (Upper West region) as shown in Table 1.

Table 1: Comparing percentage increase in consumption in the regions over the years

Region	2018 & 2019 (%)	2019 & 2020 (%)	2020 & 2021 (%)	2021 & 2022 (%)
Accra East	-4	33	-12	-23
Accra West	0	42	-15	-24
Ashanti North	10	36	-32	-26
Ashanti South	-5	22	1	-25
Brong Ahafo	6	30	-25	-22
Central	5	55	-9	-28
Eastern	13	51	-12	-24
Northern	-3	43	-26	-12
Tema	2	21	-5	-23
Upper East	1	32	-1	-12
Upper West	10	67	5	-36
Volta	-1	40	-19	-26
Western	-4	18	-12	-40
Average	**0**	**34**	**-13**	**-25**

It must be noted that the vast difference in overall water consumption over the years between Accra East, and Upper West Region (which has the lowest consumption) is due to the differences in the number of customers and water supply infrastructure coverage. Accra and Tema are mostly densely populated urban areas with high coverage of the water network, compared to the Upper West regions where the situation is the exact opposite in terms of network coverage and population density which influence customer strength. Table 2 shows the percent increase in customer strength for each region over the years. The average percentage increase in customer strength per annum prior to COVID-19 was 7%. In 2020 compared to 2019, there was an average increase of 10% while the years after the pandemic recorded an average increase of 9% and 8% respectively for 2021 and 2022. Some regions recorded significant increases in customer strength as high as 37% (Upper West), 14 % (Tema), 11% (Brong Ahafo) and 10% (Volta and Eastern). It must be indicated that, Upper West region consistently recorded an increase in customer strength due to its new water infrastructure and GWCL's general campaign to connect new customers to the network. In the main Cape Coast network, there is no expected increase in customer strength since it is the oldest urban network, densely populated and customers are already connected. It is therefore likely that, the 7% increase recorded may be due to relatively newer networks such as the Ekumfi, Baifikrom, Twifo Praso and Winneba networks in the Central region. Other reasons for the increase in water consumption were due to changes in hygiene practices, the lockdown which shifted consumptive uses and announcement of "free water" policy in addition to the expected natural increase due to population growth (Aquatech, 2020; Lüdtke et al., 2021).

The heightened campaign on hygiene practices such as hand washing, regular bathing and cleaning of surfaces contributed to an increase in water consumption in 2020. Due to the lockdown, institutional and industrial water uses shifted to domestic consumption (Aquatech, 2020; Cooley et al., 2020). As people stayed and worked from home, there were changes in lifestyle and adoption of new hobbies such as backyard gardening. In order to encourage the maintenance of hygiene practices, the government's announcement of "free water for all" policy led to access to water services 24/7 to Ghanaians irrespective of their status as customers of GWCL. This led to increase in customer strength due to reconnection of previously disconnected metres and reactivation of inactive accounts. Also, urban areas without pipe borne water or hitherto suffered intermittent supply were served with water in tankers (Abubakari et al., 2023). In some networks, where there is heavy reliance on public standpipes, commercial operators were mandated to allow people to fetch water freely. Furthermore, there is an expected natural increase in consumption due to population growth, however, it is not clear whether the 2022 consumption differences are purely due to

Table 2: Percentage increase in customer strength for each region over the years

Regions	2019 - 2018 (%)	2020 - 2019 (%)	2021 - 2020 (%)	2022-2021 (%)
Accra East	7	7	7	6
Accra West	6	8	8	6
Ashanti North	4	7	8	6
Ashanti South	2	4	4	4
Brong Ahafo	8	11	6	6
Central	11	7	12	8
Eastern	7	10	9	8
Northern	11	8	6	6
Tema	9	14	10	9
Upper East	5	8	15	23
Upper West	16	37	25	17
Volta	7	10	7	6
Western	4	5	6	4
Average	**7**	**10**	**9**	**8**

to natural increase or hygiene practices which have remained with people.

3.1 Effects of "free water" policy on water consumption

Before the actual model was estimated, the Cumby Huizinga test was conducted to determine the maximum number of lags to be included. Lag (1) was tested against a null of Lag (0). The results show that, the errors of the outcome variable are not serially correlated (p-value of 0.088). ITSA was therefore carried out at level. Table 3 shows the coefficients and Newey-West standard errors of the ITSA carried out. From the table, the base volume of water before the start of the interruption was estimated as 12,200,000 cubic metres. The coefficient for the time variable was 23,420 which means that there was a positive natural trend in monthly water consumption over time, before the intervention of the "free water" policy was announced. This trend was however not significant at 10% alpha level. In the first month of the interruption, there appeared to be a significant increase in volume of water used by 4,048,293 cubic metres at a significant level of 1%. This indicates that the announcement of "free water" policy led to a huge jump in bulk water consumption suggesting that, the pandemic had a major impact due to increased awareness of hygiene practices such as hand washing, regular bathing and cleaning of surfaces.

Table 3: Impact of Covid-19 on Water Consumption

Variable	Coefficient (Newey-West Standard Errors)
Time (β_1)	23420.61 (22590.8)
Intervention (β_2)	4048293*** (675659.4)
Time*Intervention (β_3)	-127563.5*** (32382.5)
Constant (β_0)	12,200,000 *** (278942.9)
Treated	-104142.9 (23201)

Note: *** significant at 1%; ** significant at 5% and * significant at 10

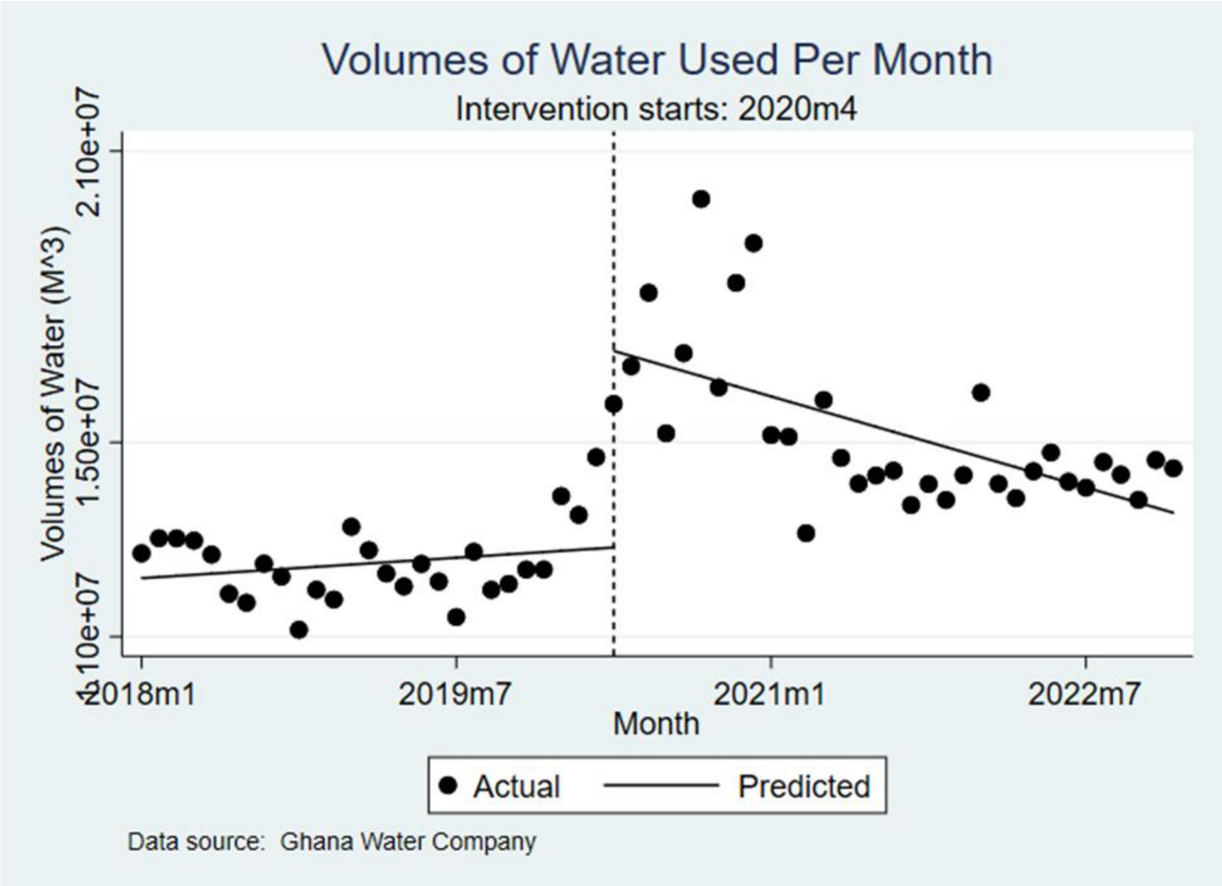

Figure 1: Single group ITSA with Newey–West standard errors and zero lag

There is a significant difference in the monthly trend before and after the interruption. However, there is a decrease in monthly bulk consumption post interruption, which is evident in the coefficient of -127,564 significant level of 1%. This suggests that the withdrawal of the "free water" policy had an effect on water consumption over time as payment for water services started in February 2021 and people needed to adjust their consumptive uses in order to avoid paying more for water. It must also be indicated that, the decreasing trend may have been sustained due to the recent hikes in tariffs. There was a 22% increase in water tariffs in September 2022 and a further increase of 8% in February 2023 (Ntow, 2023; PURC, 2022). Therefore, a further decrease is expected to bring consumption close to the pre-pandemic levels. The overall average increase in consumption due to the pandemic as indicated earlier was 34%. However, this study is unable to differentiate the changes in domestic, institutional and industrial consumption. Also, because monthly consumption volumes are used, the changes in typical daily patterns such as delayed morning peak and higher morning peaks as in Aquatech (2020) were not discussed.

The findings of this study concludes that the hygiene requirements of the Covid era, along with the "free water" policy from the government of Ghana led to increased water consumption.

4.0 CONCLUSION

The outbreak of the pandemic brought about the need to enhance hygiene practices as an important measure to control the spread of SARS - CoV2 (COVID-19) disease. The study sought to investigate the effects of the enhanced hygiene practices and measures such as the "free water" policy, on water consumption in Ghana, during and after COVID-19 pandemic. From the study, it can be concluded that there was a significant change in bulk water consumption during the COVID-19 pandemic. The study revealed an average increase in water consumption of 34%. This increase is attributed to changes in consumer behaviour (increased use of water for hygienic purposes), a more consistent supply of water to consumers (through activities such as reconnection of disconnected consumers by GWCL, and water provision through tanker services) and a 10% increase in customer size. The subsequent announcement of the "free water" policy also contributed significantly to an increase in consumption volumes across the nation. Moreover, this impact changed over time, which suggests that the free water supply policy may have had a varying effect on the different regions of the Ghanaian population. Such policies have implications on service delivery as was seen in the challenges such as abruptness of the intervention, poor communication and little or no consultation as stated in Abubakari et al. (2023).

This work has implications on further research, policy indications and engineering practice. For forecasting, planning and allocation of funds for investment purposes, a detailed study should be conducted to investigate the reasons that accounted for the increases in each region. There is the need to empirically analyse the behavioural changes in people's daily lives with respect to water use and its implications for water supply in Ghana. In preparation for future pandemics, the quantity of water required to meet the demands commensurate to fight the disease burden should be established. Also, understanding of the challenges that fraught the implementation of the "free water" policy should be documented. A future study would explore more than one intervention, for example, the "free water" policy and the first increase in tariff (in September 2022) after the policy was withdrawn. Furthermore, the influence of water tariffs on consumption in Ghana needs to be investigated.

REFERENCES

Abu-Bakar, H., Williams, L., & Hallett, S. H. (2021). Quantifying the impact of the COVID-19 lockdown on household water consumption patterns in England. Npj Clean Water, 4(1). https://doi.org/10.1038/s41545-021-00103-8

Abubakari, M., Agyemang, F. Y., & Tei, F. (2023). The limits and impact of communication and context in implementing social interventions in a pandemic: Ghana's free water policy revisited. Social Sciences & Humanities Open, 7(1), 100483.

Alda-Vidal, C., Smith, R., Lawson, R., & Browne, A. (2020). Understanding changes in domestic water consumption associated with COVID-19 in England and Wales. In Artesia Consulting and University of Manchester. https://shorturl.at/cEHKQ

Almulhim, A. I., & Aina, Y. A. (2022). Understanding Household Water-Use Behavior and Consumption Patterns during COVID-19 Lockdown in Saudi Arabia. Water (Switzerland), 14(3). https://doi.org/10.3390/w14030314

Alvisi, S., Franchini, M., Luciani, C., Marzola, I., & Mazzoni, F. (2021). Effects of the COVID-19 Lockdown on Water Consumptions: Northern Italy Case Study. Journal of Water Resources Planning and Management, 147(11), 5021021. https://doi.org/10.1061/(ASCE)WR.1943-5452.0001481

Amoah, A. (2020). Estimating averting expenditure in domestic water use: evidence from Ghana. Journal of Water, Sanitation and Hygiene for Development, 10(4), 894–904. https://doi.org/10.2166/washdev.2020.197

Aquatech. (2020). How Covid-19 impacts water consumption. https://www.aquatechtrade.com/news/utilities/covid-19-lockdowns-impact-water-consumption/

Balacco, G., Totaro, V., Iacobellis, V., Manni, A., Spagnoletta, M., & Piccinni, A. F. (2020). Influence of COVID-19 spread on water drinking demand: The case of Puglia Region (Southern Italy). Sustainability (Switzerland), 12(15). https://doi.org/10.3390/SU12155919

Birişçi, E., & Öz, R. (2021). Household water consumption behavior during the COVID-19 pandemic and its relationship with COVID-19 cases. Environmental Research and Technology, 4(4), 391–397. https://doi.org/10.35208/ert.953879

Brauer, M., Zhao, J. T., Bennitt, F. B., & Stanaway, J. D. (2020). Global Access to Handwashing: Implications for COVID-19 Control in Low-Income Countries. Environmental Health Perspectives, 128(5), 057005. https://doi.org/10.1289/EHP7200

Campos, M. A. S., Carvalho, S. L., Melo, S. K., Gonçalves, G. B. F. R., dos Santos, J. R., Barros, R. L., Morgado, U. T. M. A., da Silva Lopes, E., & Reis, R. P. A. (2021). Impact of the COVID-19 pandemic on water consumption behaviour. Water Supply, 21(8), 4058–4067. https://doi.org/10.2166/ws.2021.160

Cooley, H., Gleick, P. H., Abraham, S., & Cai, W. (2020). Water and the COVID-19 Pandemic Impacts on Municipal Water Demand. Pacific Institute. pacinst.org

Cooper, R. (2020). Water security beyond Covid-19 (Issue April).

Dapaah, E. (2020, April 5). Akufo-Addo announces free water for Ghanaians as government intensifies COVID-19 fight. Citinewsroom. https://citinewsroom.com/2020/04/akufo-addo-announces-free-water-for-ghanaians-as-government-intensifies-covid-19-fight/

Del Boca, D., Oggero, N., Profeta, P., & Rossi, M. (2020). Women's and men's work, housework and childcare, before and during COVID-19. Review of Economics of the Household, 18(4), 1001–1017. https://doi.org/10.1007/s11150-020-09502-1

Dorward, J., Khubone, T., Gate, K., Ngobese, H., Sookrajh, Y., Mkhize, S., Jeewa, A., Bottomley, C., Lewis, L., & Baisley, K. (2021). The impact of the COVID-19 lockdown on HIV care in 65 South African primary care clinics: an interrupted time series analysis. The Lancet HIV, 8(3), e158–e165.

Eastman, L., Smull, E., Patterson, L., & Doyle, M. (2020). COVID-19 Impacts on Water Utility Consumption and Revenues Through June 2020. Raftelis, June, 1–5. https://nicholasinstitute.duke.edu/sites/de-fault/files/publications/COVID-19-Resources-Im- pacts-on-Water-Utility-Consumption-and-Reve- nues.pdf

Government of Ghana. (2020). Address To The Nation By President Akufo-Addo On Updates To Ghana's Enhanced Response To The Coronavirus Pandemic. Speeches. https://presidency.gov.gh/index.php/briefing-room/speeches/1555-address-to-the-nation-by-president-akufo-addo-on-updates-to-ghana-s-enhanced-response-to-the-coronavirus-pandemic

Government of Ghana. (2021, January 3). Update No 21: Measures Taken To Combat Spread Of Coronavirus - The Presidency, Republic of Ghana. Speeches. https://presidency.gov.gh/index.php/briefing-room/speeches/1848-update-no-21-measures-taken-to-combat-spread-of-coronavirus

Graphic Online. (2020). Gov't extends free water package to December 31. General News. https://www.graphic.com.gh/news/general-news/ghana-news-gov-t-extends-free-water-package-to-december-31.html

GWCL. (2023). Company Profile – GWCL - Welcome. https://www.gwcl.com.gh/company-profile/

Hudson, J., Fielding, S., & Ramsay, C. R. (2019). Methodology and reporting characteristics of studies using interrupted time series design in healthcare. BMC Medical Research Methodology, 19(1), 1–7. https://doi.org/10.1186/s12874-019-0777-x

IWA. (2020). Managing Water Loss During Lockdown. Water Loss. https://iwa-connect.org/group/water-loss/timeline

Kalbusch, A., Henning, E., Brikalski, M. P., Luca, F. V. de, & Konrath, A. C. (2020). Impact of coronavirus (COVID-19) spread-prevention actions on urban water consumption. Resources, Conservation and Recycling, 163(August). https://doi.org/10.1016/j.resconrec.2020.105098

Kalra, S., Kelkar, D., Galwankar, S. C., Papadimos, T. J., Stawicki, S. P., Arquilla, B., Hoey, B. A., Sharpe, R. P., Sabol, D., & Jahre, J. A. (2014). The emergence of Ebola as a global health security threat: From "lessons learned" to coordinated multilateral containment efforts. Journal of Global Infectious Diseases, 6(4), 164–177. https://doi.org/10.4103/0974-777X.145247

Linden, A. (2015). Conducting interrupted time-series analysis for single-and multiple-group comparisons. The Stata Journal, 15(2), 480–500.

Linden, A. (2018). Combining synthetic controls and interrupted time series analysis to improve causal inference in program evaluation. Journal of Evaluation in Clinical Practice, 24(2), 447–453.

Lüdtke, D. U., Luetkemeier, R., Schneemann, M., & Liehr, S. (2021). Increase in Daily Household Water Demand during the First Wave of the Covid-19 Pandemic in Germany. Water (Switzerland), 13(3). https://doi.org/10.3390/w13030260

Mahato, S., Pal, S., & Ghosh, K. G. (2020). Effect of lockdown amid COVID-19 pandemic on air quality of the megacity Delhi, India. Science of the Total Environment, 730(January). https://doi.org/10.1016/j.scitotenv.2020.139086

Marshallsay, D. (2020, June 30). New Waterwise article! The effect of the coronavirus lockdown on water use. https://www.artesia-consulting.co.uk/blog/New Waterwise article! The effect of the coronavirus lockdown on water use

Mattioli, M. C., Boehm, A. B., Davis, J., Harris, A. R., Mrisho, M., & Pickering, A. J. (2014). Enteric pathogens in stored drinking water and on caregiver's hands in Tanzanian households with and without reported cases of child diarrhea. PLoS ONE, 9(1). https://doi.org/10.1371/journal.pone.0084939

Muhammad, S., Long, X., & Salman, M. (2020). COVID-19 pandemic and environmental pollution: A blessing in disguise? Science of the Total Environment, 728, 138820. https://doi.org/10.1016/j.scitotenv.2020.138820

Nemati, M. (2020). COVID-19 and Urban Water Consumption. In ARE Update (Vol. 24, Issue 1, pp. 9–11). University of California Giannini Foundation of Agricultural Economics.

Niasse, M., & Varis, O. (2020). Quenching the thirst of rapidly growing and water-insecure cities in sub-Saharan Africa. International Journal of Water Resources Development, 36(2–3), 505–527. https://doi.org/10.1080/07900627.2019.1707073

Ntow, F. (2023, January 17). Electricity and water tariffs up by 29% and 8% for Q1 of 2023. Ghana News Agency. https://gna.org.gh/2023/01/electricity-and-water-tariffs-up-by-29-and-8-for-q1-of-2023/

Nyavi, G. A. (2021, January 3). Gov't extends free electricity, water initiative to March - Graphic Online. General News. https://www.graphic.com.gh/news/general-news/ghana-news-gov-t-extends-free-electricity-water-initiative-till-march.html

Penfold, R. B., & Zhang, F. (2013). Use of interrupted time series analysis in evaluating health care quality improvements. Academic Pediatrics, 13(6), S38–S44.

Portsmouth Water. (2020). Annual Performance Report. In Hilos Tensados (Vol. 1, Issue). https://www.portsmouthwater.co.uk/wp-content/uploads/2020/07/2020-APR-Portsmouth-Water.pdf

PURC. (2022). Publication of tariffs: September 2022. September. https://www.purc.com.gh

Sayeed, A., Rahman, M. H., Bundschuh, J., Herath, I., Ahmed, F., Bhattacharya, P., Tariq, M. R., Rahman, F., Joy, M. T. I., Abid, M. T., Saha, N., & Hasan, M. T. (2021). Handwashing with soap: A concern for overuse of water amidst the COVID-19 pandemic in Bangladesh. Groundwater for Sustainable Development, 13. https://doi.org/10.1016/j.gsd.2021.100561

Turner, S. L., Karahalios, A., Forbes, A. B., Taljaard, M., Grimshaw, J. M., & McKenzie, J. E. (2021). Comparison of six statistical methods for interrupted time series studies: empirical evaluation of 190 published series. BMC Medical Research Methodology, 21(1), 1–19.

WHO. (2015). Water sanitation and hygiene (WASH) package and WASH safety plans Training of trainers. https://www.who.int/csr/disease/ebola/wash-training-2015/en/

WHO. (2020). Water, sanitation, hygiene, and waste management for SARS-CoV-2, the virus that causes COVID-19: Interim Guidance (WHO/2019-nCoV/IPC_WASH/2020.4; Issue July). https://www.who.int/publications/i/item/WHO/2019-nCoV/IPC_WASH/2020.4

Yunus, A. P., Masago, Y., & Hijioka, Y. (2020). COVID-19 and surface water quality: Improved Lake water quality during the lockdown. Science of the Total Environment, 731, 139012. https://doi.org/10.1016/j.scitotenv.2020.139012

AUTHORS CONTRIBUTION

Peace Korshiwor Amoatey: Conceptualisation, background, literature review and Data Analysis (Descriptive statistics)

Godwin King-Nyamador: Literature review, data analysis theory, verification of references Micheal Martey: Data Analysis (Inferential Statistics)

Maxwell Akosah-Kusi: Data collection, organisation and preliminary analysis