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Research Paper

The Impact of COVID-19 on Water Consumption and Treatment Capacity in Tourism Area: Example of Bodrum

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Abstract: The COVID-19 pandemic has caused many countries to close their borders, and large numbers of people have begun to spend their holidays and vacation time within their own countries rather than traveling abroad. This study assesses the impact of the pandemic on water consumption and wastewater generation in a popular tourist Aegean city (Bodrum, Turkey) and its suburbia where many visitors moved in to live there for an unforeseen future. The effects of the COVID-19 pandemic on water consumption within the residential and commercial areas showed a significant decrease in water consumption in commercial areas (%23) and an increase in the residential areas (%15) during the pandemic period. The wastewater in residential areas had to be treated in many on-site wastewater treatment plants, apart from the central treatment plants which may pose a risk to the groundwater and surface water resources of the region. This shows that the treatment technologies and capacities of wastewater treatment plants need to be revised for situations such as unexpected pandemics.

Keywords *COVID-19, pandemic, water treatment, water quality, water consumption*

Introduction

Since the first reported case in December 2019, the SARS-CoV-2 virus has spread rapidly across the globe. As of August 17, 2021, more than 600 million people have reported COVID-19 positive, and about 6 million people have died (Dong *et al*. 2019). Similar to any other country, Turkey faced a severe transmission of the virus throughout its borders with more than 16 million cases and more than 100 thousand reported deaths (Republic of Turkey Ministry of Health, 2021). During the pandemic, many urban dwellers ended up moving to their summer vacation homes for extended times to avoid crowds and community spread of the virus. These summer homes are mostly located in suburbs of small towns where water and wastewater infrastructure are capable of population increase only in the recreational season. Although there have been signs of unexpected increases in water consumption and water treatment, detailed studies are needed on the impact of the pandemic on water consumption, treatment, and the factors affecting these changes (Lüdtke *et al*. 2021; Bandala *et al*. 2021; Lau *et al*. 2009; WHO 2015; Kalbusch *et al*. 2020).

Meeting safe water demand is challenging issue in rapidly growing urbanized areas where consumption exceeds sustainable utilization of resources, especially in regions where there is already an ongoing water scarcity. The fact that the COVID-19 has affected human behaviour in all areas of life due to its high contagiousness, restrictions to routine urban life had to be taken to minimize human mobility to prevent the spread of the virus. This “slowdown” of activities impacted people’s behaviour towards their environment. For example, In China, it is reported that the people's need to immerse in green spaces increased during the pandemic period in China (Cheng *et al.* 2021). When the Covid-19 virus epidemic peaked in North American cities, wealthy urban dwellers living in high-density cities fled to holiday homes in quiet neighbourhoods with locals (Balçık *et al*. 2021). During the Covid-19 period, the distribution of population densities in cities began to change. The progressive course of the epidemic caused people to migrate from urban to less populated areas and increased the population in

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rural areas. Therefore, this temporary migration situation has caused individuals to acquire a second home in rural areas and has led to the reshaping of urban density and urban order (Kunzmann 2020; Bich-Ngoc & Teller 2020). In Turkey, Bodrum is one of the most popular touristic towns in the Aegean region, receiving of visitors from across the globe during summer months. During the pandemic, sudden and permanent population increase has been also observed in this region.

Since the beginning of the pandemic, researchers published hundreds of articles in 2020 focusing on the research and discussion of COVID-19 related to water research. Various webinars were also held to timely update research and exchange ideas on COVID-19 in the water and wastewater sector. Some of these studies are on the effects of human and industrial mobility in the regions on water and wastewater sectors during the epidemic (Stoler *et al*. 2020; Howard *et al*. 2020; Donde *et al*. 2021; Bin *et al*. 2021). The number of studies on the consumption and how human migration impacted water resources though have been limited.

The purpose of this article is to investigate whether the unprecedented level of population increase create a stress on the existing water resource management plans in the region. Specific objectives were: (i) evaluate how the COVID-19 pandemic affects urban water consumption and (ii) discuss the risks that can be observed in water treatment during the pandemic period in a city with many on-site wastewater treatment plants. To the authors' knowledge, this is the first study to evaluate one-year data of COVID-19 pandemic on water consumption and treatment in tourist destinations in this region.

Material and Methods

Almost a year into the pandemic, the Health Ministry of Turkey has been taking a series of measures to slow down the spread. Soon after the first case on March 11, 2020, the government activated an emergency response plan that evolved over time with a suite of precautionary activities, also impacting Bodrum (Fig. 1). The travel restrictions along with the timing of the year, many individuals who own a second house in the Bodrum region ended up deciding to stay instead of going back to their permanent residencies which are often located in metropolises such as Istanbul, Ankara, or Izmir.

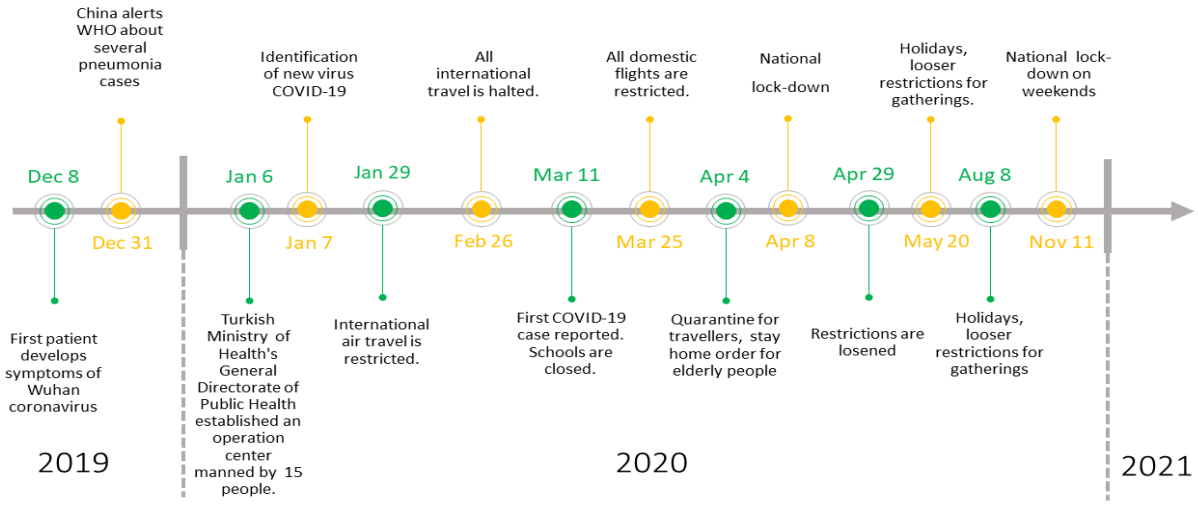

Figure 1. Timeline for COVID-19 related restrictions.

Bodrum, Turkey's most important and popular tourism region, is one of the thirteen districts of Muğla (Fig 2). Bodrum is a region that covers an area of 680 km^2 and the total coastline is 174 km (Koç *et al*. 2017). The most important settlements in the Bodrum Peninsula include Turgutreis, Ortakent (Yalıkavak), Türkbükü, and Karaova with this the center of Bodrum. The Bodrum, which is in the form of a peninsula, is located at the southwestern tip of Turkey and has both tourism and rich history due to its geographical location. The population of the Bodrum peninsula reported depends on official

registered data of the Turkish Statistical Institute (TUİK) and is based on the population of off-season residents. In order to determine the tourism season population in Bodrum, it is essential to know the people who live in summer homes, tourist arrivals, and daily visitor population. However, these data are not officially available. As people started to migrate to the region during the pandemic in the off-season in 2019, water resource management planning has been difficult. Secondary data such as information on tourism facilities and bed capacities, the total number of residences, and occupancy rates during the year are available and can be a way to address these population shifts (Koç et al. 2017). In order to compare the water consumption of the previous period and the following period of COVID-19, the 2019 and 2020 water consumption data in Bodrum were taken from the Muğla Metropolitan Water and Sewerage Administration General Directorate (MUSKI) by separating commercial and residential areas. In addition, treated water data were obtained from the 12omestic wastewater biological treatment systems operated by the MUSKI for 2019 and 2020. The locations of the central wastewater treatment systems are given in Fig. 2.

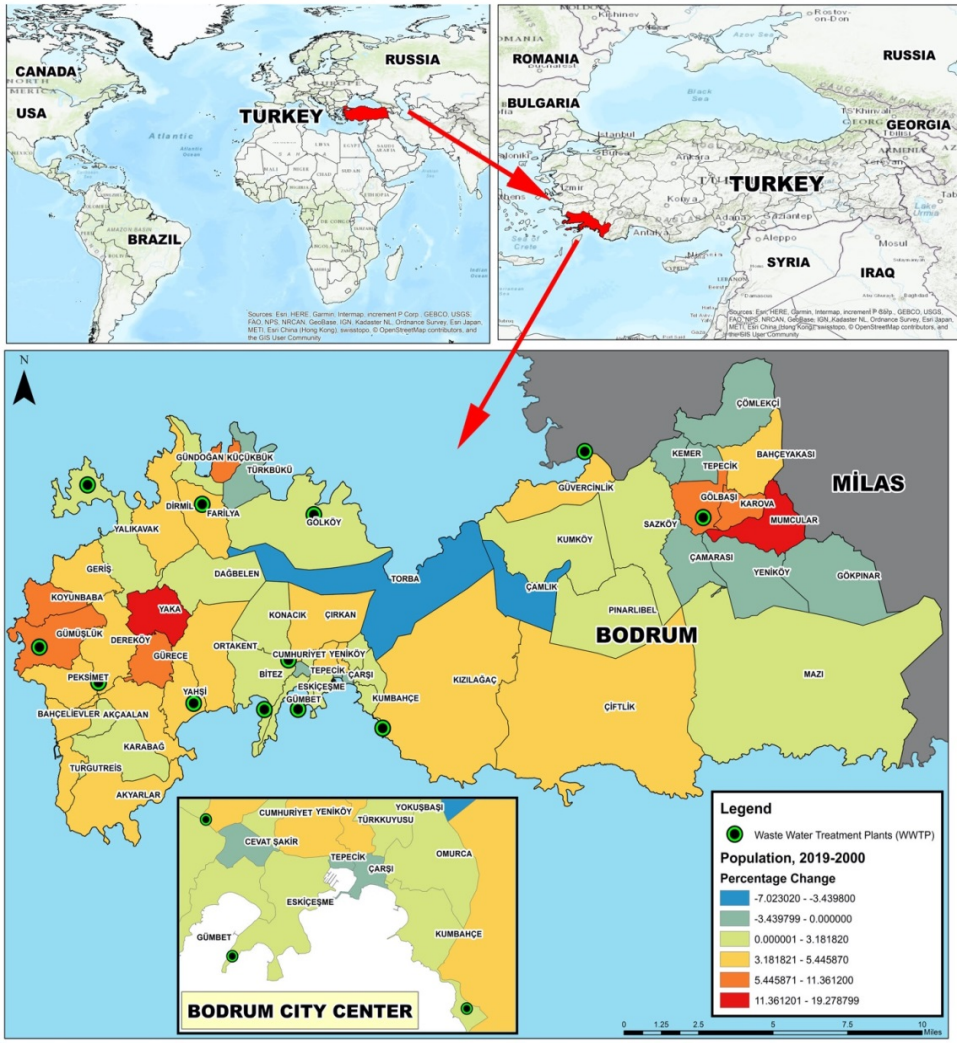

Figure 2. Neighbourhood population percentage change for 2019 -2010 in Bodrum

Statistical analysis

In this study, GIS techniques and classical statistical methods were used to produce a relation between population and water consumption value by considering wastewater treatment plants in Bodrum, Turkey. The provided consumption data are grouped on a neighbourhood basis and the annual consumption of both residential and commercial business subscribers is calculated based on the neighbourhoods. Water consumption data in the form of tables belonging to subscribers obtained from MUSKI was related to fifty-six neighbourhood areas of Bodrum District created in ESRI ArcGIS 10.3 application. The associated verbal data can be analysed in geographic information systems. Water

consumption values of houses and workplaces in 2019 and 2020 are graphically mapped. In addition, correlation analysis was applied to assess the statistical associations between all data, and correlation coefficients were used to determine the positive and negative relationship between the two detected variables. The relationship between the number of passengers arriving in Bodrum from domestic and international routes and the water consumption values in Bodrum was examined.

Results and Discussion

Seasonal population change

One of the most significant impacts of the pandemic had been the decline in air travel, which significantly affected Bodrum as this had historically been the most preferred transportation for tourists. Before the pandemic, June, July, and August have traditionally been the high season. The number of international passengers in January 2019 was only 17, which reached over 200K in July 2019. This trend was significantly impacted by the pandemic. In 2019, the total number of domestic and international passengers coming to Bodrum was over 2 M, whereas this number decreased to less than 750K people during the pandemic. The airport activity data show a 59% decrease in domestic travellers and a 75% decrease in international travellers in 2020 (Fig. 4). Similarly, the number of domestic and international flights coming to inbound Bodrum decreased by 43% and 56% respectively during the pandemic (Fig. 3). Among 161 hotels that were open before the pandemic in Bodrum, only 46 stayed operational in 2020, demonstrating a 72% decrease in lodging activities. These were the only hotels that had permits with a safety certificate issued by the central government. The number of passengers arriving in Bodrum for 2019-2020 was obtained from the General Directorate of DHMI in Milas Bodrum Airport (Fig 4). The number of incoming and outgoing passengers with domestic and international flights increased until August 2019 and then dramatically decreased. However, it is observed that the decrease in the number of these flights increased exponentially in 2020 with the COVID-19 flight bans.

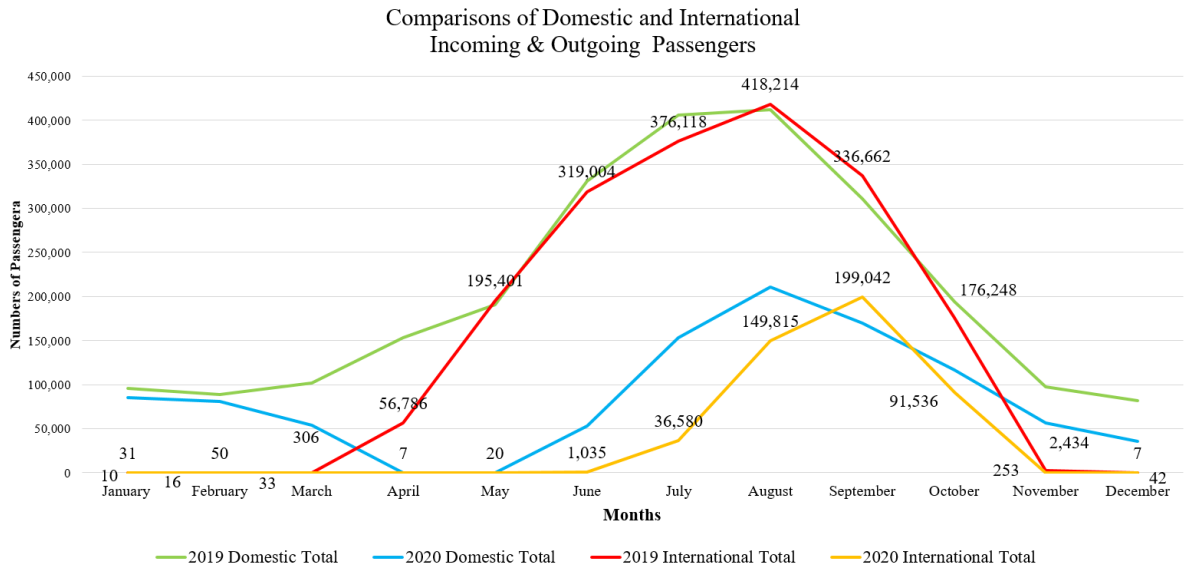

Figure 3. Domestic and international incoming and outgoing passengers pre and during pandemic

Water consumption

The amount of water used in residential and commercial buildings was compared in 2019 and 2020. Off-season winter months for these two years showed similar water consumption volumes in both residential and commercial buildings (Fig. 4). In the summer of 2019, the water consumption increased as expected during high touristic activity seasons. In the summer of 2020, however, during the pandemic, water consumption significantly decreased in commercial buildings. Residential water consumption on the other hand significantly increased in the summer months. This increasing trend continued in the last quarter of 2020, when the water consumption was twice of the previous year, the same period where it is usually known to be an off-season.

The significant relation between airfare ticket sales and water consumption before the pandemic (r^2=0.7981) decreased in 2020 (r^2=0.5578). Because the water consumption in residential areas increased, it can be concluded that people avoided already restricted air travel, some travelled by their cars for social distancing purposes and stayed longer periods of time in Bodrum, unlike they would return to their primary residential addresses.

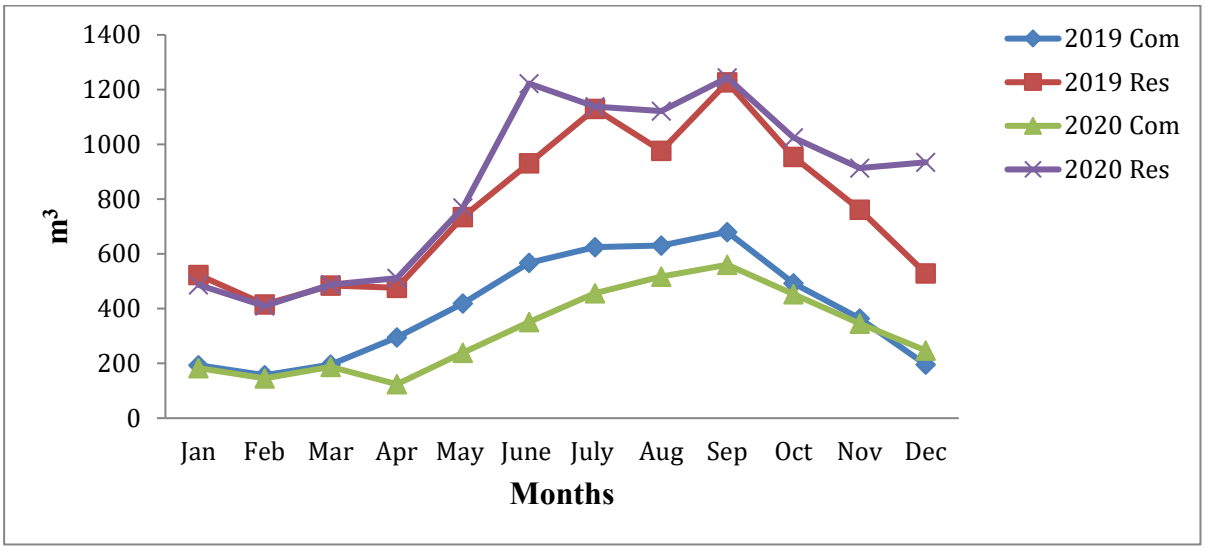

Fig 4. Water consumption of residential and commercial buildings between 2019 and 2020

Water scarcity is one of most the fundamental issues globally. Urban environments are particularly vulnerable to increased water demand due to high populations. Access to safe water becomes increasingly important during an infectious disease pandemic because handwashing is one of the primary prevention tools to reduce the spread in a particular region. In a pandemic environment, these challenges are exacerbated by enforced lockdowns where people had to stay at home for a long period of time. Our results show that increased water usage at the household level during these lockdown periods will create an additional burden on water resources, especially in regions with already have water scarcity conditions. It is clear that COVID-19 will likely be a part of our daily life in the unforeseen future, water demand will significantly increase in the future which requires additional planning for sustainable water resource management. Additional treatment efforts will be needed to bring "new water" to the planning which will also mean additional energy to be diverted to tackle this problem, which may also mean increased costs and pricing at the household level.

Kalbusch et al. (2020) analysed water consumption data of the Brazilian city of Joinville using various statistical methods, such as the Shapiro-Wilk test of normality (Ghasemi & Zahediasl 2012) and the non-parametric paired Wilcoxon test (Tian et al. 2019). The results revealed higher water consumption in residential buildings than in industrial and public buildings before and after quarantine periods. Such research studies closely monitoring different economic segments (*i.e.* high, middle, and low income) in urban settlements for possible changes in supply-demand patterns in the post-COVID-19 era will provide additional insights (Balamurugan et al. 2021). A comprehensive database for domestic and commercial water use can be leveraged with improved monitoring devices, various machine learning algorithms (Kasiviswanathan et al. 2016; Sun and Scanlon 2019), and empirical models (Balamurugan *et al*. 2021). Useful information can be provided to manage urban water needs.

Water treatment

There are twelve central wastewater treatment plants (WWTPs) in Bodrum (Fig 2). The volume of wastewater treated in these WWTPs increased starting in August 2020, where the general trend had been decreasing before the pandemic, showing that summer residents who can afford to stay, remained in these homes and did not return to their permanent residencies in other major metropolitan areas to avoid the pandemic. The volume of treated wastewater has been lower than the volume of water consumed in both years (Fig. 5). Similarly, there was no significant relation between airplane ticket sales and wastewater treatment (r^2=0.0053). This is because the central WWTPs serve commercial settings rather

than residential areas, as these buildings are located away from the city center and wastewater treatment depends on 290 on-site wastewater treatment systems. While 74 percent of the 290 on-site wastewater treatment units are in residential sites, the remaining 26% are in tourism establishments such as hotels, motels, and holiday sites (CSB 2021). Unfortunately, there is no data available for these private systems to see the actual treated wastewater quantity across Bodrum.

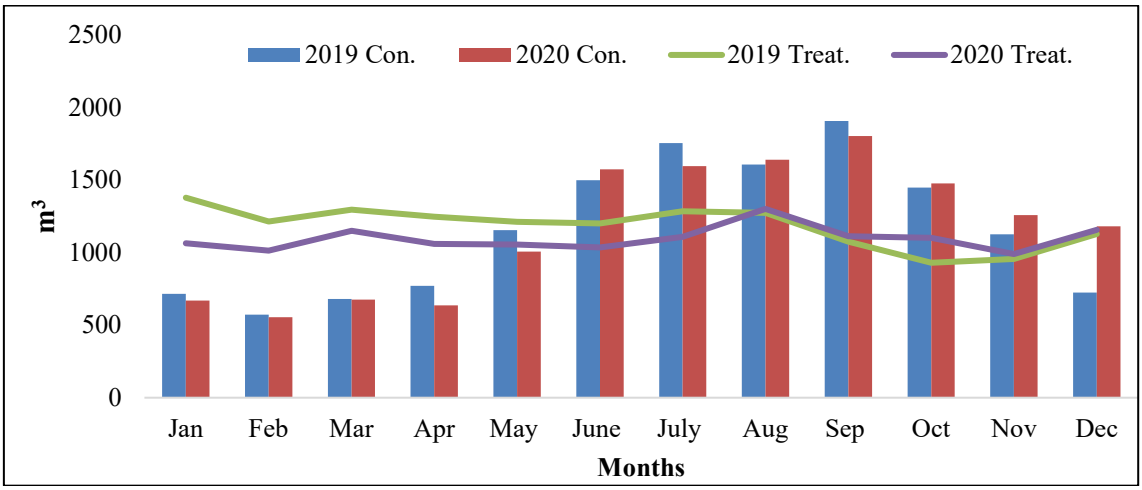

Figure 5. Total water consumption and treatment between 2019 and 2020.

There was a slight increase in the relation between airplane ticket sales and wastewater treatment in 2020, showing that even though the flights were very limited, there was some travel occurring during a pandemic, mainly due to business purposes. In fact, the relationship between the number of passengers arriving by airline and the amount of water consumed in commercial areas in Bodrum in 2020 was also significant (r^2=0.7392). In the post-COVID-19 periods, apart from the water demand and supply issues, the policies on wastewater treatment will change significantly. Since the wastewater flow values used in the planning and design of wastewater treatment plants are not constant or uniform, hourly, daily, monthly and annual changes show. In the design of the wastewater treatment plant, besides the wastewater flow rate, the current situation and future change must also be predicted.

The difference between the amount of water consumed and water treated in twelve central wastewater treatment plants (WWTPs) in Bodrum for 2019 and 2020 is given in Fig 6. The stark difference between water consumption and wastewater treatment shows a potential of 15-40% on-site treatment rather than treatment in WWTPs, particularly during the summer (Fig. 7). Interestingly, a similar trend was observed in December 2020 as well, addressing that people who arrived at Bodrum during the pandemic stayed in their summer homes throughout the winter as well.

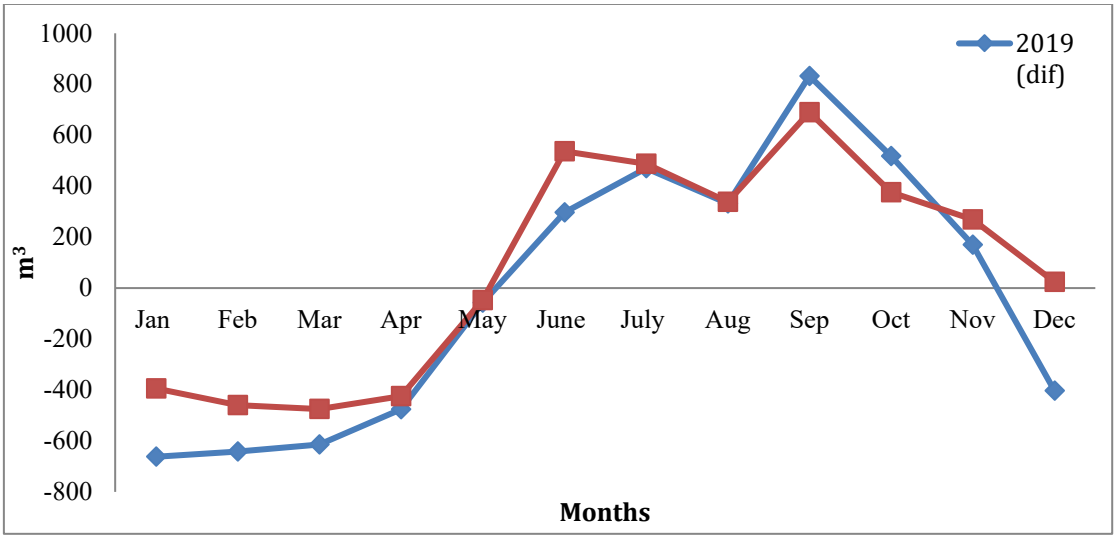

Figure 6. The difference amount of water consumed and water treated in Bodrum.

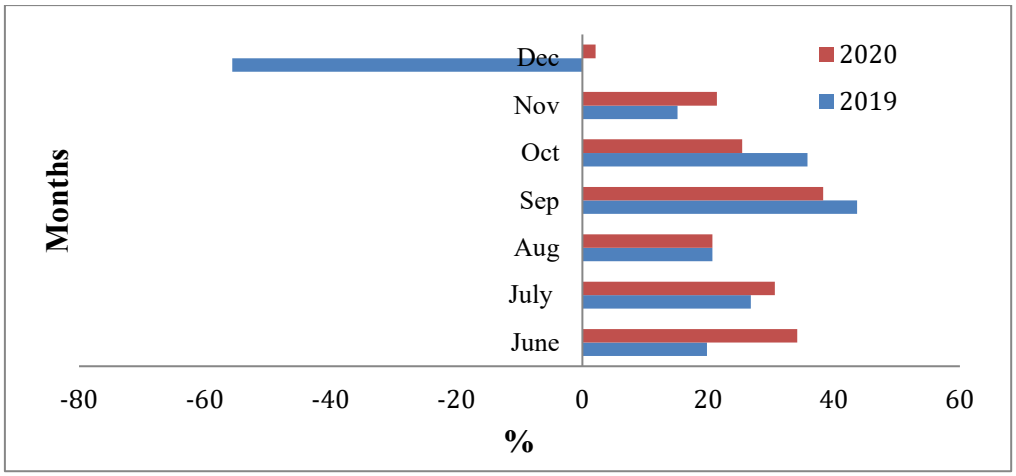

Figure 7. Percent change of water treated in on-site treatment plants in Bodrum by months.

Even though the water discharged after being treated and discharged from a large number of on-site treatment plants is used for irrigation of green areas, the excess of on-site wastewater treatment units, which are still far from control, is expected to pose a risk in the pollution of surface, underground and sea water in Bodrum. Perhaps this may be one of the causes of the mucilage-like pollution seen in the summer of 2021 in this region. Moreover, wastewater treatment plants cannot efficiently remove dexamethasone, favipiravir, hydroxychloroquine, oseltamivir, remdesivir, ribavirin drugs used in the treatment of COVID-19 and their metabolites in raw water (removal efficiency <20%). In toxicology studies, it has been determined that the main compounds of Chloroquine, hydroxychloroquine, remdesivir, ribavirin, and ritonavir or their metabolites pose a moderate ecotoxicological risk (RQ > 0.1) in the rivers (Kuroda *et al*. 2021; Eric *et al*. 2021).

In this context, as in the example of Bodrum, the determination of capacity to be determined for the treatment of wastewater in regions with very different summer and winter populations according to the period when the population is the most crowded will prevent environmental problems that may arise from the inability to dispose of wastewater originating from low capacity. It is thought that the basic technical methods and practices to be used for the selection of technology, design criteria, disinfection and reuse of treated wastewater, and the disposal of sludge generated during deep sea discharge and treatment activities of wastewater treatment plants related to the treatment of wastewater originating from settlements should be rearranged.

The lack of detailed quantitative analysis and detailed data on the water and wastewater sectors can always pose a problem for the Region. The questions given below can be considered to be issues that all countries can be addressed.

(i) How did the water use and treatment systems change in urban areas due to the changing population density and different industrial/commercial activities in the cities during the pandemic period?
(ii) What was the resilience of municipalities in coping with the sudden change in water demand and wastewater treatment systems during the quarantine?
(iii) Which cities experienced a supply-demand gap during quarantine and water supply problems during peak summer months?
(iv) Have new norms been set for water consumption and treatment after the pandemic?

Conclusion

The pandemic has given important lessons from sustainable water consumption and treatment perspective in touristic areas such as Bodrum. In touristic areas where hotel tourism is not completely dominant, and the number of detached summer houses is high, significant population pressure has occurred during the pandemic period. In these regions, which have a high population density only during the summer holidays, a serious population density had been experienced in the winter. For this reason, much more domestic wastewater was generated in summer houses. For a functional wastewater treatment plant to operate, it is critical to predicting the amount of wastewater and wastewater characteristics in the most realistic way. It is difficult to determine the daily and monthly population exchange rates in well-known touristic areas such as Bodrum, but results show that the capacity of

wastewater treatment plants was not sufficient to address unexpected and increasing populations during the off-season. In this context, it is necessary to collect data or have access to predictive models to be prepared for any sudden event, such as the unexpected COVID-19 pandemic. Such drastic and rapid change in population will require additional preparedness plans that would involve bringing alternative water resources, cost-effective water treatment, increased capacity to store and treat additional water, and not least, efficient wastewater treatment (including plans for reuse). In addition, it should be considered that with the increasing migration to regions such as Bodrum, which are intertwined with rural tourism, increases in water use and the amount of wastewater generated, and serious changes in the biological and chemical character of the wastewater.

To solve water treatment issues, it will not be enough to reduce the number of on-site treatment systems and establish conventional central wastewater treatment plants. The ecotoxicological impact of effluents should be determined before additional investments are made. Such planning needs to be made sooner than later. The pandemic situation should be recognized as a key, and capacity needs to be developed in the water sector in terms of infrastructure, wastewater treatment procedures, water, and wastewater monitoring and management of the water sector.

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References

Balamurugan M, Kasiviswanathan KS, Ilampooranan I, Soundharajan BS, (2021) COVID-19 Lockdown Disruptions on Water Resources, Wastewater, and Agriculture in India. Front. *Water*. **3**, 603531. doi: 10.3389/frwa.2021.603531.

Bandala ER, Kruger BR, Cesarino I, Leao AL, Wijesiri B, Goonetilleke A, (2021) Impacts of COVID-19 pandemic on the wastewater pathway into surface water: A review. *Sci. Total Environ.* **774**, 145586. https://doi.org/10.1016/j.scitotenv.2021.145586

Bich-Ngoc N, Teller J, (2020) Potential effects of the COVID-19 Pandemic through Changes in Outbound Tourism on Water Demand: The Case of Liège (Belgium) *Water* **12**, 2820; doi:10.3390/w12102820 www.mdpi.

Bin J, Zhao Y, Wei T, Kang P, (2021) Water science under the global epidemic of COVID-19: Bibliometric tracking on COVID-19 publication and further research needs. *J. Environ. Chem. Engin.* **9** 105357.from https://doi.org/10.1016/j.jece.2021.105357.

Cheng Y, Zhang J, Wei W, Zhao B, (2021) Effects of urban parks on residents' expressed happiness before and during the COVID-19 pandemic, Landsc Urban Plan, 212, 104118. https://pesquisa.bvsalud.org/global-literature-on-novel-coronavirus-2019-ncov/resource/pt/covidwho-1179872

CSB (2021) Repubic of Turkey Ministery of Environment and Urbanisation. Retrieved July, 2021, from https://eizin.cevre.gov.tr/Rapor/BelgeArama.aspx.

Donde OO, Atoni E, Muia AW, Yillia PT, (2021) COVID-19 pandemic: water, sanitation and hygiene (WASH) as a critical control measure remains a major challenge in low-income countries, *Water Res.* **191**, 116793. doi: 10.1016/j.watres.2020.116793

Dong E, Du H, Gardner L (2019) An interactive web-based dashboard to track COVID-19 in real time. *Lancet Infect Dis*; published online Feb 19. https://doi.org/10.1016/S1473-3099(20)30120-1.

DSİ (2010) Muğla-Bodrum peninsula drinking water treatment facility and transmission lines feasibility report (p. 213). Aydın: Ministry of Forestry and Water Affairs. General Directorate of State Hydraulic Works. XXI. Regional Directorate.

Ghasemi A, Zahediasl S, (2012) Normality tests for statistical analysis: a guide for non-statisticians. *Int. J. Endocrinol. Metab*. **10**: 486–489. https://doi.org/10.5812/ijem.3505.

Howard G, Bartram J, Brocklehurst, Colford CJM, Costa, Cunliffe D, Dreibelbis R et al (2020) COVID-19: urgent actions, critical reflections and future relevance of 'WaSH': lessons for the current and future pandemics. *J. Water Health* **18**, 613–630. doi: 10.2166/wh.2020.162

Huang NE, Qiao F, (2020) A data driven time-dependent transmission rate for tracking an epidemic: a case study of 2019-nCoV. Sci. Bull. 65: 425–427. https://doi.org/10. 1016/j.scib.2020.02.005.

Kalbusch A, Henning E, Brikalski MP, Vieira FL, Konrath AC, (2020) Impact of coronavirus (COVID-19) spread-prevention actions on urban water consumption. Resources, *Conservation & Recycling* **163**, 105098.

Kasiviswanathan KS, Saravanan S, Balamurugan M, Saravanan K, (2016) Genetic programming based monthly groundwater level forecast models with uncertainty quantification. Model. Earth Syst. Environ. 2, 27. doi: 10.1007/s40808-016-0083-0.

Koç C, Bakış R, Bayazıt Y, (2017) A study on assessing the domestic water resources, demands and it quality in holiday region of Bodrum Peninsula, Turkey. Elsevier, *Tourism Manag.* **62**, 10-19. doi:10.1016/j.tourman.2017.03.024

Kuroda K, Li C, Dhangar K, Kumar M, (2021) Predicted occurrence, ecotoxicological risk and environmentally acquired resistance of antiviral drugs associated with COVID-19 in environmental waters. Sci. Total Environ. **776**, 145710. https://doi.org/10.1016/j.scitotenv.2021.145740.

Lau JTF, Griffiths S, Choi KC, Tsui HY, (2009) Widespread public misconception in the early phase of the H1N1 influenza epidemic. *J. Infection* **59**:122–127. https://doi.org/10.1016/j.jinf.2009.06.004.

Lüdtke DU, 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* **13**, 260. https://doi.org/10.3390/ w13030260.

Republic of Turkey Ministry of Health, https://covid19.saglik.gov.tr/.

Stoler J, Jepson WE, Wutich A, (2020) Beyond handwashing: water insecurity undermines COVID-19 response in developing areas. *J. Glob. Health* **10**, 010355. doi: 10.7189/jogh.10.010355

Sun AY, Scanlon BR, (2019) How can Big Data and machine learning benefit environment and water management: a survey of methods, applications, and future directions. *Environ. Res. Lett*. **14**, 073001. doi: 10.1088/1748-9326/ab1b7d.

Tetteh EK, Amankwa MO, Armah EK, Rathilal S, (2020) Fate of COVID-19 Occurrences in Wastewater Systems: Emerging Detection and Treatment Technologies—A Review. *Water*, **12**, 2680; doi:10.3390/w12102680.

Tian F, Lu Y, Hu H, Kinzelbach W, Sivapalan M (2019) Dynamics and driving mechanisms of asymmetric human water consumption during alternating wet and dry periods. *Hydrol. Sci. J.* **64**, 507–524. doi: 10.1080/02626667.2019.1588972.

Tian H, Liu Y, Li Y, Wu C, Chen B, Kraemer MUG, (2020) An investigation of transmission control measures during the first 50 days of the COVID-19 epidemic in China. Science. https://doi.org/10.1126/science.abb6105.

WHO (2015) Water sanitation and hygiene (WASH) package and WASH safety plans Training of trainers. (World Health Organization) https://www.who.int/csr/disease/ebola/wash-training.pdf?ua=1>(accessed 02 April 2020).

World Health Organization, https://covid19.who.int/.