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Research Article

Household water consumption behavior during the COVID-19 pandemic and its relationship with COVID-19 cases

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ABSTRACT

The use of existing water resources and sustainability problems as a result of global warming and climate change became an even bigger problem with the importance of hygiene during the COVID-19 pandemic. In this research, the water consumption behavior will be researched and the correlation between water consumption and COVID-19 case numbers will be investigated in Bursa, Turkey. The monthly mean water consumption for 758,500 domicile subscribers using the central tariff from 2018–2020 was calculated. Results obtained using the SPSS 23 IBM program observed a 20.18% increase in water consumption in Bursa in general during COVID-19. As Bursa province has both rural and industrial urban structures, when this increase is examined on a county basis, increase rates were 10% in regions with dense industry and mean 34% in rural areas. When the correlation between case numbers during the COVID-19 period (March 2020-January 2021) and water consumption is examined, a negative correlation is notable (Pearson-Correlation=-0.616). As the case numbers increased in the continuing COVID-19 pandemic, the reduction in water consumption may be explained by warnings to citizens to reduce water use through written and oral media due to reservoir fill rates falling below 5%. These results provide beneficial information revealing the effects of COVID-19 on water consumption behavior and use of water resources in urban and rural areas.

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INTRODUCTION

The increasing water demands with the rapid and continuous development of urbanization, industrialization and globalization have made the imbalance between water resources more pronounced in recent periods. At this point, water resources have led to negative effects on regional socioeconomic and environmental development. The structure of water consumption is encountered as an application or criterion for urban sustainability and social inclusion. Regulation of the structure of water consumption is an important point to ensure the optimum allocation of water resources and solve imbalanced situations related to use of water resources [1]. Topics related to water consumption are an increasing problem every day within the framework of sustainability, especially in developing countries. However, development of sustainable water resources has global importance [2]. Management and consumption of water

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resources is encountered as an important topic in recent periods considering factors like one third of the world's population living in countries without adequate water resources, the increase in per person consumption linked to population increase, effects on the environment in line with human activities like climate change [3].

There has been an increase of nearly 1% per year in global water demands from 1980 to the present day linked to population increase, socioeconomic development and changing consumption behavior [4]. If the global water demand continues to increase in a similar way until 2050, an increase equivalent to 20–30% of current water use is expected linked to increasing demand for industrial and domestic consumption [5]. When this situation is considered, it is probable that severe water shortages will be experienced especially in countries with limited available water resources when increasing water demands cannot be met.

The presence of stable water resources has vital importance in protecting the health of a population, especially when epidemic diseases begin to be observed [6]. In the report published by the World Health Organization (WHO) [7] in 2018, protecting health and improving hygiene were emphasized to prevent at least 9.1% of the global disease burden and 6.3% of possible deaths. For this reason, water is a basic resource for society which plays an important role in ensuring hygiene conditions, especially during an epidemic, and reducing the spread of disease [8]. The existing water problem continued to grow with the COVID-19 pandemic emerging in Wuhan city in China in 2019. As hand-washing, self-isolation and restrictions were included among precautions with the aim of preventing the spread of the COVID-19 pandemic, it was assumed that societies, communities and households had access to acceptable levels of adequate water [4]. However, the distribution of water resources in the world does not have a fair structure. In African and South Asian countries inhabited by nearly 85% of the world's population, serious difficulties are faced in terms of accessing clean and potable water [9]. Considering this situation, it is an unavoidable reality that water crises that will be experienced in the future will be more severe, and that the need for water use will continue to increase due to COVID-19 and other diseases that may emerge.

After the emergence of COVID-19, governments in nearly all countries in the world implemented a range of precautions aiming to prevent spread of the pandemic. The most important of these precautions was quarantine of individuals to minimize the transmission risk. In this pandemic period, it was unavoidable that there were increases in consumption of water and electricity linked to individuals spending more time at home. In addition to quarantine, attention was drawn to hygiene conditions for prevention with water use playing an important role in minimizing the spread of the pandemic and preventing and controlling the spread of COVID-19. Brauer et al. [10] estimates the global access to hand washing with soap and water, and estimates 45%–55% of virus transmission reduced by hand washing. According to the WHO, one of the most effective ways to reduce the risk of transmission of the COVID-19 virus to a person was regular and frequent hand washing with soap and water. The study by Balacco et al. [11] emphasized that hand-washing habits had a determinant effect on water consumption. Recent studies considered water consumption due to hand-washing [12–15]. Not only the hand-washing habits of people, but also their general cleaning habits, such that the frequency of showering in a week increase during the pandemic period [16]. Kalbusch et al. [17] researched the effect of preventing the spread of COVID-19 on water consumption in a case study from Joinville city in the south of Brazil. In their sample, when mean water consumption is assessed within the scope of precautions, they concluded there were reductions of 53% in the industrial field, 42% in the commercial field and 30% in the public sector, while there was a mean 11% increase in residential water consumption. Another study was performed in Germany by Lüdtke et al. [18]. They concluded there was a 14.3% increase in daily water consumption during the first lockdown period of 2020 compared to the same period of the previous year. Similarly in Portsmouth in England, there was a 15% increase in water demands in residences during the period of restrictions, while there was a 17% reduction in non-residential water demands [19].

In this study, the water consumption behavior of households in Bursa province was investigated before and during the COVID-19 pandemic period. Although our study is similar to the study of Kalbusch et al [17], we are also aims to investigate the correlation with Covid-19 cases and reservoir fill levels. This research contributes to the literature about water consumption before and during COVID-19 period, it also reveals that how water consumption of household changed with the changes in the reservoir fill levels even in the pandemic period.

MATERIALS AND METHODS

Water Consumption

In this study created with the aim of investigating the effect of the pandemic on water consumption behavior, water consumption before and during the pandemic was examined with data obtained from Bursa Water and Sewerage Administration (BUSKI). Monthly water consumption data for 758,500 *domicile* subscribers between January 2018 and January 2021 were used with mean water consumption per unit subscriber-household calculated. Research data encompassed January 2018 to January 2021 with two data sets created before and during COVID-19 from March 2020 when COVID-19 was first observed in Turkey. When the data are investigated in detail, a fall in water consumption

was present for Bursa in general in April 2020. According to explanations from BUSKI, readings were not performed in April 2020 due to COVID-19, so billing used 50% of the mean water consumption information for the last three months. For this reason, consumption information for April 2020 were not included in the analysis and the study was completed with a total of 36 months water consumption data comprising 27 months before COVID-19 (January 2018-March 2020) and 9 months after first COVID-19 case identified (April 2020-January 2021). Additionally, water consumption for households is evaluated with different tariffs according to location, in the form of dam villages, attractive village, town, promoted village and center. However, with the thought that consumption by households in villages and towns may be excessive due to garden watering, analyses were limited to domicile subscribers using the *central tariff*.

ANOVA analysis was performed with the aim of investigating the association between water consumption and COVID-19 cases.

COVID-19

With the identification of the first COVID-19 case in Turkey on 11 March 2020, necessary restrictions began with the closure of schools from 16 March. With the aim of ensuring transparency during the pandemic, information in the form of case, death and test numbers for each day were shared on the Ministry of Health internet page (https://covid19.saglik.gov.tr). Here, it is necessary to emphasize that the data shared are a general tableau for Turkey, with data on a city basis not announced by the Ministry of Health. As Bursa is one of Turkey's largest cities, data from the general tableau is thought to reflect the increase or reduction in case numbers for Bursa province. Additionally, the system only included data from symptomatic patients until 10 December 2020 with *total case numbers* not given. Due to the inclusion of asymptomatic patients with positive PCR test in the total case numbers from 10 December, the daily total case numbers (including patients with positive PCR test) are unknown in earlier data. The system additionally includes daily patient numbers and daily test numbers. Using this information, an attempt was made to estimate total case numbers for the period up to 10 December with regression analysis. A regression model was created using the known case, patient and daily test numbers from 10 December-30 March 2021. The dependent variable in this regression model was daily case number, while the independent variables were daily test numbers and daily patient numbers. The selection method for variables in the regression analysis was determined as *stepwise*, and two models were obtained. For both models α=0.00 and p=0.000 were significant. The adjusted R^2 value was determined to be larger than 0.850. The second model with 0.005 significance was chosen for the effect of the two variables (daily test number and patient number) on the dependent variable (daily case number) and the regression model below was created.

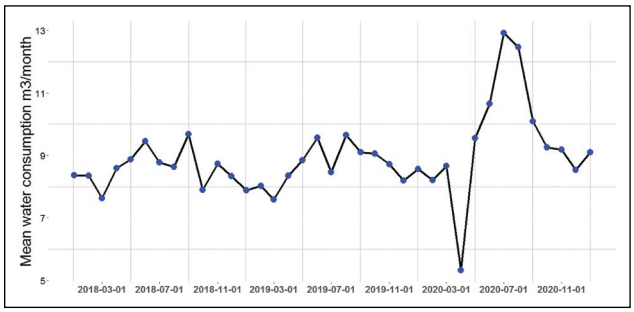

Figure 1. Unit mean water consumption for domicile subscribers in Bursa 2018–2021.

$$\widehat{\beta_1} = daily\ patient\ number$$

$$\widehat{\beta_2} = daily\ patient\ number$$

$$\hat{y} = -1605.202 + 3.361 * \widehat{\beta_1} + 0.060 * \widehat{\beta_2} \quad (1)$$

The regression model used to estimate the daily case number before 10 December 2020 is given above (1). In this model, case numbers were estimated using patient numbers and PCR test numbers.

In line with these estimations, monthly mean COVID-19 case numbers were determined and correlation analysis was performed for the association between case numbers and water consumption.

RESULTS

Data Analysis

Water consumption data in Bursa were investigated for 36 months and the following mean monthly water consumption graph was obtained (Fig. 1). Although there was seasonal differentiation in water consumption from 2018 to March 2020, generally water consumption appeared to have a stable structure. The fall in April 2020 is fully due to BUSKI, so it is not correct to make any interpretations; however, an accelerated increase in water consumption is observed from May 2020. Due to the announcement of the first COVID-19 case identified in Turkey on 11 March 2020 by the Ministry of Health, it is possible to associate this increase with COVID-19.

ANOVA analysis was performed with the aim of investigating the correlation between water consumption before and during COVID-19 period for Bursa in general. According to the ANOVA test results using SPSS 23, there was a significant difference with α=0.05 between water consumption before and during COVID-19 (p=0.000<0.05). Additionally, when descriptive results are investigated, the mean water consumption per household was 8.7719 m^3/month before COVID-19, while it was calculated as mean 10.5424 m^3/month during COVID-19 period. In comparison with the mean before COVID-19, water consumption appeared to increase by

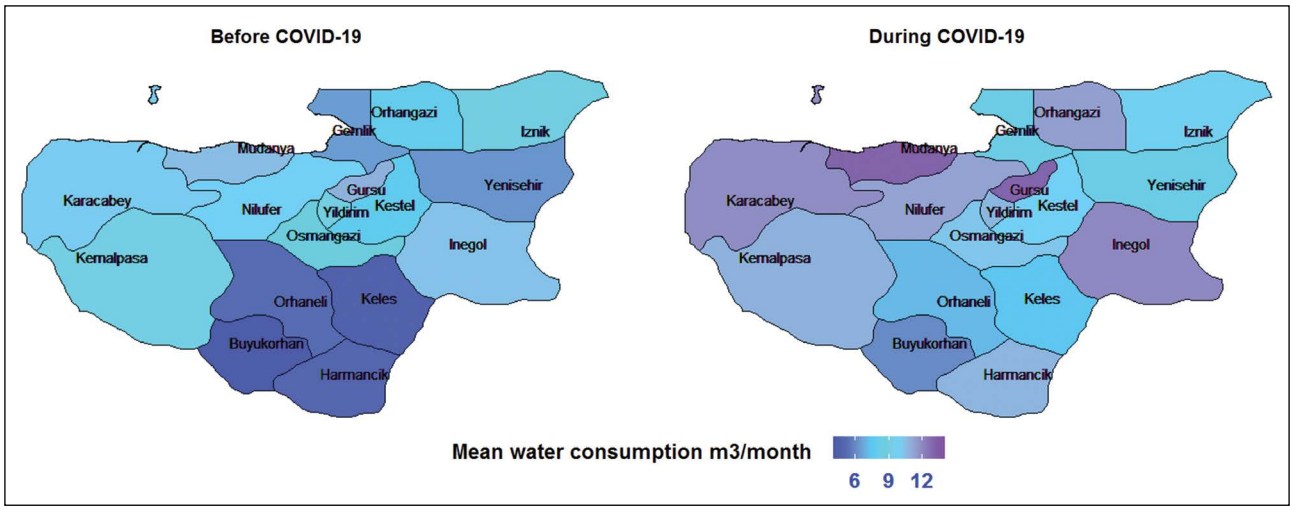

Figure 2. Water consumption intensity before and during COVID-19 for counties in Bursa.

20.18% in the COVID-19 pandemic period. These findings reveal an understanding of the behavior of households in Bursa when faced with the large-scale health threat of COVID-19.

Due to the geographical structure of Bursa, the excess of rural areas and industrial settlements is notable in the province. For this reason, there may be differences in water consumption between counties. There is a need for in-depth analysis considering each county in Bursa separately.

Bursa province includes a total of 17 counties. ANOVA analysis was performed to investigate the water consumption differences between these counties. The results of ANOVA analysis show the presence of a significant difference ($p=0.000<0.005$) between water consumption in the counties. The mean water consumption per subscriber for Bursa in general in the time period is 9.6571 m^3/month. When counties with mean water consumption per central subscriber more than 10 m^3 are examined, these include Nilüfer, İnegöl, Mudanya, Gürsu, and Karacabey counties, while counties with less than 5 m^3 consumption are Orhaneli, Keles, and Büyükorhan counties.

The water consumption intensity before and during COVID-19 period is shown in Figure 2. The largest increase in household water consumption was Harmancık county with 121% increase. The reason for this excessive increase in water consumption in Harmancık county may be shown to be the use of mains water for irrigation in agriculture due to the depletion of groundwater. Though the *central tariff* was considered for domiciles, the knowledge that villagers use the central tariff to water their gardens should be considered. This high increase in Harmancik county had a slight effect on the increase in Bursa province during the COVID-19 pandemic period. When we exclude this high increase in Harmancik from our analysis, general water consumption increment is still 19.62% in Bursa. On the other hand, the county with lowest increase was İznik county with 8.26% increase. The reason for this situation can be explained by the fact that the use of artesian is quite high due to the suitable climate and soil structure of the lake basin in the İznik county [20].

The increases in water consumption for the three largest counties in Bursa were as follows: Osmangazi 18.77%, Yıldırım 17.90% and Nilüfer 14.55%.

Relationship Between COVID-19 and Water Usage

Information about the relationship between water consumption increases and the COVID-19 pandemic was revealed in studies performed in recent times [14, 18, 21, 22]. To investigate this relationship, the monthly mean COVID-19 daily case numbers, estimated with a regression model based on certain assumptions, is shown in dotted on the graph in Figure 3. As seen on the graph, case numbers increasing from 11 March 2020 reached their first peak in April. However, with tight quarantine precautions case numbers began to fall in May. During May, June and July, mean daily case numbers continued at about 5000. However, a noticeable level of increase in case numbers occurred in August. These increases continued until December. The new peak in COVID-19 cases numbers experienced in November-December 2020 began a hard fall in January with the effect of rigid precautions. This fall continued in February. Later, with the removal of a certain level of restrictions with the normalization process on 1 March 2021, daily case numbers again began to increase.

When water consumption in Bursa from May 2020 to January 2021 is examined, there was an increase observed in July and August. This increase may be partly explained by seasonal effects, but it is possible to explain it with the increasing COVID-19 case numbers. In order to understand the association between water consumption in pan-

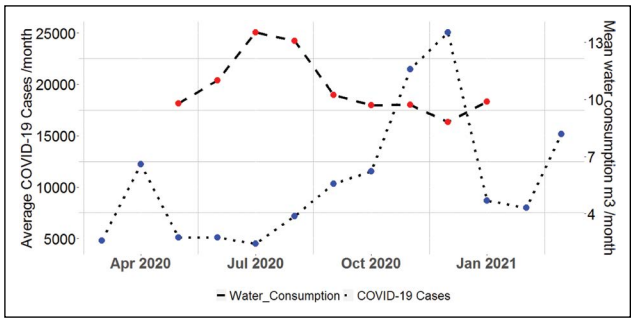

Figure 3. Monthly mean case numbers and mean water consumption.

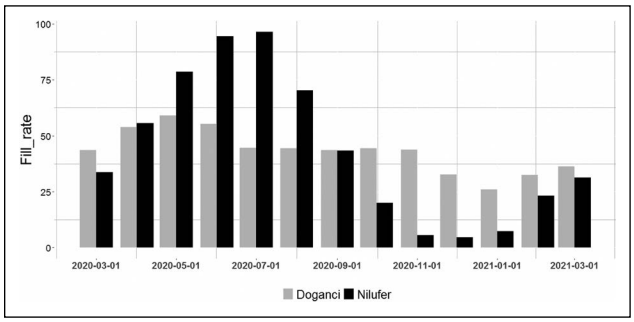

Figure 4. Fill rates for Doğancı and Nilüfer reservoirs.

demic period and the increase in case numbers, a correlation test was performed in SPSS 23. The test results found a p value of 0.077. One of the reasons for the large p number is thought to be due to the low number of data points. However, this does not change the reality that it was significant at α=0.1. The Pearson correlation coefficient of -0.616 shows a negative correlation between water consumption and case numbers in pandemic period.

The negative relationship in the Pearson correlation indicates a reduction in water consumption with the increase in case numbers. However, this reduction in water consumption during the continuing pandemic definitely does not mean that people did not abide by hygiene rules. Another cause for this reduction in water consumption is related to the water fill rate in reservoirs. Due to drought in 2020, a significant reduction occurred in the water levels in reservoirs [23].

The fill rates for two important reservoirs supplying Bursa of Doğancı and Nilüfer are given in Figure 4. A significant level of reduction occurred in the reservoirs for September, October, November and December 2020. Due to this reduction, written and oral media [24–26] continuously attracted attention to the water levels in reservoirs warning the public in news items about water. In addition, there have been many water cuts were experienced [27], these are considered to have affected the reduction in water consumption. Despite the low dam levels, mandatory restrictions remained to avoid increased public stress during lockdown, although public information campaigns on water conservation were carefully implemented [28].

Figure 4 shows that in spite of the low reduction in water level in Doğancı reservoir, the fill rate for Nilüfer reservoir fell below 5%. As a result of interviews with BUSKI management, there was not much difference in the fill rate of Doğancı reservoir due to the reduced amount of water in Doğancı being supplemented with water from Nilüfer reservoir. Additionally, nearly 85% of Bursa's water requirements were met by Doğancı reservoir in 2018, with this value being 80% in 2019 and 67% in 2020.

DISCUSSION AND CONCLUSIONS

This study researched the changes in water consumption behavior of households in Bursa before and during the COVID-19 pandemic and the correlation between increasing water consumption with COVID-19 and linked change in water amounts in reservoirs. Due to the increase in hand-washing frequency with attention paid to hygiene rules during the COVID-19 period, increases in water consumption are an expected result. A study by Sayeed et al. [15] stated that a five-person family required 50–100 liters of water per day to ensure hand hygiene and that there would be 20–25% increases in water requirements during the COVID-19 pandemic. When our study is compared with this 20–25% increase, the 20.18% increase in water consumption by residences in Bursa in general overlaps exactly. Similarly, Cook and Makin [29] determined an increase of 15–20% in domestic water consumption during COVID-19 in the United Kingdom.

This 15–20% increment in residential consumption again involves to the 20.18% percentage value for water consumption in Bursa. On the other hand, when our study compare with Lüdtke et al. [18] Cooley et al. [19] studies, which has an increase of 14% and 15% respectively, the increase in Bursa is seen to be significant. Another study by Eastman et al. [21] investigated the changes in water consumption and water bills from 2017–2020 in five different water administrations in different regions and with different sizes in the USA. They published a report about the effect of COVID-19 on water consumption. In this report there was not much change in water consumption for residential water consumption compared to previous years; however, one administration observed a 14% increase compared to the average values for April in the last three years. This 14% increase in residential consumption is again below to the percentage value for water consumption in Bursa. When every county in Bursa is considered separately, there was mean 14–18% increase in water consumption in homes in Osmangazi, Nilüfer and Yıldırım counties where the industrial and corporate sectors are located. Kalbusch et al. [17] found 11% increase in water consumption in household in regions of Southern Brazil, where industrial and corporate sectors are located, which is much

below the value for Bursa. Li et al. [30] found 2.4% increase in water consumption in regions of California's 10 urban centers, which is much below the value for Bursa. Another study in which a low percentage increase was achieved was that of Abulibdeh [31]. In this study, lockdown period increased water consumption by 6% in 2020 compared to 2019.

When studies about the effect of COVID-19 on water consumption are assessed in general, an increase in residential water consumption was observed, with a reduction in non-residential water consumption [32]. The basic reason for this is related to citizens spending more time at home linked to the precautions taken by governments to prevent the spread of COVID-19. Large reductions occurred in consumption in non-residential, especially industrial, areas linked to the reduction in production within the scope of precautions taken in the world in general. Although there was a large decrease in water consumption in the industrial areas, the study conducted by Li et al. [30] found 1.4% increase in water consumption in regions of California where industry, industrial and corporate sectors are located.

The most important component of water usage behavior is public awareness on issues related to water and drought. To determine the relationship between public awareness and water usage behavior, Quesnel and Ajami, [28] measured California drought news media coverage from 2005 to 2015 and modeled single-family residential water consumption in 20 service districts in the San Francisco Bay Area over the same period. The results showed that single-family residential customers reduced their water use at the fastest rate after heavy drought-related news media. As seen in Quesnel and Ajami 's study, [28] this study confirms the relationship between news media and water consumption.

The cause-effect relationship of 'if I don't pay attention to hand hygiene, I'll get sick' between case numbers and water consumption may be considered. To research whether this relationship really existed, correlation analysis was performed between case numbers and water consumption data. The results of the analysis found a negative correlation with acceptable alpha 0.1. However, a point which should be noted here is that some of the case numbers were estimated numbers as a result of regression analysis. Additionally, an attempt was made to examine the relationship using case numbers for Turkey in general as the Ministry of Health did not share case number information for Bursa province. The correlation between water consumption and case numbers has not been considered to date and may offer a new perspective to the literature.

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DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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