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Research Article

Analyzing the effect of the Covid-19 pandemic on the water consumption of households, workplaces, and public institutions in Kocaeli, Turkey

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ABSTRACT

The COVID-19 pandemic, which has frightening effects on the health systems all over the world, has forced the governments to take strict measures to fight the terrible consequences of the virus. Both this disease and restrictive measures have caused people to change their consumption habits in this period. In this study, the changes in the water consumption amounts of households, workplaces, and public institutions before and after the pandemic were examined. Kocaeli, a socially and economically essential city of Turkey, was chosen as the study area. Temperature and population changes, which are other parameter that may affect water consumption, were also evaluated. In addition, the month when the full lockdown was applied and the period when all bans were abolished and life returned to normal were also evaluated comparatively. The Wilcoxon test was used to determine whether there was a statistically significant difference in the amount of water consumption between the pre-pandemic, during the pandemic, and post-pandemic period. The results showed that although there was no considerable change in temperature, household water consumption increased markedly 3 months after the first case was announced in Turkey. After the implementation of the pandemic measures, the amount of workplace water usage decreased in April and in May 2020. Additionally, the amount of public water consumption in 2020 was found significantly lower than in 2019. In the full lockdown month, an increase was observed in household and workplace water consumption, in contrast to a significant decrease in the water consumption of public institutions. Among the changes experienced in the last period of 2021, when life was relatively normal, only a significant change was observed in the household water consumption value.

1. Introduction

The COVID-19 pandemic spreading in a frightening way has led to health stresses throughout the world after the first case was reported in December 2019 in Wuhan, China [1]. The impact of the Covid-19 pandemic has not only been limited to health but has also begun to be felt in the social and economic field over time.

During the pandemic period, many countries have adopted measures such as the implementation of strict quarantines, the restrictions of public meetings and transportation, and imposing social distancing, curfews, and lockdowns to prevent the spread of the virus and deal with the negative outcomes of the disease.

Both the disease itself and the measures taken by the administrators caused changes in people's daily routines. This situation has also led many researchers from different disciplines to investigate the effects of the pandemic on different fields.

For instance, Menneer et al. [2] investigated the effects of full lockdown on domestic electricity, gas, and water usage in the UK. Results showed that a 17% increase occurred in water usage during full lockdown due to spending more time at home and washing more.

There are numerous studies investigating water quality of natural resources. Liu et al. [3], Yunus et al. [4] and Selvam et al. [5] have reported improvements in water quality during pandemic. These improvements may have been caused by a decrease in the activity of the factories where wastewaters are created, and thereby, a decrease in the number of pollutants that reach the resources [6].

Özbaş et al. [7] assessed the distinction between water

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footprint values of citizens with various socioeconomic standards pre-pandemic and during the pandemic period. According to their results, even though there was a rise in water consumption of many daily activities, the average water footprint value did not rise much because of the reduction in clothing spending and changes in car washing routines. Pesantez et al. [8] examined the effects of the water consumption change experienced during the pandemic process on the water distribution network and proposed a digital twin to couple Advanced Metering Infrastructure data with a hydraulic model.

Antwi et al. [9] have investigated water-related interventions in many European countries throughout the COVID-19 pandemic period. Their results showed that these interventions were predominantly short-term precautions to provide a continued water supply and to reduce the consumers' income decreases. In addition, researchers indicated that water could take a major place to revitalize the European countries' post-COVID-19 economy.

Also, the lockdown has led households to alter their ordinary consumption attitudes, which has caused a keen rise in expenditure, particularly in essentials and foods [10]. For example, a study indicated a prominent change in aggregate water demand peak from 07:10 pre-lockdown to 09:40 during the lockdown in Germany [11]. Similarly, in a study conducted by Abu Bakar [12], water consumption data obtained from 11,528 households over 20 weeks from January 2020 were analyzed. The results of this study revealed a considerable quantifiable alter in water consumption patterns during the COVID-19 lockdown period in the UK. The results of another study indicated that the COVID-19 pandemic influenced water consumption patterns and increased the stress on the already restricted water resources in Tabriz, Iran [13].

Abulibdeh [14] examined the water and electricity consumption during the COVID-19 pandemic across six socioeconomic sectors. The results showed that there was a difference in both consumptions at the block level across all sectors and over time.

Li et al. [15] analyzed how California's urban water consumption was affected by Covid-19 and it was found that the pandemic-related measures reduced California's urban water usage by 7.9%. This reduction was considered as largely connected to an 11.2% decline in the commercial, industrial, and institutional sectors, while there was a 1.4% increase in the water consumption of the residential areas. In another study, Kalbusch et al. [16] applied the Wilcoxon and Kruskal-Wallis non-parametric tests to investigate the effect of coronavirus spread-prevention measures on water consumption in Southern Brazil. Their results revealed that the water consumption differences between pre and post-pandemic periods were statistically significant. Additionally, a decrease in water consumption in the commercial, industrial, and public categories, and an increase in the residential category were detected.

The effects of the pandemic on water consumption continue to be examined at different scales, in different sectors, in regions of the world with different socio-economic characteristics [17-21].

Access to clean water can sometimes be challenging, especially for developing countries with limited budgets. Therefore, any situation that may affect water consumption behavior should be evaluated. Knowing the impact of an unpredictable pandemic on water usage habits will enable the water management decision-making mechanism to operate current water distribution systems and plan water resources more effectively.

The purpose of this study is to investigate whether water consumption of households, workplaces, and public institutions has been affected by the pandemic process. For this purpose, a region of Kocaeli province, which is one of the important industrial cities of Turkey and makes regular and reliable measurements, was determined as the study area.

2. Material and Method

2.1 Covid-19 in Turkey

The first Covid-19 case in Turkey was announced on March 11, 2020, and the first death due to the virus was announced on March 17, 2020 [22]. According to the World Health Organization Covid-19 Data [23], Turkey is one of the countries whose case numbers have exceeded 5 million (Figure 1).

After the Covid-19 pandemic showed its effects in Turkey, in line with the recommendations of the Scientific Committee, it was aimed to reduce the negative effects of the pandemic with measures such as travel restrictions, curfews, quarantine practices, closure of shopping centers and entertainment venues [24].

2.2 Method

It is essential that the data of water distribution systems are measured accurately and continuously, and the components are traceable and controllable. However, it is very difficult to implement these applications simultaneously throughout the distribution system. Therefore, to detect, reduce, and prevent water losses, District Metered Areas (DMA) are generally used as an effective and sustainable method. The borders of DMA are separated from other regions and network elements; hence, they can be defined as zones with a clearly determined entrance. In this study, the DMA-08 isolated region, which served 24 streets with 6377 m of secondary pipes and 3461 m of main pipes, in the Kocaeli city was selected as study area [25] (Figure 2).

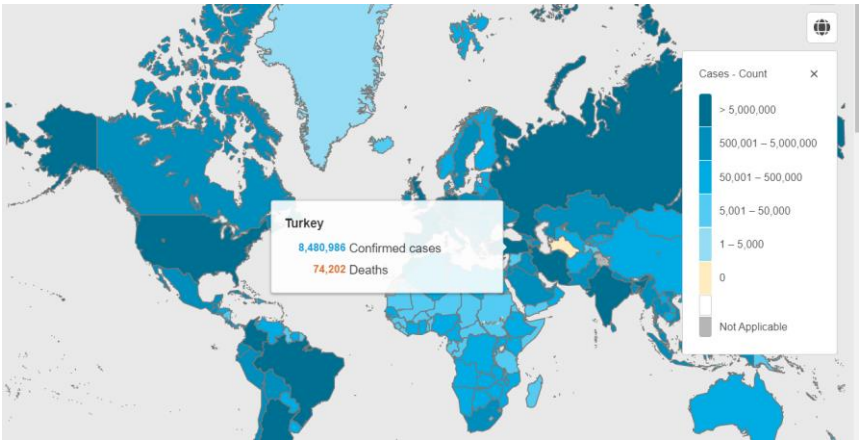

Figure 1. General Covid-19 situation in Turkey on 18.11.2021 [23]

The monthly water consumption values of the DMA-08 isolated region for 2019, 2020 and 2021, which were measured in average 3350 households, 30 workplaces, 20 public institutes, were examined. Since these numbers were not stable and changed every month, in order to make an objective comparison, the values obtained through dividing the monthly total accrual values by the total non-zero accrual number were used.

To compare the pre- and during-pandemic periods, March, when the first case was announced in Turkey, was considered as the starting month. Additionally, the date of July 1, 2021, when the restrictions were ended, all workplaces that had been suspended started their activities again, and the normal working order in public institutions was started, was accepted as the beginning of the normalization process for Turkey. Thus, a comparison of the change experienced after this date with the previous year was also used to determine the effect of the pandemic.

Figure 2. The study area [25]

Moreover, to consider population and temperature change, two other parameters that can affect the amount of water consumption, the population values of the region obtained from the Address Based Population Registration System [26] and temperature data of the Kocaeli station, were also checked.

The Wilcoxon test was used to determine whether the changes observed in the graphics and tables were statistically significant.

2.3 The Wilcoxon Test

The Wilcoxon test is a nonparametric test and used to determine if there are statistically significant differences between two dependent data sets [27]

The hypotheses for this test can be described as below:

H_0: the distributions of both data sets are equal. The sum of the positive and negative differences between the test results is equal.

H_1: the distributions are not equal. The sum of the negative differences is either very small or larger than the sum of the positive differences [27].

3. Results and discussion

3.1 Temperature and Population

The monthly average temperature values for 2019 and 2020 indicated that the temperature value in June 2020 was lower than the previous year, and it rose a few degrees above the previous year as of July (Figure 3). Additionally, the monthly average temperature value (19.4 °C) in May 2021 was equal to the average of the previous two years. Since September of 2021, the temperature values were below the other two years (except for December).

The Wilcoxon test was used to determine whether the monthly average temperature values of 2020 showed a statistically significant difference compared to 2019 and 2021.

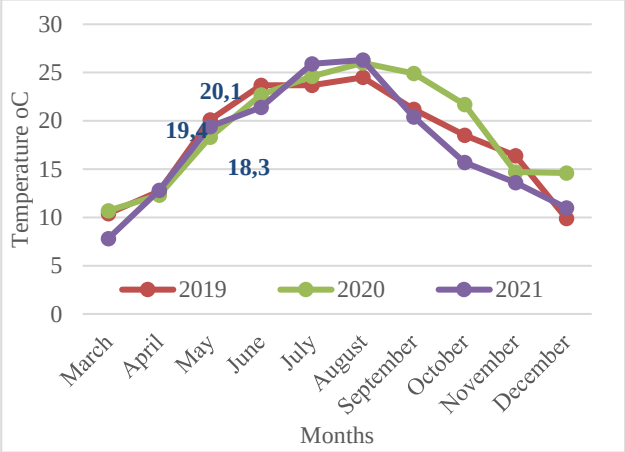

Figure 3. Monthly average temperature for 2019, 2020, and 2021

It was determined that the "z" value was -0.866 (p=0.386) for the comparison of 2019-2020, and it was -1.582 (p=0.144) for the comparison of 2020-2021. These results showed that since p values were greater than 0.05 significance level, there was no statistically significant difference between the temperature values of 2020 and the temperature values of 2019 and 2021.

Based on the results obtained from the Address Based Population Registration System, it was determined that the population of the region decreased by 0.4% and 0.77% in 2020 and 2021, respectively. It is not considered that these changes in the population had a significant effect on the amount of water consumption.

3.2 Household

It was investigated whether there were significant increases in household water consumption due to the transition to distance education, working from home in some sectors, and people's tendency to use more water by being more meticulous about protecting themselves from the virus.

Table 1 provides data on the comparison of household water consumption between 2019- 2020 and 2020- 2021. Negative values show the reductions of 2020 respect to 2019 and the reductions of 2021 respect to 2020.

It is seen that the consumptions in March 2020 and in the following two months, contrary to expectations, were less than the previous year, but there was a significant increase by 43.30% in June and remained high until the end of the year (excluding September). December was almost same with the previous year. (Figure 4). The Wilcoxon test was applied to 10-month values to determine whether the water consumption values of 2020 showed a statistically significant change compared to 2019 after the first case was announced. The test results revealed that there was no statistically significant difference between the household water consumption values of 2020 and 2019 (z=-1.274, p=0.203>0.05).

In addition, while the average temperature value was almost the same as in the other years, in May 2021, the water consumption value reached 10.79 m^3/household which was the highest value of the three years. The consumption value in May also had the highest value compared to the rest of 2021.

It was observed that since June of 2021 (excluding September), there was a decrease at varying rates compared to the 2020. The Wilcoxon test was applied to 6-month values to determine whether the water consumption values of 2021 showed a statistically significant difference compared to 2020 after the normalization steps. The test results showed that there was a statistically significant difference between the household water consumption values of 2021 and 2020 (z=-1.992, p=0.046<0.05).

3.3 Workplaces

Although their number varies on a monthly and yearly basis, there were an average of 30 workplaces in the study area. Within the scope of the pandemic measures implemented by the government, the activities of some workplaces such as cafes, restaurants, hairdressers, and sports centers were either completely stopped or restrictions were made in their working hours and capacities. Some workplaces, on the other hand, resorted to capacity reduction by putting some of their employees on paid leave or allowing them to work from home.

Table 2 shows the percentage of water consumption comparison between 2019-2020 and 2020–2021. Negative values show the reductions of 2020 respect to 2019 and the reductions of 2021 respect to 2020.

With the implementation of the restrictions within the scope of pandemic measures, the amount of water consumption decreased by 41.61% in April 2020 and 21.15% in May 2020. Although the June and July values were higher than the previous year, it can be said that water usage in 2020 was less than in 2019. However, based on the Wilcoxon test results (z=-0.734, p=0.445>0.05), it can be said that this usage difference was not statistically significant.

When the values for May 2021 were examined in terms of workplaces, it was seen that there was no decrease in the water consumption value, on the contrary, the consumption reached the highest value of three years in 2021. This situation can be explained by the fact that many workplace employees are excluded from the scope of the lockdown or continue to work with special permission. The increase in the water consumption values experienced in May 2021 decreased slightly in June and then increased again in July.

It was observed that since July of 2021 (excluding October), there was a decrease at varying rates compared to 2020. According to the Wilcoxon test results, this consumption difference is not statistically significant (z=-1.153, p=0.249>0.05).

Table 1. The household water consumption comparison between 2019 - 2020 and 2020 – 2021

%	March	April	May	June	July	August	September	October	November	December
2019_2020	-2.28	-8.18	-0.17	43.30	12.47	20.70	-3.22	12.75	8.50	-0.03
2020_2021	2.56	9.33	6.94	-32.46	-8.77	-13.49	0.14	-9.22	-10.66	-5.48

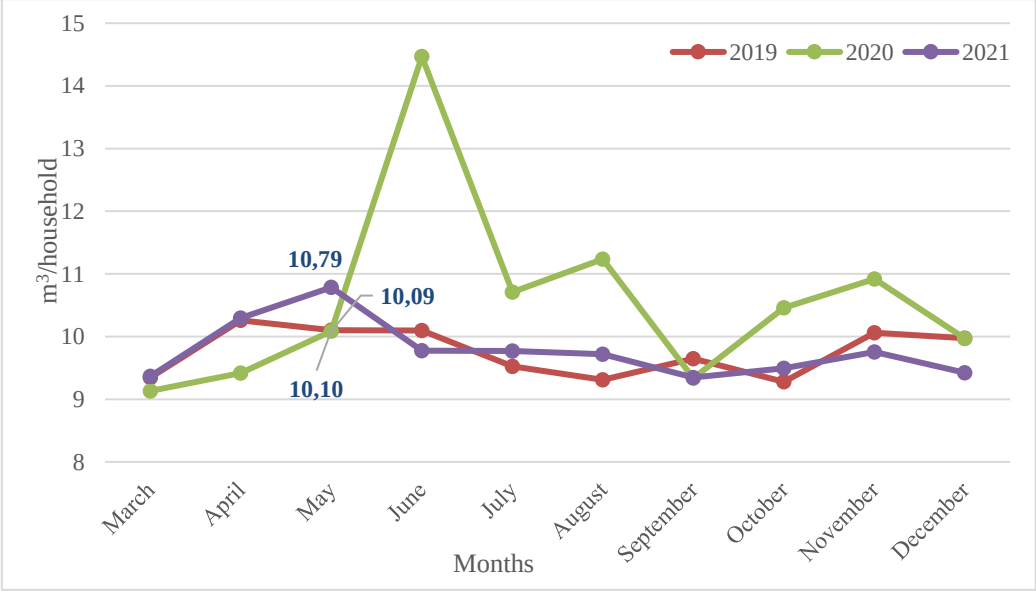

Figure 4. The monthly water consumption values of households in 2019, 2020 and 2021

Table 2. The workplace water consumption comparison between 2019 - 2020 and 2020 – 2021

%	March	April	May	June	July	August	September	October	November	December
2019_2020	9.41	-41.61	-21.15	26.76	13.86	-9.71	-1.85	-8.23	3.03	-27.26
2020_2021	-14.02	54.48	45.61	-24.47	-5.20	-4.90	-0.61	15.66	-17.31	-0.59

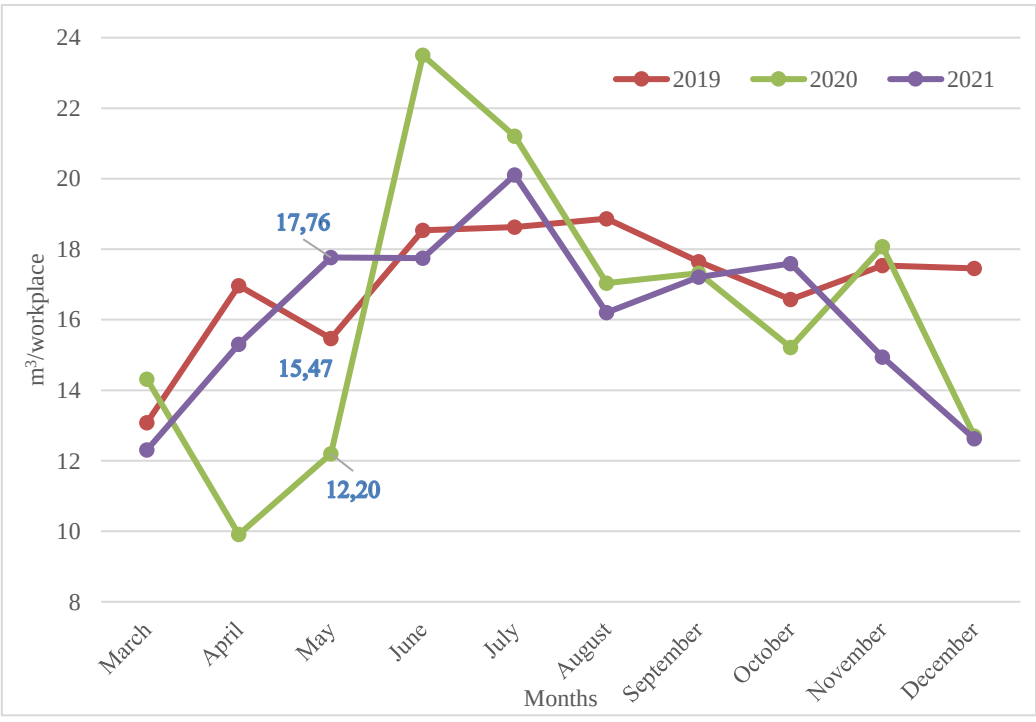

Figure 5. The monthly water consumption values of workplaces in 2019, 2020 and 2021

3.4 Public Institution

During the pandemic process, employees who were pregnant, with chronic diseases, and over the age of 65 were considered on administrative leave in public institutions. Educational institutions switched to distance education. To maintain social distance in closed places, some employees started to work on a rotating basis. While some health institutions started to serve only Covid patients, some citizens took care not to go to the hospital except for emergencies due to the fear of the virus. For these reasons, water consumption of public institutions was affected significantly. The rotating, flexible, and remote working practice, which was initiated with the circular published on March 22, 2020, within the scope of Corona Virus measures, ended on June 1, 2020. With the circular published on August 26, 2020, alternate, flexible, and remote working in public institutions and organizations was allowed again.

In the study area, there are an average of 20 public institutions. In Table 3, negative values show the reductions of 2020 respect to 2019 and the reductions of 2021 respect to 2020.

As can be seen in Table 3 and Figure 6, the water consumption amount of public institutions in 2020 was much less than the previous year, except for August. In June, July, and August, when the remote work permit was revoked, the rate of decrease in the amount of water consumption slowed down, and there was even an increase in August. The difference in consumption reached 76%, especially in the period when inspections were tightened, and events organized by official institutions, unions, and non-governmental organizations were postponed. The Wilcoxon test results showed that pandemic measures affected water consumption values in public institutions ($z=-2.293$, $p=0.022<0.05$).

When the water consumption values of public institutions in May 2021 are analyzed, it is seen that there was a dramatic decrease over the years. In addition, the water consumption values of public institutions for the rest of 2021 are higher than the consumption value in May. The water consumption values of 2021, which were significantly below the other two years until October, became more than the values of 2020 after this month and approached the values of 2019. This situation can be interpreted as the fact that the effects of the normalization process were felt more in the last two months of 2021. The Wilcoxon test results also support this situation, showing that the change in water consumption in the last 6 months is not statistically significant ($z=-0.943$, $p=0.345>0.05$).

Table 3. The public institution water consumption comparison between 2019 - 2020 and 2020 – 2021

%	March	April	May	June	July	August	September	October	November	December
2019_2020	-10.62	-43.18	-48.30	-38.31	-20.59	19.71	-66.31	-76.03	-57.58	-61.68
2020_2021	-77.46	-46.43	-51.22	-82.66	-83.62	-87.08	-57.54	0.79	41.58	22.09

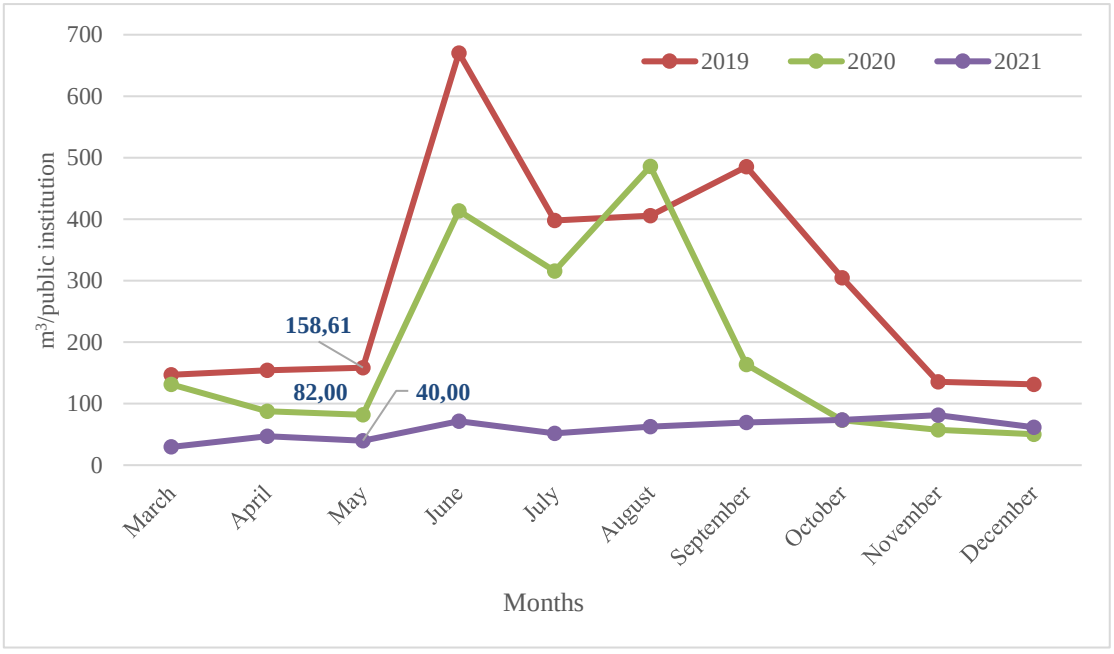

Figure 6. The monthly water consumption values of public institutions in 2019, 2020 and 2021

4. Conclusions

In this study, the effect of the pandemic process on the amount of water consumption in households, workplaces, and public institutions was investigated.

According to the results of the Wilcoxon test applied to understand whether the changes observed on a monthly basis are meaningful, as a period only the household water consumption value experienced after the normalization period and the change in the public institution water consumption values during the pandemic period compared to the previous year were found to be statistically significant.

Especially, to be able to understand the effects of the 19-day full lockdown precisely, it is necessary to reach the daily and hourly data of the subscribers separately instead of the total monthly consumption data.

Studies examining the effects of the pandemic process on water consumption are generally carried out for urban areas. However, conducting similar studies on rural water consumption is important in terms of understanding the effects of the pandemic on different socio-economic classes.

In addition, investigating the effects of the pandemic not only on the water consumption amounts of industrial facilities but also on the water demand of agriculture and livestock enterprises will allow us to see the widespread effect of the pandemic.

Declaration

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The author also declared that this article is original, was prepared in accordance with international publication and research ethics, and ethical committee permission or any special permission is not required.

Author Contributions

N. Ucler obtained the data, analyzed them, and wrote the manuscript.

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