

Article

Effect of the COVID-19 Pandemic on Residential Water Use Behavior in Japan

Kanakano Toyosada ^{1,*}, Chika Nakagawa ¹, Takehiko Mitsunaga ² and Hiroyuki Kose ³ 

¹ Department of Environmental Science, International College of Arts and Science, Fukuoka Women's University, 1-1-1, Kasumigaoka, Higashi-ku, Fukuoka 813-8529, Japan; 21mhe201@mb2.fwu.ac.jp

² Department of Architecture, School of Science & Technology, Meiji University, 1-1-1, Higashimita, Tama-ku, Kawasaki 214-0033, Japan; mitsunaga@meiji.ac.jp

³ Faculty of Information Sciences and Arts, Toyo University, 2100 Kujirai, Kawagoe 350-8585, Japan; hkose@toyo.jp

* Correspondence: kanako.toyosada@fwu.ac.jp; Tel.: +81-92-692-3116

Abstract: To investigate the effect of the COVID-19 (coronavirus) pandemic on residential water use behavior in Japan, we conducted a web-based survey of 1310 people throughout Japan in March 2021, one year after the initial spread of coronavirus. The survey was designed to provide an average picture of Japan. The survey revealed that the time respondents spent at home increased during the pandemic for both men and women in all age groups by an average of 1 h, an increase of 9%. Changes in water use behavior increased almost in proportion to the increase in time spent at home, except for the frequency of defecation, which was limited to once a day. The amount of time spent in the washroom increased by 13%, an increase of more than 1.4 times the increase in the amount of time spent at home. The additional 40% increase could be considered an effect of the awareness of disease prevention. The coronavirus pandemic is expected to end in the near future. In Japan, the pandemic has led to a strong push for the reform of work styles. Therefore, even in a post-coronavirus-pandemic society, changes in work styles may normalize the increased time spent at home and the proportional increase in water use. However, because the change in water use behavior caused by quarantine awareness is a result of the fear of coronavirus infection, it is possible that water use will gradually return to pre-pandemic levels once the source of the fear is removed. To reflect the changes in water use behavior in the design of facilities in the post-coronavirus-pandemic society, it is necessary to continue this survey even once the pandemic has ended.

Keywords: water use behavior; building plumbing design; COVID-19; coronavirus; coronavirus pandemic; questionnaire survey



Citation: Toyosada, K.; Nakagawa, C.; Mitsunaga, T.; Kose, H. Effect of the COVID-19 Pandemic on Residential Water Use Behavior in Japan. *Water* **2021**, *13*, 3129. <https://doi.org/10.3390/w13213129>

Academic Editors: Sophia Barinova and Ghassan Chebbo

Received: 30 September 2021

Accepted: 31 October 2021

Published: 5 November 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Since the COVID-19 (coronavirus) infection was reported in Wuhan, China, in December 2019, it has rapidly spread throughout the world, leading the WHO to declare a pandemic in March 2020. Since then, many countries have adopted measures such as lockdowns to prevent the spread of the disease and are making diligent efforts to end the pandemic. However, as of September 2021, there remains no clear path toward ending the pandemic.

The global spread of the coronavirus may affect not only the ecosystems and urban infrastructures but also people's lifestyles. Several studies have already reported on the effect on ecosystems and urban infrastructure [1–3]. People's behaviors and lifestyles will also change due to the pandemic; if these behaviors remain changed, the design of urban infrastructure and housing facilities will be affected. However, to date, there has been no published research on this.

An overview of the measures taken by the Japanese government to prevent the spread of coronavirus is shown in Figure 1. In Japan, there is no law that compels companies, restaurants, and so on to close for a certain period of time. Therefore, whenever there is a noticeable increase in the number of new coronavirus infections, the government encourages people to stay at home by promoting teleworking and repeatedly asking restaurants to close or reduce their business hours. Consequently, the number of new coronavirus infections has been prevented from increasing by reducing opportunities for human-to-human contact. This survey was conducted during the second state of emergency (January–March 2021). During this period, the Japanese government’s measures to prevent the spread of the coronavirus functioned efficiently throughout the country.

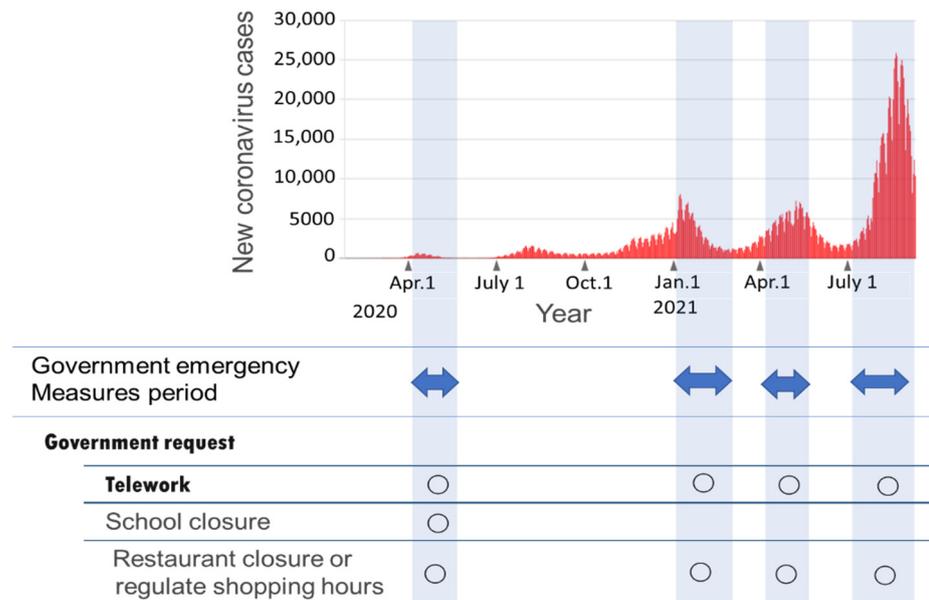


Figure 1. Government emergency measures against the COVID-19 (coronavirus) pandemic in Japan [4].

In many countries, lockdowns and other measures have been implemented to address the pandemic. Similarly, in Japan, measures such as the promotion of teleworking and requests for restaurant closures have been implemented; consequently, major changes in social activities have occurred. These changes in social activities may have also affected residential water use behavior. Water use behavior in housing is an important factor in the design of water supply and sewerage infrastructure and plumbing systems in buildings. Before the pandemic, design parameters were based on monitoring studies on water use behavior. In Japan, lifestyle changes have led to people gradually shifting from bathing using a bathtub to showering. Monitoring surveys are being conducted to identify these changes in daily lifestyles in the design units [5]. In addition, changes in water consumption due to changes in toilet bowl design and other housing equipment have been continuously investigated [6].

The change in water consumption associated with improvements in the performance of equipment will be gradual because the equipment is replaced during home renovations and so on. However, the pandemic has forced people globally to make lifestyle changes.

We have been researching the environmental impact of water infrastructure in Japan and other Asian countries. In the process, we have also researched the use behavior of water use facilities [7–9].

Water infrastructure consumes a large amount of electricity in its operation. Therefore, saving water can reduce electricity consumption, which would in turn reduce CO₂ emissions. The concept of evaluating water consumption in relation to energy has been accepted in many countries [10–13]. CO₂ emissions from water use are calculated by multiplying the amount of water used by the CO₂ emission factor for water [14]. CO₂ emissions from residential water consumption in Japan account for 5% of total emissions [13]. The method

for calculating the environmental impact of water infrastructure is determining the CO₂ emission factor of water and modeling water use behavior.

In these surveys, we conducted questionnaires in a wide area to obtain an overall picture of the frequency of facility use and then modeled water use behavior by measuring the actual amount of water used. The results of these surveys showed that it is possible to obtain an overview of water use behavior through questionnaire surveys [7–9].

As this survey was conducted in the middle of the coronavirus pandemic, it was not possible to conduct an actual measurement survey or an interview survey. Therefore, as the first phase of the survey, we conducted a wide-area questionnaire to obtain a general picture. We used a web-based questionnaire survey of the entire Japanese population to examine how residential water use behavior was affected by the coronavirus pandemic and to determine whether these effects are likely to persist in a post-coronavirus-pandemic society. We first examined changes in work patterns and time spent at home due to the coronavirus pandemic. We then checked the frequency and duration of the use of toilets, washrooms, and other water use facilities at home due to the pandemic and examined any correlation with changes in the time spent at home. We also asked respondents whether the frequency of cleaning water use facilities changed during the pandemic.

2. Investigation Overview

An overview of the questionnaire survey is shown in Table 1. The distribution and collection of the web-based questionnaire was outsourced to a research company. The questionnaire targeted men and women living in Japan between March and April 2021. Respondents were divided into the following five age groups: 15–29, 30–39, 40–49, 50–59, and 60–79 years. The overall number of valid responses was 1103.

Table 1. Overview of the questionnaire survey.

Item	Outline
Method	Web-based questionnaire
Date of Survey	March and April 2021
Target	Male and female residents in Japan. Age 15–79 years old, divided into 5 groups and equally allocated to each group.
Survey area	Throughout Japan
Valid respondents	1103

In the survey, lifestyle changes due to the pandemic were regarded as changes in the time spent at home. The relationship between the change in time spent at home and the change in the frequency and duration of using water use facilities at home was correlatively analyzed by generation and gender.

As a measure to prevent the spread of the coronavirus, the government has widely announced recommendations such as frequent hand washing. Therefore, both increased time spent at home and the awareness of quarantine may affect home water use behavior under a pandemic. Therefore, the factors that increase the frequency of water use were also estimated for each water use facility.

The questions asked in the survey are shown in Table 2. This questionnaire, titled “Questionnaire on changes in residential water use behavior due to the coronavirus pandemic,” was mainly multiple choice to make it easier to answer. Questions regarding respondents’ demographics addressed gender, age, prefecture of residence, occupation, household composition, number of family members living together, type of housing, changes in work patterns, and amount of time spent at home.

Table 2. Structure and questions.

Item	Questions
Attribute	Gender, age, prefecture of residence, occupation, household composition, number of family members living together, type of housing, and changes in work patterns and amount of time spent at home
Water use behavior by zone	Washrooms: Frequency of hand washing, reason for change in frequency, changes in the amount of time spent in the washroom
	Bathroom: Frequency of bathing, reasons for frequency change, changes in the amount of time spent in the bathroom, changes in the way respondents spend time in the bathroom
	Kitchen: Number of times cooking, cooking method, number of times pre-prepared and boxed meals are used, amount of water used, and reasons for changes in use
	Laundry: Frequency of washing, reason for change in frequency, change in washing method
Cleaning	Change in cleaning frequency (washrooms, toilets, bathrooms, kitchens, laundry)

In the question on water use behavior, we asked about changes during the pandemic for each residential water use facility. The frequency and method of cleaning each water use facility were also included in the questionnaire. In addition, when we asked about changes in behavior during the pandemic, we also asked about the reasons for the changes. The data were statistically processed to obtain the median and mean deviation. In addition, Pearson’s chi-square test was used to determine the significance of the results, with $p < 0.05$ indicating statistical significance.

3. Result and Discussion

3.1. Overview of Survey Respondents and the Effect of the Coronavirus Pandemic on Japanese Society

The regional distribution of respondents is shown in Figure 2. The regions were divided into eight regions that are commonly used in Japan. Respondents were obtained almost equally from each age group in each region of the country. In the survey, the ratio of “detached house” residents to “multi-family building” residents was roughly 1:1, which was consistent with the results of a survey on existing housing patterns in Japan [15]. The surveyed area had an average of 2.6 persons per household, which is similar to the official Japanese government statistic of 2.3 persons per household. This survey showed the composition of respondents to reflect the residential living environment of Japan and provided data for each age group in every region of the country. From this, we determined that the questionnaire survey provided a comprehensive picture of Japan.

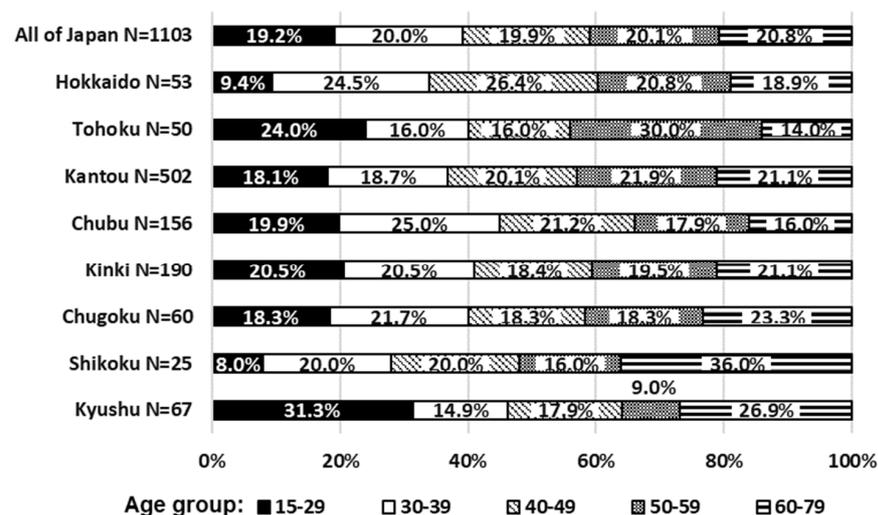


Figure 2. Regional distribution of respondents by age group.

The survey covered a wide range of age groups, from school-age to working and retired respondents. Changes in these respondents' lives due to the pandemic were examined using the questionnaire. This survey was conducted when the pandemic was still ongoing and many company employees were working from home. Figure 3 shows the average time spent at home by gender before and during the coronavirus pandemic. Although there was a large variance, significant differences were observed in the time spent at home before and during the coronavirus pandemic. The survey showed that the percentage of people who worked from home increased by 24% and the average time spent at home increased by 1 h per day on both working days and holidays due to the coronavirus pandemic. The increase in time spent at home on working days and holidays were 11% and 7%, respectively. The overall average increase was 9%. There was no difference between men and women.

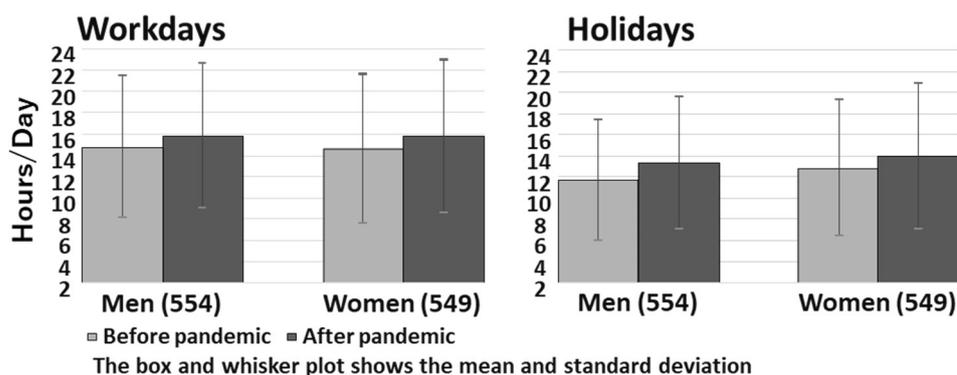


Figure 3. Average time spent at home by gender before and after the coronavirus pandemic.

The increase in hours for each generation also resulted in a large variance, as shown in Figure 4. However, the increase due to the pandemic was significant for both working days and holidays ($p < 0.001$). The number of hours spent at home increased for all age groups, including school-age and working-age respondents, on both working days and holidays. These results indicate that the Japanese people followed the Japanese government's measures to prevent the spread of the coronavirus.

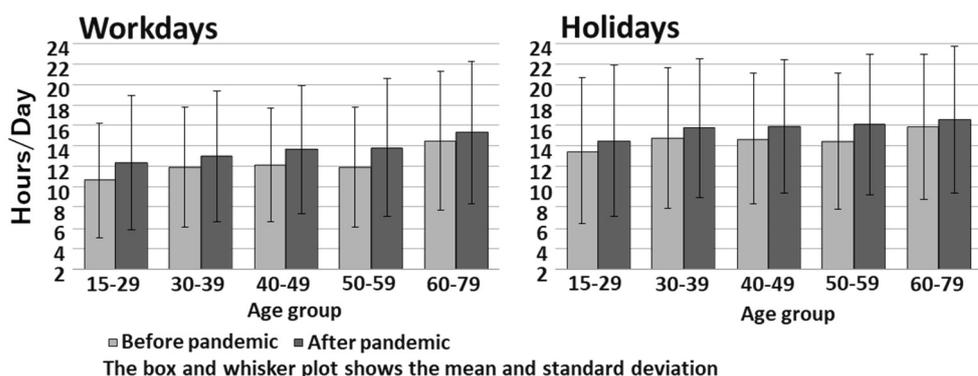


Figure 4. Change in average time spent at home during the coronavirus pandemic, by age group.

3.2. Water Use Behavior in the Washroom

Changes in residential water use behavior due to the coronavirus pandemic are thought to include lifestyle changes, such as an increase in the amount of time residents spend at home, and behavioral changes due to residents' awareness of coronavirus protection. Thus, we conducted a questionnaire survey to determine the extent to which water use behavior changed for each water use facility in the respondents' homes.

The effect of the coronavirus pandemic on the frequency and duration of hand washing in the washroom is shown in Figures 5 and 6. As mentioned above, the pandemic has increased the average time spent at home by about 9%. The questionnaire survey

showed the increases in the frequency and duration of hand washing to be 27% and 13%, respectively. The increase in duration was over 1.4 times greater than the increase in time spent at home. Out of 1103 respondents, 396 increased their frequency of handwashing during the pandemic. Figure 7 shows the reasons for the increase in hand washing time. The increases in the frequency and duration of hand washing are actually due to the increase in the time spent at home and awareness of disease prevention. The increases in the frequency and duration of hand washing were more pronounced among the older respondents. The Japanese government has repeatedly announced that older people are prone to severe coronavirus infections and should be protected from the disease. The increases in the frequency and duration of hand washing among the older respondents are proof that the government’s announcements have had a strong effect on their awareness of the need for quarantine.

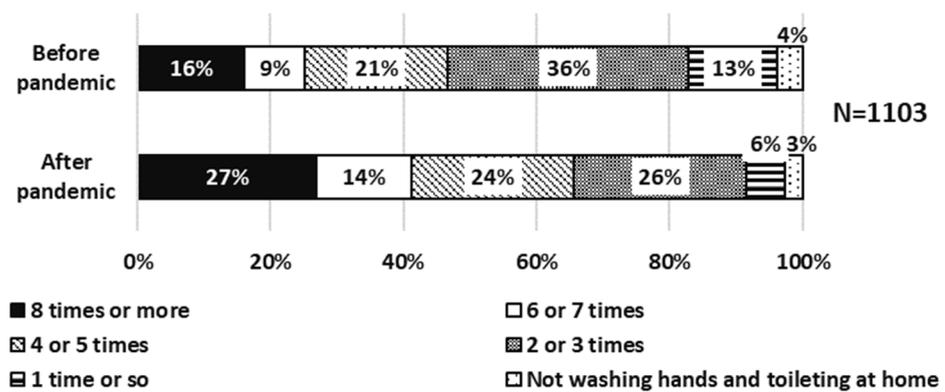


Figure 5. Daily hand and face washing frequency before and during the coronavirus pandemic.

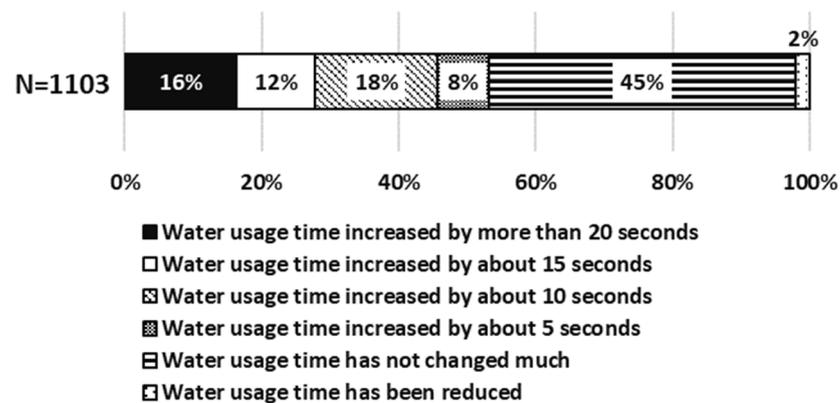


Figure 6. Changes in time spent using water during hand washing.

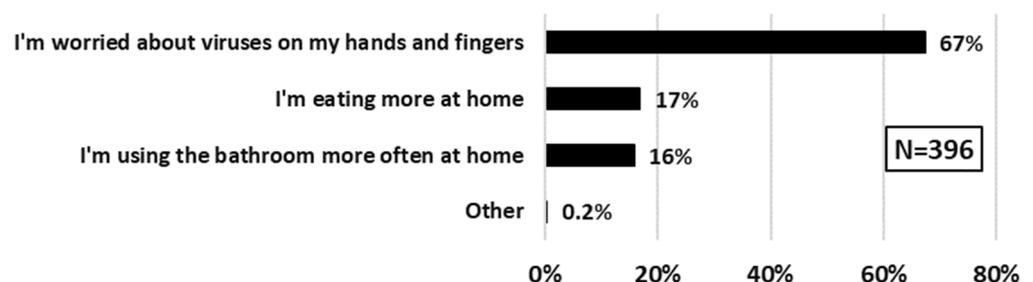


Figure 7. Reasons for increased frequency of hand washing (multiple responses).

3.3. Water Use Behavior in the Toilet

It has been reported that Japanese people defecate once and urinate four to six times per day [16]. The effect of the coronavirus pandemic on the frequency of toilet usage was investigated. The frequency of defecation increased during the pandemic in 6% (68 people) of the total respondents and did not change in 94% (1035 people); therefore, there was almost no increase overall. This trend was the same for both genders and all age groups. For both school-age children and adults, the habit of defecating only once a day at home before going to school or work is almost completely established. Therefore, they were not affected by the increased time spent at home due to the pandemic.

Regarding the frequency of urination, 12% (129 people) of all respondents reported increased urination frequency during the pandemic, while 88% (974 people) reported no change. Respondents who reported an increase in urination frequency were highly correlated with those who reported an increase in time spent at home ($p > 0.001$). The overall average urine frequency increased by 0.2–0.3 times per day. Japanese people are reported to urinate 4 to 6 times a day, as mentioned above. As these urinations occur during the 16 h in which they are awake, it can be assumed that they urinate at intervals of approximately 3–4 h. The frequency of urination during the pandemic increased by 0.2–0.3 times. Multiplying this number by the interval between urinations, we calculated the increase in time spent at home in terms of the number of urinations to be about 1 h, which is well in line with the 1 h increase in time spent at home reported in the survey. These results indicate that changes in toilet water use behavior due to the coronavirus pandemic can be explained by lifestyle changes in terms of time spent at home.

This survey was based on a questionnaire to determine the number of actions taken, not the actual measurement of water volume changes. To consider the possibility of water volume change, we also asked about changes in the way people use the toilet. The results are shown in Figure 8. As many as 260 respondents, 23% of the total 1103 respondents, reported that they had changed how they use the toilet. These responses included “I close the lid of the toilet before washing” (60.0%), “I have increased the number of times I flush the toilet” (40.8%), and “I have increased the number of times I flush the toilet using the large water volume mode” (15%). These responses also show that the awareness of quarantine and the fear of household transmission of coronavirus via the toilet has changed how people use the toilet. These behavioral changes were based on increasing water use in the toilet.

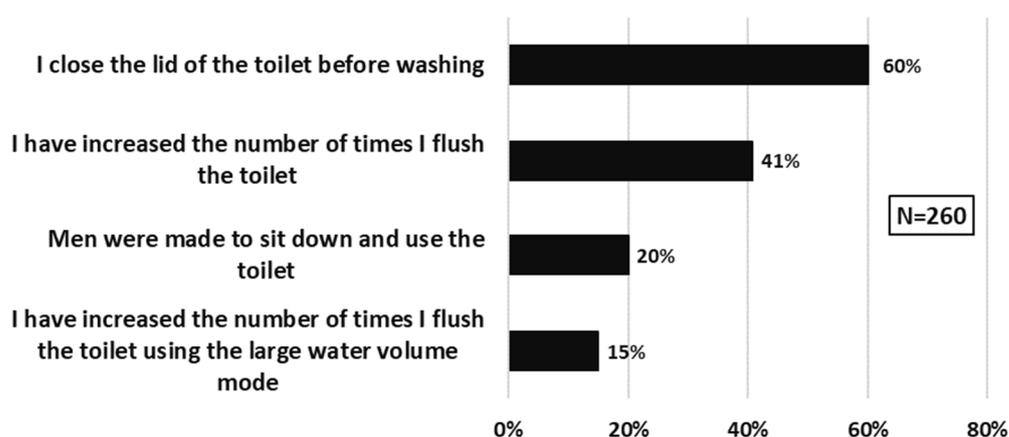


Figure 8. Changes in the way respondents use the toilet (multiple responses).

3.4. Water Use Behavior in the Bathroom

The effect of the coronavirus pandemic on bathing frequency is shown in Figure 9. The average bathing frequency before the pandemic was 5.9 times per week (0.84 times per day), but it was possible that awareness of coronavirus prevention might induce an increase in bathing frequency. However, the survey showed no significant increase in frequency. When

the 42 respondents who reported an increase in their frequency of bathing were asked about the reasons for the increase, the following responses were obtained. The most common answers were “Because of worries about viruses on my body and in my hair” (50%) and “To relax and refresh” (50%). Increased bathing frequency to wash off adherent viruses due to an awareness of quarantine was more common among the older respondents, while the increase for stress release was more common among working people in their 50s. We found that the altered consciousness caused by the pandemic may have also caused an increase in bathing frequency (Figure 10). This survey was conducted one year after the start of the coronavirus pandemic in Japan, but the pandemic has continued well into its second year, and a prolonged pandemic may likely cause further changes in water use behavior.

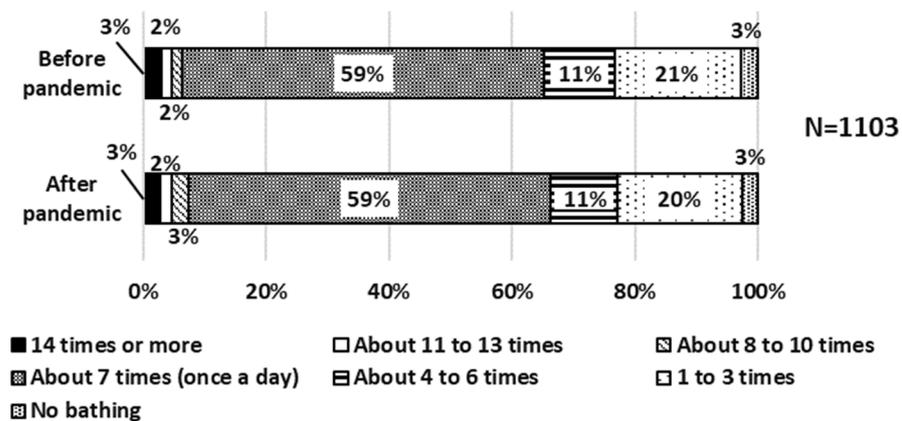


Figure 9. Bathing frequency at home before and during the coronavirus pandemic.

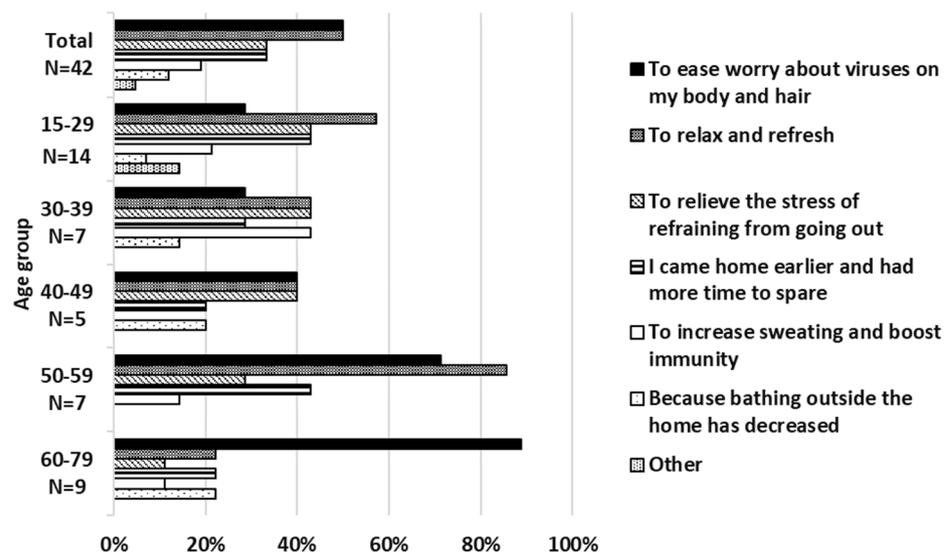


Figure 10. Reasons for increased frequency of bathing (multiple answers).

3.5. Water Use Behavior in the Kitchen

We found that before the coronavirus pandemic, men in Japan participated in cooking 10.6 times per week, which was lower than the women’s participation rate (14.2 times per week). However, during the pandemic, the rates increased to 11.3 and 15.1 times per week, respectively (respective increases of 7% and 6%). This is similar to the increase in time spent at home, and we judged that lifestyle change was a factor in the increase in cooking frequency. Water use in the kitchen was also reported to have increased by 24%. This increase was similar for all age groups, as shown in Figure 11. This was understood to be because all age groups were forced to cook more often due to the closure of restaurants in line with the government’s anti-virus measures. Meals at home can take many forms, from fully cooked

meals using raw materials to partially pre-prepared meals such as frozen foods and boxed meals. During the pandemic, there were increases in the use of pre-prepared, boxed, and fully cooked meals from raw materials (Figure 12).

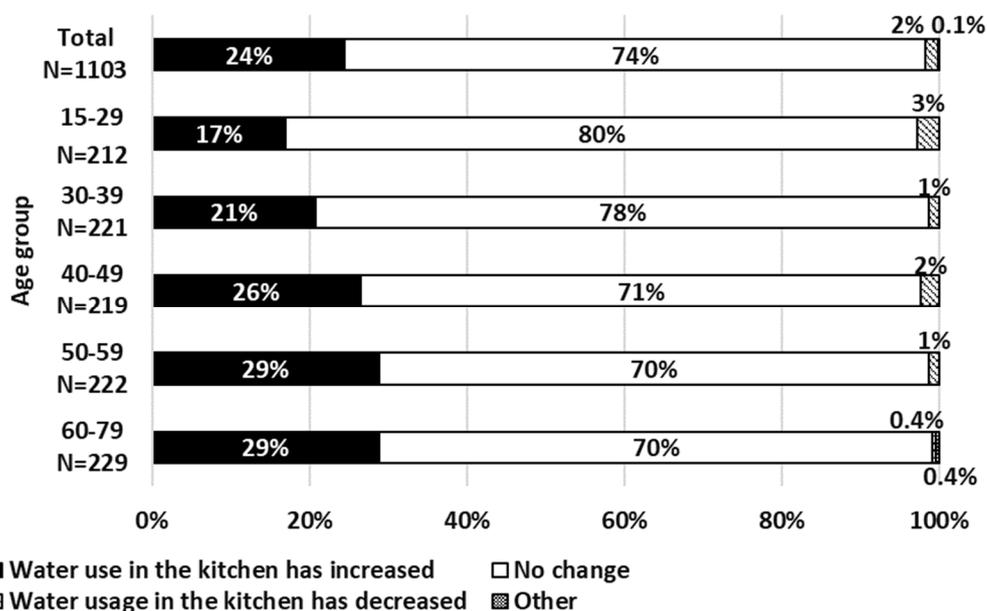


Figure 11. Changes in water usage in the kitchen.

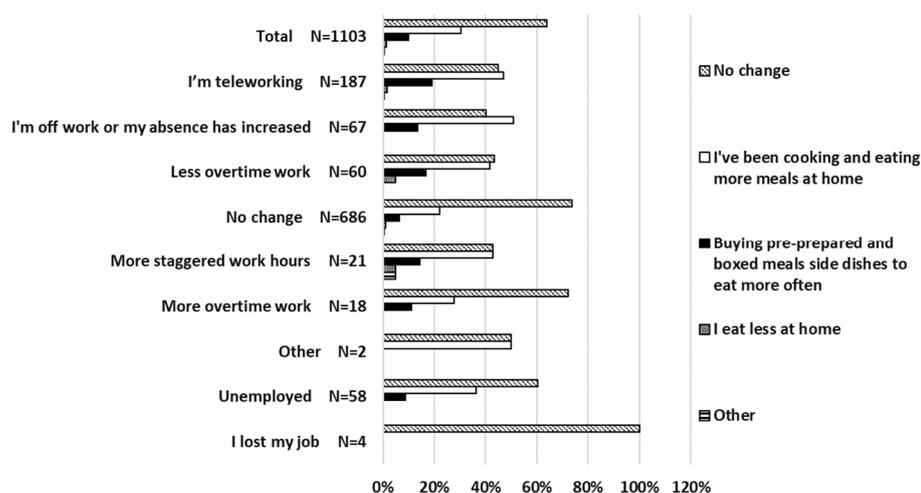


Figure 12. Changes in the way respondents prepare meals (multiple responses).

3.6. Water Use Behavior Related to Laundry and House Cleaning

The effect of the coronavirus pandemic on respondents' frequency of laundry at home was examined. Before the pandemic, the respondents washed their laundry 5.62 times per week, but this increased to 5.78 times per week during the pandemic. When asked why they washed their clothes more often, respondents answered that they started to wash their clothes more often because they wore them when they went out (56%) and that they were able to do more laundry because they spent more time at home (36%). This indicates that both the awareness of disease prevention and lifestyle change of increased time at home affected laundry behavior.

Figure 13 shows that less than 20% of respondents increased their frequency of cleaning all water use facilities, including toilets and washrooms. This was likely due to an increase in the amount of time spent at home, which increased the amount of time available for cleaning.

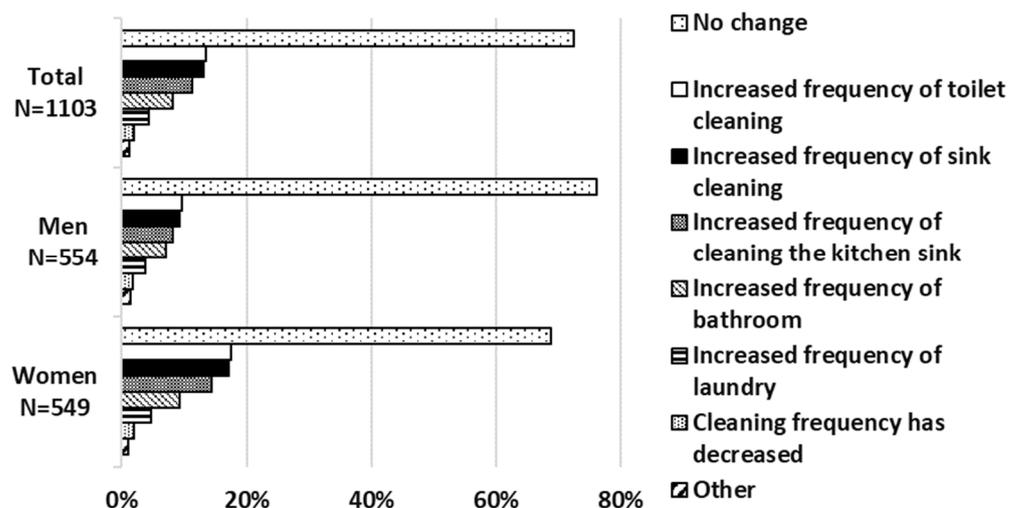


Figure 13. Changes in the frequency of cleaning for water use facilities (multiple responses).

4. Conclusions

The coronavirus pandemic has not only increased people's awareness of the need to prevent the spread of viruses but also caused lifestyle changes such as an increased amount of time spent at home. Consequently, people increased their water use activities in washrooms, toilets, kitchens, and all other water use facilities. We hope that the coronavirus pandemic will be eliminated in the near future through worldwide quarantine measures. The change in water use behavior caused by quarantine awareness is a result of the fear of coronavirus infection. Therefore, when the pandemic is over and the source of fear is removed, water use may gradually return to its previous state.

The Japanese government has been strongly promoting teleworking and other work style reforms as a countermeasure to the pandemic. The Japanese government believes that these measures will help solve various social problems that Japan is facing and is trying to make them the standard for the post-coronavirus-pandemic society [17]. In said society, the changes in water use behavior due to lifestyle changes identified in this study may become entrenched. In order to reflect changes in water use behavior in facility design, it is necessary to conduct detailed surveys such as measuring actual water consumption and modeling it in the period after the end of the coronavirus pandemic.

Author Contributions: Analysis and writing—original draft preparation: K.T.; data curation: C.N.; investigation and visualization: T.M.; supervision and review: H.K. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by the SHASE Committee on Water Supply, Drainage, and Sanitation Equipment "Subcommittee on Universal Design of Sanitary Equipment (Chief Investigator: Kanako Toyosada)" and by Fukuoka Women's University "Research Core Study on Food and Living Environment for Home Support" as part of the Kajima Foundation and JSPS KAKENHI Grant Number JP21h01497 in analysis.

Acknowledgments: We would like to express our deepest gratitude to the following individuals for their cooperation in the survey: Ukyo Takeuchi, Taichi Umetani, and Honoka Kagyo (fourth-year students at Meiji University) and Haruka Ogata, Ayaka Hakoshima, and Nanasa Watanabe (fourth-year students at Fukuoka Women's University) for their cooperation in the analysis.

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

References

1. Wartecki, A.; Rzymiski, P. On the Coronaviruses and Their Associations with the Aquatic Environment and Wastewater. *Water* **2020**, *12*, 1598. [CrossRef]

2. Kweinor Tetteh, E.; Opoku Amankwa, M.; Armah, E.K.; Rathilal, S. Fate of COVID-19 Occurrences in Wastewater Systems: Emerging Detection and Treatment Technologies A Review. *Water* **2020**, *12*, 2680. [[CrossRef](#)]
3. Núñez-Nogueira, G.; Valentino-Álvarez, J.A.; Granados-Berber, A.A.; Ramírez-Ayala, E.; Zepeda-González, F.A.; Tintos-Gómez, A. Aquatic Biota Is Not Exempt from Coronavirus Infections: An Overview. *Water* **2021**, *13*, 2215. [[CrossRef](#)]
4. Ministry of Health Labour and Welfare. Novel Coronavirus (COVID-19). Available online: https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/0000164708_00079.html (accessed on 25 September 2021).
5. Hirose, A.; Toyosada, K.; Shimizu, Y.; Iio, A. Surveillance Study on Japanese Bathing Custom and Act at the Time of the Bathing. In Proceedings of the CIBW062 International Symposium on Water Supply and Drain for Buildings, Nagano, Japan, 19 September 2013; pp. 631–644.
6. Kanako, T.; Yasutoshi, S.; Akihiko, I.; Kyosuke, S. Quantification of Environmental Impact Reduction Effect Resulting From Use of Water-saving Toilet Bowls. *J. Soc. Heat. Air-Cond. Sanit. Eng.* **2013**, *193*, 1–8. (In Japanese)
7. Kimura, H.; Hirose, A.; Toyosada, K.; Shimizu, Y.; Iio, A.; Sakaue, K. Study on the Modeling of the Bathing Behavior in Japan. In Proceedings of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, Sapporo, Japan, 5 September 2012; pp. 25–28.
8. Negishi, S.; Iio, A.; Iwasaki, A.; Shimizu, Y.; Toyosada, K.; Sakaue, K. Research on the Actual Condition of the Shower Use Act, Research on the Actual Condition of the Shower Use Act. In Proceedings of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, Akita, Japan, 3 September 2014; pp. 37–40.
9. Otani, T.; Toyosada, K.; Shimizu, Y. CO₂ Reduction Potential of Water Saving in Vietnam. *Water* **2015**, *7*, 2516–2526. [[CrossRef](#)]
10. Hackett, M.J.; Gray, N.F. Carbon dioxide emission savings potential of household water use reduction in the UK. *J. Sustain. Dev.* **2009**, *2*, 36–43. [[CrossRef](#)]
11. Walker, G. Water and energy use efficiency are increasingly linked. *Energy World* **2009**, *369*, 18–19.
12. Cheng, C.L.; Liao, W.J.; Liu, Y.C.; Tseng, Y.C.; Chen, H.J. Evaluation model of CO₂ emission for saving water strategy. In Proceedings of the 38th International Symposium CIB W062 on Water Supply and Drainage for Buildings, Edinburgh, UK, 27–30 August 2012; pp. 537–548.
13. Yasutoshi, S.; Kanako, T.; Mari, Y.; Kyosuke, S. Creation of Carbon Credits by Water Saving. *Water* **2012**, *4*, 533–544.
14. Yasutoshi, S.; Satoshi, D.; Kanako, T. The CO₂ Emission Factor of Water in Japan. *Water* **2012**, *4*, 759–769.
15. Statistics, B. Ministry of Internal Affairs and Communications: Housing and Land Statistics Survey. 2018. Available online: <https://www.stat.go.jp/english/data/jyutaku/index.html> (accessed on 30 September 2021).
16. Anuja, P.A. Increased Volume and Frequency of Urination, MSD Manual Home Edition, 05. *Kidney and Urinary Tract Disorders*. September 2017. Available online: <https://www.msmanuals.com/home/kidney-and-urinary-tract-disorders/symptoms-of-kidney-and-urinary-tract-disorders/urination-excessive-or-frequent> (accessed on 30 September 2021).
17. Ministry of Internal Affairs and Communications, Japan, Telework-related Support Information. September 2021. Available online: https://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/COVID-19/index.html (accessed on 30 September 2021).