

The coronavirus pandemic and its impact on water consumption as recorded by the water industry

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ABSTRACT

The coronavirus outbreak has been extremely difficult for water utilities. The COVID-19 epidemic has become a challenge for the water and sewage sectors due to changes in water consumption caused by disrupted business operations, services, and household activities. Higher operating costs followed by lower revenues from the sale of water as well as staff shortages have been the biggest problems of the water and sewage industry. The drop in revenues related to lower water consumption turned out to be considerable for some enterprises, while for others it was dramatic. Some operators continued to supply more water, but large increases were out of the question in their case. The paper presents innovative research on the scale of fluctuations in water demand during the COVID-19 epidemic on the example of the Krakow Water. At Krakow, the coronavirus epidemic resulted in lower water sales, which upset the last 4 y of company rewards. Water sales monthly volume was analyzed in parts divided by groups of customers. The authors based on real data which came from the billing system, where each customer belongs to a specific group or kind of conducted service or activity. The significant drop in water use was reported in the group “other customers”. The reduced sales in that whole group within specific months of the 2020 year, compared to the same month of the 2019 year (before the pandemic) varied from 4.75% to 42.37%. The water sales volume, like before the pandemic is expected to reach about 2025 year.

Keywords: Water consumption; Pandemic; Losses

1. Introduction

On March 14, 2020, an epidemic warning was introduced in the territory of the Republic of Poland (Journal of Laws, items 433 and 441). The economy plunged. Kraków and the Malopolskie Voivodeship, like other regions of Poland, Europe, and the world, were affected by restrictions, imposed due to the epidemiological situation. In March 2020, society was forced to change its everyday behaviors and habits due to the situation for which no one was prepared. The SARS-CoV-2 pandemic required adaptation

to restrictions related to leaving home, moving around, meeting family and friends, and remote work [1,2].

From the very first day, after the introduction of restrictions related to the coronavirus pandemic, the industry began to notice operation problems and struggle with uncertain prospects for the future. Overnight, most industries were forced to limit services and sales of goods. The available data show that the crisis hit most severely various entrepreneurs and companies, who have been forced to shut down their activities due to the restrictions. These are industries related to the beauty segment (hairdressers and beauty salons), as

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well as shops and retail outlets located in shopping malls. Tourism is one of the sectors directly affected by the crisis. The restrictions on movement cut down on a number of tourists, which successively affected the accommodation and gastronomy business. According to preliminary data from March 2020, approximately 935 thousand people used tourist facilities with 10 or more beds, including approximately 165 thousand foreign tourists and approximately 770 thousand locals. Compared to March 2019, the total number of tourists dropped down by 65%. In general, a decrease in the number of tourists using accommodation establishments in Małopolska exceeded the national average. Krakow, as a very popular tourist destination, is in many respects unique if compared with other large Polish cities; in 2019 it hosted over 14 million visitors, including over 3.5 million foreign tourists and also numerous students. As a result, there are more food and drink premises in the downtown area than in other Polish cities. Therefore, when travel restrictions curbed tourism, many diners and restaurants lost customers, and many of them had to be closed for several weeks [3–5].

The COVID-19 epidemic has also become a challenge for the water and sewage sector due to changes in water consumption caused by the disrupted business operations, services, and household activities. Higher operating costs followed by lower revenues from the sale of water as well as staff shortages have been the biggest problems of the water and sewage industry. The drop in revenues related to lower water consumption turned out to be considerable for some enterprises, while for others it was dramatic [6]. Some operators continued to supply more water, but large increases were out of the question in their case.

The records of the Krakow water supply system, reflect the changes in water production volume, starting from the very beginning, that is, establishing the water supply system

in 1901. At that time, a water supply system was commenced to collect water from the Vistula River in Bielany (today a housing estate in Krakow) using pumps powered by steam engines, and water was delivered to the city center [7]. Since then, Krakow has been continuously growing and its growth was accompanied by a continuous expansion of the water network to cover the whole city. Fig. 1 shows the annual water production of the KW in the years 1901 to 2021.

The diagram proves that a water volume depends not only on the size of the connected infrastructure or the number of connected properties. From 1901, this volume initially increased, but there were also periods when production declined. The maximum production volume of 101.6 million m³ was recorded in 1988. Then, due to political changes and more representative water prices, water production and sales began to decline.

The actual decline in water production was observed until 2015. It should be noted that lower water production was accompanied by a simultaneous development of the water network (new connections). In 1988, the company had approximately 1,300 km of lines in operation, while in 2020 it had 2,301 km. In 1988, the company sold water through approximately 30,000 water meters, while currently, it has 65,000 water meters in operation. According to a statistical database, the population of Krakow in 1988 was 746,440 people.

Since 2016, there has been a slight increase in water production, but it was stopped by the COVID-19 epidemic.

The objective of this paper is to introduce, based on the example of the Krakow water distribution system, the scale of the decrease in water consumption during the COVID-19 pandemic. It is also the preliminary risk assessment for the continuity of the whole water supply system in operational and economic aspects.

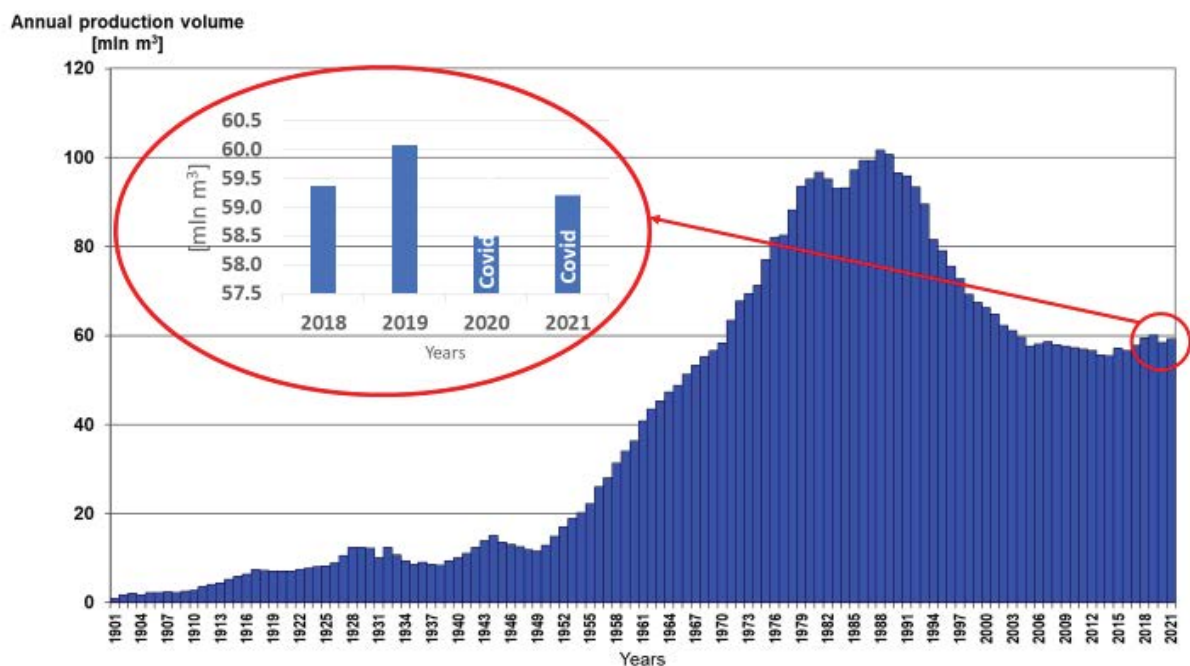


Fig. 1. Annual production of the Krakow water over the years 1901 to 2021

2. Materials and methods

2.1. Water consumption analysis to determine the functioning of the settlement unit

In the analyses of an established issues the authors based on water sales data, which come from the billing data basis. Each customer in this database belongs to a specific group or kind of conducted service. Large cities usually have more than a hundred years of history of water supply infrastructure, and consequently decades of observations of their residents' water needs. Generally, the demand is proportional to the number of households connected to the water system. It also depends on the type of household equipment as well as on the price of water or, in other words, on the availability of the cost price of water. Water consumption is also becoming more and more influenced by the use of modern devices such as washing machines or dishwashers, as well as by general environmental awareness; modern devices use less water per operation cycle and lower specific water consumption in long run. However, beginning in 2020, much larger and unprecedented changes in water demand was observed, related to the COVID-19 epidemic [8].

In this paper, the authors analyzed the monthly water sales divided into specific groups of customers. The results of analyses are shown graphically in section 3. Because of a short period of analysis (3 y), the authors only showed the trends.

3. Results and discussion

3.1. Fluctuations in water demand during the COVID-19 epidemic

In March 2020, due to the coronavirus pandemic, a lockdown was imposed, and it was recommended to introduce remote work on an unprecedented scale. Movement restrictions suppressed tourism in Krakow and numerous branches of the economy were shut down. All these actions led to lower water demand. The chart of water sales for individual months in the years 2019–2021 is shown in Fig. 2.

The chart shows the water volume for each month of 2019, using it as the reference period (before the pandemic). However, the most meaningful fluctuations could be observed between particular groups of consumers. In the

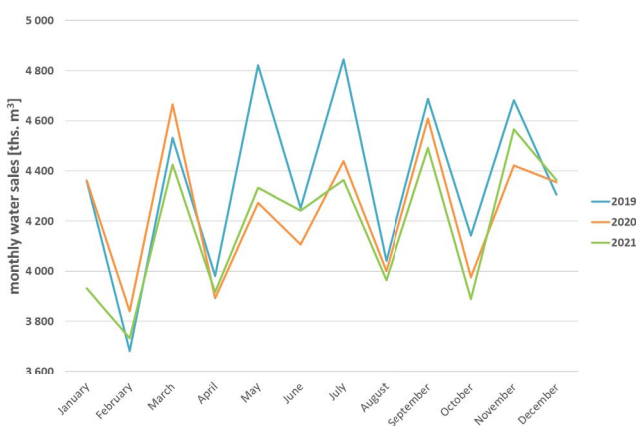


Fig. 2. Water sales per month.

first phase of the pandemic, there was a significant increase in water consumption by the largest group – households. Consumption in this group increased in April 2020 by over 3%, that is, by 83,725 m³. It should be noted that this group creates over 70% of the water demand in the Krakow system. This unexpected increase in water demand was generated by residents working remotely or by those who had to stay since their workplace had been shut down. At the same time, during the first few months, residents temporarily staying in Krakow also did not leave the city to wait out the epidemic. In addition, an official message to the public emphasized the need for frequent hand washing and the general importance of maintaining high hygiene standards. The situation changed radically after the first few months, when it became clear that epidemic restrictions and lockdowns would stay with us longer. Remote work and distance learning became a new reality, so most students from outside Krakow left for their family homes. Also, remote workers realized that they did not have to stay in Krakow and many of them left the city. Water sales to households began to decline starting from October 2020.

In the group of “other recipients”, a decrease in water consumption was already observed at the beginning of the epidemic. This is a very diverse group of recipients, very different from households or industries. The group includes the following subgroups:

- educational institutions,
- sports and recreational facilities,
- sports clubs,
- catering facilities (restaurants),
- pubs, cafes, clubs,
- museums, theaters, cinemas, community centers,
- tourism and cultural centers,
- hotels, motels, guesthouses, hostels etc.

The demand for water in this group decreased drastically due to shutdowns of individual businesses as well as ongoing restrictions on large public gatherings. Also, travel restrictions and a smaller number of tourists reduced the demand for water. The dynamics of monthly sales in the entire group of “other recipients” in 2020 vs. the corresponding month of 2019 (before the pandemic) is shown in Fig. 3.



Fig. 3. Monthly water sales for the “other recipients” in 2020 vs. the corresponding months of 2019.

To illustrate the changes in water demand, the dynamics in subgroups according to the type of activity were compared. On March 16, 2020, remote learning was introduced in all educational institutions and lasted until the summer break. From the beginning of the new school year to mid-October, stationary education was carried out at schools, and then distance learning was reintroduced. Some universities did not return to full-time education after the summer break, while others returned partially and also only for a few weeks. The volume of water supplied to educational institutions in individual months from 2019 to 2021 is shown in Fig. 4. The graph shows a clear decrease in demand beginning in March 2020. A higher demand, comparable to the same month before the pandemic, was observed in September, and then once remote learning was reintroduced, there was a further decline until the end of the year. In 2021, the lower water demand in this group continued, and only before the holiday season, it showed a slight upward trend; the values closer to the pre-pandemic period were recorded in December 2021.

Another subgroup comprises sports and recreational facilities. In these types of facilities, after an initial increase in water demand in the first quarter of 2020, a drastic decrease related to the closure of most facilities was observed. Similarly to educational institutions, the decline was smaller in September and October, and then it went down again.

The activities of sports clubs were limited, similar to those of the above-mentioned sports and recreational facilities. In this group, lower water demand was recorded beginning in March 2020, and it did not return to the pre-pandemic

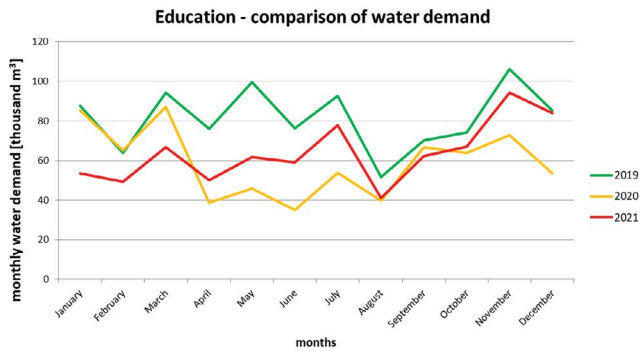


Fig. 4. Monthly water sales for all educational institutions.

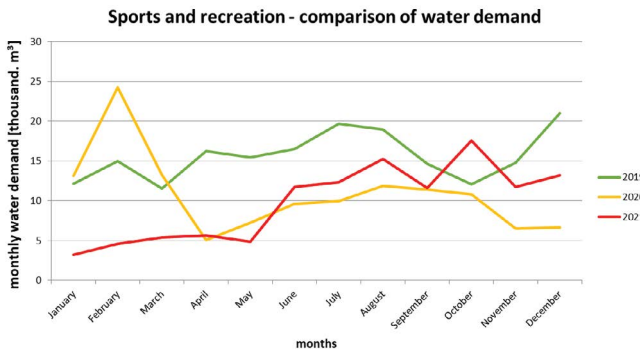


Fig. 5. Monthly water demand in sports and recreational facilities in the years 2019–2021.

value for the rest of 2020 and the entire year 2021. Monthly water consumption in this group in the years 2019–2021 is presented in Fig. 6.

A significant drop in water demand during the COVID-19 epidemic occurred in the restaurant and catering industry. In the second half of March 2020, the entire industry remained shut down, with few changes. A higher water demand was observed in the first quarter, followed by a sharp decline, and water consumption in this segment did not return to “normal” until the end of 2021. The monthly consumption of water by restaurants and catering facilities in the years 2019 to 2021 is presented in Fig. 7, while for pubs, cafes, and clubs in Fig. 8. In the pubs, cafes, and clubs subgroup, there was a reduction in water demand from the beginning of 2019; once the epidemic started, the decline grew even more.

Another subgroup of “other recipients” of water is related to public utilities. It includes museums, theaters, cinemas, community centers, etc. The activity at these facilities was significantly limited from April 2020 throughout the rest of 2020, and their water demand decreased by about 50% (from April 2020). Some members of this group may use the two-month accounting period, which explains sales volumes fluctuating between even and odd months.

The tourism industry (the subgroup of “other recipients”) has been mostly hit by the pandemic. It comprises tourism and cultural facilities as well as hotels. These groups showed a drastic decrease in water demand beginning in March 2020; in individual months, a reduction reached 75%

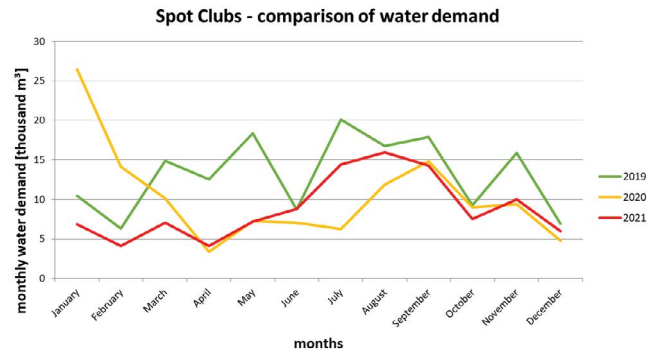


Fig. 6. Monthly water demand in sports club facilities from 2019 to 2021.

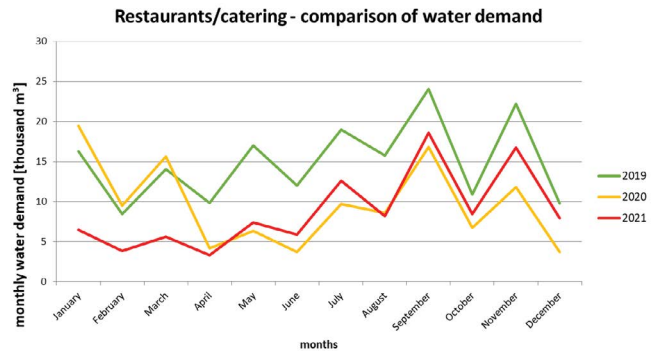


Fig. 7. Monthly water demand by restaurants and catering facilities in the years 2019 to 2021.

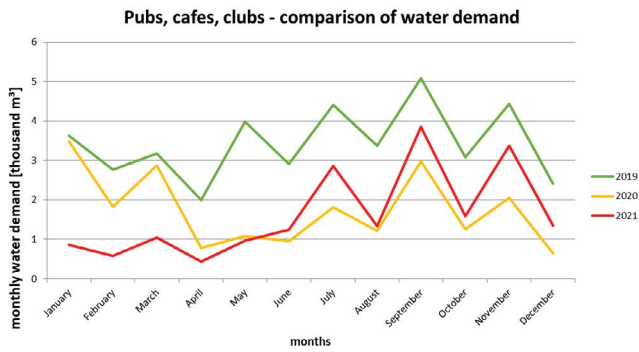


Fig. 8. Monthly water demand in facilities such as pubs, cafes, and clubs, in the years 2019 to 2021.

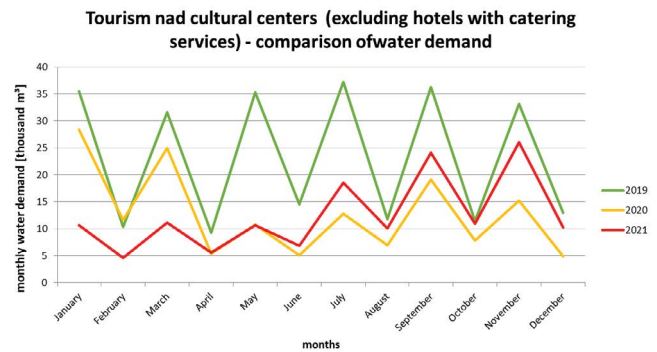


Fig. 10. Monthly water demand for tourism and cultural centers in the years 2019 to 2021.

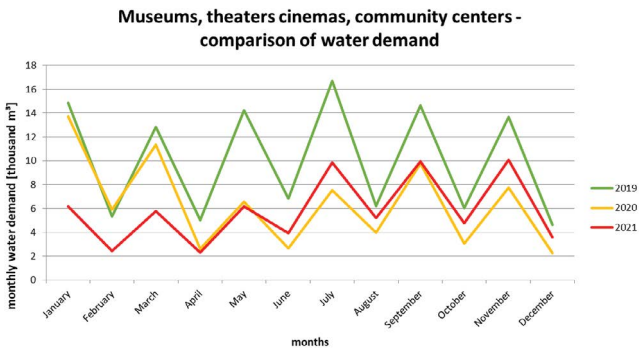


Fig. 9. Monthly water demand in public utilities in the years 2019 to 2021.

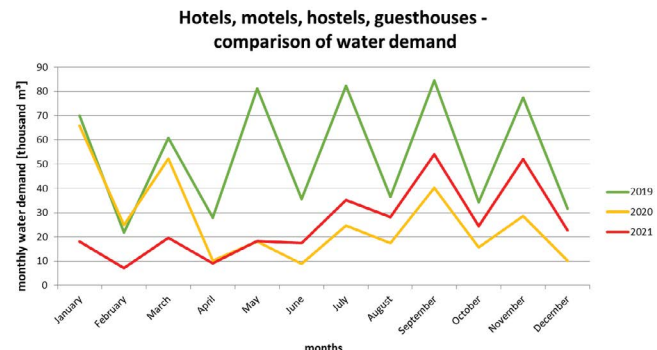


Fig. 11. Monthly water demand for hotels from 2019 to 2021.

to 78% compared to the pre-pandemic values. The monthly water demand for tourism and cultural centers is presented in Fig. 10 while that for hotels is presented in Fig. 11.

The above groups, evaluated on the basis of the Kraków water database, did not include industrial recipients, though throughout the epidemic there was “turbulence” in the operation of most industries.

The experience gained by managers of water and sewage companies indicates the need to verify the procedures, and perhaps also to implement business continuity management (BCM) standards [7].

During the COVID-19 epidemic, large water companies as well as medium and small water supply systems recorded a drop in water sales [9,10].

Water-intensive practices at the beginning of the pandemic, which have decreased over time, are confirmed by studies in other countries affected by the pandemic. The magnitude of the increase in household water use has been quantified by Cook and Makin [11] to be between 15% and 20%, while business water use has decreased by 30% to 50% [12].

The coronavirus outbreak has been extremely difficult for water utilities for several reasons. First, there was a sudden shortage of conventional disinfectants and protective agents. Then, the pandemic has disrupted the supply chains of materials for water or wastewater treatment. It also clearly showed that water supply and sewage disposal had gained exceptional importance in ensuring proper

hygiene standards as well as meeting the needs of people confined to their homes during the national quarantine. One of the most important challenges faced by water enterprises was the maintenance of infrastructure, including the water supply networks. Finally, the water supply system had to deal with the absence of healthy and ready-to-work employees to ensure continuity of services for the community, that is, staff shortages. In practice, some companies faced periods when even a dozen or so percent of the workforce was unable to work due to illness or quarantine [6,13,14].

The state of the epidemic directly affects the crisis management of enterprises. To maintain business continuity, the managers had to prepare various scenarios, including the possibility of detaining the staff at water treatment or wastewater treatment plants. Aquanet (Poznań) introduced the crew to be detained for two-week shifts and such a situation lasted for several shifts. Other companies also tried to be prepared for such plans, but fortunately, the plans were never implemented.

The approach to estimating the risk of water supply continuity in extreme conditions is a topic that the authors intend to develop in subsequent papers.

4. Conclusions

Throughout 2020, many Polish water supply companies reported a decrease in water sales related to several of the phenomena already described:

- outflow of temporary residents and students,
- smaller production at industrial recipients,
- a drastic reduction in tourism and closure of catering services.

For example, Aquanet reported a 2.7% decrease in water sales (2020) in the Poznań agglomeration and several neighboring municipalities. The drop in water sales was related to the structure of water recipients in a given commune.

At Krakow, the coronavirus epidemic resulted in lower water sales, which upset the last 4 y of company prosperity. This is despite a continuous expansion of the network (new pipes) and despite the fact that, in recent years, more than 1,500 water meters were installed on new connections each year. However, the drop in water sales, which is discussed in this article, may not disappear with the virus. It takes several years to rebuild pre-pandemic tourism, just as it takes time to bring back many workers or find new ones to replace those who stay in a remote mode. In addition, epidemic trends are compounded by a general trend to save water and use even more economical devices. It is estimated that the amount of water sold before the epidemic, that is, in 2019, would return around 2025.

And despite the fact that large water and sewage companies tried to develop strategies and plans for the event of an emergency, it must be admitted that the coronavirus epidemic has brutally verified our anti-crisis strategies.

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