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Determination of daily water consumption and its variability in a selected household located in southern Poland

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ABSTRACT

The aim of this study was to identify and assess the variability of water consumption and to determine the coefficient of daily irregularity in the analysed household located in the southern Poland. The study was carried out in autumn and winter, based on daily water meter readings. Measurements were taken in a household located in the town of Lubaczów, in the Podkarpackie Voivodeship, in the Lubaczów district. The collected measurement data were collated and subjected to a detailed analysis, taking into account the variation of water consumption in the context of seasonality (season of the year), days of the week, as well as the variable number of people actually staying in the household on particular days. The results obtained were compared with the standard values set out in the Regulation of the Minister of Infrastructure of 14 January 2002 on average water consumption standards (Journal of Laws 2002 No. 8, item 70), as well as with the average water consumption in households in other localities, which made it possible to assess the compliance of actual water abstraction with the regulations in force and to estimate any deviations from the reference values.

Keywords: rural household, water consumption, household purposes, variability of water consumption

INTRODUCTION

Water is a fundamental component of Earth's ecosystems, essential for physicochemical and biological processes [Mukhopadhyay et al., 2022; Win et al., 2024]. It is essential for human life, agriculture and industrial development, as well as for maintaining standards of personal hygiene and public health [Geels, 2005; Ochmanska et al, 2025; Zuo et al, 2025].

Water covers 75% of the surface of our planet. More than 97% of the Earth's water is found in the seas and oceans in the form of salt water. About 2% is stored in glaciers, snow-capped mountain ranges and ice caps. This leaves only 1% of the Earth's total water supply readily available to meet human needs. This water is stored in rock layers and surface waters, i.e. rivers and lakes [Guzik and Guzik, 2011]. Poland is one of the countries with limited water resources, which places it in the group of countries with low water availability. They are characterised not only by relatively small amounts of surface and groundwater, but also by significant seasonal variability and spatial variation in their occurrence [Szwed, 2015; Badora et al., 2023]. The average volume of renewable freshwater resources per capita in Poland is less than 1.600 m³ per year, which classifies the country in the water stress risk zone and indicates the need for rational water resources management [Central Statistical Office, 2020]. Nearly half of the European Union member states are experiencing a shortage of freshwater resources of less than 3,000 m³ per capita per year. The situation is particularly worrying in countries such as Poland, Malta, Cyprus and the Czech Republic, where the level of available water resources falls below the recognised water security threshold [Poskrobko et al., 2007].

The results of the analyses and studies carried out indicate a systematic decline in the level of water consumption, resulting in the mismatch - and in many cases oversizing – of existing water supply and sewage infrastructure and facilities such as wastewater treatment plants in relation to current operational needs [Lach and Opyrchał, 2014; Pawlak et al., 2018]. The decline in water consumption is due, among other things, to the dynamic increase in prices for water supply, the increasing use of water-efficient appliances (such as washing machines and dishwashers) and the increasing installation of water meters that enable precise monitoring of consumption [Świętochowski et al., 2024].

Studies on water consumption both at the level of individual households and entire water supply systems in Poland [Błażejewski and Waack, 1996; Pawełek and Długosz, 1998; Pawełek and Satora, 2001; Borowa, 2003], show that actual unit water consumption is significantly lower than the values set out in the guidelines contained in the Regulation of the Minister of Infrastructure of 14 January 2002 on average water consumption standards (Journal of Laws 2002 No. 8, item 70).

Determination of the water demand should be on a case-by-case basis, based on a detailed analysis of the available data, including: the type and use of the building, the number of off-site users, as well as the water and sewerage facilities. An important element of this analysis is the type and number of water-consuming appliances, such as toilets, showers, baths, dishwashers, washing machines, air conditioners or refrigeration units, and their efficiency. In the context of new technologies, modern appliances can significantly reduce water consumption (e.g. water-saving toilets, low-flow showers). It is also important to consider water recovery systems, such as grey water reuse systems (e.g. for garden irrigation, toilet flushing). In addition, users' habits and lifestyles, including the time spent bathing, the frequency of washing dishes, laundry, the number of people using appliances at the same time, as well as specific habits related to hand washing, cleaning or watering plants, have a key impact on water consumption. Consideration should also be given to the impact of climatic conditions, which can significantly modify water demand, especially during periods of intensive water use for cooling or irrigation purposes.

Alternatively, the values of the average demand indicators can be set at a lower level, which will allow to effectively secure an adequate amount of water for users, while minimising unnecessary losses [Piechurski, 2014].

Water supply systems that are properly designed and maintained enable a reduction in losses and more efficient use of water resources, which directly translates into economic savings [Rajani and Kleiner, 2001]. Given Poland's limited water resources, the current situation, in which water consumption is reduced, can be assessed as favourable from the perspective of natural resource conservation and long-term sustainable water management. However, for water utilities the decrease in water production brings with it significant operational challenges. Lower consumption means lower revenues, which affects profitability and the ability to finance ongoing operations and investments in infrastructure upgrades. Additionally, the oversizing of water mains and wastewater treatment plants increases maintenance costs as equipment operates below optimum capacity. As a result, companies need to adapt resource and investment management strategies to ensure that water supply systems are economically and technically efficient while meeting water supply quality and safety requirements.

STUDY MATERIALS AND METHODS

The aim of the study was to determine the volume and irregularity of water intake by a single household located in the southern Polish town of Lubaczów (Podkarpackie Voivodeship, Lubaczowski District). A Metron JS 1.5 G1 07 water meter is installed to measure and record the volume of water taken in the building (Figur e 1). This is a single-jet, dry-running water meter designed to measure the volume of cold water in water supply systems. It is a model with a nominal flow rate of 1.5 $m^3 \cdot h^{-1}$, which means it is suitable for domestic and small-scale use.

The analysed household is located on a plot of 15 acres, on which there is a well used for watering vegetation (Figure 2). The house has a connection to the water supply and sewage system, a toilet and two bathrooms, as well as a pellet cooker as a source of domestic hot water. According to the current Polish Regulation of the Minister of Infrastructure of 14 January 2002 on defining average standards of water consumption, the household is classified in group IV, assuming an average standard of water consumption of 100 $dm^3 \cdot d^{-1}$ per capita. The household is inhabited on a daily basis by two adults and one child. This number increases at weekends to six people – due to the return of people studying and working outside the family home, and to seven and more on holidays – due to the return of family members from further afield.

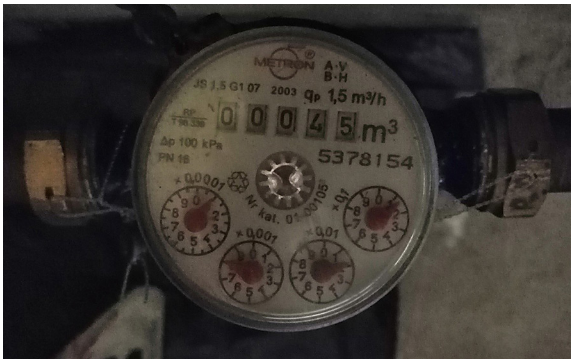

Figure 1. Metron JS 1.5 G1 07 water meter, used in the household under study

As part of the study, measurements of the water consumed were taken daily at 23[00] hours for a period of three months during the autumn season and three months during the winter season. The autumn season lasted from 1.09.2024 to 30.11.2024, while the winter season lasted from 1.12.2024 to 28.02.2025. The results of the measurements show the variation of water consumption according to season, days of the week and number of occupants. The results obtained have been compared both with the water consumption standards set out in the Regulation of the Minister of Infrastructure of 14 January 2002 on defining average water consumption standards (Journal of Laws 2002 No. 8, item 70), and with the average water consumption in households in other localities.

RESULTS AND DISCUSSION

The parameters analysed included daily water consumption (D) and daily individual water consumption (I), i.e. water consumption per capita. The variation in daily per capita water consumption in the autumn period for the surveyed household is shown in Figure 3. The average daily per capita water consumption in the three-month autumn period was 84.50 $dm^3 \cdot I^{-1} \cdot d^{-1}$. In accordance with the Regulation of the Minister of Infrastructure of 14 January 2002 on average standards for water consumption (Journal of Laws 2002 No. 8, item 70), the surveyed household was classified in Class IV, which means that the daily standard water consumption per capita should be 100 dm^3. Comparing these two values, it can be seen that the actual water consumption per capita was 15.50 dm^3 lower than the norm. The highest daily per capita water consumption occurred on 12.10.2024 and was 158.00 $dm^3 \cdot I^{-1} \cdot d^{-1}$.

Analysing individual weeks throughout the autumn period, it can be seen that 4 times the highest consumption occurred on Saturdays, 3 times on Tuesday, 2 times on Monday and Wednesday and once on Thursday. There was a noticeable increase in water consumption at weekends, which was related to the fact that on Saturdays mostly all residents spent more time at home undertaking various domestic activities such as cleaning, cooking and laundry. The lowest water consumption was recorded on Thursday 26.09.2024, where it was 29.80 $dm^3 \cdot I^{-1} \cdot d^{-1}$.

During the whole autumn period, the average daily per capita water consumption exceeded the standard 28 times, while on the other 63 days it was lower than the standard specified in the Regulation of the Minister of Infrastructure of 14 January 2002 on average standards for water consumption (Journal of Laws 2002 No. 8, item 70. Table 1 presents a comparison of the average, maximum and minimum values of water consumption in the different autumn months.

Figure 2. Location of surveyed household with plot marked in Lubaczów

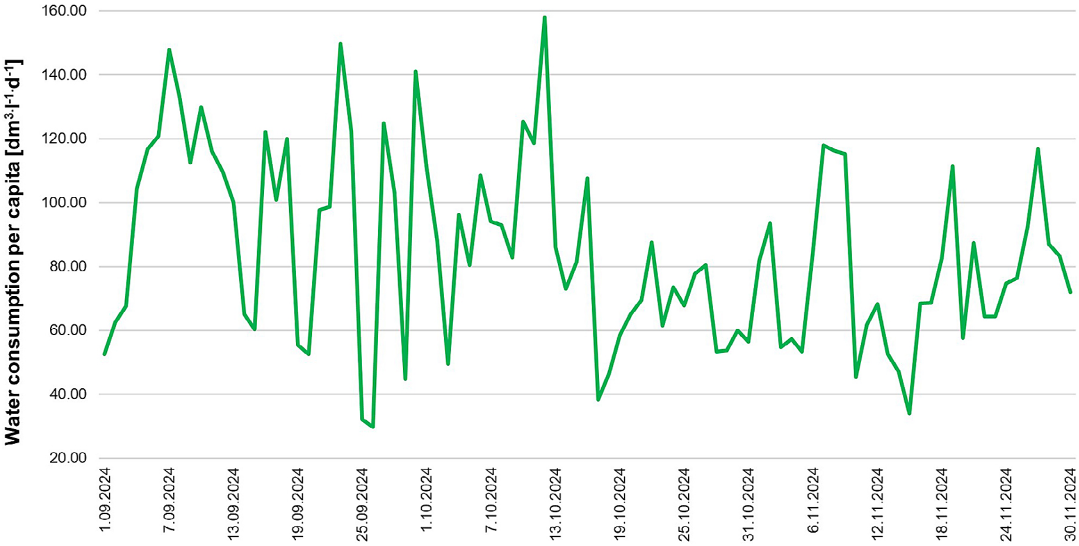

Figure 3. Variability of daily per capita water consumption for the surveyed household in Lubaczów between 1.09.2024 and 30.11.2024

The highest total monthly water consumption occurred in September 2024 and was 15.38 m^3, while the lowest was in November of the same year and was equal to 8.17 m^3. The difference between the highest and lowest value was 7.21 m^3. This situation was due to family celebrations taking place in September and residents staying in the building for longer periods of time. The highest average water consumption per household in the surveyed months occurred in September and was 512.73 $dm^3·d^{-1}$, while the lowest value was 272.30 $dm^3·d^{-1}$ and was recorded in November 2024. The month with the highest average water consumption per capita was September (96.48 $dm^3·I^{-1}·d^{-1}$), while the lowest value was read in November (76.37 $dm^3·I^{-1}·d^{-1}$).

Figure 4 shows the minimum, maximum and average values of per capita water consumption by day of the week for the autumn period under study.

The average daily water consumption, both per household and per capita, was highest on Saturday and was 452.85 $dm^3·d^{-1}$ and 92.44 $dm^3·I^{-1}·d^{-1}$, respectively. The maximum daily water consumption, which was equal to 158.00 $dm^3·I^{-1}·d^{-1}$ per capita, was also recorded on this day (intake occurred on 12.10.2024). The water abstraction on this day was the highest due to household chores (washing floors in the house, laundry, cleaning), cooking and hosting a special event. The maximum daily water consumption per household was also observed on Saturday and was 887.00 $dm^3·d^{-1}$1. The lowest average daily water consumption was observed on Sunday and was 340.92 $dm^3·d^{-1}$ per household and 74.86 $dm^3·I^{-1}·d^{-1}$ per capita. The lowest minimum daily water consumption of 136.00 $dm^3·d^{-1}$ was observed on Friday. Such a low value of water consumption on Friday was associated with residents being at work for most of the day.

The coefficient for the irregularity of daily water consumption has been calculated for the entire autumn period and for each month separately, as well as for all days of the week. The coefficient is calculated by dividing the maximum

Table 1. Whole-household and per capita water consumption by month for the surveyed households during the autumn period

Date	Household consumption				Consumption per capita		
	Monthly total	Daily average	Daily minimum	Daily maximum	Daily average	Daily minimum	Daily maximum
	[m^3]		[$dm^3·d^{-1}$]		[$dm^3·l^{-1}·d^{-1}$]		
September 2024	15.38	512.73	149.00	887.00	96.48	29.80	149.60
October 2024	11.92	384.65	192.00	790.00	80.78	38.40	158.00
November 2024	8.17	272.30	136.00	472.00	76.37	34.00	118.00

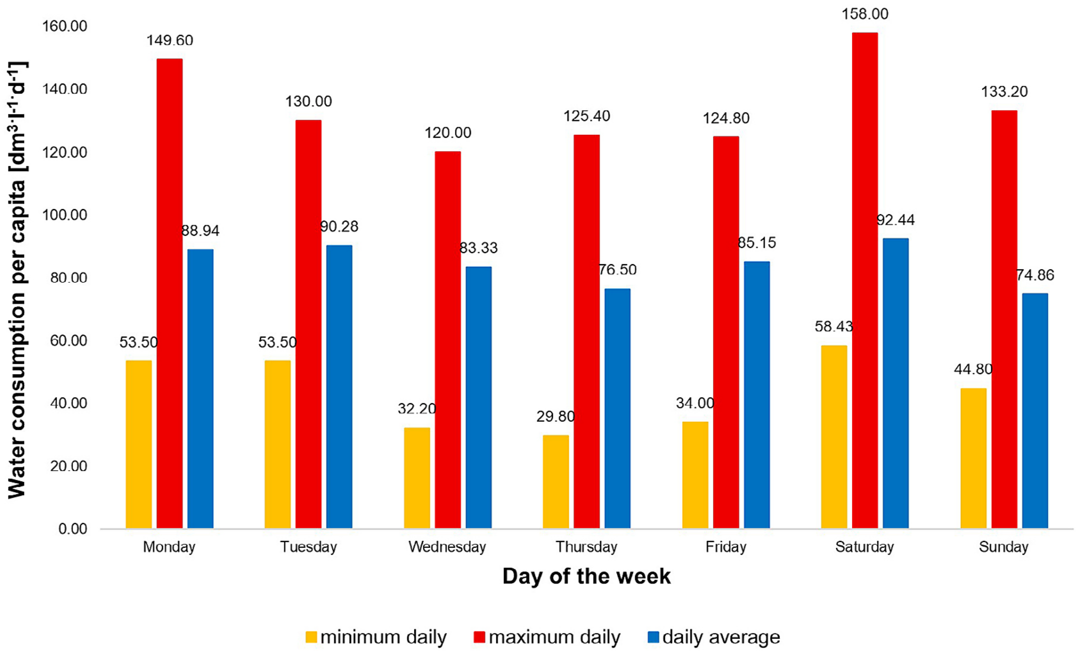

Figure 4. Water consumption per household and per capita by day of the week in the autumn period

daily demand by the average daily demand on the day with the highest water demand during the period. For single-family dwellings, the daily irregularity coefficient should be between 1.5 and 2.0 [Kwietniewski et al., 1998]. The coefficient of daily irregularity of water consumption reached its highest value in October 2024 – 1.96. For the individual days of the week in the autumn period, the coefficient of daily irregularity of water consumption reached the highest result on Sunday – 1.78, and the lowest on Tuesday and Wednesday – 1.44. The coefficient of daily irregularity for the entire autumn period was 1.59. Comparing this value with the range reported in the literature (N_d: 1.5–2.0), it can be concluded that the usable value falls within the range reported in the literature.

The variation in daily water consumption per person over the winter period for the surveyed household is shown in Figure 5. The average daily water consumption per capita over the three-month winter period was 82.43 $dm^3 \cdot I^{-1} \cdot d^{-1}$. The actual water consumption per capita was 17.57 dm^3 lower than the standard demand specified in the Regulation of the Minister of Infrastructure of 14 January 2002 on average water consumption standards (Journal of Laws 2002 No. 8, item 70). The highest daily water consumption per capita occurred on 11.01.2025 and amounted to 151.50 $dm^3 \cdot I^{-1} \cdot d^{-1}$.

When analysing the individual weeks throughout the winter period, it can be seen that up to 8 times the highest consumption occurred on Saturdays and once on Wednesday, Thursday, Friday and Sunday. The lowest water consumption was recorded on Sunday 2.02.2025, when it was 37.80 $dm^3 \cdot I^{-1} \cdot d^{-1}$.

During the whole winter period, the average daily water consumption per capita exceeded the standard 21 times, while on the other 69 days it was lower than the standard specified in the Regulation of the Minister of Infrastructure of 14 January 2002 on average standards for water consumption (Journal of Laws 2002 No. 8, item 70.

Table 2 presents a comparison of the average, maximum and minimum values of water consumption in the different winter months.

The highest total monthly water consumption occurred in January 2025 and was 9.66 m^3, while the lowest was in December 2024 and was equal to 7.89 m^3. The difference between the highest and lowest value was 1.77 m^3. This situation was due to family celebrations taking place in January and residents staying in the building for longer periods of time. The highest average water consumption per household in the surveyed months occurred in February 2025 and was 323.21 $dm^3 \cdot d^{-1}$, while the lowest value was 254.52 $dm^3 \cdot d^{-1}$ and was recorded in December 2024. The month with the highest average water consumption per household was January 2025 (87.02 $dm^3 \cdot I^{-1} \cdot d^{-1}$), while the lowest value was read in December 2024 (79.41 $dm^3 \cdot I^{-1} \cdot d^{-1}$).

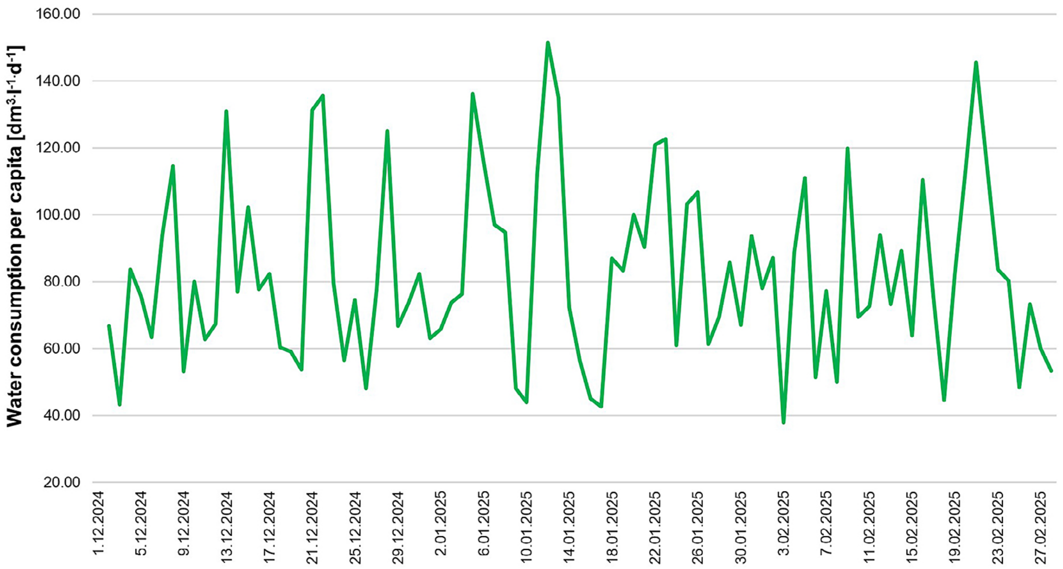

Figure 5. Variability of daily per capita water consumption for the surveyed household in Lubaczów between 1.12.2024 and 28.02.2025

Table 2. Whole-household and per capita water consumption by month for the surveyed households during the winter period

Date	Household consumption				Consumption per capita		
	Monthly total	Daily average	Daily minimum	Daily maximum	Daily average	Daily minimum	Daily maximum
	[m³]		[dm³·d⁻¹]		[dm³·l⁻¹·d⁻¹]		
December 2024	7.89	254.52	130.00	458.00	79.41	43.33	135.67
January 2025	9.66	311.48	128.00	606.00	87.02	42.67	151.50
February 2025	9.05	323.21	145.00	599.00	80.69	37.83	145.67

Figure 6 shows the minimum, maximum and average values of per capita water consumption by day of the week for the winter period under study.

The average daily water consumption, both per household and per capita, was highest on Saturday and was 427.08 $dm^3 \cdot d^{-1}$ and 108.17 $dm^3 \cdot I^{-1} \cdot d^{-1}$, respectively. The maximum daily water consumption, which was 151.50 $dm^3 \cdot I^{-1} \cdot d^{-1}$ per capita, was also recorded on Saturday. The water intake on this day was the highest due to household chores such as laundry and thorough cleaning of the house. The maximum daily water consumption per household was also recorded on Saturday and was 606.00 $dm^3 \cdot d^{-1}$. The lowest average daily water consumption was recorded on Wednesday and was 230.15 $dm^3 \cdot d^{-1}$ per household and 68.94 $dm^3 \cdot I^{-1} \cdot d^{-1}$ per capita. On Sunday, the lowest minimum daily water consumption of 37.83 $dm^3 \cdot I^{-1} \cdot d^{-1}$ was observed. Such a low value of water consumption on Sunday was associated with family trips of residents.

The coefficient of daily water consumption irregularity was calculated for the entire winter period and for each month separately, as well as for all days of the week. The coefficient of daily water consumption irregularity reached its highest value in February 2025 – 1.81, while the lowest value was in December 2024 – 1.71. For the individual days of the week in the winter period, the coefficient of daily irregularity of water consumption reached the highest value on Thursday with 1.88 and the lowest on Monday with 1.36. The coefficient of daily irregularity for the entire winter period was 1.58. Comparing this value with the range reported in the literature (N_d: 1.5–2.0), it can be concluded that the usable value is within the range reported in the literature.

In conducting the study, the influence of mean daily air temperature on water intake by the inhabitants of the surveyed household in Lubaczów was taken into account. For this purpose, meteorological data from the Institute of Meteorology and

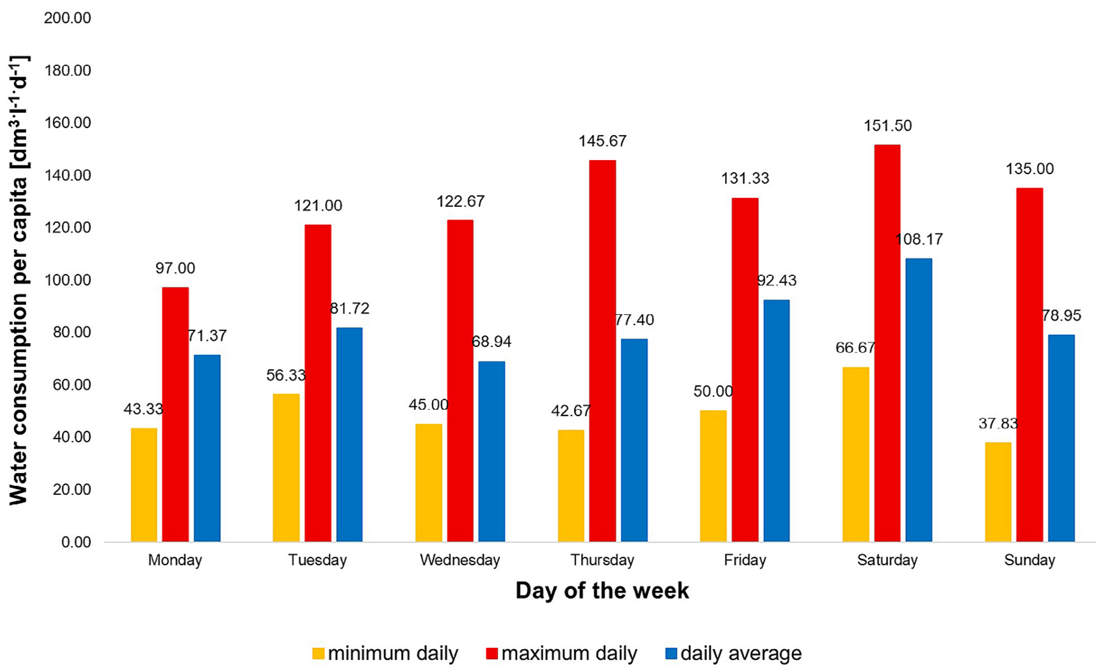

Figure 6. Water consumption per household and per capita by day of the week in the winter period

Water Management – National Research Institute, obtained from the closest measuring station, located in Dynów (Podkarpackie Voivodeship), were used [https://danepubliczne.imgw.pl/]. Summary of water consumption data with temperature information made it possible to carry out a correlation analysis to determine the strength and direction of the relationship between these variables. Pearson's linear correlation coefficients were calculated for both analysed periods to assess whether changes in air temperature affect household water demand.

In the autumn period, the Pearson correlation coefficient between average daily air temperature and residents' unit water consumption was 0.33, indicating a moderate positive relationship – meaning that higher temperatures favoured increased water consumption. In contrast, a weak negative correlation of -0.20 was recorded in winter, which may suggest that there was a slight increase in water consumption when temperatures dropped, e.g. as a result of more frequent use of hot water, reheating of rooms or reduced outdoor activities.

The difference between average daily water consumption in autumn and winter was 2.07 $dm^3 \cdot I^{-1} \cdot d^{-1}$, confirming the existence of seasonal variation in water resource management. It is worth mentioning that the surveyed farm did not use mains water for plant watering, but only water from a domestic well. If the irrigation water had come from the water supply system, the difference in consumption could have been even greater.

Table 3 presents a comparison of average daily water consumption per capita in different regions of southern Poland. The purpose of this comparison is to present the variation in water resource use by the inhabitants of different regions, which is due to differences in terrain, demographic structure, availability of technical infrastructure and geographical location [Local Data Bank – Central Statistical Office; Bergel and Kaczor, 2007; Pawełek and Woyciechowska, 2015; Pawełek et al., 2015].

The average water consumption per capita in the analysed household (Lubaczów) was compared and contrasted with the average water consumption in Stanislawice (Bochnia commune), Włostowice (Koszyce commune) and the cities of Wieliczka and Brzesko. In addition, results from five villages subordinated to the municipality of Brzesko (Jadowniki, Jasień, Okocim, Sterkowiec, Wokowice) were collated.

After analysing the results summarised in Table 3, it can be concluded that the average water consumption per capita per household in Lubaczów (83.47 $dm^3 \cdot I^{-1} \cdot d^{-1}$) is comparable to the data obtained in Wokowice (86.10 $dm^3 \cdot I^{-1} \cdot d^{-1}$). On the other hand, in Wieliczka (109.32 $dm^3 \cdot I^{-1} \cdot d^{-1}$) the average water consumption per capita is more than 1.3 times higher than in the surveyed household, while in Stanislawice (129.90 $dm^3 \cdot I^{-1} \cdot d^{-1}$) the difference is even more pronounced and exceeds 1.5 times the consumption.

Table 3. Comparison of average water consumption in the surveyed farm with values in other localities (own elaboration)

Town	Average water consumption per capita [$dm^3 \cdot I^{-1} \cdot d^{-1}$]
Lubaczów (analysed household)	83.47
Wieliczka	109.32
Brzesko	79.57
Stanisławice	129.90
Włostowice	86.10
Jadowniki	70.50
Jasień	58.20
Okocim	44.10
Sterkowiec	50.00
Wokowice	33.60

CONCLUSIONS

Based on the analysis of the water consumption data for the autumn and winter periods of the surveyed households in Lubaczów, the following conclusions can be drawn:

- the average daily water consumption for the entire autumn period was 84.50 $dm^3 \cdot I^{-1} \cdot d^{-1}$, while in the winter period it reached 82.43 $dm^3 \cdot I^{-1} \cdot d^{-1}$. These values do not exceed the established standard of 100 $dm^3 \cdot I^{-1} \cdot d^{-1}$, set out in the Regulation of the Minister of Infrastructure of 14 January 2002 on average standards of water consumption (Journal of Laws 2002 No. 8, item 70). In the autumn season, the actual water consumption per capita was 15.50 dm^3 lower compared to the applicable standard, while a decrease of 17.57 dm^3 was recorded in the winter season;
- the maximum average daily water demand occurred in September 2024 and was 96.48 $dm^3 \cdot I^{-1} \cdot d^{-1}$, while the minimum average daily water demand was observed in November 2024 and was 76.37 $dm^3 \cdot I^{-1} \cdot d^{-1}$;
- the daily irregularity coefficient was 1.59 for the autumn period and 1.58 for the winter period. Both of these results are within the range reported in the literature;
- analysing water abstraction by day of the week, it was found that in both the autumn and winter periods, the highest average water consumption occurred on Saturdays. This was mainly due to household chores such as laundry and cleaning. In addition, family celebrations were most often held on Sundays, which involves more food preparation and cleaning work on the day before;
- when analysing water abstraction by day of the week, it was found that the lowest average daily water demand during the autumn period occurred on Sunday and was 340.92 $dm^3 \cdot d^{-1}$ (converted per capita: 74.86 $dm^3 \cdot I^{-1} \cdot d^{-1}$), while during the winter period it was 230.15 $dm^3 \cdot d^{-1}$ (converted per capita: 68.94 $dm^3 \cdot I^{-1} \cdot d^{-1}$) on Wednesday;
- the diversity of water supply and sewerage infrastructure influences the efficiency of water resources use and the possibilities of their rational management. Geographical location, on the other hand, determines, among other things, the climate and hydrological conditions, which directly translates into the availability and seasonality of water resources in a given area;
- the water demand calculation guidelines currently in use, which are in most cases the basis for the dimensioning of water and wastewater facilities, result in the majority of these facilities being oversized. The design data obtained from the calculations according to the guidelines and intended to be used for the dimensioning of facilities should be verified by comparing with the actual water consumption in an area with similar water consumption targets;
- work should be undertaken to revise the existing guidelines so that their reported water consumption and irregularities are closer to the actual ones, allowing for better dimensioning of newly designed water and wastewater facilities.

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