JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2021, 22(3), 289–302
https://doi.org/10.12911/22998993/132742
ISSN 2299-8993, License CC-BY 4.0

Received: 2020.12.16
Accepted: 2021.01.14
Published: 2021.02.01

Analysis of the Impact of the Air Temperature on Water Consumption for Household Purposes in Rural Households

Tomasz Bergel[1], Anna Młyńska[2*]

[1] Department of Sanitary Engineering and Water Management, Faculty of Environmental Engineering and Land Surveying, University of Agriculture in Cracow, Mickiewicza 24/28, 30-059 Cracow, Poland

[2] Department of Water Supply, Sewerage and Environmental Monitoring, Faculty of Environmental and Power Engineering, Cracow University of Technology, Warszawska 24, 31-155 Cracow, Poland

* Corresponding author's e-mail: anna.mlynska@pk.edu.pl

ABSTRACT

The paper presents a research hypothesis assumed that the air temperature affects the amount of the water consumption per capita for household purposes (indoor water use). Investigations were conducted based on daily water meter readings of several rural households located in Mszana Górna and Włostowice (Southern Poland). Owing to the double water consumption metering, it was possible to determine the daily water consumption in households, separately for household purposes and for additional purposes. In the performed analysis, the correlation between the average daily air temperature and daily water consumption per capita was tested. For this purpose, correlation coefficients were determined and a 95% confidence interval was assumed. The obtained results showed lack of a clear dependence between the tested variables. Depending on the household, correlation coefficients indicate the existence of a correlation from slight, by weak to moderate. In addition, it was tested that the growth of the air temperature by 1°C caused an increase of the water consumption per capita in the range of 0.14 $dm^3 \cdot d^{-1} \cdot C^{-1} \cdot {}^oC^{-1}$ and 1.17 $dm^3 \cdot d^{-1} \cdot C^{-1} \cdot {}^oC^{-1}$ (Mszana Górna) and 0.41 $dm^3 \cdot d^{-1} \cdot C^{-1} \cdot {}^oC^{-1}$ and 1.78 $dm^3 \cdot d^{-1} \cdot C^{-1} \cdot {}^oC^{-1}$ (Włostowice). It can be concluded that often rapid growth of the water consumption in households in spring and summer season and the term of "water consumption per capita" used in this case, primarily concern greater water demand for additional purposes, not for residents' household purposes.

Keywords: rural households, water consumption, household purposes, indoor water use, air temperature

INTRODUCTION

An effective planning and control of the water supply systems operation, as well as facilities for sewage discharge and disposal are possible owing to the knowledge about an actual water demand. Therefore, as some papers show [Pawełek et al. 2015, Bergel et al. 2016a, 2016b, Bergel 2017], the investigations aimed at updating the information about the water consumption are particularly important for water supply and sewage infrastructure entities; this knowledge is mainly used for practical purposes.

The variety of water using purposes in rural households can be classified into two groups: household purposes (indoor water use) and additional purposes, for which, water is mainly used irreversibly, i.e. "spent water" is not discharged to the sewerage system [Bergel et al. 2016a, Bergel 2017]. It is known, because it was tested many times that the amount of water demand in rural households varies both in the annual (seasonal) [Bugajski and Kaczor 2005, Pawełek and Kaczor 2006, Chmielowski et al. 2009, Bergel et al. 2017], as well as monthly [Bugajski and Kaczor 2005, Pawełek and Kaczor 2006, Bergel and Kaczor 2007, Bergel et al. 2016b, Ogiołda and Nowogoński 2018, Ogiołda et al. 2019], weekly [Bugajski and Kaczor 2005, Bergel and Kaczor 2007, Bergel et al. 2016b, Ogiołda and Nowogoński 2018, Ogiołda et al. 2019] and daily cycles [Bergel and Kaczor 2007, Bergel et al. 2017, Ogiołda and Nowogoński 2018, Ogiołda et al. 2019]. Water consumption, among others, depends on: the

household functions and features along with the outdoor activities, the age and the number of residents and their individual habits, residents earnings, and thus, water use and sewage disposal fee as well as the degree of the households equipping with plumbing fixtures and appliances [Domene and Sauri 2006, Fan et al. 2013, Rathnayaka et al. 2014, Hussien et al. 2016, Bergel et al. 2017, Bich-Ngoc and Teller 2018, Ogiołda and Nowogoński 2018]. Irregularity of water consumption on an annual basis should be considered in relation to the seasons; similarly to the monthly water consumption irregularity, this is related to the impact of meteorological conditions on water intake. As the everyday experiences of tap water users show and many research studies confirm [Pawełek and Kaczor 2006, Bergel et al. 2017], both high temperatures and precipitation deficits contribute to the water consumption growth in spring and summer season and in the months falling within this period. However, based on the research of Haque et al. [2015], stronger correlation between the air temperature and water consumption can be stated than between rainfall and water consumption. The increased water demand in this period is mainly related to the use of significant amounts of water for additional purposes, mainly for the vegetation irrigation. This is observed mainly in rural areas, where agricultural production is carried out intensively in spring and summer; this necessitates provision of a proper amount of water. Moreover, in the second and third quarter of the year, significant amounts of water are used irreversibly e.g. for washing vehicles and agricultural machinery, keeping home yards clean or for recreational purposes, such as filling home swimming pools. Similarly, one may wonder whether the residents' water consumption for household purposes (e.g. washing and bathing, drinking and meals preparing, keeping home clean or laundry) is correlated with the weather conditions changing over the year e.g. the air temperature. For example, Bugajski and Kaczor [2005] suggest that the observed growth of the water consumption in households in the summer may result from the increased water demand for additional purposes, as well as greater residents' water needs for household purposes.

In this paper, a research hypothesis about the dependence of the water consumption for household purposes (indoor water use) on the air temperature was assumed. Therefore, some previous studies related to the household water consumption in term of the weather conditions were analysed. It should be stressed that it is difficult to compare directly, for example, the water consumption inthe countries located in a different climate zones or in the countries with a different availability of water resources. In addition, it is often difficult to determine unambiguously, what specific water consumption purposes are included in the term of "water consumption per capita" used by the authors, i.e., is it only the indoor water use for household purposes or does it also include the outdoor water use. The methodology of many research papers does not provide separate information about the water demand for household purposes and for additional purposes; that makes it difficult to obtain a clear answer to the above-mentioned question. Nevertheless, in the literature, some research results like these of the Akuoko-Asibey et al. [1993] can be found. On the basis of the Canadian city of Calgary, they proved that the water consumption growth with increasing air temperature may be observed only above 15ºC (i.e. during spring and summer period); below 15ºC, there was no correlation between the water consumption and the air temperature. Similar conclusions can be drawn based on the water consumption investigations carried out in other cities: Greater Melbourne (Australia) [Sarker et al. 2013], Montreal (Canada) [Rasifaghihi et al. 2020], Portland (Oregon, USA) [Chang et al. 2014] and Albuquerque (New Mexico, USA) [Gutzler and Nims 2005]. On the basis of the papers citied above, Dimkić [2020] has made an interesting analysis. The author has determined the estimated water consumption growth in the cities with a temperature growth by 1ºC above the threshold temperature value (i.e. above 15ºC). As the results showed, the calculated water consumption growth was less than 3% (Montreal), about 4% (Calgary), a little over 5% (Portland) and nearly 7% (Albuquerque). In turn, based on the other research of Praskievicz and Chang [2009], the water consumption growth of less than 1% by the air temperature above 15ºC was recorded in Seoul (South Korea). Similarly, the investigations of Dimkić [2020] in two Serbian cities, Belgrade and Niš, have shown the water consumption growth of less than 1%. In Poland, similar dependences may be observed. For instance, the investigations carried out on the example of the city of Wrocław indicated a very clear impact of the daily air temperature on the daily water intake in the summer months i.e. for the temperature of above 13÷15ºC [Hotloś 2013].

Taking into consideration a current state of the knowledge on the impact of the air temperature on the water consumption for household purposes (indoor water use) and lack of the clear research reports in this research area, an attempt to investigate these dependences with respect to the water consumption in households located in rural areas was made in this paper.

CASE STUDY

The research was conducted on the basis of the water consumption data collected in rural households located in two villages in the Southern Poland: Mszana Górna (about 50 km to the south from Cracow) and Włostowice (about 50 km to the east from Cracow). In Mszana Górna, the investigations lasted for two years and six households inhabited by four to eight persons were tested. In Włostowice, the water consumption was measured over the one year period in four households inhabited by three to six persons (Table 1).

All of the analysed rural households were characterised by the highest category of plumbing fixtures equipping. During the investigation period, relevant households were supplied with water from the collective water supply system and they were connected to the collective sewerage system. Both Mszana Górna and Włostowice are typical agricultural villages, focused on plant cultivation and livestock farming. Therefore, as it can be expected, the water taken from the water supply network then was used not only for residents' household purposes, but also for additional purposes related to the agricultural production (i.e. animal husbandry, plants watering, agricultural vehicles and machines maintenance, farm yards cleaning or dilution of plants protection products). Therefore, in order to be able to control the water consumption for household purposes (indoor water use) and for additional purposes separately, two water meters were installed in the tested rural households. Using the main one (placed at the water service line), total water consumption in rural household was recorded. An additional water meter (placed outside the residential building), measured only water consumption for additional purposes. The difference between the both water meters readings was the amount of the water consumption only for household purposes.

On the basis of the data summarised in Table 1, it can be stated that the water needs in the tested rural households varied significantly; for sure, it was due to their different characteristics and

Table 1. Characteristics of the tested rural households

Localization / Detail	Mszana Górna					Włostowice				
The number of tested households	6 (M1, M2, M3, M4, M5, M6)					4 (W1, W2, W3, W4)				
The number of residents in each household	between 4 and 8					between 3 and 6				
Research period	from January to December									
The length of the research period	24 months (year A and year B)					12 months (year B)				
Average daily water consumption in rural households ($dm^3 \cdot d^{-1}$)	household	year	in total	household purposes	additional purposes	household	year	in total	household purposes	additional purposes
	M1	A	443.8	367.4	76.4	W1	B	266.2	230.8	35.4
		B	418.7	326.2	92.5					
	M2	A	485.5	406.4	79.1					
		B	484.1	395.2	88.9	W2		286.4	267.5	18.8
	M3	A	517.9	431.2	86.7					
		B	529.3	398.9	130.4					
	M4	A	334.9	268.6	66.3	W3		405.0	287.2	117.8
		B	334.3	273.1	61.2					
	M5	A	597.3	500.8	96.5					
		B	541.1	455.3	85.8	W4		285.3	282.8	32.5
	M6	A	516.2	261.9	254.4					
		B	525.3	254.7	270.7					

residents' activities. In Mszana Górna, the water for additional purposes represented from about 16% of total average daily water consumption (M5) to about 50% (M6). In Włostowice, these values ranged from less than 7% in rural household W2 to 29% in rural household W3.

METHODOLOGY

In order to analyse the dependence of the indoor water use for household purposes and the air temperature, the daily water consumption measurements data were used; for the rural households located in Mszana Górna, it was a two-year investigation period; for Włostowice, it was a one-year investigation period. Owing to the double metering of the water consumption in the tested rural households, it was possible to determine the amount of the water consumption for household purposes. In turn, the knowledge about the number of residents in each of the rural households made it possible to determine the daily water consumption for household purposes per capita.

The values of the average daily air temperatures in the analysed investigation periods were obtained from the Institute of Meteorology and Water Management in Cracow; these came from

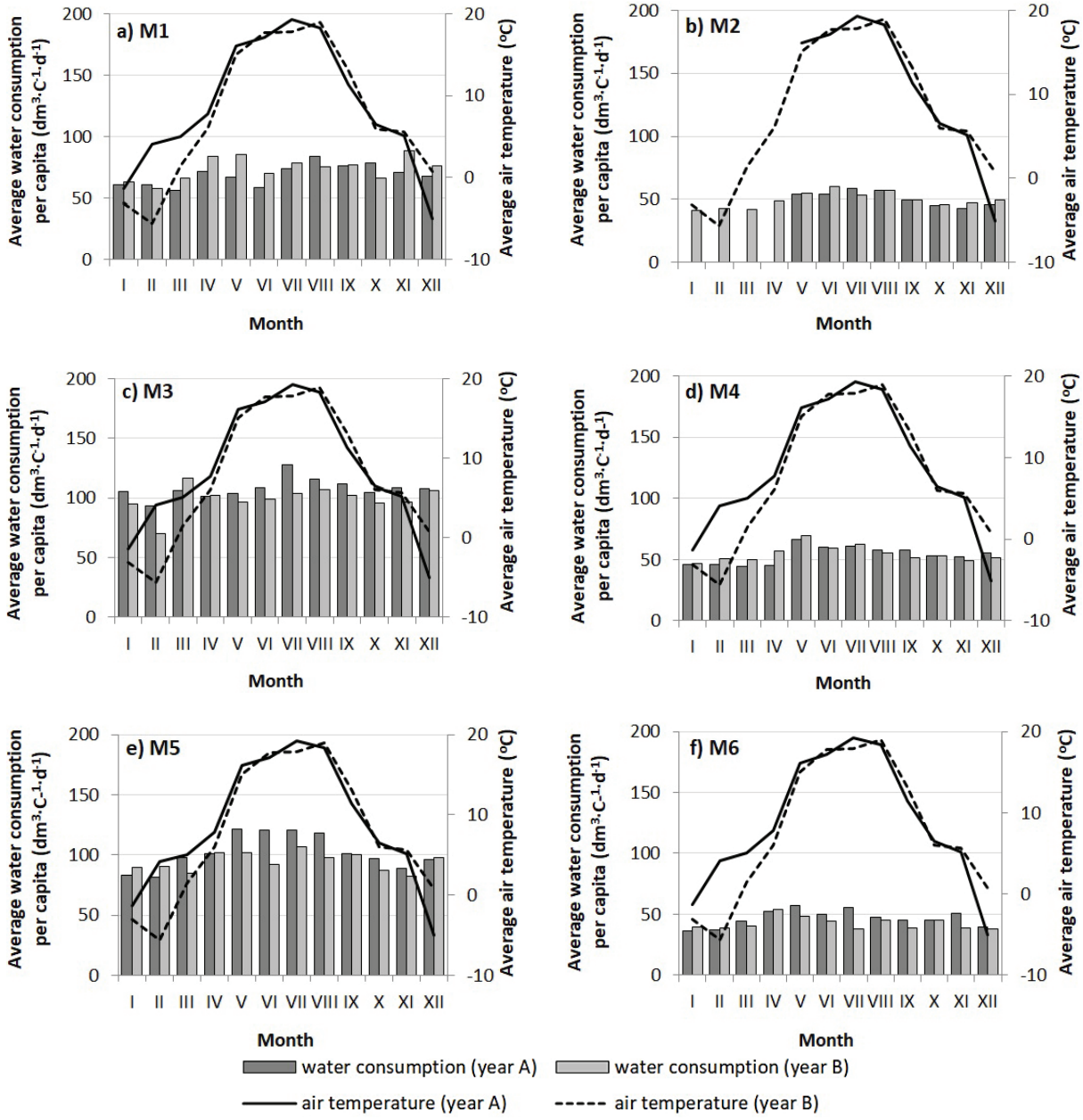


Figure 1. The average daily water consumption per capita for household purposes in household M1, M2, M3, M4, M5 and M6 (Mszana Górna) in each month of the year A and year B

the measurements carried out at the meteorological stations located nearby subject villages; it was the Limanowa station for Mszana Górna and the Igołomia station for Włostowice.

The temperature measurements carried out at the Limanowa station showed that in year A, the coldest month was December with the average monthly temperature of –5.0ºC; in turn, the warmest month was July (average monthly temperature 19.3ºC). In year B, the coldest month was February (average monthly temperature –5.6ºC) and the warmest month was August (average monthly temperature 18.9ºC). In Włostowice, in the year B, similarly as in Mszana Górna, the lowest average monthly temperature of –5.6ºC was noted in February; the highest average monthly temperature (20.0ºC) in the year B was recorded in August.

The preliminary results analysis involved comparing the average daily water consumption per capita for household purposes for each month with the average daily air temperatures changing over time (Fig. 1). Next, a statistical analysis of the dependence of the average daily water consumption per capita for household purposes and the average daily air temperature was conducted. For this purpose, assuming a 95% confidence interval (significance level of $\alpha = 0.05$), the values of correlation coefficients (r) were determined. The strength of the relationship between the tested variables was interpreted according to the Guilford classification [1965]: $r = 0.0$ – lack of the correlation, $0.0 < r \leq 0.1$ – slight correlation, $0.1 < r \leq 0.3$ – weak correlation, $0.3 < r \leq 0.5$ – moderate correlation, $0.5 < r \leq 0.7$ – high correlation, $0.7 < r \leq 0.9$ – very high correlation, $0.9 < r < 1.0$ – nearly complete correlation, $r = 1.0$ – complete correlation.

RESULTS AND DISCUSSION

As it can be seen in the Figure 1, 2, 3 and 4, the water consumption per capita for household purposes inthe tested households of Mszana Górna and Włostowice was at different levels. Polish Regulation of the Minister of Infrastructure [2002] determines that the average water consumption per capita in households with the highest standard of plumbing fixtures equipping and with the collective sewerage system connecting is about 100.0 $dm^3 \cdot C^{-1} \cdot d^{-1}$. Therefore, referring

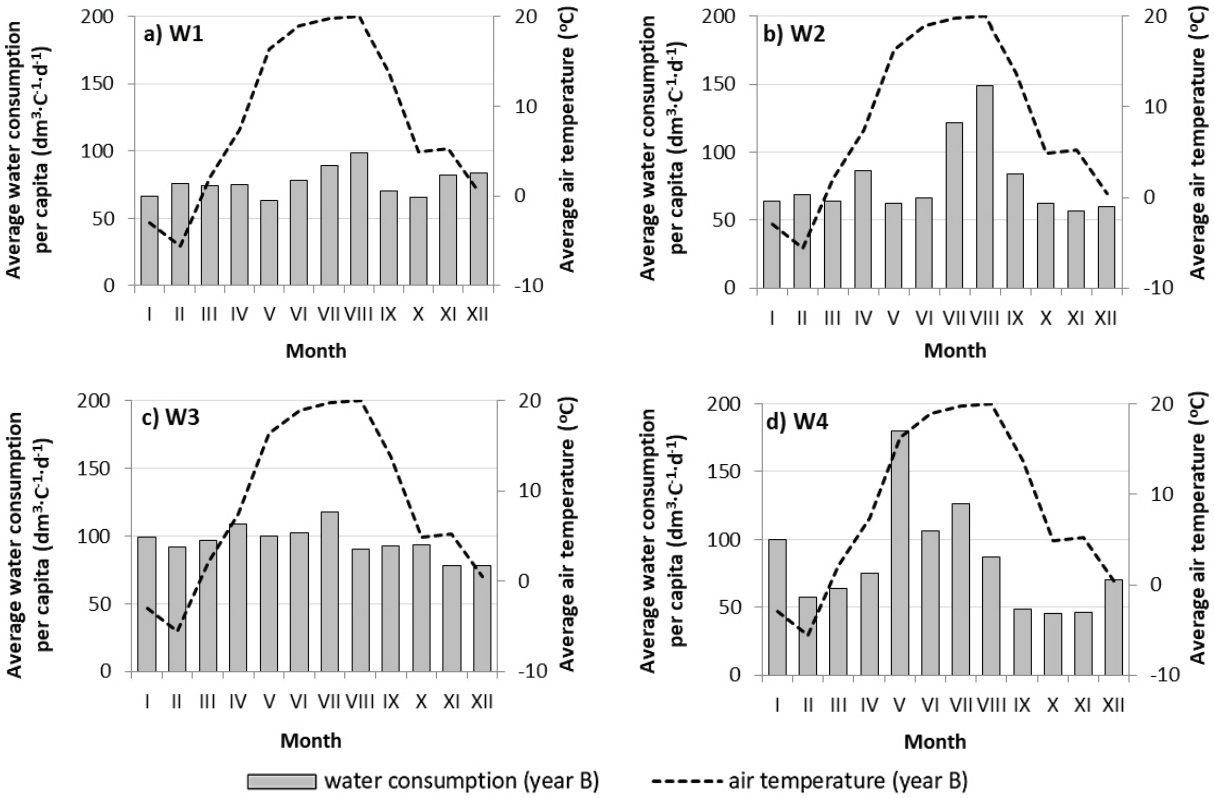


Figure 2. The average daily water consumption per capita for household purposes in household W1, W2, W3 and W4 (Włostowice) in each month of the year B

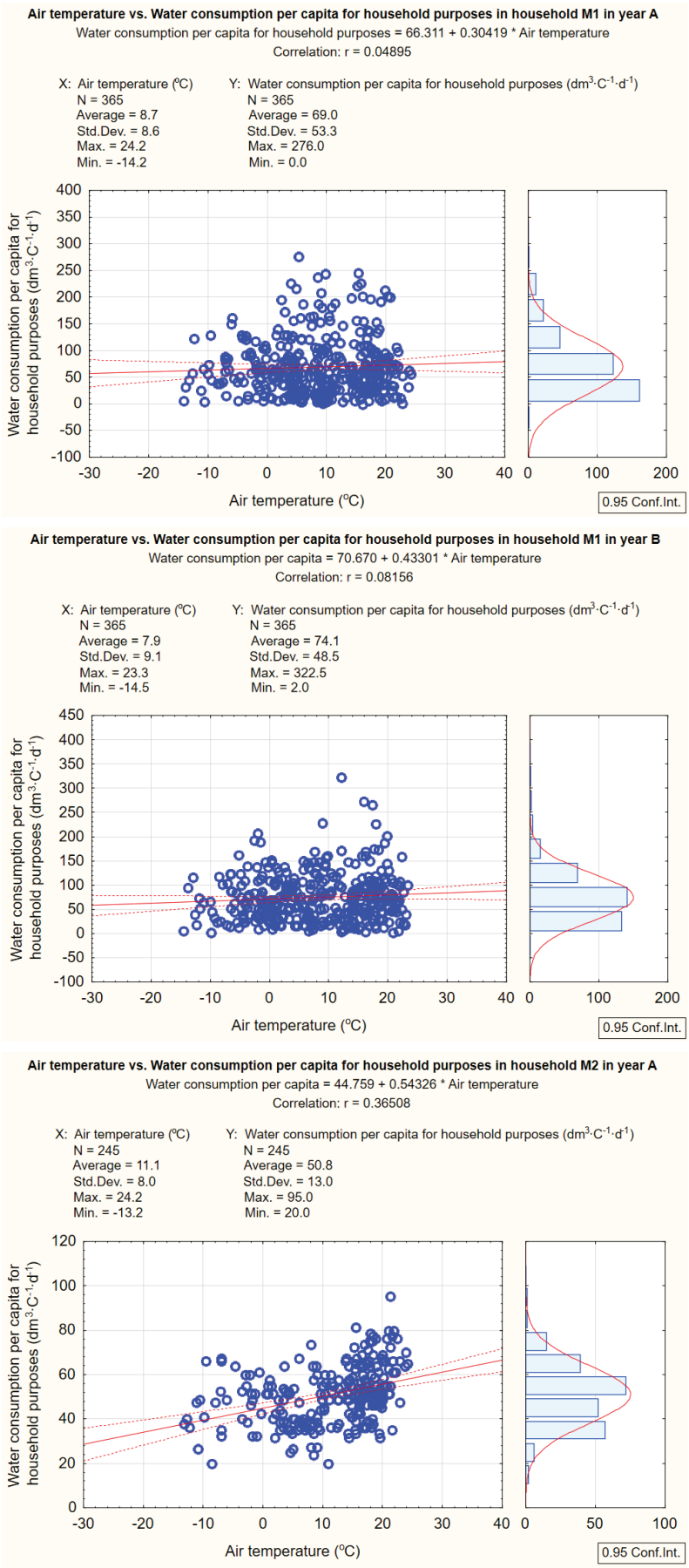
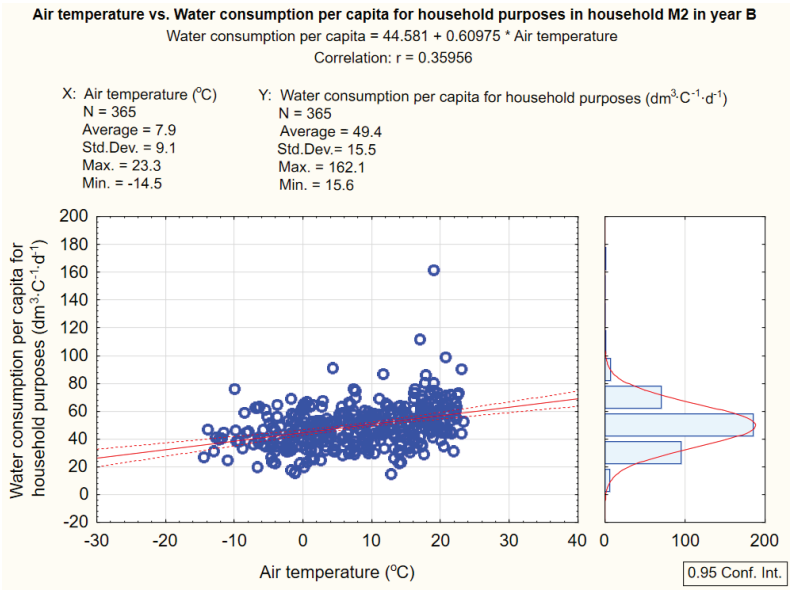
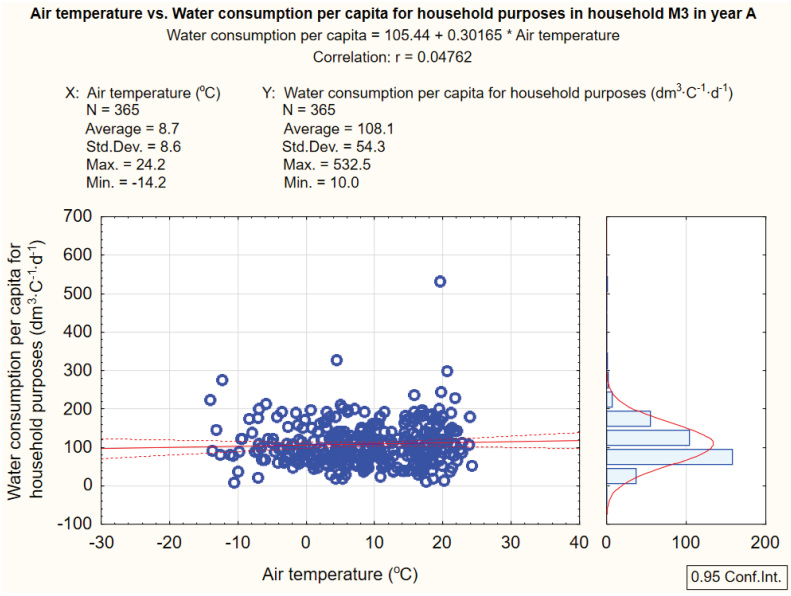


Figure 3. The dependence of daily water consumption per capita for household purposes in household M1, M2, M3, M4, M5 and M6 (Mszana Górna) and the air temperature in year A and year B





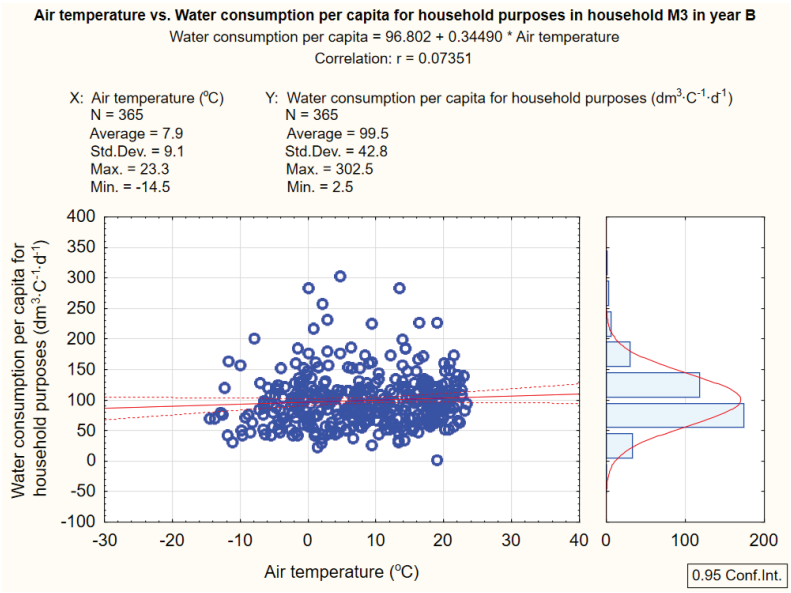


Figure 3 (Continued). The dependence of daily water consumption per capita for household purposes in household M1, M2, M3, M4, M5 and M6 (Mszana Górna) and the air temperature in year A and year B

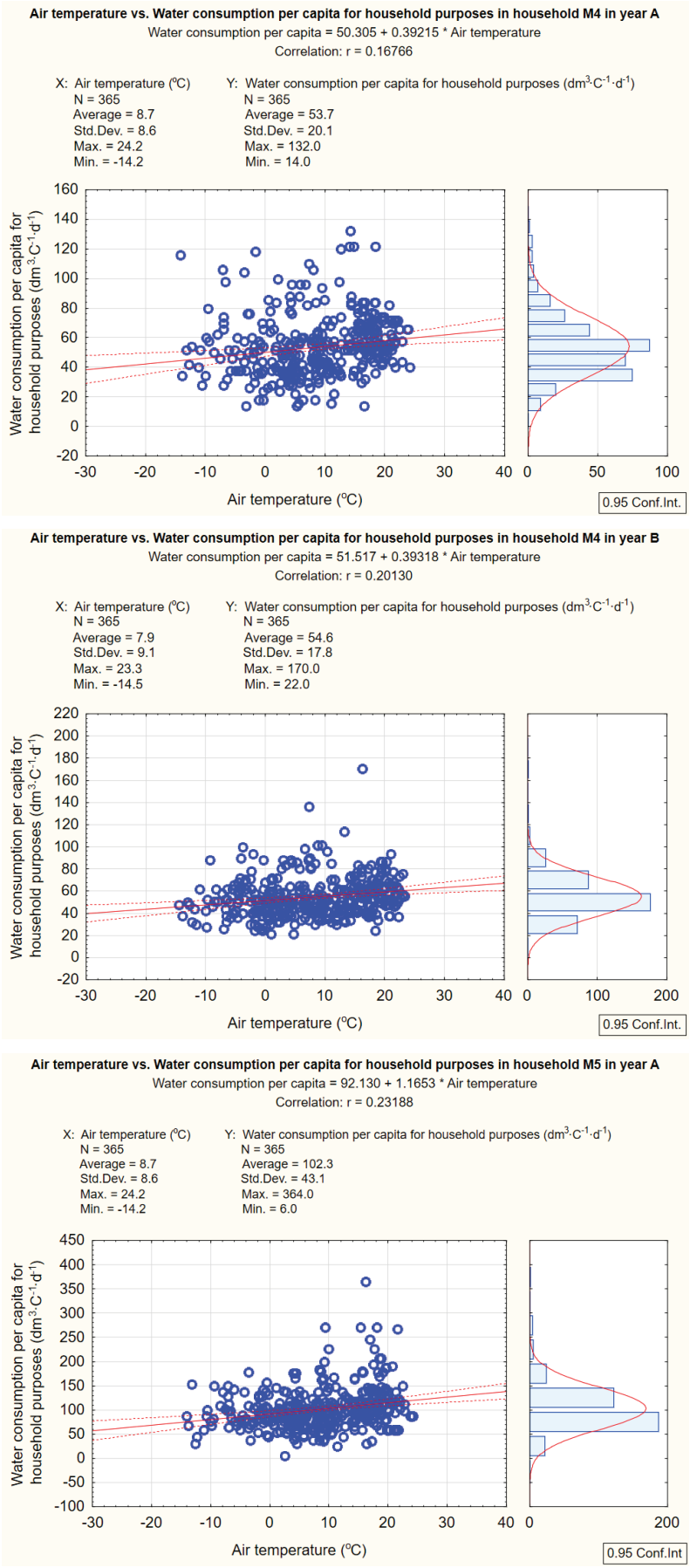
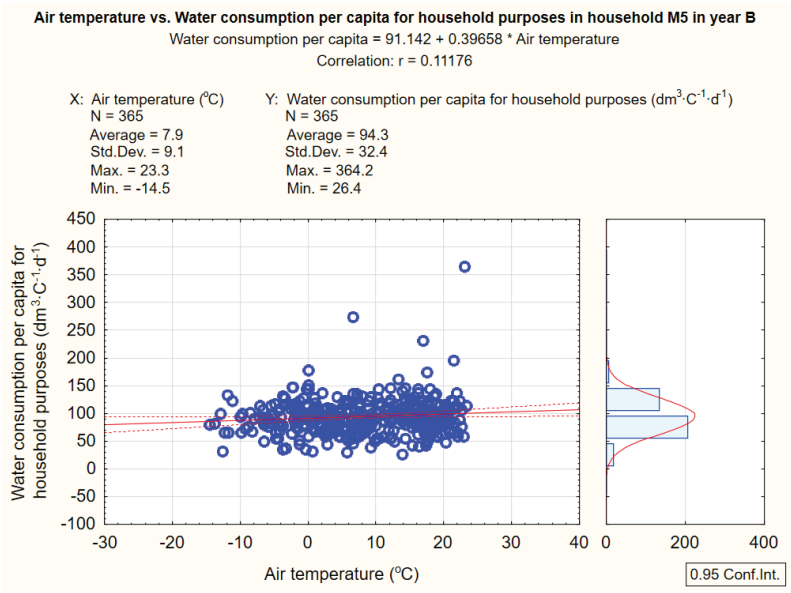
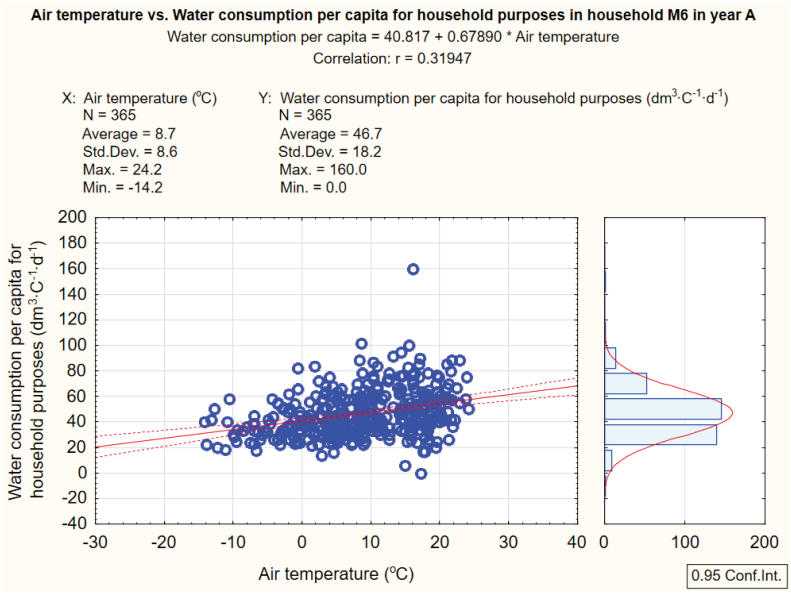


Figure 3 (Continued). The dependence of daily water consumption per capita for household purposes in household M1, M2, M3, M4, M5 and M6 (Mszana Górna) and the air temperature in year A and year B





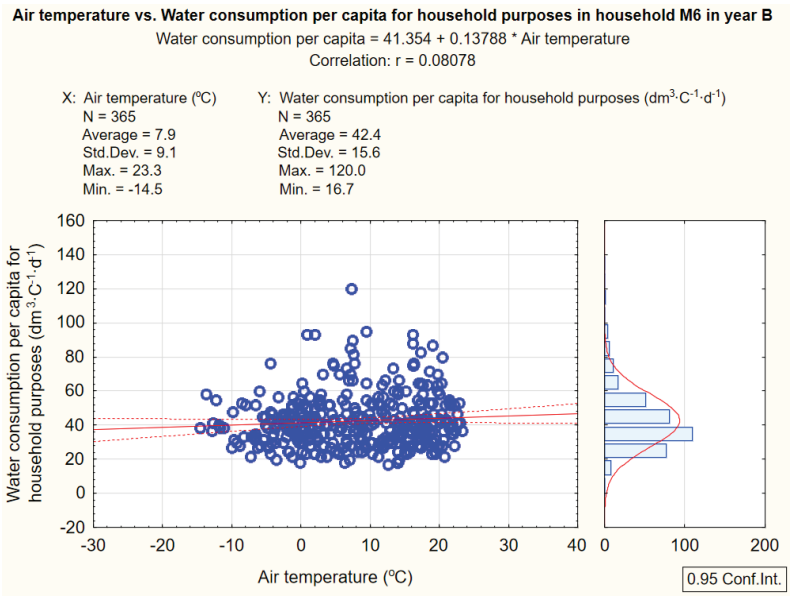


Figure 3 (Continued). The dependence of daily water consumption per capita for household purposes in household M1, M2, M3, M4, M5 and M6 (Mszana Górna) and the air temperature in year A and year B

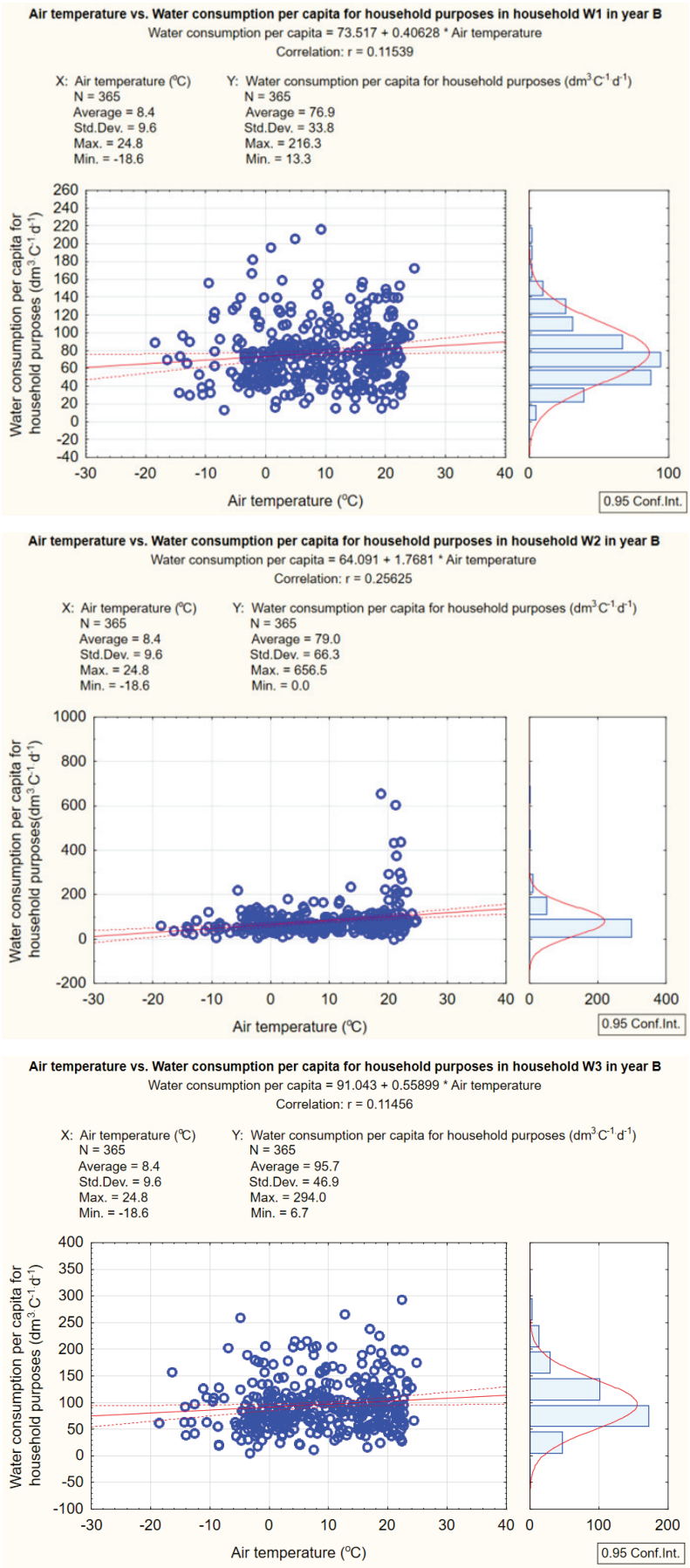


Figure 4. The dependence of daily water consumption per capita for household purposes in household W1, W2, W3 and W4 (Włostowice) and the air temperature in year B

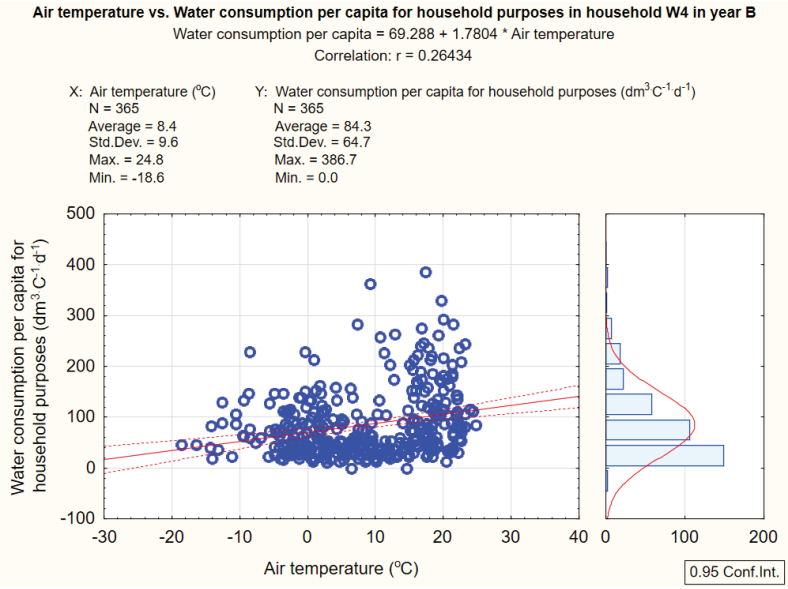


Figure 4 (Continued). The dependence of daily water consumption per capita for household purposes in household W1, W2, W3 and W4 (Włostowice) and the air temperature in year B

to this value, in the analysed households, both smaller and significantly exceeded average daily water consumptions per capita were noted (Fig. 3a,c,e, Fig. 4b,c,d). The water consumption per capita changing over time and lesser or greater water demand can be related to the typical for a given period of year residents' activity. Because the summer months are warmer compared to others and simultaneously, greater activity of rural residents focused on the work on the farms is observed at that time, it can be assumed that in the tested households, more water was used in this period for washing, bathing or for laundry. The aim of the data set in the Figure 1 and Figure 2 was the analysis of the annual water use changes for household purposes in relation to the average monthly air temperatures. Although the presented results not prove unambiguously that the air temperature growth causes an increase of the water consumption per capita for household purposes, nevertheless, on the example of some households, e.g. M2 (Fig. 1b), M4 (Fig. 1d), M5 (Fig. 1e), W2 (Fig. 2b) or W4 (Fig. 2d), one can notice the existence of a such dependence. In the warmest months of the year, i.e., from May to August, compared to the other months, greater daily water consumption per capita for household purposes can be observed. It should be emphasised that the amount of daily water consumption per capita depends not only on the type of the household works carried out, but also on the other factors, such as the age and an individual habits of residents.

The determined statistical dependences between the average daily air temperature and the average daily water consumption per capita for household purposes in six tested households of Mszana Górna and in four households located in Włostowice (Fig. 3, Fig. 4, Table 2), in general, do not indicate the existence of a clear dependence between the tested variables. The correlation coefficients (r) for households in Mszana Górna ranged from 0.048 to 0.365; therefore, these indicate the existence of a slight correlation, through weak to moderate correlation in the case of several households. Statistically insignificant results, i.e. those for which p-values were greater than the assumed significance level of $\alpha = 0.05$, refer to those households for which the correlation between the air temperature and the water consumption was slight. In turn, for the tested households located in Włostowice, the correlation coefficients (r) ranged from 0.115, through 0.256 to 0.264; these values prove the existence of a weak and moderate correlation.

On the basis of the results of the statistical analysis it was possible to determine an expected growth of the water consumption per capita for household purposes along with an increase of the air temperature by 1°C (Table 2). As it turns out, for the households located in Mszana Górna, the growth of the water consumption per capita in the range of 0.14 $dm^3 \cdot d^{-1} \cdot C^{-1} \cdot {}^oC^{-1}$ and 1.17 $dm^3 \cdot d^{-1} \cdot C^{-1} \cdot {}^oC^{-1}$ may be observed. However, as the results obtained for Włostowice show,

Table 2. The results of the statistical analysis on dependence of the average daily water consumption per capita for household purposes in the households of Mszana Górna and Włostowice and the average daily air temperature

Mszana Górna					Włostowice				
Household	Year	Correlation coefficient *r*	*p-value*	Growth of the water consumption ($dm^3 \cdot d^{-1} \cdot C^{-1} \cdot {}^oC^{-1}$)	Household	Year	Correlation coefficient *r*	*p-value*	Growth of the water consumption ($dm^3 \cdot d^{-1} \cdot C^{-1} \cdot {}^oC^{-1}$)
M1	A	0.049	0.351	0.30	W1	B	0.115	0.028	0.41
	B	0.082	0.120	0.43					
M2	A	0.365	0.000	0.54					
	B	0.360	0.000	0.61	W2		0.256	0.000	1.77
M3	A	0.048	0.364	0.30					
	B	0.074	0.161	0.35					
M4	A	0.168	0.001	0.39	W3		0.115	0.029	0.56
	B	0.201	0.000	0.39					
M5	A	0.232	0.000	1.17					
	B	0.112	0.033	0.40	W4		0.264	0.000	1.78
M6	A	0.319	0.000	0.68					
	B	0.081	0.123	0.14					

with an increase of the air temperature by 1ºC, one can expect the growth of daily water consumption per capita of about 0.4 $dm^3 \cdot d^{-1} \cdot C^{-1} \cdot {}^oC^{-1}$ as the minimum to about 1.8 $dm^3 \cdot d^{-1} \cdot C^{-1} \cdot {}^oC^{-1}$.

The results presented above indicate that the residents' daily water consumption for household purposes relates to the changes of the air temperatures in varying degree. It can be concluded that the increased activity of rural inhabitants that is typical to the summer months, is associated with greater water needs and thus, with greater water consumption for household purposes. However, as it was mentioned before, the increased water use in the summer season may be also influenced by additional factors that are individual for a given household and its residents.

CONCLUSIONS

Many research papers related to the investigation of the impact of meteorological conditions on water consumption confirm that the growth of the air temperature causes an increase of the water consumption by the water supply systems users. The existence of a strong correlation between these variables can be observed in rural households, especially in the spring and summer seasons; this is the result of using significant amounts of water for additional purposes, e.g. for animal husbandry, watering of home gardens and crops, washing vehicles or for recreational purposes. This paper, in turn, presents a research hypothesis about the dependence of the water consumption only for household purposes (indoor water use) on the air temperature. This results from the assumption that the increased activity of rural inhabitants related to work in rural households in the spring and summer months (and at the same time, in the period of higher temperatures), causes the use of larger amounts of water, e.g. for drinking, washing, bathing or for laundry.

The results of the research conducted in several households of Mszana Górna and Włostowice did not indicate any strong correlation between the air temperature and daily water consumption per capita for household purposes. Although in the case of some of the tested households, increased daily water consumption per capita was observed in the warmest months of the year (from May to August), statistical analysis on dependence of daily water consumption per capita for household purposes and daily air temperature indicated slight to moderate correlation (Mszana Górna) and weak to moderate correlation (Włostowice). An attempt to determine the growth of daily water consumption along with an increase of the air temperature by 1ºC showed that the maximum growth of water consumption of about 1.2 $dm^3 \cdot d^{-1} \cdot C^{-1} \cdot {}^oC^{-1}$ and about 1.8 $dm^3 \cdot d^{-1} \cdot C^{-1} \cdot {}^oC^{-1}$ can be expected for some households of Mszana Górna and Włostowice, respectively. It can be concluded that the increase of the air temperature may affect the amount of the water used

for residents' household purposes only to some degree; this is because the amount of water used by the household's residents is strongly supported by the other factors, such as households' features and functions, residents' age and their individual habits.

Although the results obtained in this paper do not prompt unambiguously to entirely reject the assumed hypothesis, it should be always emphasised that a rapid growth of the water consumption observed in rural households in the spring and summer season is primarily the consequence of increased water demand for additional purposes. Therefore, the term of "water consumption per capita" that is used very often should be clarified; i.e., it should be clearly emphasised what water use purposes in detail are considered then: whether only for residents' household purposes (indoor water use) or these mentioned above along with additional purposes.

REFERENCES

1. Akuoko-Asibey A., Nkemdirim L.C., Draper, D.L. 1993. The impacts of climatic variables on seasonal water consumption in Calgary, Alberta. Canadian Water Resources Journal**,** 18:2, 107–116. https://doi.org/10.4296/cwrj1802107.
2. Bergel T. 2017. Practical implication of tap water consumption structure in rural households. Journal of Ecological Engineering, 18(1), 231–237. DOI: 10.12911/22998993/67102.
3. Bergel T., Kaczor G. 2007. Quantity and irregularity of water intake by individual rural households. Infrastructure and Ecology of Rural Areas, 1, 125–136 (in Polish).
4. Bergel T., Kaczor G., Bugajski P. 2016a. Analysis of the structure of water consumption in rural households in terms of design guidelines water and sewage systems. Infrastructure and Ecology of Rural Areas, IV/4, 1899–1910. DOI: http://dx.medra.org/10.14597/infraeco.2016.4.4.143.
5. Bergel T., Kotowski T., Woyciechowska O. 2016b. Daily water consumption for household purposes and its variability in a rural household. Journal of Ecological Engineering, 17(3), 47–52. DOI: 10.12911/22998993/63312.
6. Bergel T., Szeląg B.., Woyciechowska O. 2017. Influence of a season on hourly and daily variations in water demand patterns in a rural water supply line – case study. Journal of Water and Land Development, 34(VII-IX), 59–64. DOI: 10.1515/jwld-2017-0038.
7. Bich-Ngoc N., Teller J. 2018. A review of residential water consumption determinants. Proc. of the 18th International Conference on Computational Science and Its Applications – ICCSA 2018, Melbourne, Australia, 2-5 July 2018, 685–696. https://doi.org/10.1007/978-3-319-95174-4_52.
8. Bugajski P., Kaczor G. 2005. Structure of expenditure of cold and hot water in one-family apartment. Infrastructure and Ecology of Rural Areas, 2, 17–26 (in Polish).
9. Chang H., Praskievicz S., Parandvash H. 2014. Sensitivity of urban water consumption to weather and climate variability at multiple temporal scales: The Case of Portland, Oregon. International Journal of Geospatial and Environmental Research, 1(1).
10. Chmielowski K., Satora S., Wałęga A. 2009. Variability of the unitary average daily water consumption by Mszanian man. Infrastructure and Ecology of Rural Areas, 5, 61–71 (in Polish).
11. Dimkić D. 2020. Temperature impact on drinking water consumption. Environmental Sciences Proceedings, 2(1), 31. https://doi.org/10.3390/environsciproc2020002031.
12. Domene E., Sauri D. 2006. Urbanisation and water consumption: Influencing factors in the metropolitan region of Barcelona. Urban Studies, 43(9), 1605–1623. https://doi.org/10.1080/00420980600749969.
13. Fan L., Liu G., Wang F., Geissen V., Ritsema C.J. 2013. Factors affecting domestic water consumption in rural households upon access to improved water supply: Insights from the Wei River Basin, China. PLoS ONE, 8(8). doi: 10.1371/journal.pone.0071977.
14. Guilford J.P. 1965. Fundamental statistics in psychology and education. McGraw-Hill, New York.
15. Gutzler D.S., Nims J.S. 2005. Interannual variability of water demand and summer climate in Albuquerque, New Mexico. Journal of Applied Meteorology and Climatology 44(12), 1777–1787. https://doi.org/10.1175/JAM2298.1.
16. Haque M.M., Egodawatta P., Rahman A., Goonetilleke A. 2015. Assessing the significance of climate and community factors on urban water demand. International Journal of Sustainable Built Environment, 4(2), 222–230. http://dx.doi.org/10.1016/j.ijsbe.2015.11.001.
17. Hotloś H. 2013. Analysis of influence of meteorological factors on water demand variations in municipal water supply system. Ochrona Srodowiska, 35(2), 57–62 (in Polish).
18. Hussien W.A., Memon F.A., Savic D.A. 2016. Assessing and modelling the influence of household characteristics on per capita water consumption. Water Resources Management, 30(9), 2931–2955. https://doi.org/10.1007/s11269-016-1314-x.
19. Ogiołda E. Nowogoński I. 2018. The irregularity of water consumption in settlements with varying numbers of inhabitants. E3S Web of Conferences 45, INFRAEKO 2018. https://doi.org/10.1051/e3sconf/20184500059.

20. Ogiołda E., Nowogoński I., Pietrzak P. 2019. Characteristics of water consumption in Chocianów, Parchów and Pogorzeliska, Lower Silesia Province. Civil and Environmental Engineering Reports, 29(2), 13–21. https://doi.org/10.2478/ceer-2019-0012.
21. Pawelek J., Kaczor G. 2006. Unit water consumption per household during 8-year period of observations. Infrastructure and Ecology of Rural Areas, 2(1), 159–170 (in Polish).
22. Pawełek J., Bergel T., Woyciechowska O. 2015. Variation in water consumption in rural households during the multi-year period. Acta Scientiarum Polonorum Formatio Circumiectus, 14(4), 85–94 (in Polish). http://dx.doi.org/10.15576/ASP.FC/2015.14.4.85.
23. Praskievicz S., Chang H. 2009. Identifying the relationships between urban water consumption and weather variables in Seoul, Korea. Journal Physical Geography, 30(4), 324–337. https://doi.org/10.2747/0272-3646.30.4.324.
24. Rasifaghihi N., Li S.S., Haghighat F. 2020. Forecast of urban water consumption under the impact of climate change. Sustainable Cities and Society, 52. https://doi.org/10.1016/j.scs.2019.101848.
25. Rathnayaka K., Maheepala S., Nawarathna B. George B., Malano H., Arora M., Roberts P. 2014. Factors affecting the variability of household water use in Melbourne, Australia. Resources, Conservation and Recycling, 92, 85–94. https://doi.org/10.1016/j.resconrec.2014.08.012.
26. Regulation of the Minister of the Infrastructure of 14 January 2002 on determination the average standards for water consumption (in Polish).
27. Sarker R.C., Gato-Trinidad S., Imteaz M. 2013. Temperature and rainfall thresholds corresponding to water consumption in Greater Melbourne, Australia. Proc. of the 20th International Congress on Modelling and Simulation (MODSIM2013), Adelaide, Australia, 1-6 December 2013, 2576–2582.