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# Analysis of Water Consumption in the Campus of Warsaw University of Life Sciences in Years 2012–2016

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**ABSTRACT**
On the basis of the registered indications of the water meter, a study on the size and variability of water consumption on the WULS campus in the academic years 2012/16 is presented. The average specific water consumption at a time when classes are implemented amounted to 26.6 $dm^3$ per student per day for full-time studies student and 19.7 $dm^3$ per student per day for the student part-time studies. During the holiday season, the rates are lower at 18.4 and 11.8 $dm^3$ per student per day, respectively. These ratios were determined without taking the water consumption in the dorms into account. The daily peaking factor amounted ($N_d$) to 1.36, while the hourly peaking factor ($N_h$), reached 1.71. Within the week cycle, the highest water consumption was observed in Tuesdays and the lowest – in Sundays. The average Tuesday demands are 40% higher than the Sunday demands. The water consumption peaks during the day occur between 11 a.m. and 1 p.m. as well as 11 p.m. and 1 a.m. The hourly structure of the water distribution in the WULS-SGGW campus is similar to the weekend structure of water distribution in multi-family residential buildings, with the exception of the later occurrence of the evening summit.

**Keywords:** water supply, daily peaking factor, hourly peaking factor, unit indicator of water consumption

## INTRODUCTION

In order to design water-pipe networks, one has to know the water demand of consumers connected to the system being analyzed as well as a time variability of water consumption. Several methods are used for the forecast:

- statistical extrapolation of a time trend of water consumption – it is based on the predictions of future water consumption using the data from the past through the extrapolation of variables by means of certain functions,
- correlation of predictions of water consumption – based on a data set and mathematical function, a correlation graph is being determined by means of the least squares method,
- indicator-based prediction of water consumption – uses unit indicators of water consumption for individual groups of consumers of water from the water supply.

The two first methods require the access to a large quantity of data from many years which are to be statistically analyzed by means of computer software. An increasing use of monitoring of water-pipe networks contributes to creation of empirical data bases which – after a numerical processing – allow, e.g. to model water flows. The indicator method is the simplest – it uses average standards of water consumption for individual consumers. The water consumption in utility buildings is provided for so-called reference unit. The unit indicators for selected objects connected with the didactic and research activities are presented in Table 1.

The yearly variability of water consumption is characterized by a daily peaking factor expressed by Eq. (1):

$$N_d = \frac{Q_{dmax}}{Q_{da}} \qquad (1)$$

where: $Q_{dmax}$, $Q_{da}$ – maximum and average daily water demand in the analyzed period, (m$^3$ · d$^{-1}$),

The daily variability of water consumption is characterized by an hourly peaking factor. It is determined for a day with the highest daily water demand and defined by Eq. (2):

$$N_h = \frac{Q_{hmax} \cdot 24}{Q_{dmax}} \tag{2}$$

where: $Q_{hmax}$ – maximum hourly water consumption for a day with a maximum daily demand, (m$^3$ · h$^{-1}$),

In the literature, based on the empirical data, the information on water consumption both for living needs (Bugajski, 2009; Grafton et al., 2011; Willis et al., 2013; Chao et al., 2015) for utility buildings and production activity (Studziński et al., 2012; Steinhoff-Wrześniewska et al., 2013; Styles et al., 2015) is provided. An analysis of water consumption in the WULS-SGGW campus was carried out for the academic year 2012/13 (Wichowski et al., 2015). One can find peaking factors for individual water consumers (Podwójci, 2011; Kępa et al., 2013). The paper is focused on the presentation of quantity and structure of water consumption as well as calculation of unit indicators of consumption and peaking factors for water consumption in the campus of Warsaw University of Life Sciences – SGGW in the years 2012–2016.

## MATERIALS AND RESEARCH

The SGGW campus is located in the southern part of Warsaw, in the district of Ursynów. The older, eastern part of the campus and the newer, western part are divided by ul. Nowoursynowska. In the east the campus borders on a nature reserve Skarpa Ursynowska (Ursynów Bank), in the south the area is closed by ul. Ciszewskiego and in the west – by al. Jan Rodowicz-„Anoda" (Fig. 1). There are 49 buildings in the campus, among them 10 student dormitories, having in total 3460 accommodation places (WULS-SGGW, 2017), including the „Ikar" hotel. The student dormitories are used all-year-round. The remaining buildings are didactic, research and service buildings as well as the university management offices.

The campus is supplied with water by an internal cyclic water-pipe network fed from own deep water intakes localized in the Scientific Research Water Pumping Station (NBSW). The water outflow from the pumping station is measured by a water meter PoWoGaz MWN150NO equipped with an optical transmitter. The physical data (flow rate and water meter reading) are transformed into a digital signal by a PA-5 type converter and registered on a computer hard disk. The hourly, daily, monthly and yearly water consumption in the academic years 2012–2016 was determined based on the registered indications of the water meter. Average values, standard deviation and median were calculated for the daily and hourly water consumption in individual months.

Moreover, a unit indicator of water consumption in relation to a number of students learning in the campus was determined. The consumption recorded in weekdays (i.e. from Monday to Friday) was referred to the number of full-time students, whereas the weekend consumption (Saturday and Sunday) – to the number of part-time students. The number of students learning in the campus in the years being analyzed is presented in Table 2.

**Table 1.** Selected coefficients of specific water consumption (Regulation of the Minister of Infrastructure of January 14, 2002 on determining the average water consumption standards. Journal of Laws of 2002 No. 8, item 70)

| Type of object | Reference unit (r.u.) | Average standards of water consumption | |
|---|---|---|---|
| | | dm$^3$ · (r.u. × day)$^{-1}$ | m$^3$ · (r.u. × month)$^{-1}$ |
| Vocational schools and higher education institutions | 1 student | | |
| without laboratories | | 15.0 | 0.45 |
| with laboratories | | 25.0 | 0.80 |
| Dormitories and student hostels | 1 student | 100 | 2.4 |
| Scientific research institutes and institutions | 1 employee | | |
| without laboratories | | 15.0 | 0.45 |
| with laboratories | | 25.0 | 0.80 |

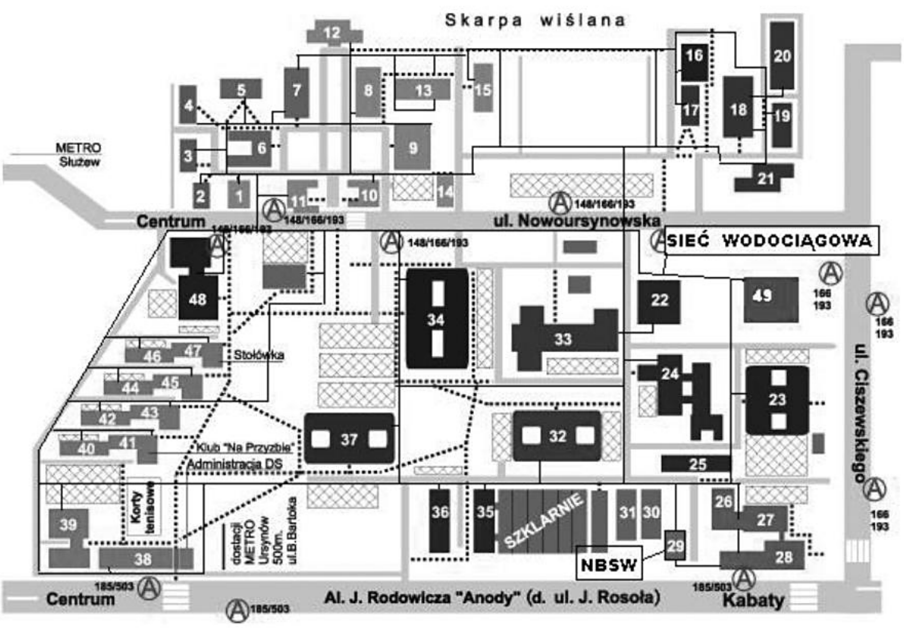


**Fig. 1.** Plan of the WULS-SGGW campus. 1–3, 8–12, 14–16, 20, 22, 25–27, 29–31, 48 – service buildings and the university administration, 4–7, 13, 17–19, 21, 23–24, 28, 32–37, 49 – buildings in which research and teaching activities are realized, 38–47 – residential buildings.

## RESULTS OF INVESTIGATIONS AND THEIR DISCUSSION

On the basis of the collected data, the characteristic flow rates and water consumption peaking factors were calculated for the analyzed academic years (Table 3).

The average monthly water consumption in individual months for the analyzed academic years is presented in Figure 2.

Figure 3 shows that the monthly water consumption is quite diversified. The highest monthly consumption is observed in May and June, whereas the lowest – in August. High water consumption is registered for the months involving exam sessions and a lot of tests, i.e. in January and June, as well as on the beginning of the academic year, i.e. in October. Low water consumption is registered for the months with holidays, i.e. July, August and February. High water consumption since January 2016 may be result of the celebrations of the 200th anniversary of the founding of WULS-SGGW and numerous events accompanying this jubilee.

The variability of hourly and daily water consumption in individual months in the SGGW campus for the academic years being analyzed is presented in Table 4.

For the period being analyzed, the highest daily water consumption occurred in 2015–08–04 and amounted to 1492.9 $m^3/d$, and the lowest – 2015–12–26 – 155 $m^3/d$. It is clearly visible that the lowest daily water consumption occurs in the feast periods. The hourly peaking factors Nh, determined for monthly periods, oscillate within the limit values 1.35–2.36 with the mean value of 1.71, whereas the daily peaking factor Nd falls into the range 1.15–2.57 with the mean value of 1.36. A high value of the daily peaking factor Nd was observed in August 2015. This was due to the very high water consumption in 2015–08–04, which remained at a high level through the whole day, also in the night, and could be due to the network rinsing in that time. The mean hourly (Nh) and daily (Nd) peaking factor assumes values which are comparative to those found in the literature for multi-family dwelling houses. For the multi-family buildings in Bolesławiec Nh = 2.13 and Nd = 1.1, in Pasłęk Nh = 1.70 and Nd = 1.06,

**Table 2.** Number of people studying at the WULS-SGGW campus (WULS-BIP 2017).

| Academic year | 2012/13 | 2013/14 | 2014/15 | 2015/16 |
|---|---|---|---|---|
| Full-time students | 14052 | 14300 | 14507 | 14659 |
| Part-time students | 11296 | 11028 | 10053 | 9931 |

**Table 3.** Characteristic water consumption along with peaking factors for the WULS campus in the academic years of 2012/2016

| Characteristic flow rates | Unit | Academic year | | | |
|---|---|---|---|---|---|
| | | 2012/13 | 2013/14 | 2014/15 | 2015/16 |
| Flow rate per year Qyr | ($m^3 \cdot yr.^{-1}$) | 245263 | 221069 | 226034 | 265881 |
| Average flow rate per day Qdśr | ($m^3 \cdot d^{-1}$) | 672 | 606 | 619 | 726 |
| Maximum flow rate per day Qdmax | ($m^3 \cdot d^{-1}$) | 1029 | 942 | 1493 | 1320 |
| Minimum flow rate per day Qdmin | ($m^3 \cdot d^{-1}$) | 217 | 174 | 191 | 155 |
| Maximum flow rate per hour Qhmax | ($m^3 \cdot h^{-1}$) | 75.26 | 67.99 | 84.06 | 103.31 |
| Minimum flow rate per hour Qhmin | ( $m^3 \cdot h^{-1}$) | 2.32 | 2.35 | 3.44 | 4.12 |
| Daily peaking factor Nd | (-) | 1.54 | 1.56 | 2.41 | 1.82 |
| Hourly peaking factor Nh | (-) | 1.53 | 1.57 | 1.35 | 2.00 |

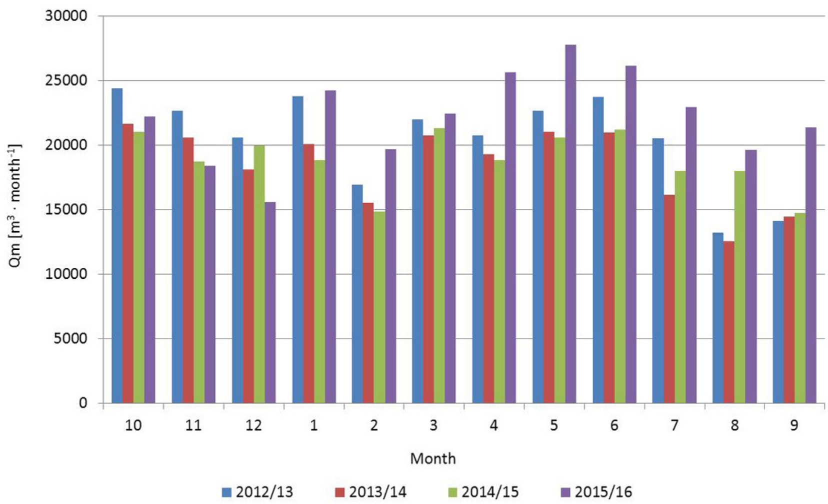


**Fig. 2.** Water consumption per month for the WULS campus in the academic years of 2012/2016

in Płock 1.65 and 1.2, respectively (Podwójci, 2011). According to other investigations (Kępa et al., 2013) carried out in Częstochowa on an area of single-family houses, these coefficients are higher and amount Nh = 2.69 for the year 2010 and 1.85 for the year 2011 as well as Nd = 3.5 and 1.94, respectively.

The changes of water consumption in a weekly cycle were also noticed. Average daily water consumption in individual days of week, calculated as mean values for individual academic years, is presented in Fig. 3. The highest water consumption occurs in Tuesdays, the lowest – in Sundays. It is visible a distinct regressive trend of water consumption from Tuesday to Sunday. The water consumption in Tuesdays is 40% higher in average than that in Sundays. The weekly cycle differs from those found in the literature for dwelling houses where the highest consumption occurs in weekend and the lowest in weekdays. (Podwójci, 2011; Bergel et al., 2016). It can be stated that in the SGGW campus the part-time students do not use such quantity of water as the full-time students on weekdays, moreover many students from the student dormitories come back home on weekends. The highest consumption occurs on Tuesdays probably due to the fact that there are most people in the dormitories in those days because the class schedules are often made in such way that Monday or Friday is a day off.

While analyzing the hourly water consumption, two peaks a day can be noticed (Fig. 4): the mid-day peak occurs between 11 a.m. and 1 p.m., the midnight peak – between 11 p.m. and 1 a.m.. In average, the lowest water consumption falls at 5 a.m. and the highest – at 12 p.m.

The investigations carried out for recent years show that for the dwelling houses located both on rural and urban areas two peaks of daily water consumption are observed. There is no distinct mid-day peak observed. On the urban areas, the daily water consumption peaks occur in the morning (7–10) and evening hours (20–23) (Podwójci, 2011; Kępa et al., 2013), whereas on rural areas the daily water consumption peaks occur slightly earlier (Bergel and Kaczor, 2007), which

**Table 4.** Variability of hourly and daily water consumption in the WULS campus for each month in the academic year of 2012/2016

| Academic year/ month | | Hourly water consumption | | Std. deviation | Median | Factor $N_h$ | Daily water consumption | | Std. deviation | Median | Factor $N_d$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Range | Average | | | | Range | Average | | | |
| | | ($m^3 \cdot h^{-1}$) | | - | - | - | ($m^3 \cdot d^{-1}$) | | - | - | - |
| 12/13 | 10 | 6.1- 65.9 | 32.8 | 13.8 | 34.2 | 1.45 | 587.8 – 992.3 | 787 | 132.3 | 816.1 | 1.26 |
| 13/14 | | 4.5 – 59.1 | 27.2 | 13.5 | 29.8 | 1.47 | 523.8 – 867.9 | 697.7 | 114.3 | 757.0 | 1.24 |
| 14/15 | | 4.2 – 68.3 | 28.2 | 14.8 | 28.3 | 1.89 | 354.7 – 866.5 | 677.6 | 137.6 | 729.3 | 1.28 |
| 15/16 | | 6.0 – 64.4 | 29.9 | 6.3 | 13.6 | 1.47 | 282.6 – 922.2 | 716.8 | 150.6 | 768.2 | 1.29 |
| 12/13 | 11 | 5.7 – 65.4 | 31.4 | 14.8 | 33.7 | 1.53 | 292 – 1029.4 | 754.4 | 184.8 | 821.7 | 1.36 |
| 13/14 | | 5.7 – 64.9 | 26.5 | 13.6 | 29.0 | 1.76 | 253.0 – 885.8 | 686.0 | 170.4 | 757.4 | 1.29 |
| 14/15 | | 3.4 – 73.9 | 26.0 | 14.7 | 25.6 | 1.77 | 190.8–1001.3 | 623.9 | 178.1 | 645.7 | 1.60 |
| 15/16 | | 4.8 – 65.3 | 25.5 | 5.8 | 13.0 | 1.76 | 284.2 – 801.6 | 612.2 | 140.3 | 667.0 | 1.31 |
| 12/13 | 12 | 6.4 – 64.8 | 27.6 | 13.8 | 25.9 | 1.42 | 216.8 – 943.4 | 663.2 | 204.1 | 668.0 | 1.42 |
| 13/14 | | 5.5 – 60.2 | 23.6 | 13.6 | 24.3 | 1.48 | 174.2 – 880.9 | 583.5 | 227.5 | 618.1 | 1.51 |
| 14/15 | | 4.1 – 71.3 | 26.9 | 44.1 | 22.2 | 1.54 | 312.6 – 811.5 | 644.4 | 150.9 | 703.3 | 1.26 |
| 15/16 | | 4.1 – 51.1 | 20.9 | 8.3 | 12.6 | 1.48 | 155.0 – 726.3 | 501.9 | 199.8 | 529.5 | 1.45 |
| 12/13 | 1 | 9.3 – 55.2 | 32.0 | 11.4 | 32.8 | 1.50 | 502.4 – 883.4 | 767.7 | 104.6 | 810.8 | 1.15 |
| 13/14 | | 4.0 – 56.1 | 25.5 | 11.9 | 27.7 | 1.53 | 387.8 – 798.0 | 647.4 | 131.7 | 718.8 | 1.23 |
| 14/15 | | 3.9 – 68.2 | 25.3 | 14.2 | 23.4 | 1.57 | 320.42–802.7 | 608.1 | 130.2 | 673.2 | 1.32 |
| 15/16 | | 7.0 – 68.2 | 32.6 | 9.3 | 13.9 | 1.53 | 244.0 – 1148.0 | 782.3 | 223.2 | 823.0 | 1.47 |
| 12/13 | 2 | 6.6 – 52.5 | 25.2 | 9.9 | 24.2 | 1.54 | 465.6 – 820.2 | 604.6 | 100.3 | 582.1 | 1.36 |
| 13/14 | | 3.6 – 49.1 | 22.3 | 9.0 | 24.2 | 1.50 | 406.4 – 740.6 | 554.9 | 80.8 | 542.8 | 1.33 |
| 14/15 | | 5.7 – 63.3 | 17.9 | 10.9 | 11.5 | 1.60 | 289.7 – 815.9 | 530.4 | 90.8 | 494.8 | 1.20 |
| 15/16 | | 8.5 – 59.3 | 28.2 | 5.0 | 10.1 | 1.50 | 521.0 – 875.0 | 677.9 | 119.1 | 641.0 | 1.29 |
| 12/13 | 3 | 7.9 – 56.4 | 29.5 | 13.6 | 33.1 | 1.6 | 228.4 – 848.7 | 708.7 | 159.9 | 781.7 | 1.2 |
| 13/14 | | 4.1 – 63.7 | 26.4 | 12.7 | 28.0 | 1.76 | 476.2 – 823.1 | 668.5 | 100.8 | 720.6 | 1.23 |
| 14/15 | | 7.5 – 65.9 | 28.6 | 12.9 | 29.4 | 1.87 | 465.9 – 847.2 | 687.3 | 108.6 | 735.6 | 1.23 |
| 15/16 | | 6.4 – 59.6 | 30.1 | 8.1 | 13.6 | 1.76 | 312.0 – 937.0 | 722.7 | 195.2 | 782.0 | 1.30 |
| 12/13 | 4 | 6.2 – 69.3 | 28.8 | 13.5 | 28.8 | 1.73 | 254.6 – 962.1 | 692 | 162.2 | 635.4 | 1.39 |
| 13/14 | | 5.1 – 64.7 | 25.7 | 12.9 | 25.0 | 1.76 | 256.2 – 882.3 | 643.3 | 171.9 | 665.5 | 1.37 |
| 14/15 | | 7.4 – 69.5 | 26.2 | 14.2 | 28.0 | 1.77 | 260.6–789.2 | 628.3 | 188.3 | 722.1 | 1.26 |
| 15/16 | | 9.0 – 87.4 | 35.6 | 6.2 | 14.2 | 1.76 | 540.0 -1155.0 | 854.2 | 149.1 | 914.5 | 1.35 |
| 12/13 | 5 | 7.2 – 75.3 | 30.4 | 13.9 | 30.4 | 1.86 | 307 – 973.3 | 730.1 | 191.2 | 795.6 | 1.33 |
| 13/14 | | 5.0 – 63.6 | 26.6 | 13.2 | 28.6 | 1.82 | 368.9 – 835.3 | 679.0 | 135.4 | 749.6 | 1.23 |
| 14/15 | | 8.3 – 68.5 | 27.6 | 13.0 | 26.5 | 1.81 | 329.1 – 908.1 | 663.2 | 159.1 | 693.1 | 1.37 |
| 15/16 | | 6.6–103.3 | 37.3 | 8.7 | 15.1 | 2.00 | 506.0 -1320.0 | 895.8 | 207.7 | 912.0 | 1.47 |
| 12/13 | 6 | 9.0 – 74.3 | 32.9 | 12.2 | 32.4 | 1.74 | 597.6 – 1026.6 | 790.5 | 102.5 | 815.7 | 1.3 |
| 13/14 | | 4.2 – 61.5 | 27.6 | 12.8 | 28.0 | 1.57 | 497.6 – 942.3 | 699.2 | 120.9 | 732.9 | 1.35 |
| 14/15 | | 7.9 – 83.9 | 29.4 | 13.2 | 28.6 | 2.15 | 370.8 – 927.8 | 705.6 | 137.9 | 727.9 | 1.31 |
| 15/16 | | 5.4 – 91.5 | 36.3 | 11.8 | 22.0 | 1.57 | 386.0 -1190.0 | 870.5 | 283.1 | 1023.0 | 1.37 |
| 12/13 | 7 | 2.3 – 65.1 | 27.6 | 10.7 | 25.3 | 1.8 | 487.1 – 868.4 | 661.6 | 98 | 667.3 | 1.31 |
| 13/14 | | 3.1 – 56.1 | 20.0 | 10.6 | 22.3 | 1.85 | 317.0 – 679.6 | 520.3 | 106.6 | 528.6 | 1.31 |
| 14/15 | | 5.6 – 80.2 | 24.2 | 13.9 | 20.4 | 1.78 | 300.7–886.1 | 579.8 | 151.7 | 567.8 | 1.53 |
| 15/16 | | 13.2–63.5 | 30.8 | 4.1 | 9.6 | 1.85 | 529.0 – 957.0 | 740.1 | 99.5 | 737.0 | 1.29 |
| 12/13 | 8 | 4.3 – 46.3 | 17.8 | 8.4 | 16.7 | 2.36 | 314.6 – 545.4 | 427.2 | 68.8 | 420.1 | 1.28 |
| 13/14 | | 3.3 – 68.0 | 16.0 | 9.7 | 13.4 | 1.82 | 263.9 – 568.1 | 404.2 | 74.3 | 409.3 | 1.41 |
| 14/15 | | 6.3 – 84.1 | 24.2 | 14.1 | 19.9 | 1.35 | 330.1 – 1492.9 | 581.2 | 222.5 | 549.9 | 2.57 |
| 15/16 | | 11.3–58.7 | 26.4 | 3.4 | 8.1 | 1.83 | 501.00–852.00 | 632.9 | 81.6 | 638.0 | 1.35 |
| 12/13 | 9 | 5.1 – 47.2 | 19.4 | 7.4 | 21.1 | 1.75 | 346.5 – 647.9 | 470.6 | 73.7 | 453.1 | 1.38 |
| 13/14 | | 2.4 – 59.9 | 18.8 | 10.1 | 21.0 | 1.92 | 299.6 – 719.2 | 482.1 | 96.4 | 467.3 | 1.49 |
| 14/15 | | 5.0 – 57.3 | 20.5 | 9.1 | 19.5 | 2.08 | 371.7 – 662.0 | 491.9 | 79.2 | 502.2 | 1.35 |
| 15/16 | | 7.4 – 70.2 | 29.7 | 4.8 | 9.3 | 1.92 | 516.00–988.00 | 711.6 | 115.6 | 682.0 | 1.39 |

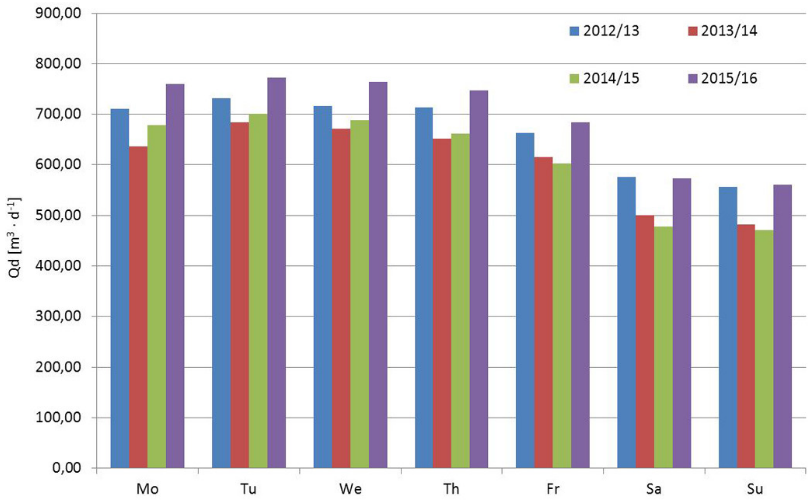


**Fig. 3.** Average water consumption per day for the WULS campus for each day of week in the academic years of 2012/2016

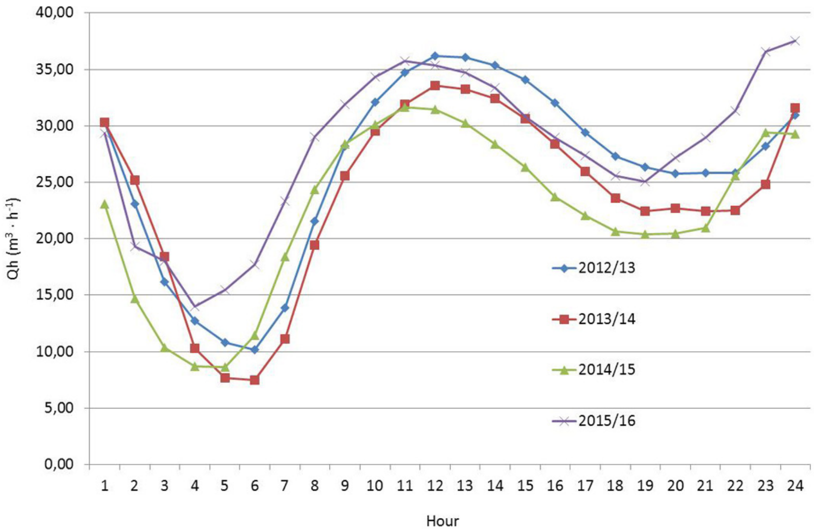


**Fig. 4.** Average water consumption per hour for the WULS campus in the academic years of 2012/2016

is probably connected with a specificity of functioning pertaining to rural farms and necessity of commuting to work. It can be observed that the water consumption structure is more stabilized in weekends. There is no distinct morning peak observed – it starts later and joins together with the mid-day one. A similar trend can be observed if one analyzes the water consumption in the SGGW campus. The water consumption structure in the campus, both in weekdays and in weekends, is closer to the weekend structure of water consumption in dwelling houses – with the exception of later occurrence of the evening peak.

Table 5 presents the variability range and mean values of daily water consumption for individual months with division into weekdays and weekends. A part of the water consumption, however, is generated by the dormitories for which separate measurements were not carried out; thus – for the sake of data analysis – it was assumed that the normative specific water consumption for these buildings, equals 100 $dm^3$ per student per day (Regulation of 2002, No 8 item 70). For the number of accommodation places in the SGGW campus – 3460 – it yields in average daily water consumption equal to ca. 346 $m^3 \cdot d^{-1}$. The accommodation places are used all-year-round, also in holidays. After the reduction of the average daily water consumption by the estimated consumption in the dormitories, the water consumption in other buildings was determined with division into weekdays and weekends. Relating this consumption to the number of full-time and part-time students, one can calculate the monthly unit factors of water consumption. These factors for the years 2012–16 amount in average 24.5 $dm^3 \cdot d^{-1}$ for

**Table 5.** Variability of daily water consumption in the WULS campus in weekdays and weekends for each month in the academic years of 2012/2016

| Academic year/month | | Daily water consumption | | | | Average water consumption in the dorms | Specific water consumption in the other buildings | |
|---|---|---|---|---|---|---|---|---|
| | | Weekdays | | Weekends | | | | |
| | | Range | Average | Range | Average | | Weekdays | Weekends |
| | | ($m^3 \cdot d^{-1}$) | | ($m^3 \cdot d^{-1}$) | | ($m^3 \cdot d^{-1}$) | $dm^3 \cdot (stud.\ d)^{-1}$ | |
| 12/13 | 10 | 598.4 – 992.3 | 850.5 | 587.8 – 726.9 | 643.9 | 346.0 | 35.9 | 26.4 |
| 13/14 | | 524.5 – 867.9 | 745.0 | 523.8 – 657.5 | 561.7 | 346.0 | 27.9 | 19.6 |
| 14/15 | | 354.7 – 866.5 | 738.5 | 466.7 – 537.8 | 446.6 | 346.0 | 27.1 | 15.7 |
| 15/16 | | 611.1 – 922.2 | 795.4 | 282.6 – 581.7 | 524.6 | 346.0 | 30.7 | 18.0 |
| 12/13 | 11 | 292.0 – 1029.4 | 811.0 | 386.3 – 719.1 | 532.3 | 346.0 | 33.1 | 22.4 |
| 13/14 | | 261.6 – 885.8 | 759.8 | 253.0 – 603.7 | 513.9 | 346.0 | 28.9 | 15.2 |
| 14/15 | | 450.4 – 1001.3 | 716.3 | 190.8 – 554.0 | 439.1 | 346.0 | 25.5 | 9.3 |
| 15/16 | | 440.7 – 801.6 | 684.5 | 284.1 – 508.0 | 443.5 | 346.0 | 23.1 | 9.8 |
| 12/13 | 12 | 216.8 – 943.4 | 717.0 | 242.8 – 696.4 | 491.0 | 346.0 | 26.4 | 17.2 |
| 13/14 | | 174.2 – 880.9 | 642.1 | 238.1 – 651.8 | 490.7 | 346.0 | 20.7 | 13.1 |
| 14/15 | | 312.6 – 811.5 | 759.9 | 322.6 – 683.2 | 338.4 | 346.0 | 25.9 | 10.5 |
| 15/16 | | 161.0 – 726.3 | 538.6 | 155.1 – 529.5 | 396.3 | 346.0 | 13.1 | 5.1 |
| 12/13 | 1 | 502.4 – 883.4 | 802.3 | 582.9 – 745.5 | 593.9 | 346.0 | 30.1 | 28.5 |
| 13/14 | | 389.8 – 798.0 | 685.7 | 387.8 – 616.0 | 537.1 | 346.0 | 23.8 | 17.3 |
| 14/15 | | 356.2 – 802.7 | 642.1 | 320.4 – 673.1 | 525.0 | 346.0 | 20.4 | 17.8 |
| 15/16 | | 244.7 – 1148.2 | 848.1 | 280.4 – 923.4 | 644.0 | 346.0 | 34.3 | 30.0 |
| 12/13 | 2 | 531.7 – 820.2 | 635.7 | 465.6 – 596.1 | 517.8 | 346.0 | 20.6 | 15.2 |
| 13/14 | | 461.8 – 740.6 | 579.6 | 406.4 – 603.2 | 493.2 | 346.0 | 16.3 | 13.3 |
| 14/15 | | 430.3 – 815.9 | 550.2 | 289.7 – 612.4 | 480.9 | 346.0 | 14.1 | 13.4 |
| 15/16 | | 552.7 – 875. 2 | 717.4 | 521.8 – 655.9 | 574.1 | 346.0 | 25.3 | 23.0 |
| 12/13 | 3 | 383.8 – 848.7 | 779.4 | 228.4 – 708.9 | 591.9 | 346.0 | 28.1 | 19.5 |
| 13/14 | | 635.7 – 823.7 | 733.3 | 476.2 – 559.9 | 531.6 | 346.0 | 27.1 | 16.8 |
| 14/15 | | 652.9 – 851.2 | 534.3 | 465.9 – 590.5 | 480.9 | 346.0 | 13.0 | 13.4 |
| 15/16 | | 324.3 – 937.0 | 763.9 | 312.4 – 724.0 | 592.1 | 346.0 | 28.5 | 24.8 |
| 12/13 | 4 | 254.6 – 962.1 | 726.4 | 548.0 -659.6 | 538.6 | 346.0 | 27.1 | 23.0 |
| 13/14 | | 326.85 – 882.3 | 673.6 | 256.2 – 818.7 | 560.1 | 346.0 | 22.9 | 19.4 |
| 14/15 | | 247.3 – 983.0 | 720.6 | 231.4 – 730.6 | 510.7 | 346.0 | 25.8 | 16.4 |
| 15/16 | | 639.1 – 1155.3 | 928.8 | 540.0 – 764.0 | 680.1 | 346.0 | 39.8 | 33.6 |
| 12/13 | 5 | 307.0 – 973.3 | 756.1 | 326.3 – 945.7 | 627.2 | 346.0 | 26.9 | 27.4 |
| 13/14 | | 380.6 – 835.3 | 736.7 | 368.9 – 645.2 | 538.0 | 346.0 | 27.3 | 17.4 |
| 14/15 | | 351.3 – 908.1 | 745.2 | 329.1 – 568.4 | 492.3 | 346.0 | 27.5 | 14.6 |
| 15/16 | | 507.0 – 1320.0 | 962.6 | 506.1 – 846.7 | 743.3 | 346.0 | 41.4 | 40.0 |
| 12/13 | 6 | 699.8 – 1026.6 | 845.8 | 597.6 – 789.1 | 679.9 | 346.0 | 35.6 | 29.6 |
| 13/14 | | 499.3 – 942.3 | 755.1 | 497.6 – 650.1 | 568.7 | 346.0 | 28.6 | 20.2 |
| 14/15 | | 370.8 – 927.8 | 751.3 | 460.3 – 682.0 | 579.9 | 346.0 | 27.9 | 23.3 |
| 15/16 | | 420.3 – 1190.0 | 656.6 | 482.3 – 1106.6 | 600.4 | 346.0 | 21.2 | 25.6 |
| 12/13 | 7 | 573.7 – 868.4 | 700.5 | 487.1 – 667.8 | 549.8 | 346.0 | 25.2 | 18.0 |
| 13/14 | | 404.5 – 679.6 | 564.0 | 317.0 – 481.8 | 394.4 | 346.0 | 15.2 | 4.4 |
| 14/15 | | 425.2 – 886.1 | 629.9 | 300.7 – 634.4 | 436.0 | 346.0 | 19.6 | 9.0 |
| 15/16 | | 648.3 – 957.2 | 788.1 | 529.4 – 739.1 | 651.1 | 346.0 | 30.2 | 30.7 |
| 12/13 | 8 | 302.7 – 881.3 | 446.9 | 314.6 – 642.7 | 308.7 | 346.0 | 10.2 | 9.4 |
| 13/14 | | 325.7 – 568.1 | 441.2 | 263.9 – 374.4 | 326.4 | 346.0 | 13.7 | 4.6 |
| 14/15 | | 428.8 – 1492.9 | 672.5 | 330.1 – 447.8 | 389.4 | 346.0 | 22.5 | 4.3 |
| 15/16 | | 513.2 – 851.7 | 664.5 | 501.2 – 610.3 | 554.5 | 346.0 | 21.7 | 21.0 |
| 12/13 | 9 | 432.1 – 647.9 | 482.5 | 346.5 – 551.4 | 423.0 | 346.0 | 10.3 | 6.8 |
| 13/14 | | 418.8 – 719.2 | 517.4 | 299.6 – 436.7 | 384.8 | 346.0 | 12.0 | 3.5 |
| 14/15 | | 440.7 – 662.0 | 528.3 | 371.7 – 430.0 | 390.8 | 346.0 | 12.6 | 4.5 |
| 15/16 | | 578.3 – 988.4 | 751.6 | 516.3 – 678.3 | 601.6 | 346.0 | 27.7 | 25.7 |

a full-time student as well as 17.7 $dm^3 \cdot d^{-1}$ for a part-time student (Table 6). They are comparable to the specific value given in Table 1 for universities with laboratories.

The average unit factors of water consumption during the educational period, i.e. from October to June, are 26.6 and 19.7, respectively, and in holidays 18.4 and 11.8. The highest average specific water consumption was observed for the May of 2016 and it was equal to 41.4 $dm^3$. It is 66% higher than the value given in the directive (Regulation of 2002, № 8 item 70).

The unit factors of water consumption in the campus are significantly lower than those for households. The average specific consumption in households provided by Central Statistical Office (GUS, 2016) amounts to 88.22 $dm^3$ per capita per day. According to the investigations, the specific water consumption is diversified –in the Brzesko district – 46.7 $dm^3$ per capita per day (Pawełek et al., 2015), the town of Kańczuga – 49.85–66.34 $dm^3$ per capita per day (Studziński et al., 2012), towns Oborniki Śląskie, Bystrzyca Kłodzka and Klodzko, located at the lower Silesian Voivodeship 100.3–116.3 $dm^3$ per capita per day (Malczewska and Szeląg, 2016), multi-family houses in Cracow – 54.7–72.4 $dm^3$ per capita per day (Bugajski, 2009), or Toruń – 98 $dm^3$ per capita per day (Pasela and Gorączko, 2013). single-family houses in malopolskie province, in Włostowice (typical rural household) – 86.1 $dm^3$ per capita per day and in Stanisławice (typical urban household) – 129.9 $dm^3$ per capita per day (Bergel and Kaczor, 2007). In 6 rural farms in Gorlice and Ząbkowice Śląskie, the water consumption fell within the range 110–180 $dm^3$ per capita per day, even higher consumption was observed in summer (Pawęska et al., 2013). The investigations in 43 single-family houses in Koszalin showed the average specific yearly water consumption equal to 129.3 $dm^3$ per capita per day but differences were observed which can result from demographic or economical factors (Żuchowicki and Gawin, 2013). The specific water consumption in households increases along with the number of inhabitants in a town and amounts ca. 100–120 $dm^3$ per capita per day (Sawicka-Siarkiewicz and Gmitrzuk, 2010). The specific water consumption in Poland is relatively low if compared to other countries. In the rich Dubai, the water consumption per inhabitant amounts ca. 500 $dm^3$ per capita per day. It is lower in Europe – equal to 270 $dm^3$ per capita per day in Spain, 188 $dm^3$ per capita per day in Sweden, 129 $dm^3$ per capita per day in Germany (Kuczyński and Żuchowicki, 2010).

However, the investigations carried out in a primary school in Bologna showed a water consumption which is comparable to the one in the campus and amounts to 18 $dm^3$ per capita per day (Farina et al., 2011). The analysis of utility companies in 6 urbanized areas also showed a similar water consumption in day care centers for children 8–36 $dm^3$ per capita per day and offices 33–49 $dm^3$ per capita per day (Sawicka-Siarkiewicz and Gmitrzuk, 2010).

## CONCLUSIONS

Due to the specificity of the activities related to universities, the distribution of water consumption in such units can be different from other users of water-pipe network. There is no information in the literature concerning the water demands in universities. Instead, many publications can be found concerning the water consumption in single- or multi-family houses located in towns of different size, as well as the information on the water consumption in selected utility buildings.

The paper determined the structure of water consumption for the periods being analyzed. The unit factors of water consumption were

**Table 6.** Average unit water consumption indicators in academic years 2012/16

| Period | Students | Academic year | | | |
|---|---|---|---|---|---|
| | | 12/13 | 13/14 | 14/15 | 15/16 |
| All year | Full-time | 25.8 | 22.0 | 22.0 | 28.1 |
| | Part-time | 20.3 | 13.7 | 12.2 | 23.9 |
| The period of study October – June | Full-time | 29.3 | 24.8 | 23.4 | 28.6 |
| | Part-time | 23.2 | 16.9 | 14.6 | 23.3 |
| Holiday period July – September | Full-time | 15.2 | 13.6 | 18.2 | 26.5 |
| | Part-time | 11.4 | 4.2 | 5.9 | 25.8 |
| Average for 2012/16 | Full-time | 24.5 | | | |
| | Part-time | 17.7 | | | |

calculated as well as hourly and daily peaking factors were determined. The following conclusions can be drawn on the basis of the conducted work:

1. The average daily water consumption in the SGGW campus in the academic years 2012–2016 amounted to 656 $m^3 \cdot d^{-1}$ and the maximum daily consumption – 1493 $m^3 \cdot d^{-1}$. In the pertinent day, the maximum hourly consumption amounted 84.0 $m^3 \cdot h^{-1}$.
2. The highest consumption was observed on Tuesdays, the lowest – on Sundays. The average Tuesday consumptions are higher than the Sunday consumptions by 40%. The weekly cycle differs from those provided in the literature for dwelling houses where a higher consumption is observed in weekends and lower in weekdays.
3. Two peaks of the hourly water consumption occur in a day. The midday peak occurs between 11 a.m. and 1 p.m., the midnight peak – between 11 p.m. and 1 a.m. The hourly structure of the water consumption in the SGGW campus is close to the weekend structure in multi-family dwelling houses with exception of later evening peak.
4. Without taking into account the water consumption in the dormitories, the average consumption in the period of realization of didactic classes amounted to 26.6 $dm^3 \cdot d^{-1}$ for a full-time student and 19.7 $dm^3 \cdot d^{-1}$ for a part-time student. These factors are lower in holidays and equal to 18.4 and 11.8 $dm^3 \cdot d^{-1}$, respectively. These factors are comparable or lower than the factor recommended for design which amounts 25 $dm^3 \cdot d^{-1}$.
5. In the period being analyzed, the average daily ($N_d$) and hourly ($N_h$) peaking factors amounted to 1.36 and 1.71, respectively. These factors are comparable to the values presented in the literature for multi-family dwelling houses.

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