

## Consumption and Savings of Drinking Water in Selected Objects

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### ABSTRACT

Water is essential to the proper functioning of kindergartens and schools. Nevertheless, water consumption in public facilities is usually high, often exceeding the average household water consumption. Recently, increasing pressure on this valuable and depletable natural resource has been noticed and, therefore, it is interesting to study the water consumption in kindergartens and the possibilities of water saving. The present work examined 6 kindergarten facilities in Kyjov, Czech Republic, where the equipment has been enhanced with the faucet water saving technology. The work analyzed the impact of the equipment on the reduction of water consumption as a raw material and on the financial and economic profitability. The results were estimated based on the variation of two parameters such as average daily water consumption and demand per person. The experiment showed that installing the savers resulted in water savings ranging from 8% to 18.7% for average daily consumption and from 10.02% to 23.2% for per capita demand.

**Keywords:** Water savers, Water consumption, Profitability analysis, Water use in kindergarten

### INTRODUCTION

Water is not only a necessity of life but also an essential natural resource that is required in producing food, energy, industrial materials, services, etc. (Chai et al., 2020). The availability of water and supplies of drinking water have become a global problem to the rapidly growing population and its concentration in some regions (Marinoski et al., 2018). Long spells of drought and increasing areas without a sufficient water supply have recently also been concerning the Czech Republic (CR). Water resources are diminishing, which particularly applies to the groundwater in the Czech territory. Urbanized areas exhibit ever increasing surfaces reinforced with concrete and asphalt, which hamper water infiltration into the

soil and promote extinction of natural drainage points (Hamel et al., 2013; Ren et al., 2020; Boas et al., 2018; Vijayan et al., 2020). This leads to reduced rainwater retention in the landscape, and hence to more frequently occurring floods alternated by long periods of drought (Zheng et al., 2021). The global consumption of water (both drinking water and service water) is high, and the world may face its deficiency in the future (Sadr et al., 2016; Feizizadeh et al., 2021). In the Czech Republic, more than a half of currently used water comes from surface reservoirs. Over the last ten years, the availability of drinking water markedly increased worldwide. In the period from 2000 to 2015, the percentage of people with access to safely managed drinking water increased from 61.4% to 71.2%. Although the trend

is encouraging, there are still great differences persisting between the rich and poor countries (Feizizadeh et al., 2021). However, frequent differences in water availability exist within individual countries, among metropolises and scarcely inhabited regions (De Clerq et al., 2018). The reserves of drinking water are limited, and in some parts of the world such as northern and western China, northern and eastern India, North Africa and northern parts of Middle East an urgent risk exists that the drinking water resources will become depleted in the future (Crellin, 2018). The satellite research conducted by NASA (Richey et al., 2015) indicates that dry regions become further dried out due to the climate change and human activities while wet regions are recording further increase of water quantities.

Approximately 70% of global water consumption are used in agriculture (Shabbir et al., 2014; He et al., 2021; Wu et al., 2021), 20% are used in industries and only 10% are consumed in households. Nevertheless, in industrial countries such as Belgium, the consumption of water in this industrial sector may exceed 80% of total consumption (Water consumption statistics, 2019). The data about the consumption of water in households worldwide are not unified. According to OECD (Safe Drinking Water Foundation, 2019), the USA consumption per capita is 335 l/day. De Dardel (2018) mentions the per capita consumption of 475 l/day, which is a substantially higher value than that reported by OECD. By contrast, the World Business Council for Sustainable Development claims only 215 l/day. Thus, it can be stated that the criteria for assessing the household water consumption are not given clearly and it is therefore difficult to compare the data as they greatly differ from individual sources.

In CR, the water consumption in households is ca. 65%, which is a value considerably different than the world average (10%). The remaining 35% are used in industries, primarily for cooling, and for irrigation of fields in agriculture (Kriš, 2006). In 2018, the daily water consumption per capita amounted to 133.5 l, out of which 89.2 l were used in households. Since the last year, the water consumption increased by 0.6 l and the historically lowest water consumption (87.1 l) was recorded in 2013. In the 1980s, the values were around 170 l per day, which is much more than today. However, it was greatly due to a different mentality of the then government. The household

water demand consists of more components. On the basis of the average values and the method of use, an overview (Table 1) was constructed of minimum water consumption values (Kriš, 2006).

A scientific study published by the British organization Energy Saving Trust (Sellwood, 2013) informs that the highest household consumption corresponded to the use of tap water and showering which represented 29% and 25% of total consumption. Flushing of toilets recorded a high consumption, too (22%). Water leakage in households is a normal phenomenon and amounts to about 8% of total water consumption. Water can leak anywhere within the internal distribution circuit of the consumer. Leakages often occur due to poorly maintained or obsolete valves, defective seals or flowing toilettes. Generally, dripping taps can lose between 3–30 litres per day, leakage from toilet cisterns can range from 10 litres per day for invisible leaks to 340 litres per day or more for the leaks large enough to be seen and/or have an audible refilling sound. Mayer et al. (1999) found out in their Residential End Uses of Water Study that leakages constitute 13.7% of the indoor per capita consumption of a single residential house in North America. Therefore, identifying internal leaks enables customers to fix the problem, by which they can save both water and money (Seyoum et al., 2017).

The price of water has been rapidly increasing in CR in the last ten years. In 2000, average water and sewage rates ranged around 1.15 EUR/m<sup>3</sup>; the value increased to 3.46 EUR/m<sup>3</sup> in 2019. The growing price of water is the main reason for improving the water saving technologies. The best and cheapest way to save drinking water with immediate return is a change of habits. Recent studies have reported that the water conservation behaviours may pose a significant influence on water conservation quantities (Millock and Nauges, 2010; Randolph and Troy, 2008; Russell

**Table 1.** Per capita water consumption in households in litres per day (Kriš, 2006)

Water consumption	per capita in l/day
Direct consumption, cooking	5
Personal hygiene	5 – 10
Showering	Max. 50
Bathing	150 – 250
WC	30 – 50
Cleaning and laundry	5 – 20

and Fielding, 2010; Lee and Tansel, 2013). Another way to save water is seen in water saving appliances and fittings which control the outflow of water from the piping. In recent years, potable water plumbing design and operations have transitioned towards energy and water saving, low-flow devices (Brazeau and Edwards, 2013; Salehi et al., 2018). Low-flow faucets have resulted in flow reductions by 30% (Salehi et al., 2018). Using these devices, the highest water savings in households can be achieved in showers, sinks, toilets and washing machines (Gao et al., 2017; Fidar et al., 2016). One of the most common examples may be the toilets with double flushing: intense and mild (6 and 3 liters as a standard). These systems allow reducing water consumption in toilets by more than 50% but they depend on the correct use by people. The largest savings can be reached in showers which are responsible for about a third of total water consumption in households. Installation of regulators or water saving shower heads may allow reducing the flow rate from 25 litres to 6 – 14 litres per minute, which is 50% of saved water and energy, or even more, depending on the used head type or regulator adjustment. Water savings amount to ca. 40 – 50% (Marinoski et al., 2018).

The use of water savers makes it possible to reduce the consumption of water from taps (Salehi et al., 2018). The taps can be built-in or installed at the end of faucets (Fig. 1). The devices mix the flowing water with air, which making it feel like there is a larger water flow. It also has a stable water pressure owing to which the most of people do not notice any difference in the amount of water coming out of aerated faucet (Umesh and Sitaram, 2014). Nevertheless, aerators come in various designs that not only reduce water consumption but also reduce the accumulation of debris in the pipe at the end section. Comprehensive parameters such as flow rate and pressure range, among others, need to be considered when creating an aerator design so that the aerator can realize its full potential (Hasnol and Zaharuddin, 2020). Commercial faucet aerator usually has parts such as steel body, water-inlet, Wire meshes & other internal geometry, restrictions (for stream-lining of flow). In addition to the air inlet, the number of plastic restrictors is an important geometric parameter (Umesh and Sitram, 2014). Variations in the cross-section or shape of fittings can cause fluid flow disturbances and thus pressure losses (Kalenik et al., 2020).

The return of water savers is nearly immediate as their cost is ca. 7,69 EUR. They represent one of the cheapest and most efficient ways for reducing water consumption (Plotěný and Bartoník, 2015). The only disadvantage may be a longer time of filling bottles and similar vessels, caused by the reduced flow rate.

While analyzing the above-mentioned specifics of the devices, it was noted that there are gaps in the literature regarding the water demand in kindergartens (in which pupils do not pay attention to its excessive consumption) and how it varies from season to season. The aim of this work was to determine the economic and environmental effects of new technical implementations adopted for water savings (water-efficient appliances) to reduce the water consumption in Czech Republic schools.

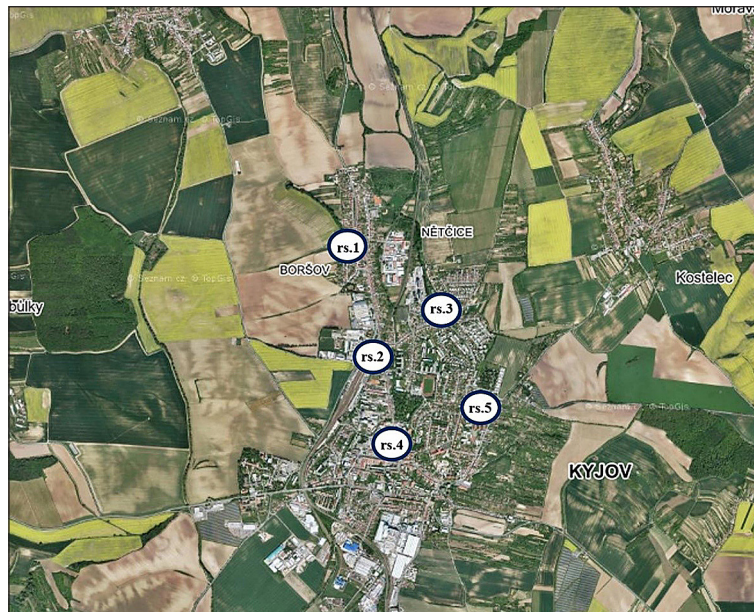
## MATERIALS AND METHODS

### Characteristics of explored objects

The explored objects were located in the town of Kyjov (cadastral area 29.88 km<sup>2</sup>). In the cadastral area of the city, there are six kindergartens, four elementary schools and two special schools. Five research sites registered as kindergartens (MŠ) were selected for the study, i.e.: MŠ Boršovská (rs.1), MŠ Nádražní (rs.2), MŠ Za stadionem (rs.3), MŠ Střed (rs.4), MŠ of Dr.Joklík (rs.5) and ZŠ of Dr.Joklík (rs.6). Their location is shown in Figure 1 below.

The address of rs.1 is Boršovská 3241, Kyjov. It has one class with a capacity of 25 children and three adult employees. The building is used by 28 persons. In the kindergarten, 10 water savers were installed on all faucets on 11 December 2018. The address of rs.2 is Nádražní 829, Kyjov. Altogether, it has 4 classes. The total number of children in the school is 100 and there are 15 adult employees. The object is used by 115 persons. In the kindergarten, 32 water savers were installed on all used faucets on 11 December 2018. The address of rs.3 is Za Stadionem 1224/27, Kyjov. The kindergarten has 3 classes with a total capacity of 75 children, which is full, and there are 11 adult employees. The object is used by 86 persons. In the MŠ building, 22 water savers were installed on all used faucets on 11 December 2018. The address of rs.4 is Mezi Mlaty 811/2, Kyjov. The kindergarten has 4 classes with a total capacity of





**Figure 1.** Localization of research objects in the town of Kyjov (mapy.cz, modified, 2021)

104 children and 13 adult employees. The object capacity is full and the number of persons using water in the school is 117. In the MŠ building, 25 water savers were installed on all used faucets on 10 December 2018. The address of Elementary school and Kindergarten (ZŠ and MŠ) of rs.5 is sídliště U Vodojemu 1261, Kyjov. The object consists of two buildings (ZŠ and MŠ), separated with a fence. MŠ operates 4 classes with 96 children and 13 adult employees. ZŠ has currently 440 pupils and 48 employees. The object is used by 488 persons. In the buildings of ZŠ and MŠ, 42 water savers were installed on all faucets on 11 December 2018.

In December 2018, all faucets in the research objects were provided with water savers. The water savers with the patented technology allow reducing flow rate by up to 40% (Marionski et al., 2018). Savings are not just about water consumption itself, but also about the energy needed to heat the water. To this date, total water consumption in  $m^3$  was recorded for the period since the water meter installation. The objects undertook to record the water consumption in  $m^3$ . On the basis of the data, the saving of drinking water in the objects before the installation of water savers were calculated, which served for economic assessment and evaluation of the success of measures. The water savings in the respective objects were calculated by comparing average daily water consumption in the period before the installation of

water savers and average daily water consumption after their installation.

### Types of water savers used

Three types of water savers were used in the research objects (Fig. 2). The first one (a) is the dispenser with internal thread and sleeve size 22x1 mm, dedicated mostly to kitchen faucets. The second one (b) is an external thread dispenser with a slightly larger sleeve (size 24x1 mm), used mainly in bathroom faucets but also in kitchen faucets. The third saver (c) is installed between the shower faucet and the hose in bathrooms. Aerators have a special, patented, tapered grid that allows mixing water with air. At the bottom of the dispenser there is an opening through which air enters the accumulator and a reasonable amount of water flows out of the accumulator. The saver has a built-in constriction that restricts the flow of water, thus guaranteeing reduced water consumption.

### Calculation average daily water consumption

Average daily water consumption (ADC) ( $m^3/day$ ) was calculated according to the equation:

$$ADC = \frac{Q}{N} \quad (1)$$

where:  $Q$  – total consumption of water,  $m^3$ ;

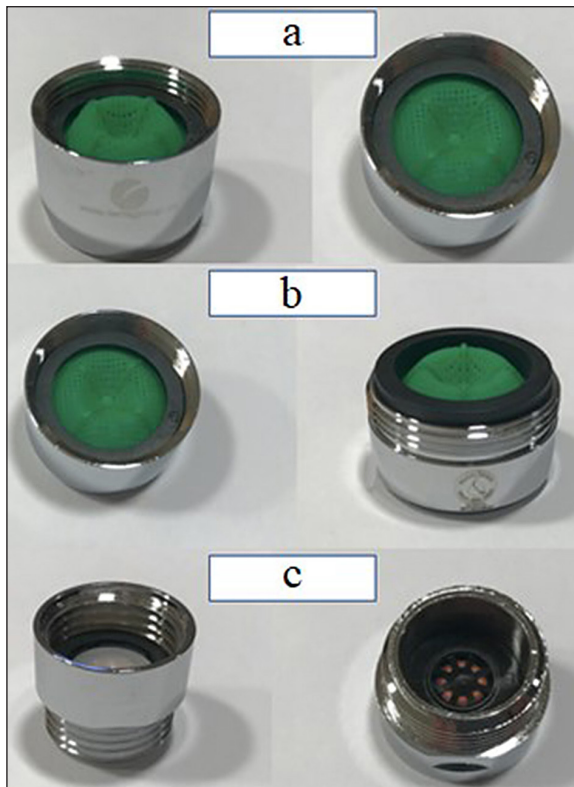


Figure 2. Water savers used in kindergardens

$N$  – number of days in the studied period, days.

Per capita demand (PCD) ( $\text{m}^3/\text{capita}/\text{day}$ ) was calculated according to the equation:

$$PCD = \frac{ADC}{P}, \quad (2)$$

where:  $P$  – population, persons.

The water consumption savings using ADC were calculated as follows:

$$E = \left( \frac{ADC_n}{ADC_{n'}} - 1 \right) \cdot 100\%, \quad (3)$$

where:  $ADC_n$  – average daily water consumption before the installation of water savers,  $\text{m}^3/\text{day}$ ;

$ADC_{n'}$  – average daily water consumption after the installation of water savers,  $\text{m}^3/\text{day}$ .

The water consumption savings using PCD were calculated as follows:

$$E = \left( \frac{PCD_n}{PCD_{n'}} - 1 \right) \cdot 100\%, \quad (4)$$

where:  $PCD_n$  – per capita demand before the installation of water savers,  $\text{m}^3/\text{capita}/\text{day}$ ;

$PCD_{n'}$  – per capita demand after the installation of water savers,  $\text{m}^3/\text{capita}/\text{day}$ .

## RESULTS AND DISCUSSION

Figure 3 presents values of water consumption in the respective objects before and after the installation of water savers in rs.1

In the above-mentioned object, the total consumption of water in the period from 1 January 2018 to 10 December 2018 amounted to  $467 \text{ m}^3$ . This consumption was divided by the number of days in the studied period (344 days). On the basis of the calculation, an average daily water was introduced for calculating consumption in the given period was found to be  $1.358 \text{ m}^3/\text{day}$ . A similar procedure average daily water consumption after the installation of water savers. The

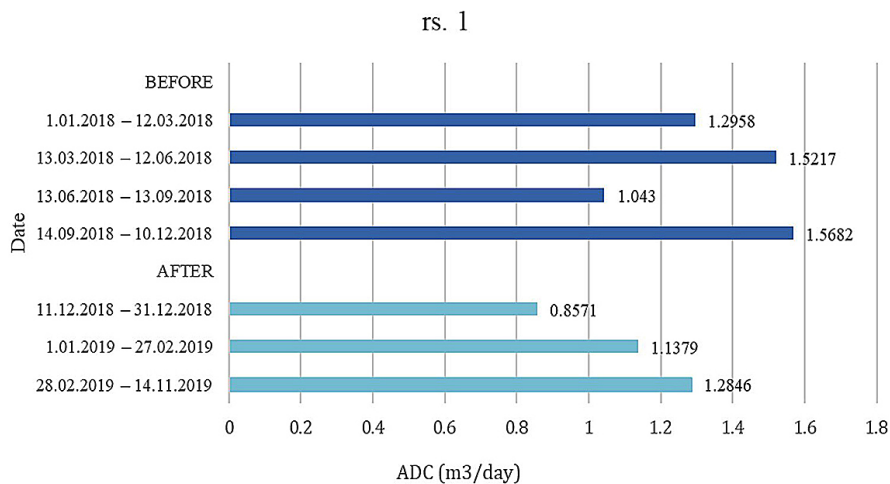


Figure 3. Water consumption in rs.1 in 2018 – 2019

period in question was from 11 December 2018 to 14 November 2019 (338 days) and the total consumption of water was 418 m<sup>3</sup>. Following the introduction of savers, the rounded average daily water consumption was 1.237 m<sup>3</sup>/day. On the basis of the data, a percentage difference in water consumption was calculated in the studied object and in the studied period as a ratio of average daily water consumption after the installation of savers and average daily water consumption prior to the installation, deducted from 100%. The average daily consumption of water in the object decreased by ca. 8.9% in the given period.

Figure 4 presents values of water consumption in the respective periods before and after the installation of water savers in rs.2.

In the above-mentioned object, the total consumption of water in the period from 1 January 2018 to 11 December 2018 amounted to 413 m<sup>3</sup>. This consumption was divided by the number of days in the studied period (345 days). On the

basis of the calculation, an average daily water consumption in the given period was found to be 1.197 m<sup>3</sup>/day. A similar procedure was introduced for calculating average daily water consumption after the installation of water savers. The period in question was from 12 December 2018 to 14 November 2019 (337 days) and the total consumption of water was 371 m<sup>3</sup>. Following the introduction of savers, the rounded average daily water consumption was 1.101 m<sup>3</sup>/day. On the basis of the data, a percentage difference in water consumption was calculated in the studied object and in the studied period as a ratio of average daily water consumption after the installation of savers and average daily water consumption prior to the installation, deducted from 100%. The average daily consumption of water in the research object decreased by ca. 8.0% in the given period.

Figure 5 presents the values of water consumption in the respective periods before and after the installation of water savers in rs.3.

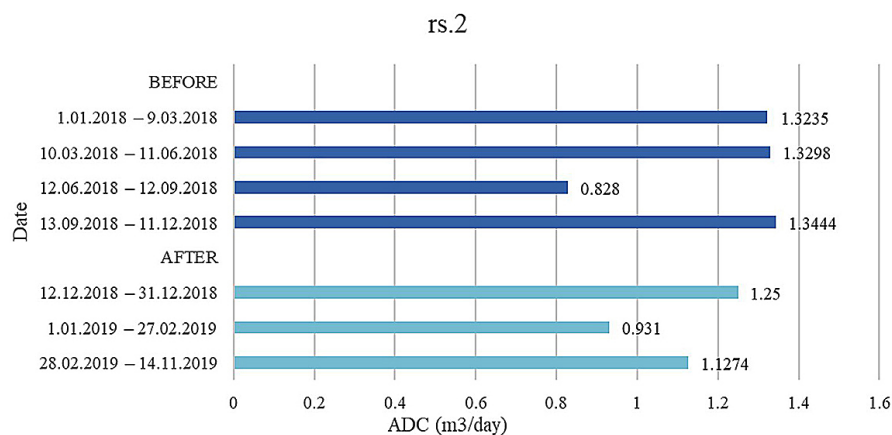


Figure 4. Water consumption in rs.2 in 2018 – 2019

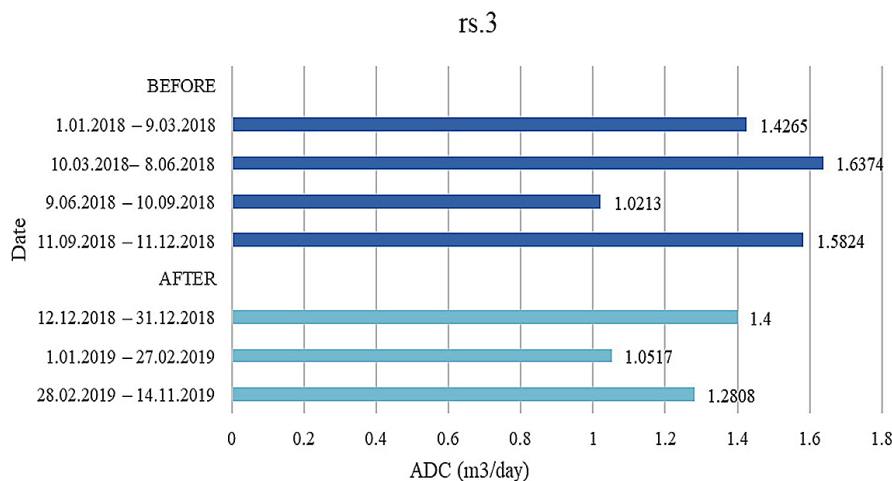


Figure 5. Water consumption in rs.3 in 2018 – 2019

In the above-mentioned object, the total consumption of water in the period from 1 January 2018 to 10 December 2018 amounted to 486 m<sup>3</sup>. This consumption was divided by the number of days in the studied period (344 days). On the basis of the calculation, an average daily water consumption in the given period was found to be 1.413 m<sup>3</sup>/day. The same procedure was introduced for calculating average daily water consumption after the installation of water savers. The period in question was from 11 December 2018 to 14 November 2019 (338 days) and the total consumption of water was 422 m<sup>3</sup>. Following the introduction of savers, the rounded average daily water consumption was 1.249 m<sup>3</sup>/day. On the basis of the data, a percentage difference in water consumption was calculated in the studied object and in the studied period as a ratio of average daily water consumption after the installation of savers and average daily water consumption prior to the installation, deducted from 100%. The average daily consumption of water in the research object decreased by ca. 11.6% in the given period.

Figure 6 presents the values of water consumption in the respective periods before and after the installation of water savers in rs.4.

In the above-mentioned object, the total consumption of water in the period from 1 January 2018 to 10 December 2018 amounted to 225 m<sup>3</sup>. This consumption was divided by the number of days in the studied period (344 days). On the basis of the calculation, an average daily water consumption in the given period was found to be 0.654 m<sup>3</sup>/day. The same procedure was introduced for calculating average daily water consumption after the installation of water savers.

The period in question was from 11 December 2018 to 14 November 2019 (338 days) and the total consumption of water was 192 m<sup>3</sup>. Following the introduction of savers, the rounded average daily water consumption was 0.568 m<sup>3</sup>/day. On the basis of the data, a percentage difference in water consumption was calculated in the studied object and in the studied period as a ratio of average daily water consumption after the installation of savers and average daily water consumption prior to the installation, deducted from 100%. The average daily consumption of water in the research object decreased by ca. 13.2% in the studied period.

Figure 7 presents values of water consumption in the respective periods before and after the installation of water savers in rs.5.

In the above-mentioned object, the total consumption of water in the period from 1 January 2018 to 10 December 2018 was 1,666 m<sup>3</sup>. This consumption was divided by the number of days in the studied period (344 days). On the basis of the calculation, an average daily water consumption in the given period was found to be 4.843 m<sup>3</sup>/day. The same procedure was introduced for calculating average daily water consumption after the installation of water savers. The period in question was from 11 December 2018 to 14 November 2019 (324 days) and the total consumption of water reached 1,935 m<sup>3</sup>. Following the introduction of savers, the rounded average daily water consumption was 3.935 m<sup>3</sup>/day. On the basis of the data, a percentage difference in water consumption was calculated in the studied object and in the

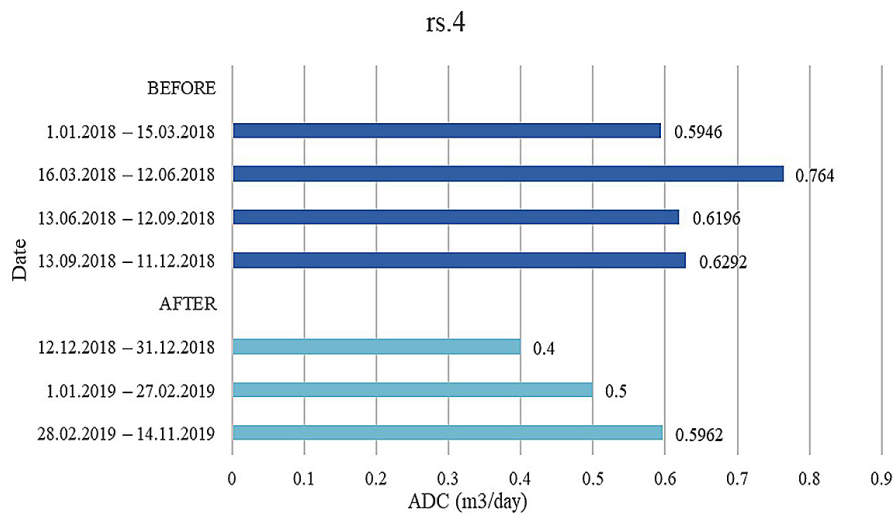


Figure 6. Water consumption in rs.4 in 2018 – 2019



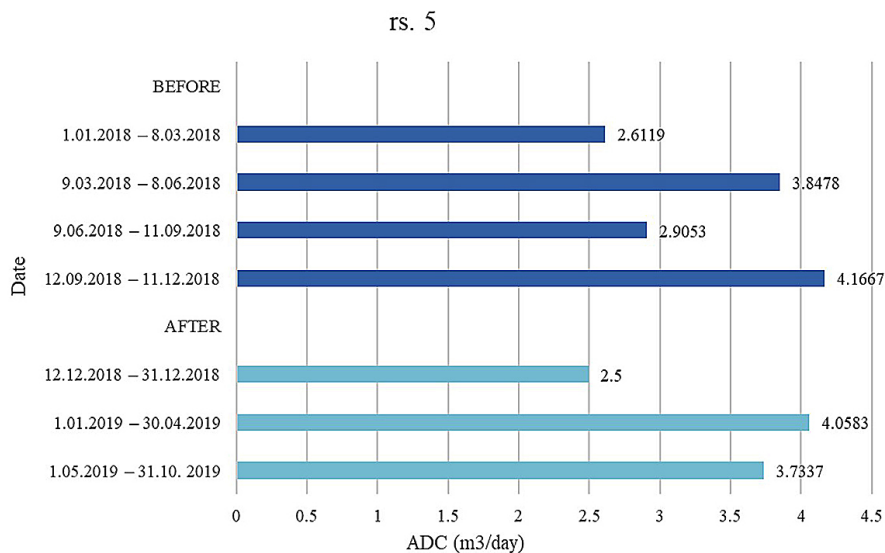


Figure 7. Water consumption in rs.5 in 2018 – 2019

studied period as a ratio of average daily water consumption after the installation of savers and average daily water consumption prior to the installation, deducted from 100%. The average daily water consumption in the research object decreased by ca. 18.7% in the studied period.

Figure 8 shows the values of water consumption in the respective periods before and after the installation of water savers in rs.6.

In the above-mentioned object, the total consumption of water in the period from 1 January 2018 to 10 December 2018 was 1,180 m<sup>3</sup>. This consumption was divided by the number of days in the studied period (344 days). On the basis of the calculation, an average daily water consumption in the given period was found to be 3.430 m<sup>3</sup>/day. The same procedure was introduced for calculating average daily water consumption after the installation of water savers. The period in

question was from 11 December 2018 to 31 October 2019 (324 days) and the total consumption of water reached 1.224 m<sup>3</sup>. After the introduction of savers, the rounded average daily water consumption was 3.778 m<sup>3</sup>/day. On the basis of the data, a percentage difference in water consumption was calculated in the studied object and in the studied period as a ratio of average daily water consumption after the installation of savers and average daily water consumption prior to the installation, deducted from 100%. The average daily water consumption in the research object increased by ca. 10.1% in the studied period.

Rs.5 was the only object in which the consumption of water did not decrease but it increased instead. It can be deduced from the other research results that the increased water consumption is very unlikely to have been caused by the installation of water savers. The phenomenon was

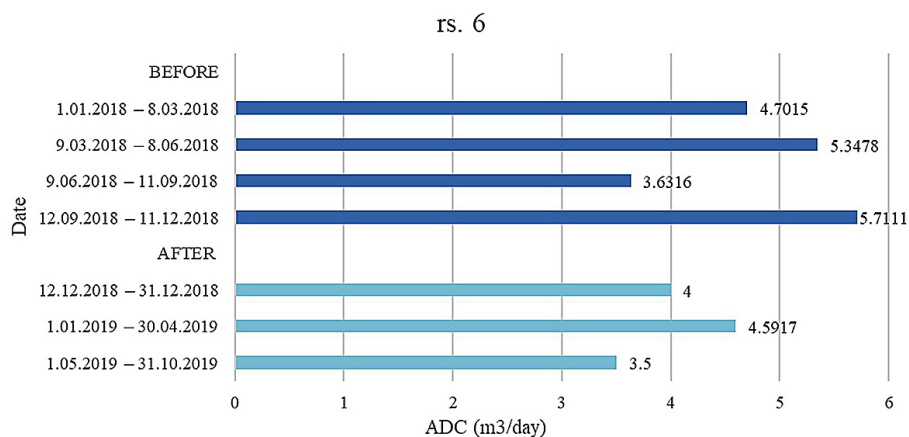


Figure 8. Water consumption in rs.6 in 2018 – 2019



presumably caused by something else – perhaps water leakage from the piping system or incorrect functioning of one or more appliances. Another possibility could be change in water management or rapidly increased number of children in the kindergarten. However, a consultation with the object director suggested that no such changes had occurred, and this is why such a situation was not taken into account. It is therefore possible to state that the increased water consumption was almost certainly due to the defective piping or appliance. A detailed inspection in the research object focused on the correct functioning of water supply system and regular control of water consumption are recommended.

The calculations of water savings considered two parameters, i.e. *average daily water consumption* (Fig. 9) and *per capita demand* (Fig. 10). The results of these calculations can see at the Table 2.

Table 2 shows that the installation of savers resulted in water savings from 8–18.7% using ADC and 10.02–23.2% using PCD. Table 1

shows that the installation of savers resulted in water savings from 8 – 18.7% using ADC and 10.02 – 23.2% using PCD. While analysing the calculation of average savings using two parameters, the difference between them can be seen.

This table brings an overview of water consumption changes in the respective objects with the exception of rs.5 where no savings were recorded. The differences in water consumption were converted to the differences in money savings achieved by the installation of water savers. The water supplier in Kyjov is the company Vodovody a kanalizace Hodonín, a.s. water and sewage prices of which for 2019 were set to 1.33 EUR/m<sup>3</sup> and 1.65 EUR/m<sup>3</sup>, respectively. Thus, the total price for 1 m<sup>3</sup> of water is 3.32 EUR (Skrblík, 2019).

The lowest water savings were recorded in rs.3 and the highest savings were recorded in rs.6. The annual savings converted into money from the price of 1 m<sup>3</sup> of water in rs.4 ranged around 146.06 EUR and in rs.3 around 115.31 EUR.

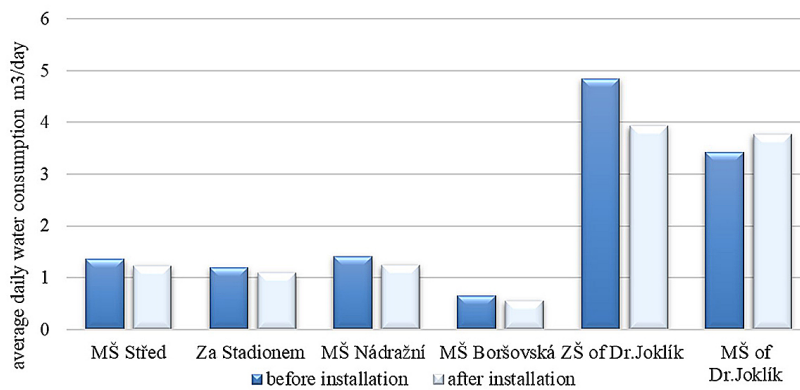


Figure 9. Average daily water consumption at the analysed objects, m<sup>3</sup>/day

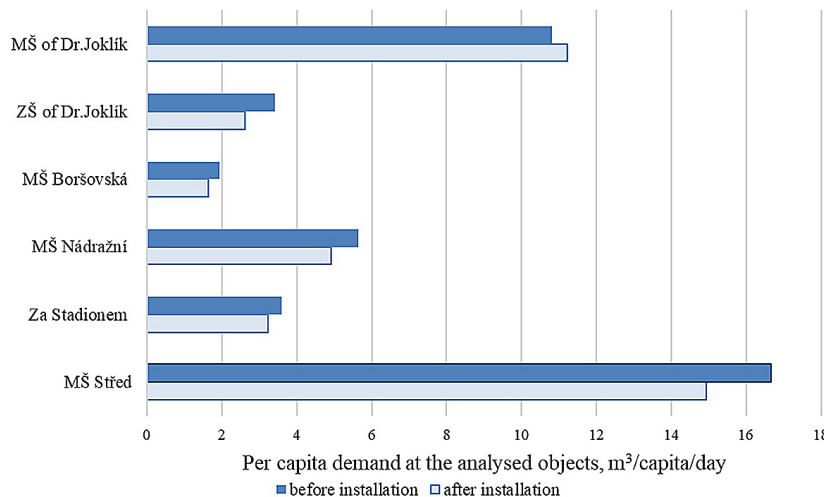


Figure 10. Per capita demand at the analysed objects, m<sup>3</sup>/capita/day

**Table 2.** Overview of results from the studied objects.

Object	∅ Daily consumption before installation of savers	∅ Daily consumption after installation of savers	% Difference	Per capita demand before installation of savers	Per capita demand after installation of savers	% Difference	Daily difference in money	Annual difference in money
rs.1	1.358 m <sup>3</sup>	1.237 m <sup>3</sup>	- 8.91	16.67	14.92	-10.5	0.40 EUR	146.49 EUR
rs.2	1.197 m <sup>3</sup>	1.101 m <sup>3</sup>	- 8.04	3.59	3.23	-10.02	0.32 EUR	116.20 EUR
rs.3	1.413 m <sup>3</sup>	1.249 m <sup>3</sup>	- 11.63	5.65	4.91	-13.1	0.55 EUR	198.53 EUR
rs.4	0.654 m <sup>3</sup>	0.568 m <sup>3</sup>	- 13.16	1.92	1.64	-14.5	0.28 EUR	104.09 EUR
rs.6	4.843 m <sup>3</sup>	3.935 m <sup>3</sup>	- 18.74	3.41	2.62	-23.2	3.01 EUR	104.09 EUR

\* Converted from CZK to EUR based on the exchange rate as of 24.02.2021

Annual savings in rs.2 can be expected at ca. 199.87 EUR and in rs.1 at ca. 103.78 EUR. In rs.6, where the best results were observed, annual savings can be expected to reach ca. 1095.47 EUR. Average savings amounted to 12.1%, which can be considered a good result. The percentage savings in the kindergartens were lower than in the elementary school rs.6. The fact might be given by the lower number of persons in one object or by the lower consumption of water from faucets by children of pre-school age compared with school children. Thus, it can be stated that the water savers in elementary schools are more efficient than those in kindergartens. However, verifying the theory would require more extensive research with a higher number of elementary schools and kindergartens. Further research and a follow-up analysis are envisaged. The highest water savings were recorded in rs.6. With its per capita water consumption of ca. 90 litres per day, the CR ranks with countries with lower water consumption. Various technologies have been used to reduce the amount of consumed water such as economical shower heads, washing machines, water savers etc. The products considerably reduce the amount of consumed water and hence the financial costs.

### Discussion of the achieved results

An analogous study of the efficiency of water savers was undertaken by a hotel in Zaragoza, Spain (Barberán et al. 2013). In 2008, the owner estimated a daily water consumption of 50,975 liters (18% hot water and 82% cold water). Considering the frequency of guest arrivals, the daily water consumption per guest was 396.5 l resulting in a daily water cost of 115.6 EUR. Due to the increasing costs, the hotel owner decided to introduce water saving devices including: faucets with eco-friendly cartridges and a dual flow system, aerators limiting the flow to 6 l/min in sinks

and bidets, and discs limiting the flow to 9 l/min installed in showers. The fixtures were installed for guest bathrooms and public toilets and sinks. In order to determine the exact water consumption, cold and hot water meters were installed in 2 representative bedrooms. Additionally, the following parameters were also taken into account to determine the differences more precisely: seasonal effects, number of guests staying divided into single and double rooms, number of banquet and other attendees, and number of people using meals (breakfast, lunch, and dinner). After the retrofit measures, the average water consumption of the hotel was 252 liters. Monitoring of 2 bedrooms showed that the average water consumption per 1 guest using hotel services is 124.3 liters which is 50.7% of the water consumed by the hotel with profitability varying from 932% to 7022%. The study conducted in Zagroza clearly indicated the validity of using water saving devices in public spaces.

In contrast, another group of researchers sought short-term solutions to reduce the water consumption in the city of Kabul, Afghanistan (Shokory and Rabanizada, 2020). The reason for the action was to achieve the 2030 Sustainable Development Goals, which include ensuring the availability and efficient management of water and sanitation in all sectors. Among the group of actions were the use of low-flow fixtures, the introduction of dual-flush toilets, and the reuse of gray water. The solutions were applied to bathroom sinks, kitchens, bathtubs and showers in Macrorayon apartments in the 9th district of Kabul city. Researchers found that the application of low-flow devices could reduce the water consumption from 125 liter/capita/day to 75 LCD. The district water supply is currently estimated at 4.5 million cubic meters per year, which could be reduced to 2.09 million cubic meters with the application of low-flow devices. The reduction in

water consumption would result in an additional 119,298 residents being able to be included in the water supply system. Again, it has been noted that, among other things, the use of aerators has a positive impact on the rational use of water, the amount of bills and comprehensive environmental protection.

On the other hand, Farmer (2019) from the state of Tennessee, in his study of the mechanical ways to save water, used a community survey to assess how residents felt after installing low-flow shower heads and aerators for faucets and toilets. The data was collected from 215 surveys from a potential 626 homes. The researcher applied a 28-question survey method to different age groups. After statistical analysis of the results, it was noted that regardless of age, gender, ethnicity, and whether residents were exposed to both the non-restrictive and restrictive water-saving devices and the restrictive water-saving devices, there were no significant differences in their mean score ratings, which ranged from >3 on a 5-point scale. The study showed that water conservation can be achieved by using, among other things, aerators without sacrificing the resident satisfaction and compfrence. The experience of Tampa Department (Mayer et al. 2004) with a one-question survey also confirms the public's satisfaction with mechanical flow restrictors. On a five-point scale, residents rated, among other things, the toilet flush efficiency at 4.52 (n=26), the water head flow efficiency at 4.27 (n=26), the kitchen faucet flow and shower head flow at 4.27 (n=26), and the bathtub faucet aerator efficiency at 4.33 (n=18).

The examples cited above confirm that water saving devices which do not contribute to the loss of satisfaction of consumption, but also take care of the natural and exhaustible water resource all over the world, should be installed in every public place as well as in homes.

## CONCLUSIONS

On the basis of the gained data, it can be state that the established hypothesis was confirmed, and the installation of water savers resulted in both economic and environmental benefits especially in public places like schools. For calculations of water savings in research objects, two parameters were taken into account, namely average daily water consumption and per capita demand. The installation of savers resulted in water

savings from 8–18.7% using ADC and 10.02–23.2% using PCD. While analysing the calculation of average savings using two parameters, a difference between them was observed. Such difference did not impact the amount of economics effect. This is due to the cost of 1 m<sup>3</sup> of water. The economic benefits were 1153 EUR per year. The school has now a possibility to use the money for other purposes. It is also an environmental benefit as a considerable amount of water was saved, which is a valuable natural resource, and wastewater generation was reduced at the same time. Sound water management with the use of savers may lead to the fulfilment of a so-called win-win strategy, i.e., to both financial and environmental benefits. This approach of municipalities, institutions, firms and households to water saving will lead to the achievement of sustainable development goals in the Czech Republic.

## REFERENCES

1. Barberan R., Egea P., Gracia-de-Renteria, Salvador M. 2013. Evaluation of water saving measures in hotels: A Spanish case study. *International Journal of Hospitality Management*, 34 (1), 181–191.
2. Boas Berg A., Jeznach J., Radziemska M., Adamcova D., Brtnicky M. 2018. Rain water not in sewers but in the garden – the study case of The Netherlands and Polish experience. *Acta Scientiarum Polonorum Architectura*, 17(1), 79–88. <https://doi.org/10.22630/ASPA.2018.17.1.8>
3. Brazeau R.H., Edwards M.A. 2013. Water and energy savings from on-demand and hot water recirculating systems. *Journal of Green Building*, 8 (1), 75–89.
4. Chai L., Han Z., Liang Y., Su Y., Huang G. 2020. Understanding the blue water footprint of households in China from a perspective of consumption expenditure. *Journal of Cleaner Production*, 262, 121321. <https://doi.org/10.1016/j.jclepro.2020.121321>
5. Crellin C. 2018. Global Freshwater Availability Trends. *Future Directions International*, 1–9.
6. De Clerq D., Smith K., Chou B., Gonazalez A., Kothapalle R., Li C., Dong X., Liu S., Wen Z. 2018. Identification of urban drinking water supply patterns across 627 cities in China based on supervised and unsupervised statistical learning. *Journal of Environmental Management*, 223, 658–667. <https://doi.org/10.1016/j.jenvman.2018.06.073>
7. Dinka M.O. 2018. *Safe Drinking Water: Concepts, Benefits, Principles and Standards*. IntechOpen. 10, 164–182. <https://doi.org/10.5772/intechopen.71352>

8. Farmer D. 2019. Apartment Residents' Understanding of and Satisfaction with Water Savings Devices. Electronic Theses and Dissertations. Paper 3595. <https://dc.etsu.edu/etd/>
9. Feizizadeh B., Ronagh Z., Pourmoradian S., Gheshlaghi H.A., Lakes, T., Blaschke, T. 2021. An efficient GIS-based approach for sustainability assessment of urban drinking water consumption patterns: A study in Tabriz city, Iran. *Sustainable Cities and Society*, 64, [102584]. <https://doi.org/10.1016/j.scs.2020.102584>
10. Fidar A.M., Memon F.A., Butler D. 2016. Performance evaluation of conventional and water saving taps. *Science of the Total Environment*, 541, 815–824. <https://doi.org/10.1016/j.scitotenv.2015.08.024>
11. Gao H., Zhou C., Li F., Han B., Li X. 2017. Economic and environmental analysis of five Chinese rural toilet technologies based on the economic input–output life cycle assessment. *Journal of Cleaner Production*. 163, 379–391. <https://doi.org/10.1016/j.jclepro.2015.12.089>
12. Hamel P., Daly E., Fletcher T.D. 2013: Source – control stormwater management for mitigating the impacts of urbanisation on baseflow. *Journal of Hydrology*, 485 (1), 201–211. <https://doi.org/10.1016/j.jhydrol.2013.01.001>
13. Hsanol M.Z., Ahmad Zaharuddin M.F. 2020. Development of Aerator for Water Saving. *Jurnal Mekanikal*, 43, 55–64.
14. He G., Geng C., Zhai J., Zhao Y., Wang Q., Jiang S., Zhu Y., Wang L. 2021. Impact of food consumption patterns change on agricultural water requirements: An urban-rural comparison in China. *Agricultural Water Management*, 243, 106504. <https://doi.org/10.1016/j.agwat.2020.106504>
15. Kalenik M., Chalecki M., Wichowski P. 2020. Real values of local resistance coefficients during water flow through welded polypropylene T-junctions. *Water*, 12(3), 895. <https://doi.org/10.3390/w12030895>
16. Kriš J., Božíková J., Čermák O., Čermáková M., Škultetyova I., Tóthová K. 2006. *Vodárenstvo I: Zásobovanie vodou*. Bratislava.
17. Lee M., Tansel B. 2013. Water conservation quantities vs customer opinion and satisfaction with water efficient appliances in Miami, Florida. *Journal of Environmental Management*, 128, 683–689. <https://doi.org/10.1016/j.jenvman.2013.05.044>
18. Marinoski A. K., Rupp R.F., Ghisi E. 2018. Environmental benefit analysis of strategies for potable water savings in residential buildings. *Journal of Environmental Management*, 206, 28–39. <https://doi.org/10.1016/j.jenvman.2017.10.004>
19. Mayer P.W., De Oreo W. B., Opitz E.M., Kiefer J.C., Davis W.Y., Dziegielewski B., Nelson J.O. 1999. Residential end uses of water. AWWA Research Foundation and American Water Works Association.
20. Mayer, P., DeOreo, W., Towler, E, Martien, L., & Lewis, D. 2004. Tampa Water Department residential water conservation study: The impacts of high efficiency plumbing fixture retrofits in single family homes. Study for Tampa water department and the US EPA.
21. Millock K., Nauges C. 2010. Household adoption of water-efficient equipment: the role of socio-economic factors, environmental attitudes and policy. *Environmental and Resource Economics*, 46, 539–565. <https://doi.org/10.1007/s10640-010-9360-y>
22. Plotěný K., Bartonik A. 2015. Rešerše – hospodaření s vodou, 1–41.
23. Randolph B., Troy P. 2008. Attitudes to conservation and water consumption. *Environmental Science & Policy*, 11(5), 441–455. <https://doi.org/10.1016/j.envsci.2008.03.003>
24. Ren X., Hong N., Li L., Kang J., Li J. 2020. Effect of infiltration rate changes in urban soils on storm water runoff process. *Geoderma*, 363, 114158. <https://doi.org/10.1016/j.geoderma.2019.114158>
25. Richey A. S., Thomas B.F., Lo, J. M.-H., Reager T., Famiglietti J. S., Voss K., Swenson S., Rodell M. 2015. Quantifying renewable groundwater stress with GRACE. *Water Resources Research*, 51, 5217–5238. <https://doi.org/10.1002/2015WR017349>
26. Russell S., Fielding K. 2010. Water demand management research: a psychological perspective. *Water Resources Research*, 46(5), 1–12. <https://doi.org/10.1029/2009WR008408>
27. Sadr S.K., Memon F.A., Jain A., Gulati S., Duncan A.P., Hussein W., Savic D., Butles D. 2016. An Analysis of Domestic Water Consumption in Jaipur, India *British Journal of Environment and Climate Change*, 6 (2), 97–115.
28. Salehi M., Abouali M., Wang M., Zhou Z., Nejadhashemi A.P., Mitchell J., Caskey S., Whelton A.J. 2018. Case study: Fixture water use and drinking water quality in a new residential green building. *Chemosphere*, 195, 80–89. <https://doi.org/10.1016/j.chemosphere.2017.11.070>
29. Sellwood P. 2013. At home with water: The biggest ever review of domestic water use in Great Britain. *Energy Saving Trust*, 1–36.
30. Seyoum S., Alfonso L., van Andel S.J., Koole W., Groenewegen A., van de Giesen N. 2017. A Shazam-like Household Water Leakage Detection Method. *Procedia Engineering*, 186, 452–459. <https://doi.org/10.1016/j.proeng.2017.03.253>
31. Shabbir G., Thapat S., Pariyapat N., Rattanawan M., Sylvain P., Nuttapon C. 2014. Water footprint and impact of water consumption for food, feed, fuel crops production in Thailand. *Water*, 6, 1698–1718. <https://doi.org/10.3390/w6061698>



32. Shokory J.A.N., Rabanizada E. 2020. Sustainable household water-saving and demand management options for Kabul City. *Earth and Environmental Science*, 511. <https://doi.org/10.1088/1755-1315/511/1/012003>
33. Umesh U., Sitaram N. 2014. Hydraulic performance of faucet aerator as water saving device and suggestion for its improvements. *International Journal of Research in Engineering and Technology*, 3, 2319–1163.
34. Vijayan D.S., Rose A.L., Sivasuriyan A., Jayaseelan R., Amuthadevi C. 2020. Automation systems in smart buildings: a review. *Journal of Ambient Intelligence Humanized Computing*. <https://doi.org/10.1007/s12652-020-02666-9>
35. Wu D., Cui Y., Li D., Chen M., Ye X., Fan G., Gong L. 2021. Calculation framework for agricultural irrigation water consumption in multi-source irrigation systems. *Agricultural Water Management*, 244, 106603. <https://doi.org/10.1016/j.agwat.2020.106603>
36. Zheng Z., Duan X., Lu S. 2021. The application research of rainwater wetland based on the Sponge City. *Science of The Total Environment*, 771, 144475. <https://doi.org/10.1016/j.scitotenv.2020.144475>
37. Water consumption statistics. Worldometers [online: 2019–09–19]. Access from: <https://www.worldometers.info/water/>
38. De Dardel, François. Dardel. info: Domestic water consumption. 2018, 1–2 [online: 2019–09–20]. Access from: <http://dardel.info/EauConsumption.html>
39. Místopisný Průvodce po České Republice: Kyjov [online: 2019–09–19]. Access from: <https://www.mistopisy.cz/pruvodce/obec/8243/kyjov/pocet-obyvatele/>
40. Skrblik.cz. Skrblik 2012–2019 [online: 2019–12–09]. Access: <https://www.skrblik.cz/radce/mesto/kyjov>
41. Water Consumption. Safe Drinking Water Foundation. Kanada. 2019 [online: 2019–09–19]. Access from: <https://www.safewater.org/fact-sheets-1/2017/1/23/water-consumption>