JEE Journal of Ecological Engineering

Journal of Ecological Engineering, 2025, 26(4), 285–290
https://doi.org/10.12911/22998993/196617
ISSN 2299–8993, License CC-BY 4.0

Received: 2024.11.14
Accepted: 2025.01.31
Published: 2025.02.17

The uniqueness of motor rest areas in the context of uneven water consumption based on the example of a facility located on the S8 road

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ABSTRACT

The aim of the article was to present the results of research on the characteristics of water consumption changes in a motor rest area (MRA) based on the observations conducted monthly and daily in 2022 and 2023. MRA facilities show significantly different water consumption patterns compared to residential or public buildings. Water consumption is closely tied to vehicle traffic, which exhibits considerable variability daily, weekly, and annually. Literature reports indicate increased water consumption at MRA during weekends. However, data analysis for the chosen facility indicated higher water usage during weekdays. Significant differences were also observed between water usage in 2022 and 2023, as well as between colder (autumn-winter) and warmer periods (spring-summer) of the year.

Keywords: Motor Rest Areas, uneven water distribution, water consumption.

INTRODUCTION

Motor rest areas (MRA) are road infrastructure elements designed to provide rest for drivers and passengers traveling on motorways and expressways. The access to this type of facilities not only ensures comfort during longer journeys, but above all increases road safety by providing a place of rest for tired drivers as fatigue is considered a result of fast, long distance driving (Borshchenko, 2017). MRA facilities are classified into three categories depending on the infrastructure they offer:

- category I – rest function with parking spaces and basic sanitary facilities;
- category II – rest and service function with parking spaces and basic sanitary facilities, fuel stations and food services;
- category III – rest and service function with parking spaces and basic sanitary facilities, fuel stations and food services as well as lodging for travelers.

Regardless of the category, the essential elements of MRA include rest areas and sanitary facilities, often equipped with showers. The continuous water supply for these facilities is crucial for handwashing, bathing, and toilet flushing (Ghaitidak & Yadav, 2013).

Many variables affecting the intensity of use of MRA limit the ability to precisely estimate the amount of water used in the sanitary facilities. In the case of MRA, using commonly available data for estimating water consumption, as well as literature reports concerning water usage in residential buildings, public utility buildings, or service facilities, is highly risky. On one hand, it may lead to overestimating the design parameters for the water supply system, and on the other hand, to underestimating them. In both cases, there is a significant risk of operational difficulties regarding water supply.

Research on literature reports concerning water consumption at motor rest areas reveals significant variation in daily water usage, ranging from 1.0 m³ to as much as 56.78 m³ (Marek et al., 2023). The large fluctuations in water consumption at MRA result from the class and specific nature of such facilities, where traffic and number of visitors varies throughout the day, week, and year. According to literature data, the highest traffic on expressways is recorded on weekends and during vacation periods (holidays, summer breaks) (Kao et al., 2019). Truck traffic and the related driving bans for vehicles or vehicle combinations with a gross weight exceeding 12 tons, in effect on holidays and vacation weekends, have a significant impact on water consumption patterns at MRA. During these periods, motor rest areas become overnight stops for truck drivers, resulting in a considerable increase in water consumption. The number of visitors also depends largely on the location of the facility, including its distance from the cities and other facilities with sanitary amenities. In addition, water consumption can be influenced by the types of sanitary devices provided – including traditional sinks and toilets or water-saving devices (Englart & Jedlikowski, 2019).

The unevenness of water consumption is extremely important considering the maintenance of the good technical condition of the network, but also for user safety. A steady, consistent water flow from the network minimizes the risk of stagnation periods in the water pipes as well as the associated buildup of biological and chemical deposits (Liu et al., 2017). Large fluctuations in the amount of water, and consequently in the flow rate, can cause fragments of biofilm to break off from the pipes, leading to re-contamination, which poses a sanitary risk to consumers (Liu et al., 2016). Following a period of stagnation (such as overnight, when there is no traffic in the case of MRA), a sudden increase in water consumption can lead to a decline in water quality due to changes in color, increased turbidity, and higher concentrations of ammonium nitrogen and iron, while the free chlorine content, which serves as a disinfectant, decreases. A concerning factor is the increase in total organic carbon, which may result from the washing out of organic substances accumulated in the system, including pathogenic bacteria (van der Wielen et al., 2016).

The high unevenness of water consumption at MRA also has a direct impact on the effectiveness of wastewater treatment if the facility is equipped with a local treatment system. It can also pose a problem for the collection of wastewater in septic tanks, affecting not only their volume but also their quality. Solving the problem by connecting MRA to the sewage network is impossible due to the large distance of such places from urban areas. The need to treat or store wastewater at the place of its production poses an additional challenge for MRA operators. What is more, inadequate treatment of wastewater from such facilities, which typically exhibit very high concentrations of ammonium nitrogen, can pose a direct threat to the environment (Pawęska & Bawiec, 2019).

The main aim of the research was to determine the characteristics of water consumption changes during the observation period, taking into account monthly and daily variations.

MATERIALS AND METHODS

Observations of the daily dynamics of water consumption were conducted from April 2022 to December 2023 at a facility located along the S8 expressway. This is a category I facility equipped with basic elements, such as parking spaces for cars, trucks, and buses, rest areas, and sanitary facilities. The sanitary part of the facility consists of a building divided into two zones based on the gender of the travelers. The sanitary installation at the facility includes a total of 5 sinks, 5 toilet bowls, and 2 urinals. The facility is equipped with a water meter that indicates the amount of water consumed by the installation. Water meters were read manually twice a day. Statistical analyses were performed using the STATISTICA software.

RESULTS AND DISCUSSION

The range of changes in water consumption varied from a minimum value of 0.0 L/day, associated with a lack of vehicle traffic at the MRA, to a maximum value of 7644.0 L/day. The average daily water consumption was 2209.6 L based on 629 observations (standard deviation 1061.1 L/day).

The high range of changes indicates a significant load on the sanitary system, which is related to the characteristics of the facility and the variable intensity of vehicle traffic on this section (including the number of visitors). The variability in water consumption at the MRA also depends on the year of observation, month, and day of the week (Table 1). The analyzed data show significant differences in water consumption during the period from 2022 to 2023. Water usage in 2023 was lower (average annual value of 1941.5 L/day) than in 2022 (average annual value of 2580.2 L/day), and the observations obtained from the water meter in 2023 exhibited lesser variability.

Table 1. Monthly water consumption characteristics at the motor rest area during the measurement period from April 2022 to December 2023

Parameter	Unit	2022											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Average	L/d	–	–	–	2103.7	3610.8	4054.8	3492.2	2704.4	1995.9	1896.3	1677.2	1501.7
Minimum	L/d	–	–	–	435.0	899.0	1010.0	1873.0	1395.0	817.0	213.0	649.0	680.0
Maximum	L/d	–	–	–	3232.0	6791.0	7644.0	4887.0	4500.0	3376.0	3460.0	3431.0	2487.0
Stand. dev.	L/d	–	–	–	768.0	1229.2	1376.6	728.8	850.0	575.3	787.9	680.0	405.7
		2023											
Average	L/d	1531.2	528.9	556.2	917.4	767.9	820.7	734.6	804.6	752.7	553.3	654.3	496.9
Minimum	L/d	23.0	669.0	0.0	832.0	1000.0	950.0	1758.0	902.0	706.0	666.0	521.0	500.0
Maximum	L/d	3055.0	2609.0	2822.0	5963.0	4157.0	4694.0	4413.0	4199.0	3802.0	3095.0	3552.0	2500.0
Stand. dev.	L/d	571.3	528.9	556.2	917.4	767.9	820.7	734.6	804.6	752.7	553.3	654.3	496.9

Note: – no observation.

In 2022, the highest average value occurred in June (4054.8 L/day), which may be related to increased tourist traffic and the easing of travel restrictions during the pandemic. The lowest average water consumption in 2022 was recorded in December (1501.7 L/day), which is associated with low traffic during the winter season and the holiday period. Similarly, in 2023, the lowest average monthly water consumption was measured in December (496.9 L/day). The highest average value for 2023 occurred in January (1531.2 L/day). The highest daily water consumption for the analyzed facility occurred in different months: in 2022, the highest daily value was recorded in June (7644.0 L/day), while in 2023, it was in April (5963.0 L/day). The differing observation dates for maximum water consumption values may indicate potential changes in usage patterns, visitor behavior, or the influence of other external factors. A comparison of water consumption values in 2022 and 2023 is presented in Figure 1. To identify potential seasonality in

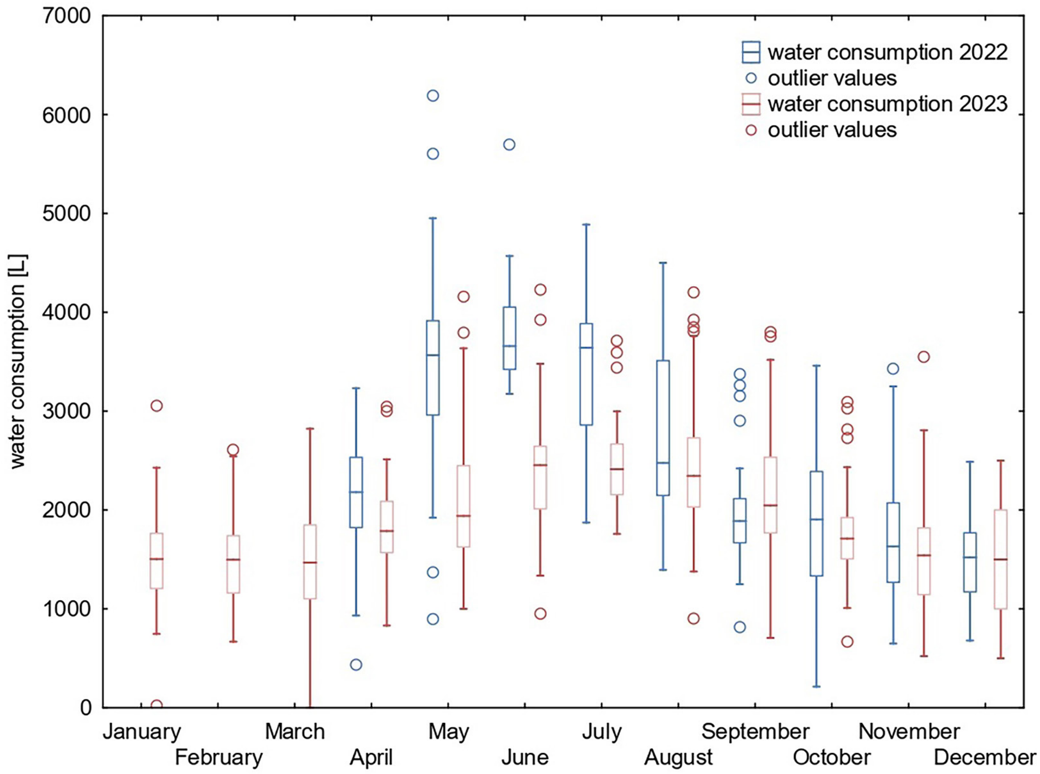

Figure 1. Monthly water consumption in the analyzed MRA in 2022 and 2023

water consumption changes, Figure 2 presents a heat map showing water consumption figures for each day of the analyzed month. The variability in color intensity throughout the month indicates fluctuations in water consumption at the facility. In the case of the studied MRA, water consumption decreases in the later months of the year from autumn to winter, while it increases in the warmer months (from spring to summer). Within each month, darker points (purple in this case) can be distinguished, which indicate the highest water consumption in the facility. This may indicate individual events causing temporary spikes in water usage (e.g., the stop of several buses in a short

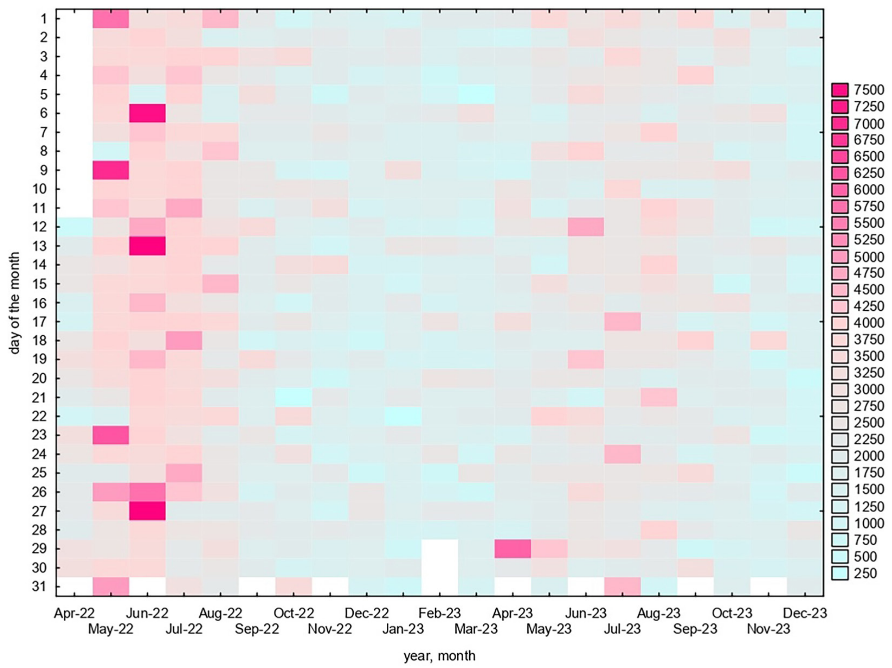

Figure 2. Heat map of daily water consumption during the observation period for the chosen Motor Rest Area

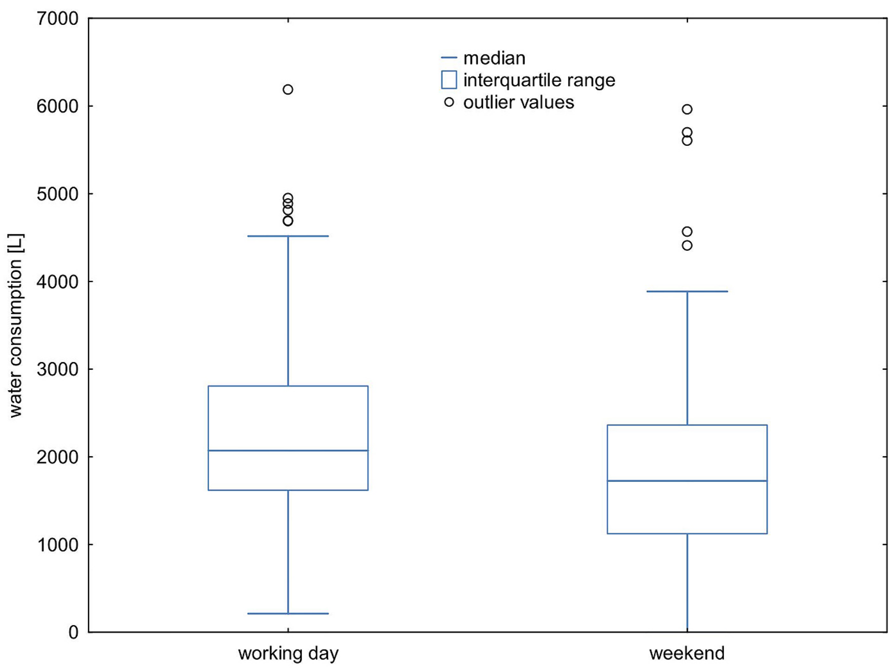

Figure 3. Water consumption during the observation period for the studied Motor Rest Area, divided into weekdays (Monday – Friday) and weekends (Saturday – Sunday)

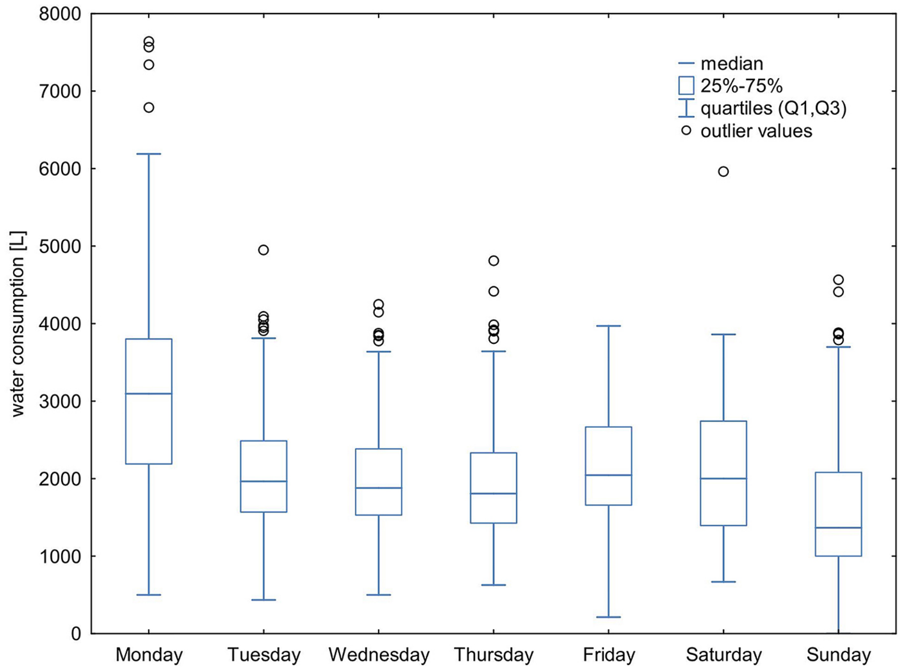

Figure 4. Water consumption figures during the observation period for the motor rest area on a weekly basis

period of time). Variability in water consumption is also evident concerning the day of the week (Figure 3). On weekdays (Monday to Friday), the median water consumption (2072.0 L/day) was slightly higher compared to weekends (1725.5 L/day). The higher median and greater variability of water consumption on weekdays may suggest a larger number of visitors to the MRA (higher activity), likely due to regular traffic from commuting individuals or increased heavy truck movement.

Monday is the day with the highest median water consumption (3095.0 L/day), which may indicate an increase in traffic and activity at the MRA for vehicles after the weekend. The following days from Tuesday to Thursday show similar medians (1964.0 L/day, 1879.5 L/day, and 1,806.5 L/day, respectively), which can be interpreted as a stabilization of traffic on this section. In the subsequent days from Friday to Saturday, slight increases in the median are visible, suggesting increased activity of travelers leaving the city for the weekend (2045.5 L/day, 2000.0 L/day). The lowest water usage was indicated on Sunday, reaching 1366.0 L/day. Water consumption at the studied facility on individual days of the week is presented in Figure 4.

CONCLUSIONS

The analysis of water consumption data at the Motor Rest Area on the expressway showed that the highest water usage at this facility occurred on Mondays, while the lowest values were recorded on Sundays. Throughout the week, water consumption remained at a steady level, with a slight noticeable increase on Fridays and Saturdays. The results obtained differ from those presented in the literature (Kao et al. 2009), which clearly identify increases in water consumption on weekends and during holiday periods (summer and winter breaks). Giving the exact reason for such diversified water consumption is not possible without a thorough analysis of the number of MRA users. Unfortunately, due to the lack of data on the number and types of vehicles stopping at the MRA, the analysis is based on the authors' own observations.

Motor Rest Areas are facilities that vary significantly in both their specifics (class of the facility and equipment) and their location, which affects vehicle traffic intensity. Due to the significantly differing baseline conditions between facilities and their individual characteristics, generalizations related to water consumption or the quantity and quality of generated wastewater are overly simplistic. Therefore, designing solutions for MRA should be individualized, which poses serious challenges during the design and construction phases of new facilities. Underestimating or overestimating design values can lead to numerous problems during the operational phase.

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