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## UNEVENNESS OF WATER CONSUMPTION IN SETTLEMENT ON THE CASE OF DOBOJ

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### SUMMARY

Water consumption in a settlement is an extremely variable size that changes constantly over time. Changes in water consumption occur on an annual, monthly, weekly, daily and hourly basis, and depend on many factors such as: climate, season, temperatures, hours of work, consumer habits, etc.

Extreme value of consumption, ie. the peak hour flow is defined as the product of the average daily consumption and the hourly non-uniformity coefficient. Non-uniformity coefficient is defined as the ratio of maximum flow to mean flow over a day, and given that actual flows fluctuate constantly over time, then it is easy to conclude that the non-uniformity coefficient is a variable that varies over time. In this case, the non-uniformity coefficient can be represented as a function  $C=f(t)$ , which has local extremes at certain points, while at all other time intervals it has a smaller value.

With the known function of uneven consumption, using computer technology, it is possible to program different simulations of consumption and flow in the water supply system. In this way it is possible to optimize the system itself in terms of water consumption, dimensions and capacities of facilities in the system, as well as energy consumption for water transport.

Keywords: *water supply system, water consumption, non-uniformity coefficient*

### INTRODUCTION

Water is one of the most significant resources in the modern world. According to the World Health Organization, fresh water on planet Earth is only 2.5%. It is estimated that only 1% of fresh water, or 0.007% of the total amount of water, can be used for water supply to the population. Water is essential for the survival of all living organisms and is indispensable in many technological processes. The quantities of water that can be used for water supply are limited and consumption is increasing day by day. Insufficient water supply in a wider geographical area is an obstacle to the development of social and economic activities.

Water quality is also very important for the water supply of settlements, and it may deteriorate in environmental pollution. Therefore, it is necessary to apply increasingly complex and expensive treatment procedures for drinking water, and in some cases long-term loss of water resources for the supply of water to the population. The problem of lack of sufficient quantities of water today is significant for most developed countries and is persistent in water poor countries. The current trend of increasing water demand is creating increasing conflicts, including wars over the distribution of scarce water resources.

Bosnia and Herzegovina is still one of the few countries with significant drinking water reserves. Therefore, our responsibility is greater in terms of the need to make every effort to maintain this state of affairs. Drinking water owned by BiH is one of the strategic resources of this country whose significance will be even greater in the future. It is very important that a strategy is defined and that the necessary activities are undertaken in a timely manner to preserve the existing water fund.

One of the key segments of water management is how to use water for water supply, that is, how to ensure sufficient quantities of drinking water at minimal cost and negligible environmental impact. Ensuring the correct hydraulic conditions in the water supply network is dependent on, among other things, good estimation of the unit demand for water in the settlement unit and determination of consumer's preferences with regard to the elevated and reduced water consumption. Therefore, during the designing and modernization of water supply networks, it is required to determine the daily and hourly non-uniformity of water consumption over the course of a year, and sometimes even a multi-year period.

## WATER CONSUMPTION IN THE SETTLEMENT

Water consumption is a result of the needs of the population in a particular settlement. Water consumption is not a constant size but is constantly changing over time. Therefore, it is very important to consider all the factors that affect water consumption as well as the timing of consumption [1].

During the planning and design of water supply systems, it is necessary to first define the quantity and quality of water needed by the settlement considering all possible existing and future water consumers. The primary task of a water supply network is to supply consumers with water in the appropriate amount, under the proper pressure and with the proper quality at any time of day or night [2]. Therefore, it is necessary to consider all possible water consumers and define their needs for water quantities and quality. The current water needs are considered, as well as the needs at the end of the planning period, which usually ranges from 20 to 50 years [3].

Domestic drinking water consumption is one of the most significant segments of residential water consumption. Here we include the consumption of water for basic necessities of life such as: drinking, preparing food, maintaining personal hygiene and living space hygiene, watering greenery and smaller gardens and the like.

The consumption of water in a settlement outside the household is the consumption of water for communal purposes such as: street washing, watering parks, smaller industrial plants, craft services, public institutions, etc.

Water consumption for technological purposes is also a significant segment of water consumption in the settlement. This group includes water consumption in various industrial plants, energy and agriculture.

A significant amount of water is also consumed during the worker's stay at work, for basic sanitary purposes, for maintaining personal hygiene and for eating. In rural settlements, among other things, water is consumed for farming livestock as well as for other agricultural activities.

Consumption of water for fire fighting is also an indispensable element in the analysis of water consumption. It is quantitatively defined by the Rulebook on hydrant fire extinguishing network.

Each of these consumption groups has specific requirements in terms of quantity, quality and consumption patterns and should be considered during the planning the water supply systems. Certainly, water losses in the water supply system, which can often have a significant impact on overall water consumption, should not be left out.

Considering all the types of consumers mentioned above, water consumption can be expressed over specific water consumption as a basic indicator of consumption.

Specific water consumption is the basic size for water supply system planning. It can be given by norms and guidelines or it can be calculated. After the analysis of all consumers in the water supply, in accordance with their unit consumption, all needs are collected during the year and divided by the number of days in the year, and the average daily consumption is obtained. If this consumption is divided by the population of the area, specific water consumption per capita will be obtained [2].

Mean daily water consumption is the product of specific water consumption and population in the area considered, ie. [4,5]:

$$Q_m = q_{sp} \cdot N$$

where:

$q_{sp}$  - specific water consumption  
 $N$  - number of inhabitants

The number of inhabitants and all other users in a particular area is determined on the basis of spatial and economic development plans for the considered planning period of the water supply system.

Water consumption changes throughout the year according to the climatic conditions and economic activity of the area (eg tourist resorts or seasonal industrial activity).

Maximum daily water consumption is defined by:

$$Q_{max,d} = Q_m \cdot C_d$$

where:

$C_d$  – daily non-uniformity coefficient

Daily non-uniformity coefficient represents the ratio of water consumption in the day of maximum consumption to average water consumption [6,7].

Water is consumed unevenly throughout the day, and the difference between day and night consumption is especially large. Water consumption during one day usually ranges between the minimum consumption values in the late night hours to the maximum values in the morning and late afternoon (daily consumption extremes).

The maximum hourly consumption is calculated according to the form:

$$Q_{max,h} = Q_m \cdot C_d \cdot C_h$$

where:

$C_h$  - hourly non-uniformity coefficient

The hourly non-uniformity coefficient is the ratio of maximum water consumption during one day to the mean water consumption during the same day [1,8].

## UNEVENNESS OF WATER CONSUMPTION IN THE SETTLEMENT

For sizing the distribution network and other supporting objects in the water supply system, the basic input parameter for sizing is the maximum hourly water consumption  $Q_{max,h}$  representing the product of water consumption on the day of maximum consumption ( $Q_{max,day}$ ) and the hourly non-uniformity coefficient  $C_{h,max}$  [9].

The maximum hourly non-uniformity coefficient is adopted as a constant size, which, depending on the size and type of settlement, usually ranges from 1.25 to 2.00 [1]. In this way, the maximum flow rate  $Q_{max,h}$  is obtained, which is used to dimension the pipeline and other supporting elements of the distribution network. This approach is justified in terms of pipeline capacity satisfaction, but may be irrational in terms of system functioning and energy consumption for water transport. The maximum value of water consumption  $Q_{max,h}$  theoretically occurs only at one point during the day, while at all other time intervals this consumption is lower (in the long part of the day and much lower).

Hourly non-uniformity coefficient is the ratio of the maximum hourly water consumption  $Q_{max,h}$  and mean water consumption during the day  $Q_{max,d}$ , and given that water consumption is variable over time, it is clear that the hourly non-uniformity coefficient also changes in time. Therefore, the hourly non-uniformity coefficient can be represented as a time function  $C_h = f(t)$ .

Below is an analysis of the uneven water consumption of one distribution zone of Usora settlement within the water supply system of Dobož. Usora is located in the southern part of Dobož. There are currently 736 ports in this distribution area. It is mainly about household water consumption and small craft activities. An automatic flowmeter is installed in the distribution area of Usora settlement, and it is possible to read water flow data every 60 seconds [10].

For the purpose of analyzing the imbalance of consumption, one typical week was adopted in the spring, from March 29, 2019 to April 4, 2019, and an additional weekend day, April 7, 2019. For the period considered, readings of measured consumption data were made every hour. Figure 1 shows the water consumption for 24 hours for the eight considered days.

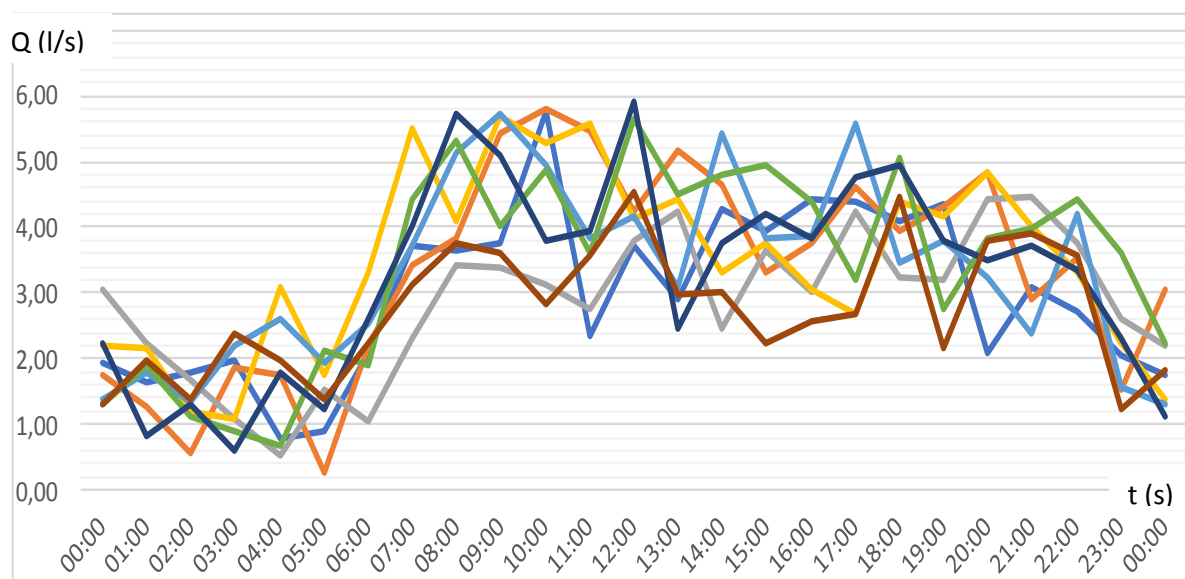


Figure 1. Water consumption in Usora for one week

The diagrams in Figure 1 show that there are some variations in water consumption for different days, but in principle the diagram behavior is similar. Daytime extremes are evident in the morning with a slight decrease towards the end of the day and minimal consumption in the late hours of the night.

Certainly there are some discrepancies in the dynamics of water consumption on weekdays compared to weekends.

If the working days and weekends are separated and if the average water consumption for the considered week is calculated for each considered hour, the two diagrams shown in Figure 2 are obtained.

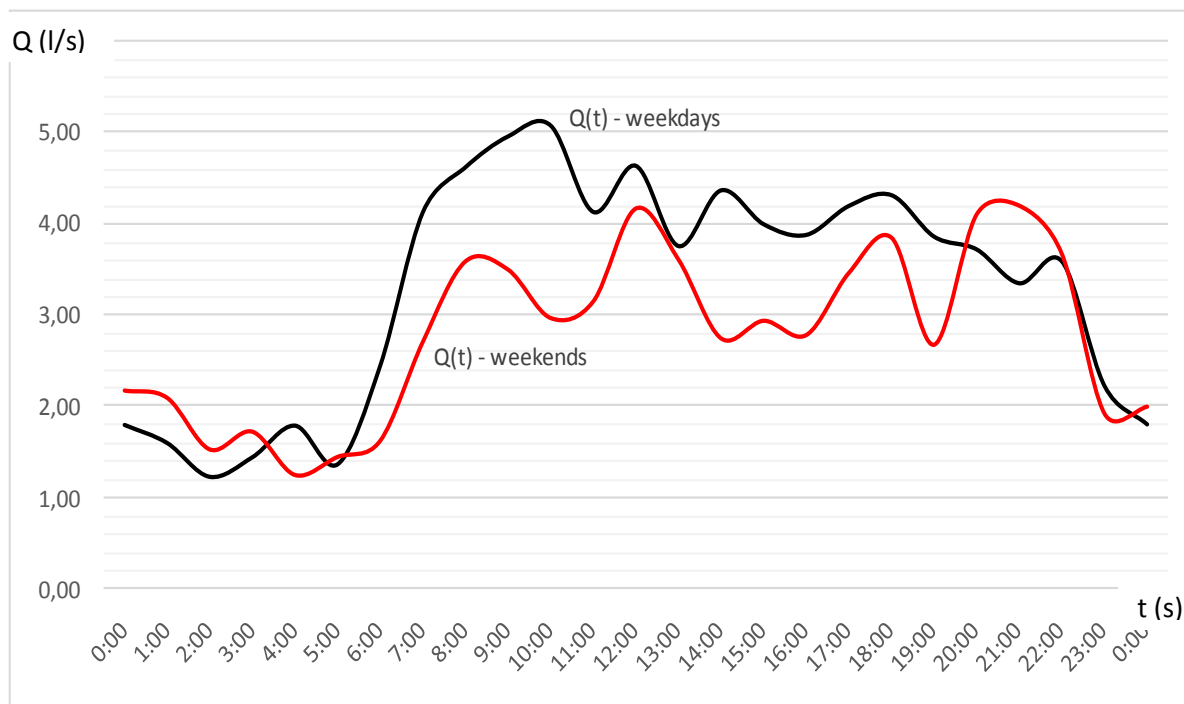


Figure 2. Average water consumption on weekdays and weekends

The diagram above shows water consumption for weekdays, while the diagram below represents water consumption on weekends. The water consumption shown in the ordinate is expressed in l/s. The average daily water consumption for weekdays is 3.42 l/s, while for weekends it is 2.83 l/s. It can be observed that the weekday consumption chart has a more pronounced peak in the morning hours than the weekend consumption chart.

This form of diagram is expected because it is an indicator of increased water consumption at the time of peak population activity. In the morning, the population gets ready for work, children at school or kindergartens, etc. and increased consumption compared to the rest of the day [11,12].

On the other hand, on weekends, we have a much smaller morning peak in consumption and the situation that such spending more or less stays on during the day with certain oscillations. At the end of the day on weekends (between 7:00 pm and 10:00 pm), there is a slight increase in consumption, which may be indicative of the population's preparation for the coming work week. It is also noticeable that the average daily water consumption is lower on weekends compared to weekdays.

This situation is also typical of this type of settlement, where the population largely goes out of town over the weekend, and thus consumption is reduced.

It is important to emphasize here, when it comes to weekend days, they are generally understood to be Sundays. Saturday consumption is slightly declining on weekdays, but significantly higher than on Sundays, which is also one of the characteristics of water consumption in countries such as Bosnia and Herzegovina where Saturday is a work day.

Consumption of water at any time during the day is a product of the average consumption during the considered day and the non-uniformity coefficient. As water consumption changes constantly throughout the day, as can be seen from Figure 2, it is clear that the non-uniformity coefficient is a variable that varies with time.

We now consider the hourly non-uniformity coefficient as a time function  $C_h=f(t)$ , whereby the ordinate of this function, at any time  $t$ , is obtained if we divide the ordinate  $Q_{max,h}$  from Figure 2 by the mean daily water consumption in the day considered. Since the mean water consumption on a given day is a constant magnitude during that same day (invariant at time  $t$ ), we obtain in the manner described above a function parallel to the function  $Q_{max,h}(t)$ . The uneven coefficient curve  $C_h=f(t)$  is shown in Figures 3 and 4.

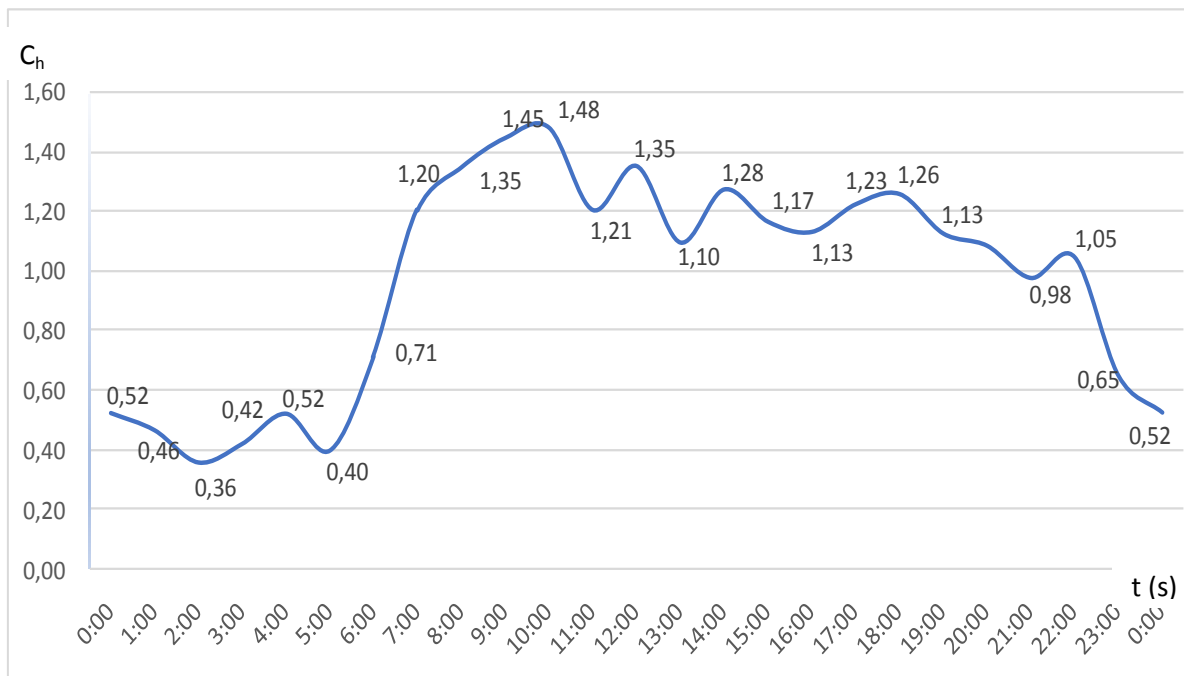


Figure 3. Hourly non-uniformity coefficient  $C_h(t)$  for a typical workday

Figure 3 shows the non-uniformity coefficient curve for a typical workday. It can be seen that the hourly irregularity coefficient ranges from a minimum value of 0.36 to a maximum value of 1.48 during the day.

It can be seen from the Figure 3 that the behavior of the diagram of non-uniformity coefficient  $C_h(t)$  is similar to the behavior of the water consumption diagram  $Q(t)$ .

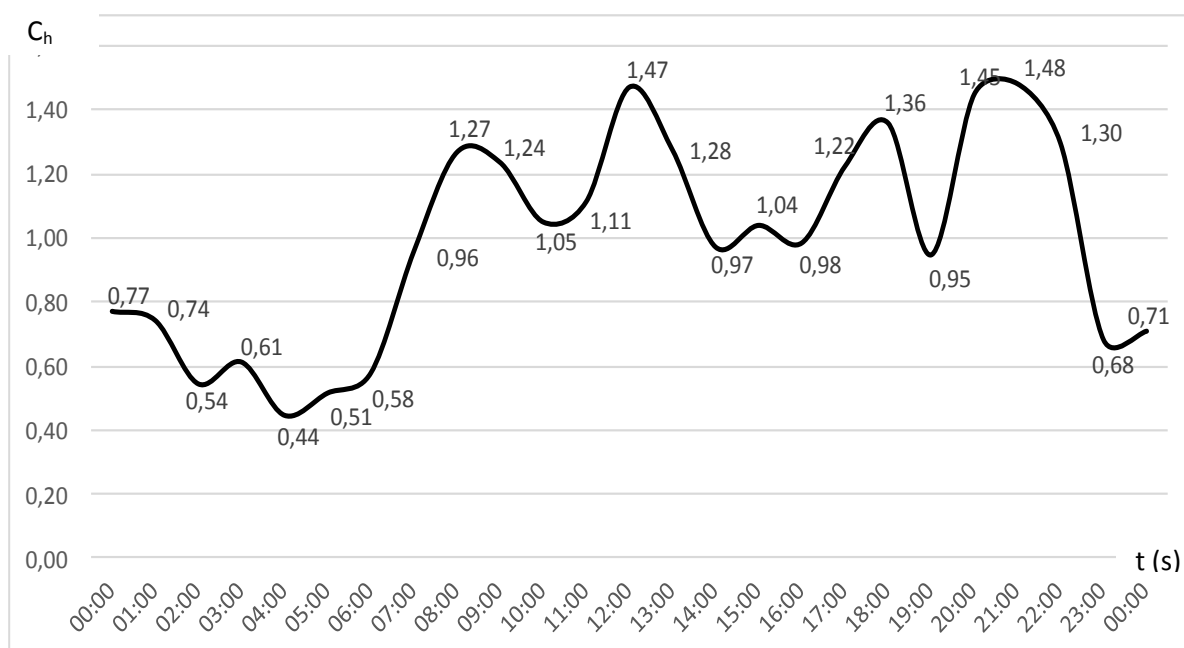


Figure 4. Hourly non-uniformity coefficient  $C_h(t)$  for weekend

Figure 4 shows the non-uniformity coefficient curve for weekend days. Hourly non-uniformity coefficient curve for weekend days ranges from a minimum of 0.44 to a maximum of 1.48 during the day. The maximum ordinate of the curve in Figure 3 and Figure 4 represents the maximum hourly non-uniformity coefficient  $C_{h,max}$ , while the minimum ordinate represents the value of  $C_{h,min}$ .

With the known regime of water consumption in the settlement, it is possible to optimize the operation of all elements in the water supply system [13,14]. It is possible to program different mathematical models of water consumption in the settlement by applying hydraulic simulators and the function of the non-uniformity coefficient [15].

## CONCLUSIONS

Water consumption in a settlement is an extremely variable amount that changes over time. By measuring the water consumption in the water supply system at certain time intervals and the statistical processing of the measured data, it is possible to construct a hydrogram of water consumption (water consumption as a function of time), which with a certain percentage of reliability will certainly occur in the observed or similar water supply system.

Based on the known hydrogram of consumption, it is possible to construct a curve of the non-uniformity coefficient. The function of the non-uniformity coefficient  $C=f(t)$  can be numerically constructed by some of the interpolation tools used in numerical mathematics (eg "Spline" interpolations).

With the known function of the non-uniformity coefficient of consumption  $C=f(t)$ , or the function of the hydrogram of consumption  $Q=f(t)$ , it is possible to program different mathematical models of the water supply system and different simulations of water flow in the system.

In this way, it is possible to program the flow of water into the distribution network, which will have an optimal match to the water consumption in the settlement. This will optimize the dimensions and functionality of constituent objects within the water supply system.

The main objective of this analysis is the multi-criteria optimization of the water supply system, which should ultimately result in a reduction in water consumption and a reduction in the initial and operating costs of the water supply system, while preserving the environment and available drinking water reserves.

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