III Sanitary Engineering and Sustainable Water Use

NUMERICAL ANALYSIS TO DETERMINE THE TECHNICAL WATER LOSSES IN A WATER SUPPLY SYSTEM

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Abstract

In N. Macedonia for many years, even decades, decreasing the capacities of water resources has been discussed, as well as increasing the specific water consumption per individual consumer. These circumstances of increased water consumption are directly related to, and caused by increased water losses in water supply system.

The great losses in water supply systems, as well as ordered Non Revenue Water contribute to further restrict clean water supply. Namely, this contributes to increased amount of water entering the distribution system and additional unjustified investment in the capacities of supplied raw water, rather than investment into remodeling and subsequent management of the network.

Recently, technological development facilitates a more active application of all available data; namely, the amount of information collected from water supply systems is increased, as well as the number of measurement points, the type of measurement data and the frequency of readings. As a result, control of water supply networks is improved, as well as knowledge for what in fact happens in the water supply systems. By using a measurement technique and by determining measurement points, we obtain data for the amount of water in water supply systems, which can be analyzed to determine the water losses in water supply systems.

The measurements taken from the water supply system and the analysis of the experimental readings gave a full picture for the water loss state in the water supply system of Strumica.

Leakages and pressure at specific measurement spots were also analyzed, and the total water loss and real losses on a daily and yearly basis were calculated, shown in percentage in relation to the water entering the distribution system in the water supply of Strumica.

Keywords: water supply systems; water losses; measurement points; analysis water losses.

1. Introduction

Many countries that have water management strategy, water losses in water supply systems take a significant place in the successful management of water and water supply systems. Of course, the level of economic development and ecological awareness influences the modernization and management of water resources, but the reduction and management of water losses improves the existing water supply systems and makes them efficient and sustainable. However, all plumbing systems face water loss, even the best and the most modern systems cannot eliminate the occurrence of water loss. But with continuous monitoring of the system, with the introduction of new technical measures and consistent implementation of management procedures, as well as the application of institutional measures, it is enabled to effectively manage the loss of water and the rationalization of water consumption.

In all water supply systems, the impact of water losses on their sustainability is great, and therefore when sustainability and the impact of water losses are mentioned, it is necessary to highlight the following impacts: economic, technical, social, ecological, etc. While during water loss management there are several elements that can justify the measures taken and the increased cost of water loss management such as:

- efficiency of operating costs,
- efficiency of capital costs,
- improved metering and invoicing,
- reduced health risks,
- increased security of water supply,
- less infrastructure damage,
- reduced sewage load,

- improved user satisfaction,
- publicity and willingness to increase the payment,
- reduced burden on the environment

In Macedonia, as a developing country, the level of awareness about reducing water losses is still at a very low level compared to developed countries that pay great attention to the problem of rationalizing consumption and the functionality of water supply systems and make great efforts to reduce water losses.

That is why the aim of this paper is through a numerical analysis with a selection of measuring points in the water supply network of the City of Strumica, to analyze the water losses, especially how much of it is technical and how much is administrative.

2. Defining water losses

Water losses can be expressed in many ways, but the most common way to express water losses is expressed in a percentage of water produced. Since the term "water loss" is rather broad and undefined and can be interpreted differently, the scientific community has adopted the term "uninvoiced water", that is, water that is produced and not paid for. So, we can divide water losses in water supply systems into apparent and real.

2.1. The real losses

Real losses are amounts of water lost as a result of network failures, damage to pipes and equipment, bad management and other network losses between the water entry into the distribution network and the end users' water meters.

Real losses refer to the loss of a specified amount of water over a given period of time through all types of leaks, cracks and overflows.

The reason for the real water losses are the pipes, the shaped and connecting elements, the type of material and the age, but various other factors that are related to the environment in which the installation is placed.

2.2. Apparent losses

Apparent losses represent amounts of water that occur as a difference between incoming water and sold water. Apparent water losses are not losses that occur due to the physical leakage of water, but are due to other factors that we can divide based on their origin and specificity, namely:

- Incorrect measurements, Inaccuracy of water meters due to untimely replacements and irregular calibration, both of house and control ones
- Errors with data processing and calculations, invoicing to consumers
- Unauthorized, illegal consumption due to theft of water and unauthorized connections

2.3. Unbilled allowed consumption

Unbilled permitted consumption represents the amount of water that was delivered to the system, but was used for own needs, such as testing of the water supply network, washing and flushing of the network, leaks during repair of defects and other incidental interventions in the network, i.e. it includes all amount of water that is justifiably not invoiced.

2.4. Non-revenue water (NRW)

The real and apparent water losses together with the uninvoiced allowable consumption represent the Non-Revenue Water (NRW) in the water supply system.

2.5. Irrational consumption of water

Irrational consumption of water according to IWA recommendations is not calculated as a component of water loss and is not included in the calculations in the water balance, because this consumption occurs after the measurement of the water meters. However, this amount of water can represent a significant part of metered and unmetered consumption. Practically, it can be divided into deliberate irrational consumption of water by the consumers themselves, where the cause would be damage to the taps and their continuous flow, or when we have consumption due to a failure of the internal plumbing system or overflowing of the toilet cisterns.

Irrational water consumption can also occur in the water supply company itself through excessive or negligent use of water for operational purposes, for example: during repair of defects, when flushing the water supply network, as well as when washing filters and other needs in the same technological process of the Filter stations.

2.6. Water balance

With the correct definition and accurate determination of the water balance, we get a calculation that will be a good basis for assessing water losses in the water supply system. The water balance is a calculation of the state of produced water, consumed water and losses.

Table 1. Water balance as recommended by IWA

<table>
<tr><td rowspan="10">Quantity which enters into the system QI</td><td rowspan="5">Authorized consumption QA</td><td rowspan="3">Billed authorized consumption QBA</td><td>Billed delivered water</td><td rowspan="2">Income water</td></tr>
<tr><td>Billed measured consumption</td></tr>
<tr><td>Billed Not measured consumption</td><td rowspan="6">Non-revenue water</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption QUA</td><td>Unbilled measured consumption</td></tr>
<tr><td>Unbilled Not measured consumption</td></tr>
<tr><td rowspan="5">Water loss QL</td><td rowspan="2">Apparent Losses QAL</td><td>Unauthorized consumption</td></tr>
<tr><td>Inaccuracy in consumer water meters and data handling errors</td></tr>
<tr><td rowspan="3">Real losses QRL</td><td>Leakage in main and distribution pipes</td></tr>
<tr><td>Leaks and overflows in tanks</td></tr>
<tr><td>Leakage of connections to consumers’ water meters</td></tr>
</table>

In the past, a variety of forms and definitions were used when calculating the water balance, but the International Water Association (IWA) provided a best practice approach that a number of countries and water supply companies have accepted and adopted the water balance, following the IWA terminology, so the basic and fundamental need is to calculate all the components of non-revenue water and terminologically to unify the individual components of the water balance.

3. Analysis of water losses on a real system in Macedonia

The aim of this paper is to determine the water losses in the water supply system of the city of Strumica using the IWA methodology.

The water supply of the city of Strumica functions as a modern water supply system that has been built and is continuously being built, expanded and constantly modernized for more than 50 years.

At first, the city was supplied with water through a pumping station in the Sofilar area until the construction of the old filter station and the pipeline from the dam Vodocha. In 1978 the new filter station was put in use through which the city of Strumica is still supplied with water today, but a pipeline from the Turia accumulation was built, from where the untreated water comes by gravity to the water processing plant through a 15 km long pipeline derived from asbestos cement pipes f600 and in the last 600m. passes into a steel pipeline f500 mm. For the need to purify and process raw water and provide clean water a Filter station with a capacity of 240 l/s was built.

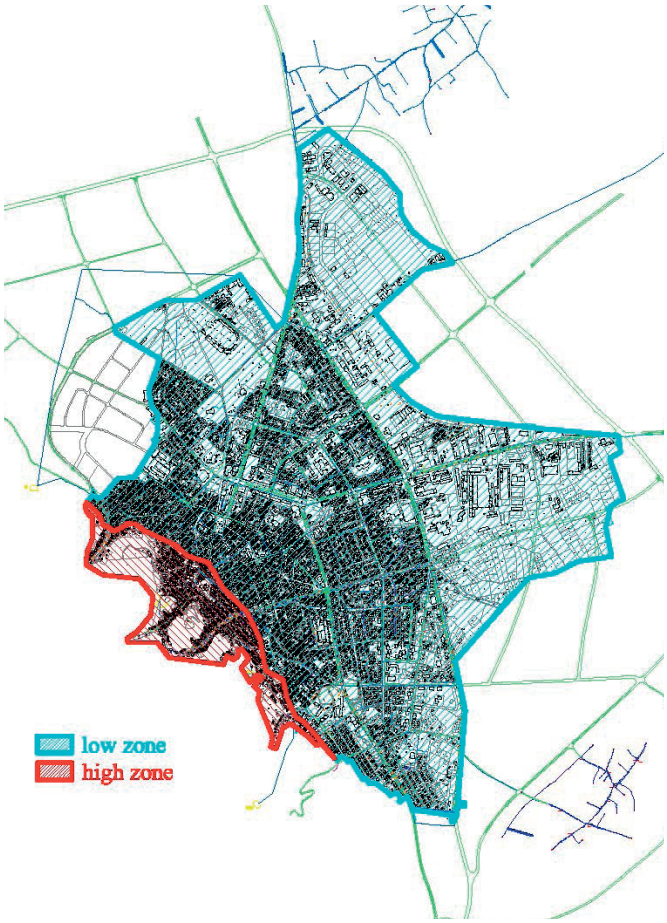

Figure 1. Map of Strumica water supply network

3.1. Analysis of water consumption in the water supply system of Strumica

The data on water consumption were provided by JPKD Komunalec for the last 30 years. These data refer to purchased raw water which is monthly read and invoiced by the Water Management Department of the Republic of Macedonia, data are also given on invoiced clean water to households and industry (business entities), as well as for the consumed technical water.

The following image shows total water losses, which are given as a ratio of invoiced water and purchased raw water expressed in percentage.

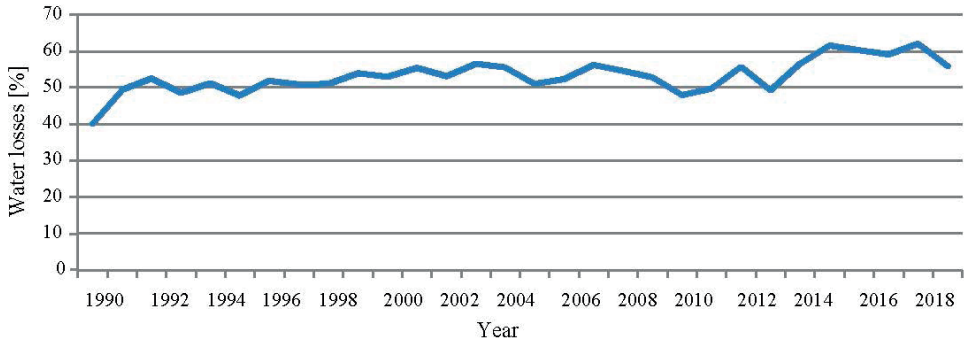

Figure 2. Total water losses in water supply system of Strumica

It should be noted that the measurement of raw water is carried out at the dam Turija at the entrance to the pipeline through which the raw water is transported to the Filter Station. This means that we present the water losses in the water supply system of the city of Strumica as total losses, which also include the losses of the pipeline to the Filter Station in a length of 15 km. and the consumption of water required for the technological process itself for the production of clean water. Of course, these data include all other losses, real and apparent, as well as authorized nonvoiced consumption.

When we look the numbers, we get a picture that in this period the total water losses range from 46% to 62%, it shows that the water losses are gradually increasing, the value of the invoiced water is gradually decreasing, while there are no

major changes in the amount of incoming water. This tells us that the impact of reported water and invoicing to citizens, along with all other administrative water losses, have a large percentage in the total water losses.

3.2. Real measurements of the total consumption of the city of Strumica

In order to define the total consumption of the city of Strumica, the total entry into the water supply system of the city of Strumica is monitored, which implies installation of ultrasonic flow meters on the two pipelines DN 300 mm and DN 400 mm that represent the entry of water into the water supply system for the city (exit from the water plant).

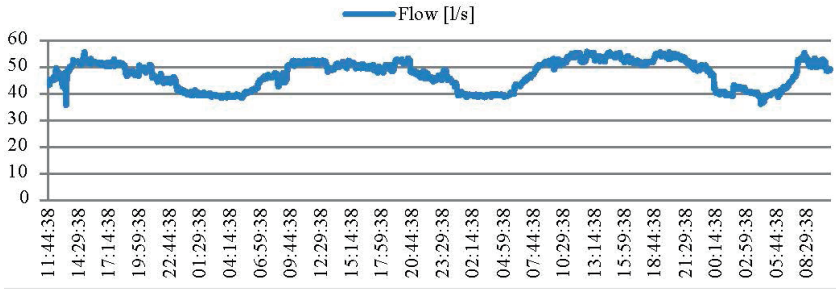

Figure 3. Flow measurement of pipeline DN300mm from filter station

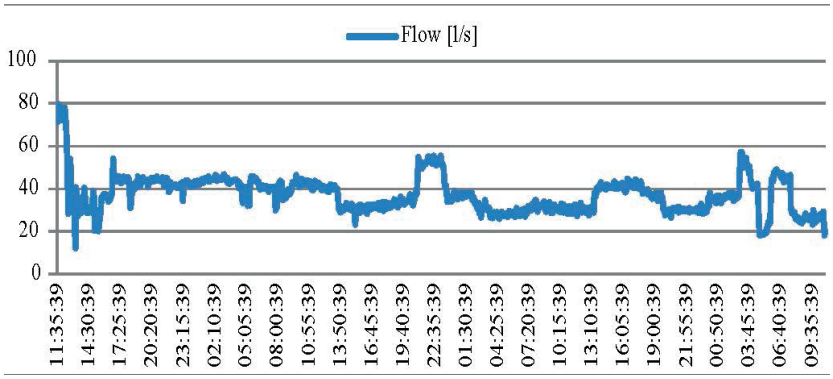

Figure 4. Flow measurement of pipeline DN400mm from filter station

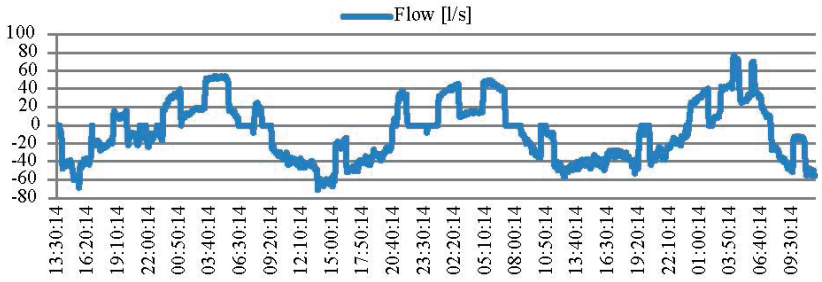

Figure 5. Flow measurement of pipeline DN600 mm in front of tank low zone 5000 m³ (Values with a negative sign are due to water flowing in the reverse direction – the measurement is in front of the tank where water goes in two directions to and from the tank)

Due to the large capacity of the low zone tank (5000m³), it was necessary to simultaneously monitor its flow by installing an additional ultrasonic flow meter on the DN600 mm pipeline, which represents the output of the low zone/input of the low zone tank. (Flow measurement with an ultrasonic flow meter is a non-invasive method, which involves installing sensors on the outer pipe wall and monitoring and memorizing the current pipe flow at pre-defined time intervals).

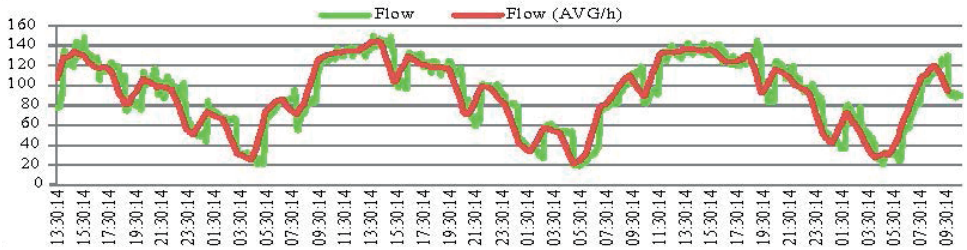

Figure 6. Total measured flow for low zone (AVG/h - The measurement was made at an interval of 10 minutes, therefore the average flow in one hour is shown)

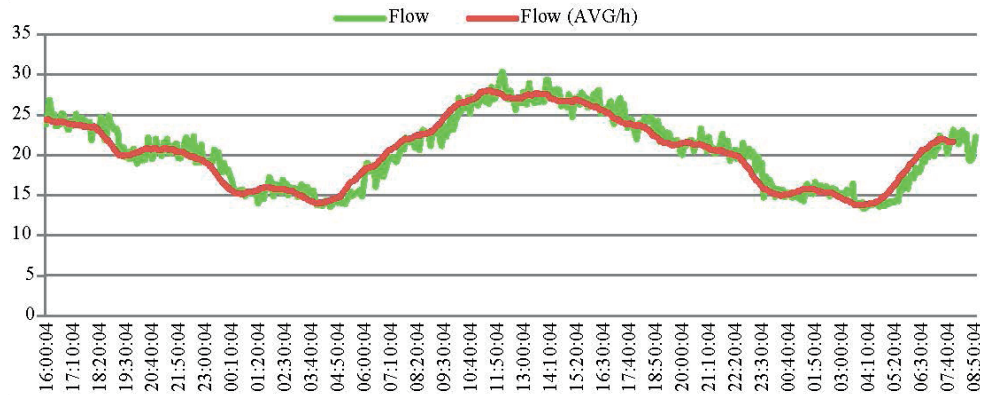

Figure 7. Total measured flow for high zone (AVG/h – The measurement was made at an interval of 10 minutes, therefore the average flow in one hour is shown

3.3. Analysis of results of experimental measurements

The analysis of the results of the experimental measurements were used for the analysis of water losses, while according to the specificities of the water supply system of the city of Strumica, we have to make a divided analysis for the low and high zones, from where the total water losses were obtained by summarizing the results.

The actual water losses in the water supply system of the city of Strumica were determined using the following method:

This method can be applied because reliable flow data is available at time intervals of 10–15 min. What are the conditions for performing the analysis? Measuring the minimum night consumption is one of the essential activities that should be undertaken to define the level of technical water losses. With a simple examination of the night minimum, it is possible to diagnose many problems. The losses are small and the network is in a relatively good condition, if the night consumption is very low, at most 13–18% of the daily average. This is based on the assumption that the nighttime activity of the population is reduced to a minimum, and thus the need for water. However, the losses depend on the time of day, and at night they are higher due to the increased pressure.

When we talk about the measured minimum night flow, it is not appropriate that this value represents the loss of water, because there is still a part of legally consumed water by individual and commercial users (Minimum legal night consumption), although the largest percentage is accounted for by leakages, which can be major faults on the primary network or minor faults on the secondary network.

The difference between Minimum night flow (MNF) m³/hour and Legitimate night consumption (LNF) m³/hour gives the Net night flow: m³/hour (NNF). Due to the difference in pressures during night and day, the daily flow (m³/day) should be multiplied by NDF (Night Day Factor), which is a coefficient that creates the actual average 24-hour flow, which is depending on the pressure (values vary mostly from 17 to 28). In the case of gravity water supply, the values can vary from 17–18 to 24, while in the case of pumped water supply, from 23–24 to 26–28.

Based on the realized pressure measurements and using a software tool, this low zone factor was calculated at a value of 22.58. while for high zone this factor is 23.6.

Based on the previously performed calculations for real water losses in low and high zones, the total real water losses at the level of the city of Strumica with the surrounding villages amounts to:

City of Strumica = low zone + high zone

Daily flow: 1095 m³/day + 1037 m³/day = 2132 m³/day
or 26.97% of the total daily input into the system
Annual flow:
399765 m³/year + 378505 m³/year = 778 180 m³/year
or 16% of the total input of purchased raw water in the filter station

4. Conclusion

Analyzing these figures for the annual total losses for the analyzed year 2021, which are 56%, it can be concluded that the level of apparent water losses is high, about 40% in relation to the purchased raw water. The percentage of 16% of real losses in relation to the purchased raw water gives us an image that the water distribution network is in a relatively good condition, that these losses are still at a relatively low level, which with constant monitoring and taking measures to reduce losses can be even smaller.

But it is also necessary to note that the water losses along the supply pipeline to the Filter Station, as well as the water losses in the technological process of the Filter Station, are not separated as a quantity and as a percentage and were not the subject of this analysis. Although these losses should be calculated in the real losses, due to the lack of possibility to measure these quantities, they will remain as losses that enter into the 40% apparent losses.

But with these measurements and analysis, the aim was to perceive the water losses in the water distribution network, determining the real water losses at the output from the Filter Station, (entrance to the water supply system), then to the end users, and thus determined is the water balance required for the water supply system of the city of Strumica.

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