Analysis of selected aspects of collective water supply system operation in the selected municipality

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Abstract. The purpose of the work was to analyze the exploitation of the collective water supply system (CWSS), on the example of Czudec, Podkarpackie CWSS. The water balance was prepared. The system operation was simulated using the Epanet software. The obtained data was presented in graphical form of pressure distribution on the network during the minimum and maximum demand. Water age simulations were also prepared, that is, the period of water residence in water distribution subsystem.

1 Introduction

Collective water supply systems (CWSS) existed already in antiquity, but in the 20th century that were introduced on a mass scale, which increased the hygiene of society's life. A significant increase in the length of the water supply network was observed at the end of the 20th century and in the 21st century, in particular in rural areas. In 1989, the length of the water supply network in Poland was 88.3 thousand km, while in 2014 it increased to 292.5 thousand km. The result of building new networks is increase people number who can use tap water. The percentage of urban and rural water supply has risen from 84.8% in 2002 to 91.6% in 2014, while 84% used it in rural areas in 2014, and 96% in urban areas. Acceleration of investments related to the build of water distribution subsystem (WDS) is related to the possibility of obtaining European funds by water companies and municipalities [4,5,6,8,9].

Water companies in Poland consume water primarily for industrial and household purposes. The highest water consumption took place in the second half of the 20th century. This was caused by low price of water. The increasingly water quality standards have forced companies to develop newer and more expensive water treatment technologies, which resulted in a drastic increase in prices [1-3]. The result was a reduction of water consumption per statistical inhabitant [7].

In the era of computerization, managers of water supply companies use computer programs that enable monitoring of water distribution subsystem, its correct operation, as well as the ability to quickly eliminate water pipes failures. The aim of the paper is analysis of the WDS Czudec commune operation.

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2 Description of the analyzed system of collective water supply

The water distribution subsystem was created relatively recently. The first water pipes were built in 1994. Before that time, the inhabitants took water from their own individual wells. For the next 9 years, the water supply network did not increase. The breakthrough year was 2003, because the residents of the commune were running out of water. At that time, a decision was made to further expand WDS. It consists pipes with diameters: Ø50, Ø63, Ø90, Ø110, Ø125, Ø160, Ø225. The main material that was used to build the network is polyethylene (PE). Table 1 presents the characteristics of the WDS in 2009-2016.

Table 1. Characteristics of the WD in the Czudec commune in 2009-2016

year	Length	diameter	Number of residents	Number of residents connected to WDS	% residents connected to WDS
	[km]	[mm]	[-]	[-]	[%]
until 2009	86.569		11569	2606	22.5
2010	108.047	-	11588	3251	28.1
2011	1.250	Ø63	11749	3265	27.8
	0.750	Ø110			
	5.750	Ø160			
	3.080	Ø225			
Σ	118.877				
2012	3.765	Ø110	11777	3278	27.8
	5.835	Ø160			
Σ	128.477				
2013	4.139	Ø50	11721	3325	28.4
	4.832	Ø110			
Σ	137,448				
2014	0.024	Ø63	11723	3461	29.5
	1.662	Ø110			
	0.721	Ø160			
Σ	139.855				
2015	0.976	Ø50	11788	4139	35.1
	0.374	Ø63			
	0.081	Ø90			
	10.321	Ø110			
	1.345	Ø125			
Σ	152.952				
2016	1.351	Ø50	11798	4680	39.7
	0.134	Ø63			
	0.731	Ø90			
	10.504	Ø110			
	1.223	Ø125			
	0.336	Ø140			
	0.328	Ø160			
Σ	167.559				

At the end of 2016, the total length of WDS was 167.56 km, and the percentage of people connected to WDS reached 39.7%. The population of the Czudec commune in period 2009-2016 increased by 229 people and the number of water recipients at the end of 2016 reached 4680.

As shown in Figure 1, water intake increases. The exception is 2014, when it was 15.08 thousand m^3 of water less than in the previous year. A significant increase in water sales is also observed, which is associated with the WDS growth. In the period under analysis, a large drop in water losses can also be noticed.

Figure 2. present diagram of the WDS in the Czudec commune.

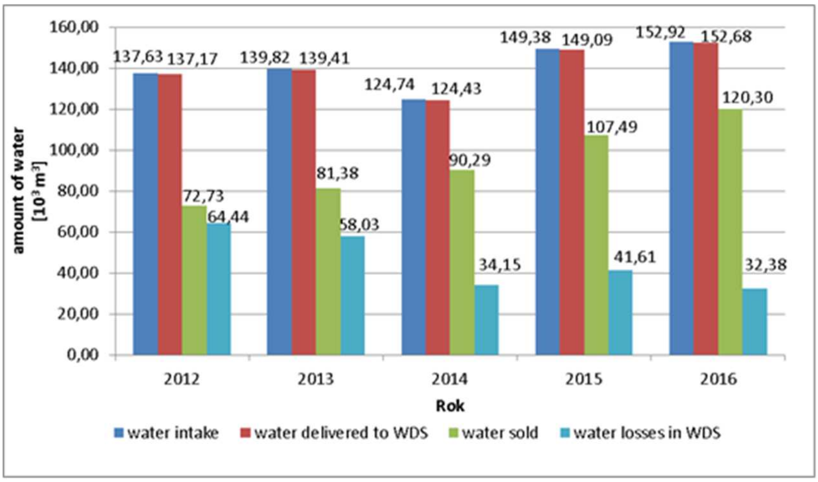

Fig. 1. Water balance in the municipality of Czudec

Fig. 2. Diagram of the WDS in the Czudec commune

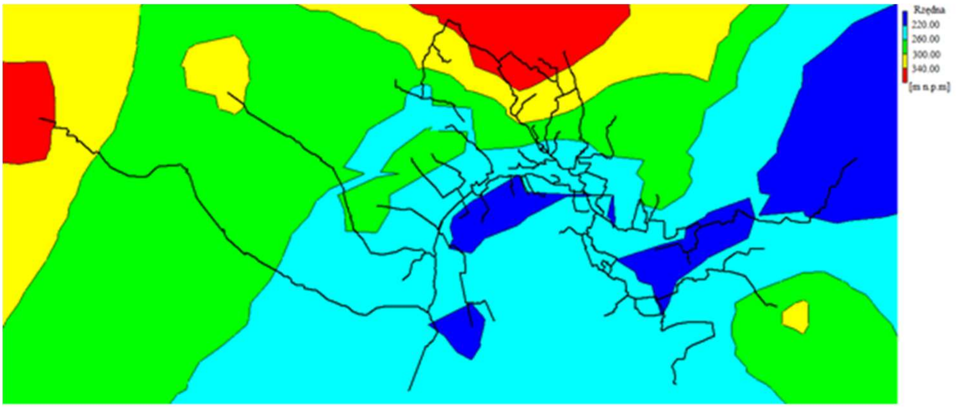

Fig. 3. The height layout of WDS in the Czudec commune

Water intakes and tanks are located in the southern and eastern part of the commune, and pumping stations are located on the entire surface of the supply area.

Czudec commune is located in a varied height. In figure 3 the height layout of WDS is presented.

3 Analysis of the pressure in WDS

For the purposes of the analysis, a hydraulic model of the water supply network was prepared. Figure 4 shows the distribution of pressure on the network during the minimum demand, while Figure 5 shows the frequency of pressure at the minimum demand.

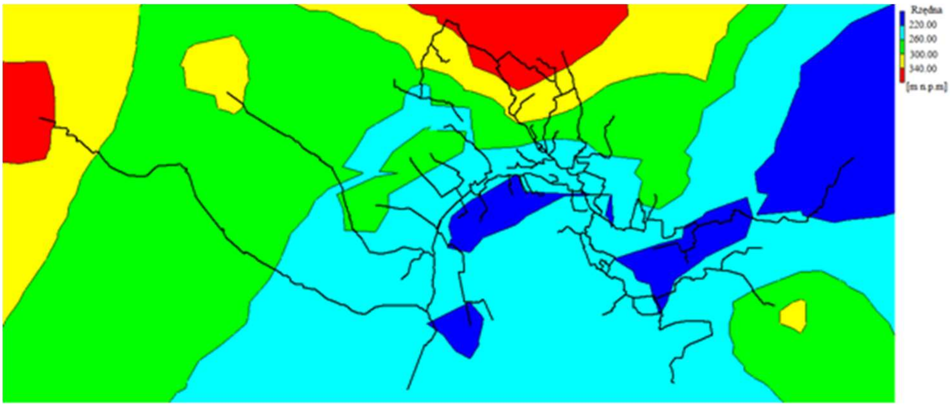

Fig. 4. Distribution of pressure on the network during the minimum demand

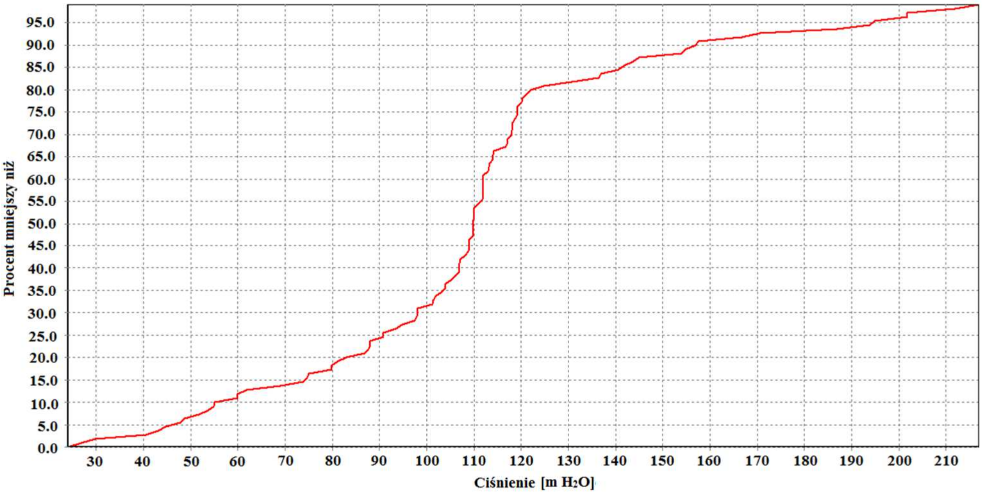

Fig. 5. Frequency of pressure occurrence during minimum demand (x-axis – pressure, y-axis - percent less than)

During the minimum demand, the pressure in the WDS ranges from 24 to 215 mH_2O, of which pressures up to 110 mH_2O account for 50%. The highest pressures occur in the northern part of the network and exceed the value of 120 mH_2O.

Figure 6 shows the distribution of pressure during the maximum water demand, while Figure 7 shows the frequency of pressure during this demand.

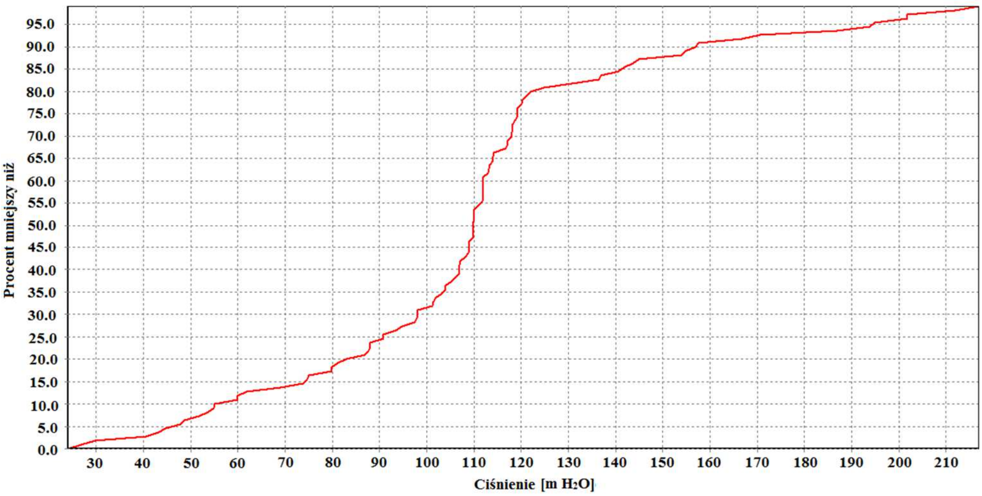

Fig. 6. Distribution of pressure on the network during the minimum demand

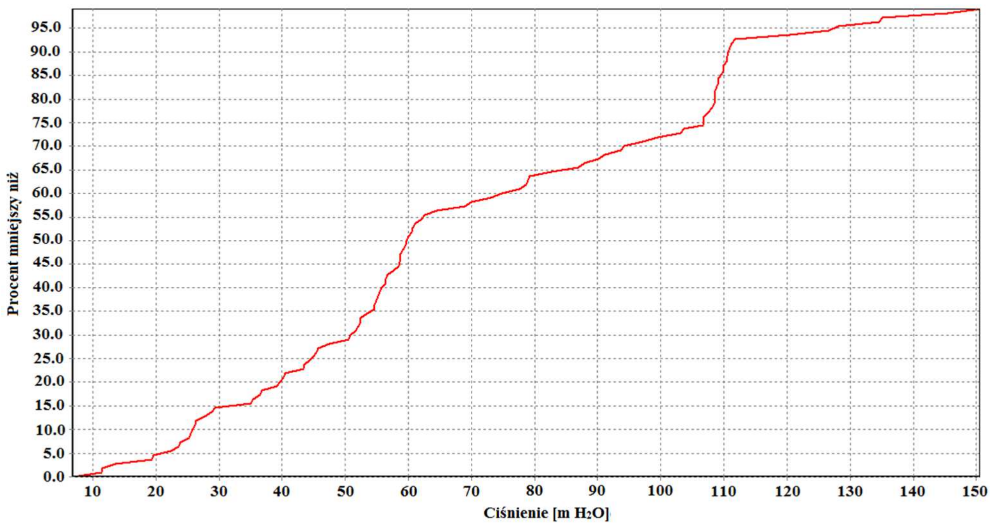

Fig. 7. Distribution of pressure on the network during the minimum demand (x-axis – pressure, y-axis - percent less than)

The highest pressure during the maximum water demand occurs in the north-western area of the WDS and exceeds 150 mH_2O. The pressure during this demand is in the range from 7 mH_2O to about 150 mH_2O, of which 50% are pressures below 60 mH_2O.

4 Water age analysis

Water age simulations were also prepared, that is, the period of water residence WDS. This simulation is shown in Figure 8.

The lowest water age below 24 hours occurs in the central, eastern and south-western parts of WDS. In the northwest and the western water supply area, the age exceeds 96 hours. These are mainly the ends of WDS in which the demand is negligible.

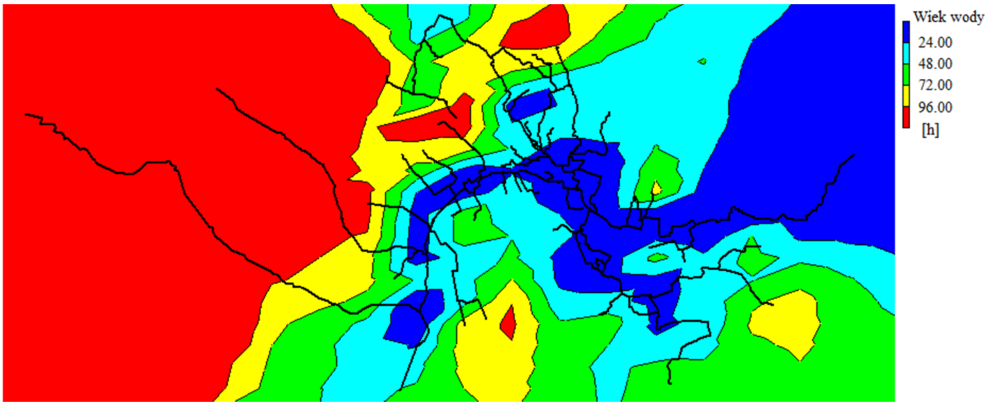

Fig. 8. Water age in the WDS

5 Conclusions

Proper operation of the CWSS allows to achieve continuous operation of the entire WDS, Thanks to hydraulic model it is possible to optimize the operation process.

During the minimum demand on a large part of the WDS, the pressure exceeds 60 m H_2O – recommended maximum for house connections. The reason for such high pressures is mostly the terrain. In places where pressure exceeds 60 mH_2O, pressure reducers are installed at house connections.

Due to the diversified terrain, there is no possibility of gravitational water supply entire WDS, therefore, where necessary, a pumping station is located (there are 11 pumping stations on the whole WDS).

The actions to be taken to reduce the pressure in WDS are primarily the installation of pressure reducers in regions where there is a gravitational supply of water. As a result, it is possible to reduce the risk of failure caused by the cracking of pipe due to high pressures. Another action that should be taken is the separation of more water pumping zones. This would reduce the lift height of the pump, and thus reduce the pressure, resulting in lower water losses.

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