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CHANGEABILITY OF WATER CONSUMPTION IN THE CITY OF RZESZÓW

The aim of the work is the analysis of water consumption in Rzeszów city. The quantity of produced water in Water Plants: Zwiężczyca I and Zwiężczyca II were performed for years 2007-2009. The individual average twenty-four hour water consumption per one inhabitant was estimated. A stable decrease was observed in annual water consumption in years 2000-2009. On the example of housing estate Nowe Miasto, the analysis of water consumption concerning the heights of the buildings was made. The biggest individual water consumption was marked in ten-storey house, and the smallest in single-family house. The next step regard the water consumption depending on the days in week. The biggest water consumption was in Thursdays, and the smallest in Sundays. Also the maximum and minimum twenty four hour water consumption in the division into months in 2009 year were determined.

1. Introduction

In Rzeszów water pipes form a vast and dense network, working at 80% in the ring. Thanks to it, greater efficiency of the entire distribution system is ensured. Pipes spread beyond the city limits, supplying water to the adjacent municipalities of Boguchwała, Głogów Młp., Krasne, Tyczyn, Świlcza, but these places are less than 8% of the total sale of water [1-4]. The water supply network consists of five water mains, which transport water from the intakes in the direction of the expansion tanks. Simultaneously, the area of the city is powered from numerous branches:

1. The water main „Rzeszów” ($\Phi 315$) is the oldest main in the city (the 1934 cast iron). It supplies water to the residents of Hetmańska Street, 3 May Street and Krakowska Street.
2. The water main „0” ($\Phi 1200$, $\Phi 1000$, $\Phi 800$) is the newest and largest main in Rzeszów. It brings water from the water treatment plant

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Zwiężczyca II to the north – west part of the city and to the tanks in Baranówka.

3. The water main „1”(Φ400) transports water from the water treatment plant Zwiężczyca I to the centre and to the northern area of the city. This pipeline has two branches, one of which feeds Boguchwała and Mogielnica, and the other one Zwiężczyca, Raclawówka and Niechobrz.
4. The water main „2” (Φ400) transports water from the water treatment plant Zwiężczyca I to the south and central part of the city.
5. The water main „3”(Φ400) is used to transport water from the water treatment plants Zwiężczyca I and II to the east and north – eastern area of the city. It powers the tanks in Pobitno. At the initial section of the water main there are two branches, Φ150 and Φ100, which supply water to the districts Budziwój and Biała.

Thanks to such layout of water mains there is the possibility to control water flow to various parts of the city, using the available pressure in the pumping station. The largest amount of water flows by the water mains „0”, „1” and „2”, powering a left-bank part of the city. They cooperate with the tanks in Baranówka. The right-bank part of the city is powered by the water main „3”, which cooperates with the tanks in Pobitno. Both parts of the city are connected by three pipelines (Φ400), which run along the bridge on the Wisłok river.

2. The quantity of water produced and treated in Zwiężczyca

2.1. Water treatment plant I

Table 1 shows the production of water in the water treatment plant I in the years 2007-2009. Data from 2007 are lower than in subsequent years because from April to December the plant was shut down due to modernization. At that period of time water was produced only in the water treatment plant II.

Table 1. The quantity of water produced in the water treatment plant I in the years 2007-2009

Year	The quantity of water	
	[m ³ /year]	[m ³ /day]
2007	1 966 743	5 388
2008	6 284 090	17 217
2009	5 970 434	16 357

2.2. Water treatment plant II

Table 2 contains data on the production of water by the water treatment plant II in the years 2007-2009. The production of water in the water treatment

plant II in 2007 is, as in the water treatment plant I, not typical, because the water treatment plant I was then modernized.

Table 2. The quantity of water produced in the water treatment plant II in the years 2007-2009

Year	The quantity of water	
	[m ³ /year]	[m ³ /day]
2007	10 912 819	29 898
2008	6 682 912	18 309
2009	6 569 113	17 998

3. Analysis of water consumption

3.1. Unit water consumption

The basic parameter for calculating water consumption is unit water consumption indicator [m³/person per day]. This is the ratio of daily water consumption (Q_d) to the number of inhabitants. Table 3 presents the decline in unit water consumption in the past three years.

Table 3. Unit water consumption of Rzeszów

Year	The number of inhabitants	Water consumption		Unit water consumption [m ³ /person per day]
		[m ³ · 10 ³]	[m ³ /d]	
2007	170 700	9 709	26 600	0,156
2008	172 700	9 479	25 970	0,150
2009	177 800	9 409	25 778	0,145

The above table and a graph show that the unit water consumption for one inhabitant per day was from 156 dm³/person per day in 2007 to 145 dm³/person per day. Unit water consumption decreases with each passing year (in 2000 it was 191 dm³/person per day).

3.2. Water consumption in the city of Rzeszów in the years 2000-2009

The analysis of water consumption over the years and in particular months was based on information from the Sales Department at Municipal Enterprise for Water and Sewage (MEWS) in Rzeszów. Data refer to the quantity of water sold to customers. Table 4 shows water consumption in Rzeszów in the past ten years.

Table 4. Water consumption in the city of Rzeszów in the years 2000-2009

Year	Water consumption	
	[m ³ /year]	[m ³ /d]
2000	11 288 000	30 926
2001	10 762 000	29 485
2002	10 418 000	28 542
2003	10 155 000	27 822
2004	9 766 000	26 756
2005	9 603 000	26 310
2006	9 640 000	26 411
2007	9 709 000	26 600
2008	9 479 000	25 970
2009	9 409 000	25 778

In the years 2000-2009 there was a decrease of water consumption in Rzeszów by 17%. The reason is, among others, use of efficient appliances in households and permanent increase in price of 1 m³ of water. The decrease of water consumption is also caused by reducing water consumption by major industrial users.

It may be noted that after years of a large drop in demand for water, there was a slight increase in water consumption, which may be partly dictated by the connection of new areas to the city (since 2006). It also proves the stabilization of the lower border value of unit water consumption in households in the city.

3.3. Monthly water consumption in Rzeszów in 2009

Water consumption in the subsequent months of the year depends on many factors. The important factor is the season of the year. In winter and holidays

Table 5. Monthly water consumption in Rzeszów in 2009

Month	Water consumption	
	[m ³ /month]	[m ³ /d]
January	738 046	23808
February	702 180	25078
March	788 888	25448
April	822 430	27414
May	781 247	25202
June	852 788	28426
July	787 909	25416
August	754 428	24336
September	808 895	26963
October	814 472	26273
November	779 820	25994
December	778 271	25106

water consumption is the lowest. When there is drought – water demand is higher (eg. for watering plots, gardens), and in rainy period customers use less water. The changing number of residents (students, people leaving on holidays, commuters and seasonal workers) is also important. Table 5 lists the water consumption in each month in 2009.

The highest daily consumption occurs in June – 28 426 m³/d and lowest in January – 23 808 m³/d.

3.4. Water consumption depending on the height of buildings

The data used in this chapter were obtained from the Housing Cooperative „New Town” in Rzeszów and from the Municipal Enterprise for Water and Sewage. The study involved use of water by the residents of selected buildings and houses in the New Town estate in 2009. Table 6 shows the number of inhabitants and water consumption depending on the height of buildings.

Table 6. Water consumption depending on the height of buildings

No	Building	Number of floors	Number of people	Water consumption	
				[m ³]	[m ³ /person per day]
1	block	X	347	16021	0,126
2	block	X	365	18432	0,138
3	block	X	421	20773	0,135
4	block	IV	267	10855	0,111
5	block	IV	471	19444	0,113
6	block	IV	203	8209	0,111
7	tenement house	III	26	867	0,091
8	tenement house	III	46	1833	0,109
9	tenement house	III	45	1585	0,096
10	house	–	3	84	0,077
11	house	–	5	192	0,105
12	house	–	4	144	0,099

Based on the data depicted in a figure, one can observe some dependence between the height of construction and water consumption. The higher the building the higher the demand for water. In ten-storey blocks water consumption is the highest, the lowest demand occurs in the houses.

3.5. Water consumption depending on the day of the week

The great regularity of water consumption can be seen in a weekly cycle. On Monday water consumption is low, then rises and reaches the highest value in the middle of the week. Then water consumption gradually decreases, reaching a minimum value on Sunday. Such a distribution of water consumption

is the result of the nature of the city – in the week, people come to work and various investments in the capital of Subcarpatian are carried out. Table 7 shows water consumption in the ordinary working week, from 18 to 24 May 2009.

Table 7. Water consumption depending on the day of the week

The day of the week	Water consumption [m ³ /d]
Monday (18.05)	37 652
Tuesday (19.05)	38 089
Wednesday (20.05)	38 349
Thursday (21.05)	39 748
Friday (22.05)	36 574
Saturday (23.05)	34 537
Sunday (24.05)	31 358

3.6. Daily water consumption Q_{\max} and Q_{\min} in 2009

Table 8 summarizes the highest (Q_{\max}) and the lowest (Q_{\min}) daily water consumption by the public in particular months in 2009.

Table 8. Q_{\max} i Q_{\min} in particular months in 2009

Month	Q_{\max} [m ³ /d]	Q_{\min} [m ³ /d]
January	41 708 (08 – Thursday)	35 315 (02 – Friday)
February	40 972 (02 – Monday)	32 564 (09 – Monday)
March	39 385 (24 – Tuesday)	31 171 (12 – Thursday)
April	40 489 (29 – Wednesday)	23 685 (12 – Sunday, Holiday) min
May	42 517 (15 – Friday)	31 333 (31 – Sunday)
June	40 152 (09 – Tuesday)	29 437 (11 – Thursday, Holiday)
July	43 563 (15 – Wednesday)	30 775 (12 – Sunday)
August	44 213 (05 – Wednesday) max	28 292 (16 – Sunday)
September	37 986 (02 – Wednesday)	30 938 (06 – Sunday)
October	38 932 (22 – Thursday)	34 211 (19 – Monday)
November	39 237 (20 – Friday)	30 027 (01 – Sunday, Holiday)
December	39 350 (02 – Wednesday)	30 369 (26 – Saturday, Holiday)

The highest daily consumption took place in August (05 August), and the lowest in April (12 April).

3.7. Water price versus inflation

The analysis was performed assuming that the price for 1 m³ of water in 2000 was 100%. Table 9 presents the formation of water prices, according to MEWS, Rzeszów and inflation, according to Central Statistical Office, in the last decade.

Table 9. Water price versus inflation in Rzeszów in 2000-2009

Year	The price for 1 m ³ of water	The percentage increase of water prices	Inflation
	[zł]	[%]	[%]
2000	1,50	100,0	100,0
2001	1,87	124,7	105,5
2002	2,04	136,0	107,4
2003	2,08	138,7	108,2
2004	2,12	141,3	111,7
2005	2,17	144,7	113,8
2006	2,18	145,3	114,8
2007	2,22	148,0	117,3
2008	2,35	156,7	121,5
2009	3,16	210,7	125,0

Over the past ten years the price for 1 m³ of water has grown steadily. The price of water increased by 110,7% and inflation by 25%. In 2009, the residents of Rzeszów paid for water two times more than in 2000.

4. Conclusion

Analysis of water consumption in Rzeszów showed that water demand throughout the year is uneven and is subject to fluctuations. It is formed by many factors, including climatic conditions, local conditions, holidays, public holidays, lifestyle, accidents, the amount of pressure in the network, failures in the network and equipment failures etc [5].

The winter months are characterized by less use of water than the summer months. In 2009, the highest demand for water was in June, the lowest in January. One could also note that the highest water consumption occurred on working days, while the lowest was on Sundays and public holidays. Detailed analysis showed that the highest amount of water per year is consumed by households (74,29%) and the lowest by industry (10,41%).

The phenomenon of decreasing consumption of tap water, which occurred during study, can be assessed as positive, because it is associated with a rational water management and saving. Significant positive changes have occurred in the factors that previously caused the waste of water. Better and more modern materials and fittings for installation appear on the market. All of this creates the technical possibilities of reducing or even eliminating water losses due to leakage in residential installations [6-9].

Apart from technical reasons for reducing water consumption, clearly favourable economic factor – increasing price for 1m³ of water – also occurred. All this results in rationalization of water consumption, leading consequently to a decline in unit water consumption. The performed analysis shows that

population increases and unit water consumption decreases – from 156 m³/d in 2007 to 145 m³/d in 2009.

References

- [1] Pietrucha K.: Analiza czasu odnowy i naprawy podsystemu dystrybucji wody dla miasta Rzeszowa, Instal, z. 10, 2008, s. 113-115.
- [2] Rak J., Studziński A.: The chosen problems of Rzeszów water supply system exploitation, 10th Scientific Conference Rzeszów-Lviv-Kosice „State of art. Trends of development and challenges in civil engineering”, Technical University of Kosice, Slovakia 2005, pp. 328-335.
- [3] Kwietniewski M., Rak J.: Niezawodność infrastruktury wodociągowej i kanalizacyjnej w Polsce – stan badań i możliwości jej poprawy, Komitet Inżynierii Lądowej i Wodnej PAN, Warszawa 2009.
- [4] Solecka M.: Zużycie wody w mieście Rzeszowie, Politechnika Rzeszowska, Rzeszów 2010 (praca niepublikowana).
- [5] Bugajski P., Satora S.: Zmienność jednostkowego zużycia wody przez mieszkańców Olkusza, Infrastruktura i Ekologia Terenów Wiejskich, nr 5/2009, s. 51-60.
- [6] Rak J., Tchórzewska-Cieślak B.: Analiza zużycia wody przez mieszkańców Dębicy, Zeszyty Naukowe Politechniki Rzeszowskiej, seria Budownictwo i Inżynieria Środowiska, vol. 42, 2007, pp. 113-122.
- [7] Rak J., Tchórzewska-Cieślak B.: Analiza zużycia wody do picia w mieście Rzeszowie, mat. konf. IV Międzynarodowej Konferencji, XVI Krajowa Konferencja „Zaopatrzenie, jakość i ochrona wód”, PZITS O/Wielkopolski, Kraków-Poznań 2000, s. 927-933.
- [8] Rak J., Tchórzewska-Cieślak B.: Analiza zużycia wody do spożycia w wybranych osiedlach miasta Rzeszowa, mat. Konferencji Naukowo-Szkoleniowej „Problemy budownictwa wodnego i gospodarki wodno-ściekowej w Polsce ze szczególnym uwzględnieniem regionu Podkarpacia”, Myczkowce 2001, Wydaw. RZECH-DRUK, Rzeszów 2001, s. 236-240.
- [9] Rak J., Tchórzewska-Cieślak B.: Zużycie wody do spożycia w mieście Rzeszowie z uwzględnieniem wysokości zabudowy, mat. konf. VI Międzynarodowej Konferencji Naukowej Rzeszów-Lwów-Koszyce, Wydaw. Politechniki Lwowskiej, Lwów 2001, s. 6-13.

ZMIENNOŚĆ ZUŻYCIA WODY W MIEŚCIE RZESZOWIE

Streszczenie

W pracy przedstawiono analizę zużycia wody w mieście Rzeszowie. Dokonano analizy wyprodukowanej i uzdatnionej wody w ZUW I oraz ZUW II w latach 2007-2009. Oszacowano jednostkowy wskaźnik zużycia wody. Analiza zużycia wody w Rzeszowie wykazała, że zapotrzebowanie na wodę w ciągu roku jest nierównomierne i podlega wahaniom. Przedstawiono zużycie wody w zależności od wysokości zabudowy. Największe zużycie wody zaobserwowano w piętro-
wych blokach z płyt, natomiast najmniejsze – w domach jednorodzinnych. Wykazano dużą prawidłowość zużycia wody w cyklu tygodniowym – w poniedziałek zużycie wody jest niskie, następnie wzrasta i największą wartość osiąga w środku tygodnia. Zestawiono doby o największym i najmniejszym zużyciu wody przez odbiorców w poszczególnych miesiącach w 2009 r.

