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QUANTITATIVE AND ECONOMICAL ASPECTS OF WATER LOSS IN WATER-PIPE NETWORKS IN RURAL AREAS

An analysis of water management during one calendar year in four selected rural waterworks located in Lesser Poland voivodeship was conducted. On the basis of available data, the amount of water loss and its financial consequences were defined. Water loss in the water-pipe networks of interest ranged between 5.1 and 49.7% of water pumped into the system causing a financial loss from 3.7 to 70.6 thousand zł·year^{-1}. Computed loss ratios were compared with Polish and international standards. Moreover, technical and organizational solutions limiting water loss were described which mostly include water-pipe network renovation using thermoplastic materials and the replacement of old indoor plumbing.

1. INTRODUCTION

The main reason for poor municipal water management during last decades in Poland was the very low water price. This caused a huge amount of water waste and water losses were ignored. Ignored water losses are mentioned as some of main reasons behind water shortages, which many countries are facing all over the world. A significant decrease in water usage during last several years forced waterworks companies to search for ways to reduce costs related to water intake, treatment, and distribution. Many companies determined that one of the most effective ways of reducing costs is to reduce water loss, which in many water-pipe networks is a high percentage of water pumped into the system.

Water-pipe network water loss is described as the difference between the volume of water pumped into the network plus the needs of waterworks and the volume of water sold to consumers. Water loss occurs in the water-pipe network from the intake to the place of usage. The majority of losses occur because of leaks caused by a poor technical state of the water-pipe network. According to HOTLOŚ [1], German studies

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proved that water leakage into the ground from an external water-pipe networks causes 80–100% of the real water loss.

Water loss poses a problem for waterworks managers all over the world, although the amount of loss varies. In Polish cities, losses are approximately 20%; however research carried out by BERGEL and BUGAJSKI [2] showed that water losses may even reach 74%.

The problem of water loss in rural water-pipe networks has not yet gained similar interest to that in urban networks; thus the analyses related to this phenomenon in rural water-pipe networks are unavailable. For this reason, the Department of Water Supply and Sewage Systems of the Agricultural University of Cracow has begun studying this problem in southeastern Poland.

2. RESEARCH PROCEDURES

The aim of this research was to analyze the management of water in four chosen rural waterworks in 2007 in terms of water loss. The following data essential for the analysis was obtained from the waterworks companies:

- volume of water supplied to the network, used for individual needs of the waterworks company, and sold to consumers,
- water sale price,
- technical data of the water-pipe networks (material structure and system length),
- number of consumers and connections,
- number of failures.

Table 1

General characteristics of water-pipe networks

Specification	Unit	Water-pipe networks			
		G	R	T	Z
Number of consumers	–	550	1380	2180	1070
Water production	$m^3 \cdot d^{-1}$	165	104	340	215
Network length (with connections)	km	12.3	18.3	45.7	20.5
Number of connections	pieces	138	332	560	329
Unitary network length	m per capita	22.4	13.3	21.0	19.2
Material structure of network:					
PE	%	31	100	21	11
PVC	%	19	–	7	19
steel	%	50	–	72	67
cast iron	%	–	–	–	3
AC	%	–	–	–	–
Failure rate	$failure \cdot km^{-1} \cdot year^{-1}$	1.38	0.55	1.68	1.41

The amount of water loss and its financial consequences were defined using available data. Computed loss ratios were related to Polish and international standards. Moreover, technical, organizational and financial remedies for minimizing water loss were illustrated.

The water-pipe networks of interest are located in Lesser Poland voivodeship. Their specifications are shown in table 1.

3. RESULTS AND DISCUSSION

The effect of damage, leaks and system failures is a water flow reduction in the distribution system, normally called "a loss". The most common convention is to present water loss as a percentage in relation to the volume of water supplied to the system (W_{lv}). The water-pipe networks of interest were characterized by different losses. The smallest losses occurred in the water-pipe network R – 5.1% (table 2). This is most likely due to the material used for building the system, namely polyethylene (PE). As reported by KWIETNIEWSKI [3], PE is vastly superior to other materials in terms of operational reliability. In this study, the value of PE failure rate was 0.55, which was the lowest out of all the water-pipe networks (table 1).

Table 2

Water loss indexes in water-pipe networks

Water loss index	Unit	Water-pipe network			
		G	R	T	Z
V_{loss}	$m^3 \cdot d^{-1}$	78.0	4.0	59.0	81.0
$V_{\text{loss adm.}}$	$m^3 \cdot d^{-1}$	29.5	43.9	109.7	49.2
W_{lv}	%	49.7	5.1	19.4	40.0
$q_{\text{av SP}}$	$dm^3 \cdot d^{-1}$ per capita	141.8	2.9	27.1	75.7
q_{ul}	$m^3 \cdot h^{-1} \cdot km^{-1}$	0.26	0.01	0.05	0.16
RLB	$dm^3 \cdot conn^{-1} \cdot d^{-1}$	565.2	12.0	105.4	246.2

In the remaining water-pipe networks, the situation was much worse; however, in the water-pipe networks T, losses were on the level of the country average. Notably, the water-pipe networks G and Z fared far worse. 50–72% of the piping network are composed of steel and cast iron. These materials are the most susceptible to failure as shown by the failure rate for these systems.

KASPRZAK and LEMAŃSKI [4] report that economical aspects should be taken into account when reducing water loss. According to them, 8–10% water loss may be accepted and recognized as economically justified.

It should be noted that the water loss percentage fails to clearly illustrate the situation since this value neglects system length. Thus, the unitary water loss ratio q_{ul} is a preferred parameter. The admissible value of q_{ul} is dependent on the so-called water-pipe network load intensity ratio. Based on this ratio, the admissible value of q_{ul} was accepted as 0.1 $m^3 \cdot h^{-1} \cdot km^{-1}$ [5]. Comparing this with the ratios in table 2, it was inferred that only the water-pipe networks R and T remained below the admissible value. Additionally, the size of the real daily loss V_{loss} confirms this; in these two water-pipe networks, the real daily loss ranged from 9 to 54% of admissible loss values $V_{\text{loss adm}}$. In the remaining two water-pipe networks, the V_{loss} value was 0.4÷2.6 times higher than the admissible value.

The water-pipe networks G and Z obtained very poor results in terms of the q_{avSP} value. Unitary water loss from the water-pipe networks Z nearly matches the expected consumption of 80 dm^3·per capita per day given by the Infrastructure Ministry ordinance [6]. The water-pipe networks G fared even worse; in order to maintain the given unitary water consumption, as much as 221.8 dm^3 per capita per day has to be pumped into the system.

The index describing water-pipe network loss is the amount of real water loss in relation to the number of network connections. This ratio, defined by the IWA (International Water Association), is called "the real loss benchmark" (*RLB*). The values in table 2 can be compared with the results from research conducted on 27 water-pipe networks in the world, of which only 7 exceeded 650 $dm^3 \cdot conn^{-1} \cdot d^{-1}$ [7]. These values can also be compared with the results from 17 cities in Poland, in which the mean *RLB* value was 540 $dm^3 \cdot conn^{-1} \cdot d^{-1}$ [8]. Based on this comparison it can be inferred that the water-pipe networks analyzed are characterized by water losses below the recommended maximum permissible value. Once again, the water-pipe networks R achieved the best results with its *RLB* being only 12.0 $dm^3 \cdot conn^{-1} \cdot d^{-1}$.

Table 3

Financial losses in 2007 due to unsold water

Specification	Unit	Water-pipe network			
		G	R	T	Z
Water production	thous. $m^3 \cdot year^{-1}$	60.2	38.0	124.1	78.5
Water sale	thous. $m^3 \cdot year^{-1}$	30.3	36.0	100.0	47.1
Unsold water	thous. $m^3 \cdot year^{-1}$	29.9	2.0	24.1	31.4
Cost of water	zł·m^{-3}	2.25	1.84	2.30	2.25
Potential income (produced water)	thous. zł·$year^{-1}$	135.5	69.9	285.4	176.6
Income from the water sale	thous. zł·$year^{-1}$	68.2	66.2	230.0	106.0
Financial loss (NRWB)	thous. zł·$year^{-1}$	67.3	3.7	55.4	70.6

Water losses cause a defined financial loss for the company. Table 3 shows the losses of the waterworks of interest stated in 2007 as unsold water. They are called "the non-revenue water benchmark" (*NRWB*). The IWA suggests that such losses should be compared in an open international forum. *NRWB* describes the difference between the volume of water produced and sold. Thus, this index is always higher than the water loss index, because it takes into account the volume of water used for the operation of the waterworks. The difference between the *NRWB* and W_{lv} in the water-pipe networks analyzed remained below 2%.

Comparing water production and its sale, it has been concluded that the amount of unsold water was 2,000 $m^3 \cdot year^{-1}$ only for the waterworks R. In the remaining three waterworks, the amount of unsold water was even higher at approximately 28,000 $m^3 \cdot year^{-1}$. Waterworks companies attempt to recover these losses by increasing the unit cost of one m^3 of water. Table 3 shows that the waterworks R sold water at the lowest price despite higher treatment costs due to filtration and disinfection. In the other systems, the water price was about 22% higher even though they lack treatment processes. Financial losses in these companies ranged from 55,400 to 70,600 $zł \cdot year^{-1}$.

4. CONCLUSIONS

The increasing importance of water losses lies in the introduction of a market economy and the withdrawal of state water subsidies in the 1990's. This problem has been made more difficult in last several years due to a decrease in per capita water consumption resulting in reduced incomes for water producers. Furthermore, consumer expectations for water quality continue to rise. Improving water quality translates into higher treatment and distribution expenses. Thus, reducing water loss should become a major priority for waterworks companies since this leads to cost reductions while at the same time increasing the volume available for sale.

From the analysis, water losses in rural water-pipe networks have been shown to be an ever-present problem, sometimes very significant. In two out of four networks, the loss was as much as 40 and even about 50%. Furthermore, unitary water losses, particularly in relation to the consumers and connections, demonstrated the seriousness of this problem and the extent of financial losses waterworks companies face. Only one of the networks analyzed had an acceptable level of loss. This was a result of the good condition of a distribution system. This underlines the importance of proper maintenance, specifically the need to prevent and repair a network failure.

In order to reduce water loss, waterworks companies should carry out a systematic distribution system renovation, including repairs, modernization, and conservation work, especially:

- water-pipe network renovation using thermoplastic materials,
- replacement of old indoor plumbing, using materials of higher operational reliability,
- implementation of intense leak-searching in a general maintenance program.

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ILOŚCIOWE I EKONOMICZNE ASPEKTY STRAT WODY W SIECIACH WODOCIĄGOWYCH NA OBSZARACH WIEJSKICH

Dokonano analizy gospodarowania wodą w ciągu jednego roku kalendarzowego w czterech wybranych wodociągach wiejskich w województwie małopolskim. Na podstawie dostępnych danych określono wielkość strat wody i ich skutki finansowe. Straty wody w analizowanych wodociągach wyniosły od 5,1 do 49,7% ilości wody wtłoczonej do sieci, co skutkowało stratą finansową od 3,7 do 70,6 tys. zł·rok^{-1}. Obliczone wskaźniki strat odniesiono do standardów polskich i międzynarodowych. Wskazano także możliwości techniczno-organizacyjne ograniczenia strat wody, do których zaliczono przede wszystkim systematyczną renowację sieci wodociągowych z wykorzystaniem tworzyw termoplastycznych oraz wymianę starego uzbrojenia sieci na nowoczesne o wysokich walorach technicznych i użytkowych.