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Reduction of Apparent Water Losses

Mindaugas Rimeika[1], Ramunė Albrektienė[2]

[1]Department of Water Management, Faculty of Environmental Engineering,
Vilnius Gediminas Technical University, Vilnius, Lithuania
[2]Department of Chemistry and Bioengineering Fundamental Faculty,
Vilnius Gediminas Technical University, Vilnius, Lithuania
E-mails [1]mindaugas.rimeika@vgtu.lt (corresponding author); [2]ramune.albrektiene@vgtu.lt

Abstract. The water loss levels are very different between European countries as water loss varies from 7% to 50%. According to data from the Lithuanian Water Supply Association, in 2015 about 124 mln. m³ of ground water was supplied to the network, but only 94 mln. m³ of it was sold, while the remaining share represented water losses – 30 mln. m³ per year. An average water loss level in Lithuania is 24%, varying from 52% to 17%. Local water utilities take a little care of apparent water losses. This article deals with an investigation of apparent losses in Alytus and other cities in Lithuania. The reduction of apparent water losses is quite a different field as it does not require large additional investments and can produce quick and efficient results. Article presents the results on the ways for reduction of apparent water losses in Lithuanian water supply systems. The aim of research is to show that apparent water losses consist of considerable share of water losses and to prove that inconsiderable efforts can significantly cut down water losses and improve the utilities' financial situation. Article present findings of night water consumption, used for DMA allowed minimum water calculation. Analysing water consumption data in blockhouses the minimum night water volume was determined (0.9 l/h/flat).

Keywords: apparent water losses; water meters; night water consumption.

Conference topic: Water engineering.

Introduction

Water management is an important part of the urban infrastructure. Its condition and quality have a direct impact on population welfare and health as well as economic development. The country has 58 water utilities which supply, by centralised networks, about 95% of the total water volume consumed in the country. The chart presented in Fig. 1 shows water losses at Lithuanian water utilities (Lietuvos vandens tiekėjų… 2015). At the best utilities losses represents 17%, at the worst – exceed 50%. Officially are no evident which part consist apparent losses. Some utilities simply do not have bulk water meters installed in blockhouses, while others do not analyses the existing situation. Rough evaluation that apparent water losses are around 20% of the total water losses.

Only groundwater is used for centralised water supply in Lithuania. Not a single water utility uses surface water, which is only used in the energy sector and to some extent in the industry. The country has enormous groundwater resources of which a mere 15% is currently being exploited. Therefore, there is no motivation for saving water resources. Over 80% of the country's population is connected to the water-supply network. In cities the degree of connection reaches 99%, while in rural areas is below 50%. The current system has sufficient capacity to connect new customers, because the available wellfields, water processing facilities and networks are designed for consumption two times larger than the current one. Since 1990, water consumption in the country dropped by around 2.5 times (Rimeika 2013). Consequently, there is no motivation for using saved water volumes for the connection of new customers.

In order to enhance the efficiency of water supply systems and ensure sustainable use of water it is particularly important to minimise water losses. Most water utilities in Lithuania do not have sufficient practice of efficient water loss reduction, lack information about practical measures to cut down water losses; and do not use specialised equipment for the detection of losses; and there is an especial shortage for internal motivation and legal regulation. Generally, utilities even difficult identify the proportions of apparent and real water losses and their components.

The last motivation is financial benefit. In Lithuania, the price of water and wastewater is relatively low, on average, 1.69 EUR/m^3 and ranging between 1.37 EUR/m^3 and 3.53 EUR/m^3. However, plugging leaks in the water supply network would bring inconsiderable revenue to the utilities, since they would save only variable costs which actually comprise only payments for electricity and water resources. The average undertaking's expenditure on these variable costs is around 0.15 USD/m^3. All other costs of utilities, such as the salaries, taxes, administration, depreciation, fuel, equipment, heating and others, did not depend on the volume of supplied water. In order to start active search for leaks in water supply networks it is necessary to invest in equipment (40 000 EUR), the training of employees and a two-person team intended exceptionally for that particular job (30 000 EUR/year), also in a vehicle and its operation, a minimal reconstruction of the network and some other items (10 000 EUR/year). For larger utilities these are not a big extra costs but for smaller ones such additional investments are rather big. As only seven water utilities in the country has an annual turnover in excess of 4 million EUR, while the others, around 50, and are very small and financially weak. In order to make the leak activity to be financially profitable, it is necessary to find the holes through which around 280 thou. m^3 of water leaking per year.

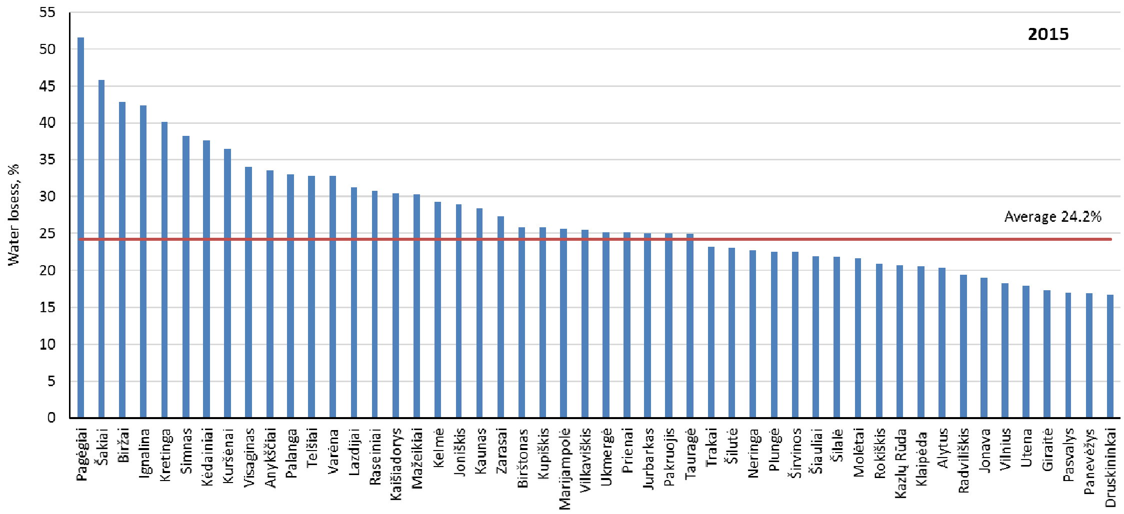


Fig. 1. Level of water losses at Water Utilities in Lithuania (2015)

Losses resulting from unauthorized water consumption (theft) and inaccuracies in water metering devices are referred to as commercial losses. Direct water thefts are rarely committed. However, measurement errors and inaccuracies of water meters is a very actual problem. Because of apparent losses is particularly serious due to the fact that consumed water usually gets into the wastewater system. A water utility provides a double service – supplies water, and collects and treats wastewater, but nobody pays for that. Hence, water utilities should be especially interested in the minimization of apparent losses, since due to these losses they sustain financial losses in terms of a full price of water and wastewater, rather than a small amount as in the case of leak stopping (Water Audits and… 2009).

Apparent losses occur as a result of inefficiencies in the measurement, recording, archiving and accounting operations used to track water volumes in a water utility. These inefficiencies can be caused by inaccurate or oversized customer meters, poor meter reading, billing and accounting practice, or weak policies. Apparent losses also occur from unauthorized consumption which is caused by individual customers or others tampering with their metering or meter reading devices, and other causes. For any types of apparent loss, it is incumbent on utility mangers and operators to realistically assess metering and billing inconsistencies, and then develop internal policies and establish programs to economically minimize these inefficiencies. It is also important to clearly communicate with customers, governing bodies of the utility and municipalities, financing agencies, and the media the problems of apparent losses and the need to control them (Arregui *et al.* 2006; Mutikanga *et al.* 2011).

Single-flow water meters of Class B are normally used for water accounting in Lithuania. In accordance with legislation, periodic verifications are conducted:

- Every 4 to 6 years for customer water meters;
- Every 2 years for bulk metering instruments, industrial and public customers.

Normally, customer water meters are replaced every 8–12 years, while bulk water meters – only when they do not pass metrological verification. Tested meters of adequate quality are re-installed at industrial water inlet.

Research methodology

The country's water utilities use meters only of metrological Class B. Such metrological definition of meters is inaccurate, as a new EU standard adopted in 2005 discontinued using such metrological classification of water meters. EN 14154-1:2005 standard defines metrological classes by Q3/Q1, ratio, which by analogy to the former Class B should exceed 50, while by analogy to Class C should be above 160. The previously applied metrological Classes B and C are much clearer and better rooted within society. Therefore, for the sake of better clarity, the article will use the accuracy terms used for Class B and C meters.

Reduction of apparent losses is important, because 99% of Lithuanian water consumers pay for water according to the readings of water meters. Customers invoiced according to the water consumption rate set by a utility account for less than 1% of the total customers. Water meter of metrological Class B is mounted in each private house or flat.

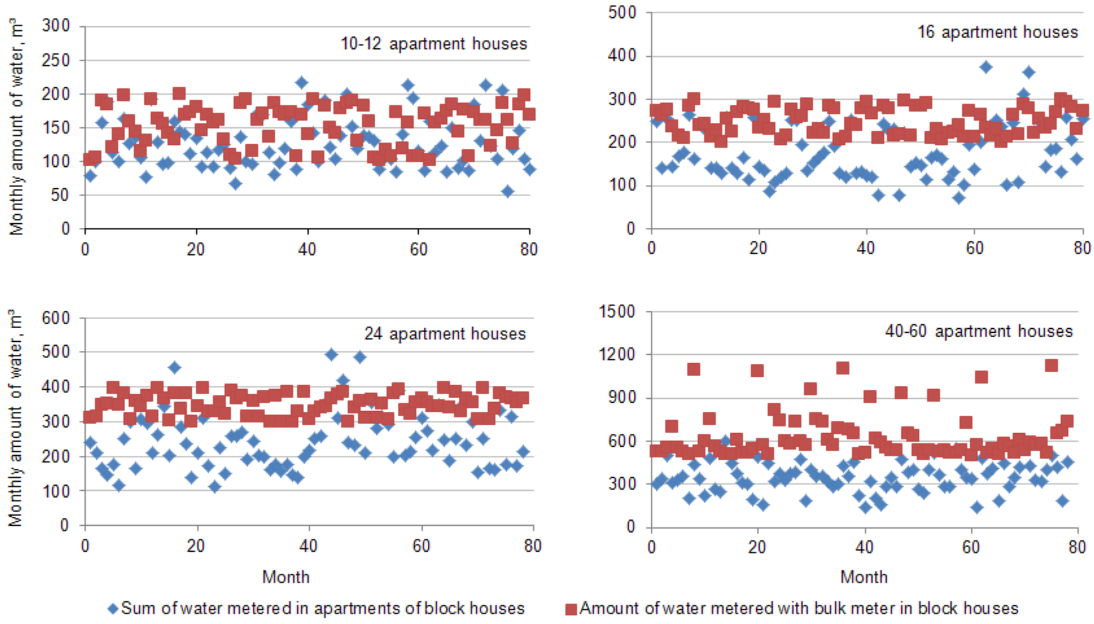


Fig. 2. Data on bulk water meter and sum of customer water meter

As a rule, all meters are installed without observing the rules: no free spaces are left before and after the meters, meters are generally turned away from the horizontal axis or mounted vertically, pipe diameters are substandard, etc. All these problems arose many years ago as meters were mounted on a massive scale between 1992 and 1995. Most houses are of old construction without places provided for the installation of meters and therefore water meters were installed at lowest cost without reconstructing the entire customer water supply network. Fig. 2 shows an obvious difference between the bulk meters readings and sum of the customer meters readings in flats. The larger house has the bigger the difference. Data used for the analysis covered 6 to 8 years and approximately 50 blockhouses. The obtained difference is none other than apparent losses which directly cause financial problems to water utilities.

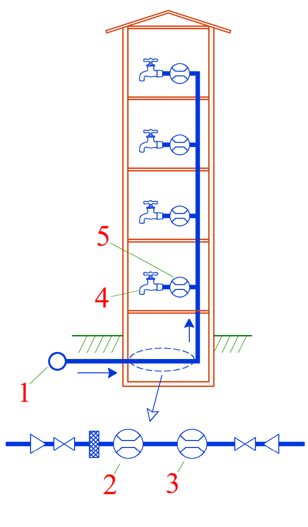


Fig. 3. Bulk water flow meters installed in series at blockhouses: 1 – water main pipe; 2 – B class water meter; 3 – C class water meter.

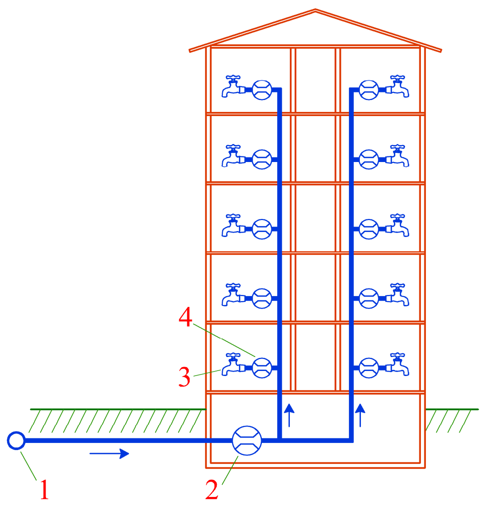


Fig. 4. Layout of water meters installed at blockhouses: 1 – water main pipe; 2 – B class bulk water meter; 3 – water user; 4 – C class customer water meter.

Where a city is dominated by private houses the estimation of apparent losses is rather complicated. However, in the case of blockhouses this is quite easy. It is necessary to install accurate and reliable bulk water meters in block-houses and the volume of water supplied to the block house will be accurately determined. Since meters in flats remain unchanged it will be possible to see the difference between water volumes supplied to the blockhouse and invoiced to the customer. After calculating apparent water losses in blockhouses it is possible to estimate water losses generating in private houses, as actually there is no difference between water consumption characteristics in private houses and flats. If utilities have no water meters installed, determination of apparent water losses is impossible. This provides an explanation why some utilities declare apparent losses of up to 35% of the total losses, whereas others do not declare them at all, although infrastructure, water meters and customers do not differ from city to city.

During the project Class B and C meters were mounted sequentially in blockhouses, their layout is given in Figure 3. Blockhouses in which apparent water losses range between 8% and 35% were selected for the tests. These blockhouses having 20 to 100 flats each, do not differ from the majority of other houses in the city and in the country.

Class B meters were mounted in these houses long ago before the test. The project used Class C meters that were operated for four years before the test. These meters were used for four years from 2007 and afterward placed in a storage facility. In order to check their reliability these meters were metrological verified. Since all meters successfully passed metrological verification and their readings complied with the standard requirements, they were used in this test. Parameters of the meters used during tests are presented in Table 1.

Table 1. Data of water meters

Model	Class	DN, mm	Start flow, l/h	Q1, l/h	Q2, l/h	Q3, m3/h	Q4, m3/h
Smart C+, PoWoGaz	C	15	5	10	16	1.6	2.0
Residia, Sensus	B	15	15	30	120	1.5	3.0
405S, Sensus	B	25	20	70	280	3.5	7
Actaris, Fludis	C	25	10	35	53	3.5	7
Master C+, PoWoGaz	C	32	21	63	100	10	12.5
Actaris, Fludis	C	32	12	60	90	6	12
MKT, Zenner	B	32	63	120	480	6	12

Alytus Water Utility started its water loss reduction project in 2012. During the project, main problems and weakest points were revised and possible and applicable measures for water losses reduction were proposed. The work was conducted together with consultants and company employers, which led to a very successful knowledge transfer. During project implementation, several methods were applied, such as water meter calibration, setting District Metering Areas (DMAs) as well as flow and noise measurements. The holistic decision support system applied to the project aims to help the water company to calculate the key performance indicators and propose a list of measures for an adequate and realistic action plan for Alytus water utility in Lithuania.

As the water loss reduction project started in 2012, the reference year of 2011 for data and calculation was used. Raw data were gathered from the company accounting system. Water extracted from the ground is measured by mechanical meters and water supplied to network is measured by magnetic flow meters. According to the readings of water meters, 99.5% of water users pay for water and water meters are installed in each private house or block flat. The rest of the customers (0.5%) are invoiced according to the water consumption rate set by the water utility. Every month, the users indicate themselves their water consumption and pay according to the tariff.

Results and Discusion

The water balance was calculated based on data available and provided by the water utility. The resulting water balance (Table 2) includes the water volumes and evaluated error margin. The water balance system boundaries start at the meter after the water treatment plant and for this reason, the water utility's own water usage before this point was not included in the water balance calculation (This includes office use at the treatment plant, wastewater treatment plants and water for filter backwashing and represents about 120,000 m^3 per year or about 4% of supplied water to network). In addition, performance indicators calculated for water utility are presented in Table 3, also include the computation of the error.

The relative difference between sequentially-mounted meters readings of Class C and B meters ranges from 4% to 18%. Measurements took 1 to 3 months, which can be treated as a sufficiently representative period because the test compared only bulk water meters whose readings do not depend on water consumption in flats. It has to be noted that readings were taken every week and an absolutely uniform trend was observed, i.e. the differences in water volume measurements were proportionate after two weeks and after two months. Consequently, a longer measurement period would not change anything. The essential and key point determined – Class C meters measure larger volumes of water, the average difference represents 0.33 m^3/d per blockhouse or 3.1 m^3/flat/year, compared to the currently used meters in Class B

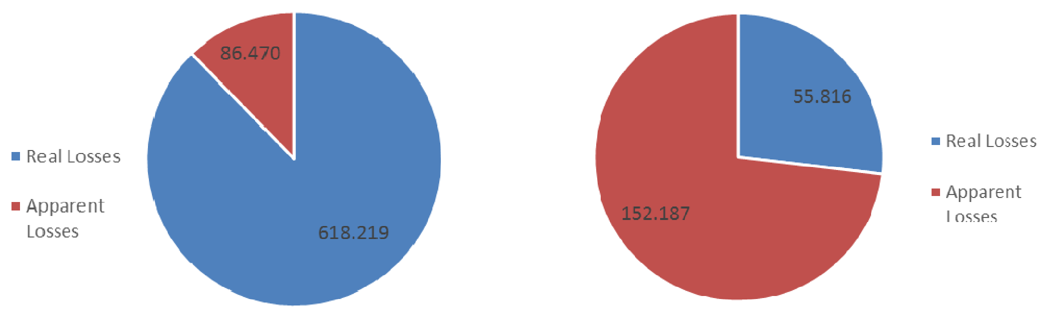
Table 2. Water balance calculation for Alytus water utility in 2011 (m^3/year) and evaluated error margin

System Input Volume 3,074,753 ±5%	Authorized Consumption 2,371,034 ±5%	Billed Authorized Consumption 2,370,064 ±5%	Billed Metered Consumption 2,365,864 ±5%	Revenue Water 2,370,064 ±5%
			Billed Unmetered Consumption 4,200 ±50%	
		Unbilled Authorized Consumption 970 ±50%		Non-Revenue Water 704,689 ±29%
	Water Losses 703,713; ±28%	Apparent Losses 85,500 ±50%		
		Real Losses 618,219 ±32%		

Table 3. Performance indicators of Alytus Water Utility, 2011

Performance Indicator	Unit	Value	Error [%]	Grade
ILI	$[-]$	2.8	34.5	B
PMI	$[-]$	1.3	5.0	Average
Real Losses per service connection	$\left[\frac{l}{N_{conn} * d}\right]$	435.3	32.9	C
Losses per main	$\left[\frac{l}{km * d}\right]$	6529.5	32.9	good
Percentage of Non-Revenue Water	[%] of System Input Volume	22.9	29.3	D
Apparent Losses per service connection	$\left[\frac{l}{N_{conn} * d}\right]$	60.2	50.5	B
ALI	$[-]$	0.7	50.2	A

The calculated apparent losses by volume do not seem so important (Fig. 5a). However, apparent losses raised a particular interest due to the fact that consumed water usually end up into the wastewater system, leading to additional costs not charged for apparent losses. Reducing apparent losses therefore brings a double benefit: customers pay for the water supply and for the associated wastewater costs (Lambert *et al.* 2010). The utility requested special interest on apparent losses and an accepted measure was to upgrade and change water meters to metrological Class C.



a. Annual water losses, m^3/yr.

b. Annual saving potential Eur/yr.

Fig. 5. Data from Water Balance, 2011. Real losses in red and apparent losses in blue

The use of Class C meters for cold water inlets into blockhouses can be useful for one purpose only – to obtain more accurate information about the actual volumes of water supplied to blockhouses and the actual apparent losses. However, Class C meters must be mandatorily mounted at all industrial enterprises and public customers, i.e. those that directly pay the utility according to the readings of bulk water meters. It has been determined that Class B meters are inefficient in measuring low flow rates and therefore they should be replaced by Class C meters. Differences in the prices of Class B and C meters are not big, up to 50 EUR, depending on the diameter and manufacturer. Therefore, the replacement of meters would pay back after 9 to 12 months at the latest. Furthermore, it is necessary to install more accurate meters at inlets into blockhouses for hot water preparation. Taking into account possible wear of meters and bigger errors of outdated meters it is recommended to replace bulk water meters by new ones at least every six years. In the event of an evident decrease in water volumes, meters can be replaced more frequently.

The aim of the second investigation was to evaluate water losses in single flats of a blockhouse. For this purpose meters were replaced in the flats of three blockhouses in Alytus city, Lithuania. The existing old customer water meters of Class B, 15 mm in diameter, were replaced by new meters of Class C. Parameters of the old and the new customer (DN15) meters are given in Table 1. Three blockhouses were chosen for the test. The choice of these houses has been prompted by the fact that it was about time to replace their meters and the water losses in these houses corresponded to the average water losses in blockhouses. The layout of water meters installed at blockhouses is given in Figure 4. Meters in these blockhouses were replaced during March 2013. The last data were received in January 2014. Approximately 150 outdated water meters (DN15) were replaced in blockhouses. Average apparent water losses in three houses totalled 68 m3 per month. After 10 months of measurement by Class C meters water losses in blockhouses dropped to 14 m^3 per month.

The evaluation of the results obtained, Alytus Water Utility since 2014, began to mount a class C meters. At the beginning of 2016 the apartment flats has replaced about 25%, individual house about 15% of water meters (DN15). Introduction of cold water meter industry is about 22% and about 95% of hot water inlet to blockhouses. By installing more accurate metering succeeded in reducing hot water consumption in multi-apartment. Between years 2013 and 2015, water meters of class C were installed for 35% of customers (flats) of Alytus city. According to research, the payback period of a Class C meter is shorter than one year. The use of class C customer water meters reduced apparent water losses by 40% as the replacement of meters allowed to increase measured water consumption by 11 liters/day/flat (Fig. 6). Considering that the price difference between customer meters of Class B and Class C is about 7 Eur, while the prices of installation and other works are the same. The replacement of Class B meters by Class C has payback period is quicker than in a year.

According to the performed calculations and approved by massive water meter replacement programe, installation of Class C meters in flats would reduce apparent water losses in private houses and blockhouses by more than three times and at the same time would ensure higher revenue for a water utility.

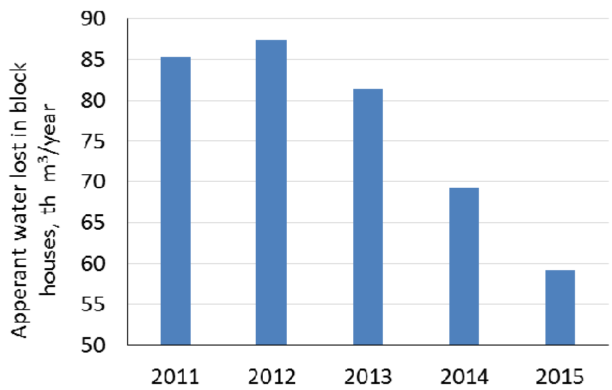


Fig. 6. Reduction of water losses in blockhouses

Water leakage management is now a continuous project and after 4 years' work, the utility gained an understanding on how DMA and ALC shall be implemented and has everything in hand to further progress. Water utility PI improved substantially during the project, as presented in Table 4.

Table 4. Performance indicators of Alytus Water Utility, 2015

Performance Indicator	Value 2011	Value 2015	Grade 2011	Grade 2015
ILI	2.8	1.4	B	A
PMI	1.3	1.3	average	average
Real Losses per service connection	435.3	208.4	C	B
Losses per main	6529.5	3214.1	good	good
Percentage of Non-Revenue Water	22.9	13.8	D	C
Apparent Losses per service connection	60.2	35.8	B	A
ALI	0.7	0.5	A	A

Bulk water meters installed in the inlet to blockhouses allows to evaluate the real night water consumption. If bulk water meter does not run all the night, that means plumbing inside a house are not leaking and we could use these data as real water consumption. During the night time no difference between apartment and individual houses, as night human activities are the same, generally limited to WC and washing. Night water consumption data are very important for analysis of DMA. After creation of zone and installation of flow meter generally not clear what could be acceptable flow rate into single DMA. Breakdown losses shall be take out according to Lambert (2009). But no indication on technical literature what is real night water consumption (European Commission 2015; Thornton 2008). Data the average night water volume consumed at one flat was calculated. Data obtained between 2 am and 4 am were used in calculations. Measurement results are given in Table 5. Tests conducted in the country's seven cities produced similar results and therefore it can be stated that the presented data well reflect night water consumption in the country.

Table 5. Data on flow measurements in the blocks of flats.

City (LT)	Number of blockhouses	Number of flats	Duration, days	Average night water consumption, l/h/flat
Ž. Naumiestis	2	56	16	0,7
Kretinga	19	740	21	1,0
Ukmergė	7	212	60	0,8
Alytus	8	364	21	0,9
Vilnius	7	580	29	1,1
Telšiai	6	280	30	0,9
Vilkaviškis	4	125	45	0,9
			Average:	0.9

After conducting measurements in blockhouses, the obtained average night water consumption was 0.9 l/h/flat. The performed analysis of each blockhouse individually has shown that water consumption depends on dwellers' habits and it is difficult to see any relationships between consumed water volumes and the number of flats. On the basis of the average water consumption per flat determined during measurements it is possible to quantify the minimum night water consumption in the zone concerned. Night water metering is conducted in different districts where different consumers are present (in terms of water consumption) and therefore the determined average night water consumption indicator can be used for establishing the permissible level of night water consumption.

Conclusions

About 99% of Lithuanian water consumers pay for water according to the readings of water meters.

When customers use water meters of metrological Class A and B apparent water losses consist about 20–30%.

The use of class C customer water meters allowed to increase measured water consumption by 11 liters/day/flat.

The replacement of meters to better metrological class are a rapid and easy way of reduce apparent water losses. An estimated pay-back period for Class C meters is one year.

The determined average minimum night water consumption by one flat (house) was 0.9 l/h/flat. This rate could be applied for water balance calculation at DMA and evaluation of actual water losses.

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