Review paper
UDC: 628.1/.2:005.71(497.6)
DOI: 10.7251/afts.2013.0508.041V

THE ANALYSIS OF THE EFFECTS OF IWA METHODOLOGY APPLICATION ON WATER SUPPLY SYSTEMS IN BOSNIA AND HERZEGOVINA

Vlaški Dalibor[1], Orašanin Goran[2]

[1] *Municipal Utility Water and Sewerage East Sarajevo, E mail: daliborvlaski@ymail .com*
[2] *Municipal Utility Water and Sewerage East Sarajevo,E mail: goranorasanin@yahoo.com*

ABSTRACT

The key problem of water utility companies in Bosnia and Herzegovina in the fight to reduce the level of non revenue water (NRW) is the lack of a unique methodology with clearly defined steps. The aim of this paper is to show the possibility of accepting the concept for the control of water loss in water supply systems, which provides the International Water Association (IWA), and based on the analysis of the effects of the application of water utility companies adopt the recommended practices as an essential step for the analysis of its water supply system, with the aim of providing quality services, creating their own concept of self-sustaining and achieving customer satisfaction. Regarding the fact, a research was conducted with the aim of determining the level of non revenue water in utilities in Bosnia and Herzegovina. One part of the survey involved assessment for the 20 water utility companies with different characteristics, while the second one is related to the measured data from 7 water utility companies. The analysis of the effects of IWA methodology application for reducing water loss was carried out by experimental measurements on a separate part of the water supply system defined as a district metered area (DMA), in Bosnia and Herzegovina.

Key words: *NRW – non revenue water, IWA – International Water Association, DMA – district metered area*

INTRODUCTION

Water utility companies in Bosnia and Herzegovina face huge problems in terms of permanent growth of water loss level in water supply systems. For most of them, the losses are huge costs with a huge impact on sustainability and operational efficiency. The main causes of these problems are dilapidated infrastructure, irregular maintenance, the lack of expertise, the lack of efficient and economical strategies within the water utility companies, problems in the organization, etc. Reducing the loss of water from the water supply system generates savings in the quantity of stored water, reduce operating costs and increase energy efficiency. Despite these facts, there are few examples that water utility companies are working systematically for the reduction. The amount of lost water from the water supply system is an important element in assessing the efficiency of water utility companies. The value of losses and their constant increase present indicators of ineffective planning and the law operational activities in the maintenance. Creating and implementing a program of active management of water loss in water supply systems is of utmost interest for the normal and rational water resources management. With the aim of successful problem solving, it is necessary to systematically introduce contemporary international standards that allow the determination of the type and level of water loss, and thus the planning of necessary measures, targets, monitoring of the implementation performance and the possibility of comparison with other systems. This paper presents the results of research on the effects of non revenue water on water utility companies in Bosnia and Herzegovina. In the case study, the parameters of flow and pressure, which are crucial for the analysis, are identified in the district metered area (DMA).

THE RESEARCH ON THE IMPACT OF NRW ON WATER UTILUTY COMPANIES IN BOSNIA AND HERZEGOVINA

The results of research on the level of non revenue water in 20 water utility companies in Bosnia and Herzegovina are presented in the figure 1. The study was conducted by surveying these companies through a questionnaire, and partly taking results of continuous measurements of produced and supplied water from existing water supply study, figure 2. The survey results in the figure 1 show a high percentage of non revenue water for the most surveyed companies. The level of non revenue water in most water utility companies is greater than 50%, indicating the need of taking extensive measures to address this problem [1].

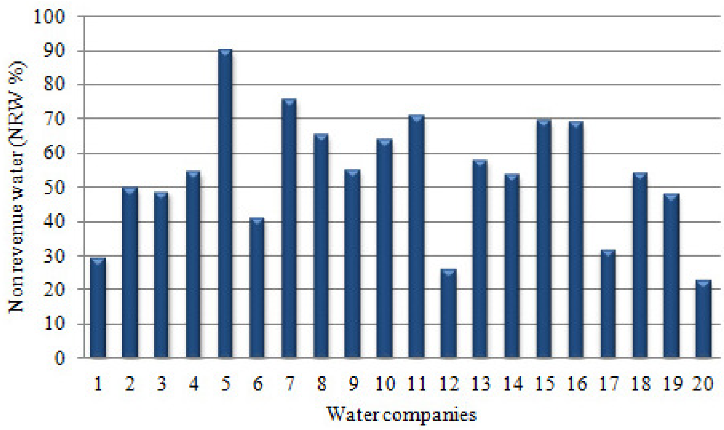

Figure 1 Surveyed water utility companies

There are results of analyzes carried out on the basis of data available for additional 7 water supply systems from Bosnia and Herzegovina. Figure 2 presents the amount of non revenue water expressed in (%).

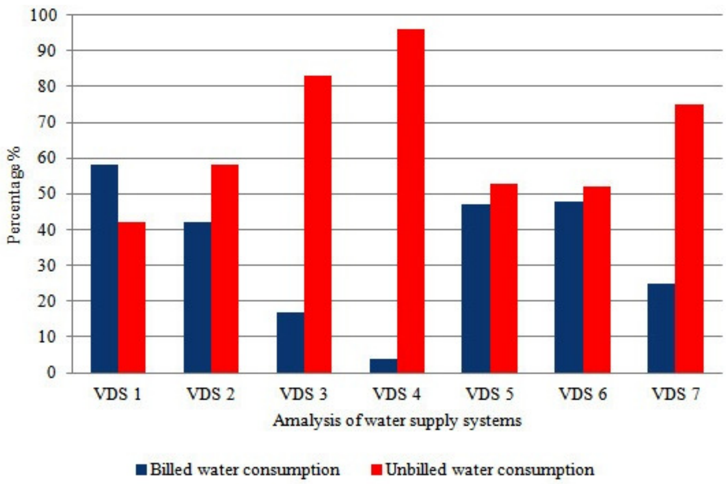

Figure 2 The comparison of the amount of the invoiced and unbilled water (%)

Based on the analysis of the level of non revenue water (NRW) in water supply systems in Bosnia and Herzegovina and their negative impacts on water utility companies, it can certainly be concluded that the water utility companies operate at the limits of economic sustainability [2].

METHODOLOGY

Based on previously reported results of analysis and high values of non revenue water (NRW) in water utility companies in Bosnia and Herzegovina, which classified the companies below the limits of economic sustainability, the methodology for non revenue water (NRW) level reduce for water utility companies will be used, as recommended by the International Water Association (IWA) [3]. It examines the effects of its application on a separate water supply sub-system in Bosnia and Herzegovina, located within the water system of East Sarajevo, defined as district meter area (DMA).

MEASUREMENT 1

District metered area of analyzed water system in East Sarajevo is presented in the figure 3. Analyzing the system from the figure 3, the following data is obtained [2,4].

- Population: app 400;
- The number of service connections: 100;
  - Individual users: app 100;
  - Industry: 0;
- The total length of the water supply network: distribution pipeline 1845 (m), the thrust line 540 (m);
- The material of pipelines: polyethylene (PE);
- Represented diameter pipelines: Ø55, Ø80.

In the district metered area (DMA) of the water supply system of East Sarajevo two measurement cycles were carried out, each lasting seven days. They have included the measurements of flow (Q) at the entrance of the district metered area (DMA) and pressure (p) in the field of characteristic points. Formed measuring area is closed, which means that the entry of water into the system is realized via a pumping station (PS) and the supply line to the reservoir (R), and then through distribution (return) pipeline to consumers. Before the establishment of the measurement process, the reading of the current state of water consumption in the consumer water meters is made and these metric data were defined as the basic state of spending first before the measurement 1. During the process, 4 flat rate consumers were found.

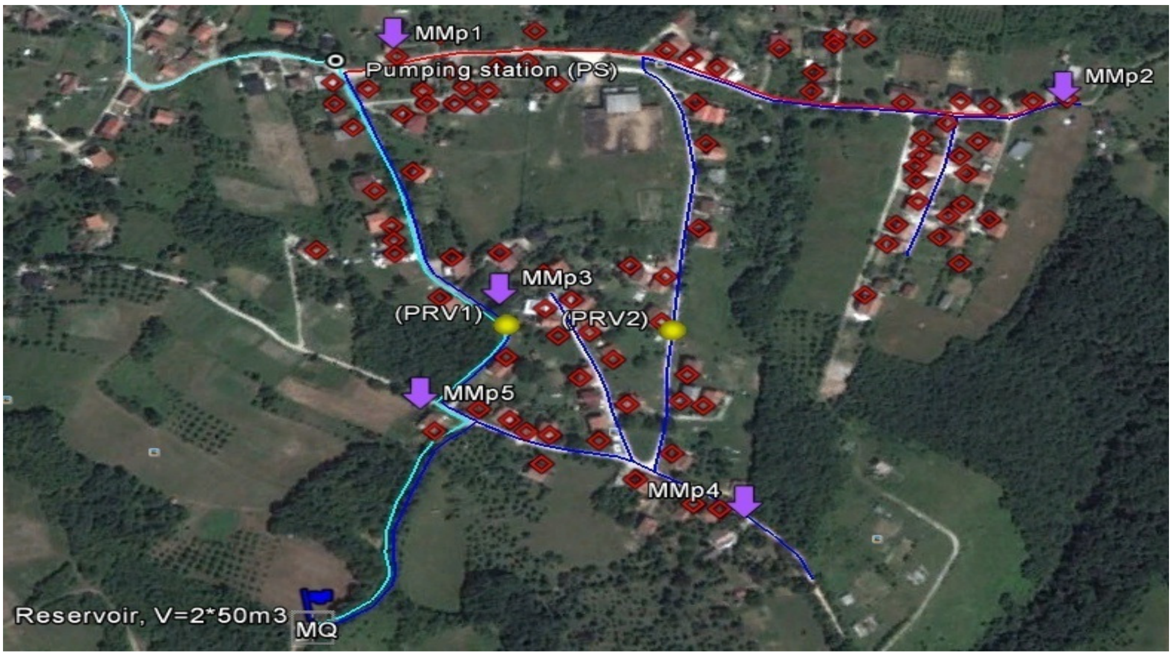

Figure 3 District metered area (DMA)

The pressure on the pump inlet was 1,5 bar. On the exit (outlet) of the pump, pressure was in the range of 7,4 – 7,9 bar. On the return pipe Ø80 (mm), at the outlet of the reservoir (R), ultrasonic flow meter was set (MQ). Analyzing the district metric area (DMA), elevations of certain points in the system were determined, based on which the particular position of pressure gauges were determined, which are placed in points: MMp1, MMp2, MMp3, MMp4 and MMp5, figure 3 [5].

During the first measurement cycle, the average value of the flow at the measuring point (MQ) ranged from 0,72 (l / s) to 0,8 (l / s), table 1.

Table 1 The average value of the flow at the measurement 1

Measurement day	1	2	3	4	5	6	7
The amount of water (m^3 /d) entered into the system	64,6	63,1	65,8	60,4	69,4	68,1	62,2
The average flow (l/s)	0,75	0,73	0,76	0,7	0,8	0,79	0,72

Taking the results of the first measurement, minimum, maximum and average values of pressure at measurement points in the district metric area are established. The average pressure in the system was 5,02 bar. A significant increase in the values of pressure was identified in the points MMp1 and MMp2, with some changes during the measurement, table 2.

Table 2 Values of pressures at measurement locations during the measurement 1

The pressure in the system in the measurement 1 (bar)	MMp1	MMp2	MMp3	MMp4	MMp5
Minimal pressure	7,17	6,93	4,3	1,77	2,96
Maximal pressure	7,93	7,8	4,7	1,96	3,29
Average pressure	7,8	7,63	4,5	1,95	3,25

CALCULATION OF WATER BALANCE 1 FOR DISTRICT METRIC AREA (DMA)

Based on results of the measurements in the district metric area (DMA), the water balance is estimated by (IWA) method [4,6] and its results are shown in Table 3.

Table 3 The water balance estimated by IWA method after measurement 1

<table>
<tr><td rowspan="4">The amount of water entered the system during measurement 1 (453,6 m^3)</td><td rowspan="2">Authorized consumption (258,56 m^3)</td><td>Billed authorized consumption (258,56 m^3)</td><td>Revenue water (258,56 m^3)</td></tr>
<tr><td>Unbilled authorized consumption (0)</td><td rowspan="3">Non revenue water (195,04 m^3)</td></tr>
<tr><td rowspan="2">Water losses (195,04 m^3)</td><td>Apparent losses (21,992m^3)</td></tr>
<tr><td>Real losses (173,04 m^3)</td></tr>
</table>

CALCULATION OF TECHNICAL INDICATORS FOR REAL WATER LOSSES

- Network length: L_d= 1,845 (km);
- Average pressure in the water system: p= 5,02 (bar-a) => P= 50 (m) water pillar;

- Average length in km of underground pipe between the edge of the street and customer meters: L_p= 6 (m) => 0,006 (km);
- Number of service connections: n= 100;
- The density of ports per one (km) network: (54,2 ports);
- (a, b, c) coefficients whose values are obtained from a statistical analysis of the measured data on various types of water supply systems in 20 countries around the world, and with sufficient accuracy to accept value (a= 18, b= 0,8, c= 25);

Unavoidable Annual Real Losses (UARL):

UARL= $(a \cdot L_d + b \cdot n + c \cdot L_p) \cdot P$ (m^3/day)
UARL= $(18 \cdot 1{,}845 + 0{,}8 \cdot 100 + 25 \cdot 0{,}006) \cdot 0{,}05$
UARL= 5,668 (m^3/day)
UARL= 56,68 (l /service connection/day)

Current Anual Real Losses (CARL):

Considering the amount of real water losses of 173,04 (m^3) (Table 3). Current annual real loss (CARL) for 100 service connections are 247,143 l/service connection/day.

Infrastructural Leakage Index (ILI):

ILI= $\frac{\text{CARL}}{\text{UARL}}$ = 4,4

THE EVALUATION OF APPARENT WATER LOSS

According to the calculated value of „ILI“ index, based on recommendations from table 4 [7,8], the efficiency category B is assigned to the analyzed water system.

Table 4 The value of „ILI“ indicator according to the IWA recommendation

The class efficiency		ILI	Real loss (liter / connection/ day) when the system is working under the pressure of				
			10 m	20 m	30 m	40 m	50 m
Developed countries	A1	< 1,5		< 25	< 40	< 50	< 60
	A2	1,5 - 2		25 -50	40 - 75	50 - 100	60 - 125
	B	2 - 4		50 - 100	75 - 150	100 - 200	125 - 250
	C	4 - 8		100 - 200	150 - 300	200 - 400	250 - 500
	D	> 8		> 200	> 300	> 400	> 500
Undeveloped and middle - developed countries	A1	< 2	< 25	< 50	< 75	< 100	< 125
	A2	2 - 4	25 - 50	50 - 100	75 - 150	100 - 200	125 - 250
	B	4 - 8	50 - 100	100 - 200	150 - 300	200 - 400	250 -500
	C	8 - 16	100 - 200	200 - 400	300 - 600	400 - 800	500 - 1000
	D	> 16	> 200	> 400	> 600	> 800	> 1000

Errors in the measurement of the consumption are estimated at 5% of the amount of water that brings in revenue, amounting 12,92 (m^3). As part of this value is estimated flat-rate consumption (for the district metered area - DMA). Illegal water consumption is estimated at 2% of the total water entered into the system and was 9,07 (m^3). Categorizing the district metered area, according to the IWA recommendations , table 5, an evaluation of apparent water loss is done [7,8]. Total apparent loss for analyzed water system, based on assessment, amounts 21,992 (m^3). The difference in the value of total water loss in the system and the estimated apparent loss makes the real water loss, amounting 173,04 (m^3). In the analyzed water system, the value of non revenue water is unacceptable, as well as the magnitude of the pressure in some points of the network. Therefore, steps are taken to reduce water loss and comprehensive work is carried out on the part of the network in order to control the water pressure. The results of the measurement 2 after the completion of the works are shown below.

Table 5 Recommended values of apparent water loss

Categories	Apparent loss			
	% of measured consumption			Liter /service connection/ day
	Errors in the measurement and errors on water consumption data management	Illegal use of water (illegal connections)	Total	
A1	< 2,5 %	< 0,5 %	< 3%	< 30
A2	2,5 % - 5 %	0,5 % - 1 %	3 % - 6 %	30 – 60
B	5 % - 10 %	1% - 2 %	6 % - 12 %	60 – 120
C	10 % - 15 %	2 % - 5%	12 % - 20 %	120 – 200
D	> 15 %	> 5%	> 20 %	> 200

MEASUREMENT 2

Regulating the pressure, repairing observed leaks and installing water meters at 4 flat-rate users, it is approached to the second measurement cycle, in a period of seven days. Ultrasonic flow meter and pressure gauges are placed on the same point as in the first measurement. At the same time a meter reading of water consumption are made in the consumer water meters in a district metric area (DMA). After seven days the reading of water consumption was made for consumers in a district metric area (DMA), and the measurement of pressure (p) data was taken as well as the quantity of water entered into the system (Q). During the second cycle of measurement, the average flow at the measuring point (MQ) ranged from 0,684 (l / s) to 0,8 (l / s). Table 6 presents the average values of flow (Q) during the measurement 2.

Table 6 The average value of the flow at the measurement 2

Measurement day	1	2	3	4	5	6	7
The amount of water (m^3 /d) that was entered into the system	64,5	69,2	68,8	63,1	62,5	64,5	59,13
The average flow (l/s)	0,75	0,8	0,8	0,73	0,72	0,75	0,684

The average pressure in the network was 4,04 (bar). At the measurement point (MMp1) and the measurement point (MMp2) the average values of the pressure with little variations during the measurement were (4,7 bar at MMp1) and (4,7 bar at MMp2). Values of the pressure after regulation and reparation of the water network are shown in the table 7.

Table 7 Values of pressures at measurement locations during the measurement 2

Pressure in the system during measurement 2 (bar)	MMp1	MMp2	MMp3	MMp4	MMp5
Minimal pressure	4,45	4,51	4,4	2,5	3,2
Maximal pressure	4,9	4,86	4,81	2,95	3,6

Average pressure	4,7	4,7	4,65	2,75	3,4

CALCULATION OF WATER BALANCE 2 FOR DISTRICT METRIC AREA (DMA)

After repairs were completed, consumption of water read on water meters, measurement 2 results taken, the balance of the water supply system was calculated, and the results are shown in Table 8.

Table 8 The water balance estimated by IWA method after measurement 2

<table>
<tr><td rowspan="4">The amount of water that entered the system during measurement 2 (451,7 m^3)</td><td rowspan="2">Authorized consumption (302,64 m^3)</td><td>Billed authorized consumption (302,64 m^3)</td><td>Revenue water (302,64 m^3)</td></tr>
<tr><td>Unbilled authorized consumption (0)</td><td rowspan="3">Non revenue water (149,06 m^3)</td></tr>
<tr><td rowspan="2">Water losses (149,06 m^3)</td><td>Apparent losses (19,64 m^3)</td></tr>
<tr><td>Real losses (123,42 m^3)</td></tr>
</table>

CALCULATION OF TECHNICAL INDICATORS FOR REAL WATER LOSS

- Network length: L_d= 1,845 (km);
- Average pressure in the water system: p= 4,04 (bar-a) => P= 40 (m) water pillar;
- Average length in km of underground pipe between the edge of the street and customer meters: L_p= 6 (m) => 0,006 (km);
- Number of service connections: n= 100;
- The density of ports per one (km) network: (54,2 ports);
- (a, b, c) coefficients whose values are obtained from a statistical analysis of the measured data on various types of water supply systems in 20 countries around the world, and with sufficient accuracy to accept value (a= 18, b= 0,8, c= 25);

<u>Unavoidable Annual Real Losses (UARL):</u>

UARL= $(a \cdot L_d + b \cdot n + c \cdot L_p) \cdot P$ (m^3/day)
UARL= $(18 \cdot 1{,}845 + 0{,}8 \cdot 100 + 25 \cdot 0{,}006) \cdot 0{,}0404$
UARL= 4,579 (m^3/day)
UARL= 45,79 (l /service connection/day)

<u>Current Annual Real Losses (CARL):</u>

Considering the amount of real water losses of 129,42 (m^3) (Table 8). Current annual real loss (CARL) for 100 service connections are 184,88 l/service connection/day.

<u>Infrastructural Leakage Index (ILI):</u>

$$\text{ILI} = \frac{\text{CARL}}{\text{UARL}} = 4$$

THE EVALUATION OF APPARENT WATER LOSS

According to the calculation of "ILI", the efficiency category (A2) is assigned to the analyzed water system (Table 4). It means that the further reduction of water loss can be uneconomical, unless there is water shortage. It is necessary to conduct a careful analysis to identify cost-effective improvements. Errors in the measurement of the consumption are estimated at 5% of the amount of water that brings in revenue, amounting 15,13 (m^3). Unauthorized water consumption is estimated at 1% of total water entered into the system and is about 4,45 (m^3). Total apparent loss for the analyzed water system, based on assessment, amounts 19,64 (m^3). On the basis of the total loss in the water supply system and the estimated apparent loss, the real water loss amounted to 123,42 (m^3).

CONSLUSION

The idea of this paper is that he application of the methodology for reducing water loss, recommended by the International Water Association (IWA), show the effects of improvements and that water supply companies in Bosnia and Herzegovina adopt the recommended steps as indispensable practice of analyzing their water supply system, in order to provide better services, improve charging and consumer satisfaction. Analyzing district metric area (DMA) and establishing a system of measurement, the balance of the water supply system is calculated and the parameters of water loss are determined. Conducting a series of steps (identifying connection and measurement points , finding leaks, setting the water gauge for flat-rate users, replacing the damaged pipelines) drawbacks were eliminated and thereafter measurement 2 was done. The results showed the efficiency of taken measures.

Considering the size of district metric area where the experiment was conducted, (two measurement cycles of seven days), it is shown that (IWA) methodology can be applied to water systems in Bosnia and Herzegovina, primarily with regards to the implementation of active leakage control, pressure management as well as quick repairs and leak detection.

We should not ignore the current practice of water loss management characteristic for water supply systems in BiH, especially former experiences that give successful results.

If the above research on the level of non - revenue water in the water utility companies in Bosnia and Herzegovina is taken as approximately correct, it is clear that the application of the presented model is to make significant savings.

(Received 10. january 2013, accepted 14. march 2013)

LITERATURE

[1] Orašanin, G., Vučijak, B. (2012). Analysis of the survey on the uncalculated water, conducted in water supply systems of Southeast Europe. Jahorina. 12 International Conference on water supply and sewerage systems. pp.309-314.
[2] Vlaški, D. (2013). Systematic approach to managing water loss in water supply systems Thesis. Podgorica. Faculty of Mechanical Engineering in Podgorica.
[3] Alegre, H., Hirnir, W., Baptista, J.M., Parena, R. (2006). Performance Indicators for Water Supply Services. London. IWA Manual Best Practice, 2nd edition.
[4] Lambert, A., Hirner, W. (2000). IWA BLUE PAGES, Losses from Water Supply Systems: Standard Terminology and Recommended Performance Measures, London.
[5] Morrison, J., Tooms, S., Rogers, D. (2007). District Metered Areas, Guidance Notes. International Water Association.
[6] AWWA. (2008). Water Audits and Leak Detection. Denver. 3rd edition, Manual M36.
[7] Liemberger, R. (2010). Recommendation for Initial Non Revenue Water Assessment, IWA Water Loss.
[8] Mutikanga, H. E. (2012). Water Loss Management: Tools and Methods for Developing Countries, Dissertation, Delft University of Technology, Netherlands.