KEY OPERATIONAL PERFORMANCE INDICATORS FOR WATER LOSSES IN WATER UTILITIES IN BOSNIA AND HERZEGOVINA

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Abstract
The paper presents the results of the evaluation of selected key performance indicators related to the NRW management in the water utilities of five B&H municipalities. Performance indicators were calculated following the IWA methodology. Non-revenue water in all water utilities is very high; 33% in one utility and from 64.7% to 89.3% in other four. The Infrastructure Leakage Index varies widely from 5.2 to 37.9, placing utilities under different categories. The study showed the applicability of the IWA methodology in B&H and potential for the use of performance indicators to achieve proper management of NRW.
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Introduction

Water supply utilities in transition countries moving from a centrally planned to a free market economy are faced with significant challenges. Although the utilities were heavily subsidized by the local administrations in the former system, the investments in the replacement of the infrastructure were mainly insufficient, resulting in a poor operational efficiency in many water utilities[1]. In cases where the water system was faced with water shortages, an immediate typical solution was to introduce a new water source and new quantities, instead of considering other options first, such as reduction of physical and apparent losses. In developing countries these problems have been augmented by financial constraints, which have placed water utilities in a very difficult position to operate without subsidies and with revenues insufficient to maintain and improve obsolete water systems. In Bosnia and Herzegovina (B&H), which is a typical transition and developing country, this set-up has created the present situation in which the water supply utilities have more than 50% of non-revenue water (NRW) on the average[2].

The present situation creates an unsustainable framework from the economic, social and environmental points of view. The utilities need to efficiently address the issue of high NRW, and this requires that adequate benchmarking performance indicators are selected and used. The International Water Association (IWA) has defined relevant procedures and indicators for NRW, but they need to be verified before they are widely used for benchmarking and NRW reduction.

This paper presents the results of the evaluation of selected key performance indicators (KPI) related to NRW management in the water utilities in B&H. The study involved water utilities of five municipalities in Central B&H. Performance indicators were calculated following the IWA methodology, based on the extensive field data collection.

Methodology

The research was based on a study carried out with the objective to develop long-term programs for the reduction of NRW in 5 municipalities in Central B&H. The study was specifically aimed at assessing and providing critical review of the existing conditions of the water distribution networks in the selected municipalities, in order to propose cohesive programs for the reduction of NRW.

In the first step the respective water distribution networks were analyzed and divided into several zones – District Metering Areas (DMAs) considering the topographical conditions, relevant water supply regimes and future plans for the network developments. Another criterion for the networks zoning was that each DMA had no more than three inflow or outflow points for flow measurements.

Following the planning and selection of the DMAs, the installation of necessary fittings, valves and other components was carried out to prepare the zones for data gathering. In some of the project municipalities it was necessary to construct measuring sites (manholes) to carry out flow measurement campaigns. Pressure and flow measurements were implemented in all five municipalities, with hydraulic measurements of the daily and night flow. The measuring campaigns were carried out at the selected DMAs and at the respective water sources. Data on water consumption, including billed consumption, was collected from the respective water utilities.

The collection of data was followed by the calculation of the water balance for each of the selected DMAs at each of the project municipalities. The water balance was also calculated for the entire municipal water supply network. The water balance was assessed using the standard IWA methodology[3].

A typical approach in the Western Balkan countries is to evaluate NRW and specifically real losses as a percentage of the total water abstraction (water used). In this study some other key performance indicators (KPIs) for NRW were also considered in order to check their applicability to the B&H water utilities. The KPIs were selected based on the IWA standards[3] and some recommendations for developing and countries in the region[1,4]:

- Apparent losses with regard to the authorized consumption. They are defined as a percentage in proportion to the volume of water supplied on an annual level. They may simply be calculated from the water balance. They are used only as a financial indicator of the general state.
- Liters (of apparent losses) per connection per day. This is defined as the volume of water lost through apparent losses per number of connections per day.
- Liters (of real losses) per connection per day. It is defined as the volume of water lost through real losses per number of connections per day.
- Liters (of real losses) per connection per meter of pressure. It represents the value of real losses expressed in relation to the number of connections and to pressure expressed as 1 meter of water.
- m^3 (of real losses) per km of pipeline per day. It is the value of real losses expressed per km of pipeline length per day.
- UARL – Unavoidable Annual Real Losses. This indicator is issued by IWA[3] and AWWA and is defined as a theoretical reference value representing the lowest possible technical level of water leakage

from a pipeline which is possible to reach by using best world technologies available nowadays. UARL is calculated based on the following formula:

$$UARL = \left(18 \times L_m + 0{,}8 \times N_C + 25 \times L_P\right) \times P \quad (l/day)$$

where L_m represents the network pipeline length (km), N_c is the total number of connections in the system, L_p is the total length of service connection pipes passing through a private property (km), and P the average pressure value in the system (m).

- CARL – Current Annual Real Losses. It represents the volume of water being lost through all physical defects in the system, either detected or not detected ones, or due to the mistake made by the operator (e.g. reservoir overflows).
- ILI – Infrastructure Leakage Index. ILI represents an indicator defining the quality of the water system operation (maintenance, repairs, rehabilitation) needed for the real loss (leakage) control. It mathematically represents a ratio between the current annual real losses (CARL) and unavoidable annual real losses (UARL). Low ILI indicates that the water utility company has managed to reduce system leakages to the UARL level or to the theoretical low limit which could be reached (≥1). Since ILI is a non-dimensional indicator, it represents a leading indicator for benchmarking water system leakages of one water utility company with the same of other water utility companies worldwide. In that sense ILI is a superior indicator, although it is harder to monitor it than for instance NRW as a % of the total system input.

The methodology of the water balance calculation in all DMAs was based on the measurement of real (physical) losses in the system. The input data used included the number of connections, the quantity of billed water and the quantity of unbilled water – all obtained from the accounting departments of the respective water utilities, than length and types of the pipes – estimated from available maps and verified on site, length of service connections – estimated on site, night consumption – estimated on the basis of measurements at a number of consumers. The inflow to and outflow from DMAs as well as the pressure in the system were measured over a 24-hour period.

Results and discussion

The calculation of the water balance and performance indicators was made for each DMA in the system as well as for the entire system. The results obtained in five selected water networks (WN) are presented in the following table.

Table 1 - Non Revenue Water as a percentage of the total water abstraction

Indicator	WN 1	WN 2	WN 3	WN 4	WN 5
Revenue Water (m^3/day)	335.3	233.8	1,325.0	1,861.1	11,967.3
Non-Revenue Water (m^3/day)	2,785.8	1,174.3	4,397.0	3,409.1	5,893.9
Total	3,121.1	1,408.1	5,722.0	5,270.2	17,861.2
NRW %	89.26%	83.40%	76.84%	64.69%	33.00%

The above table shows NRW in five different water supply networks as a percentage of the total water used. The indicator varies from 33% to even 89.26%, showing very high NRW in the systems. In four out of five water systems more than 60% of water delivered is unbilled, and in three the percentage is higher than 75%. Still it is hardly evident which measures are needed to increase the operational efficiency and reduce such high losses.

A set of additional KPIs was also assessed, and the results are presented in the following table.

Table 2 - Other Key performance Indicators for Non-Revenue Water

Key Performance Indicators for NRW	WN 1	WN 2	WN 3	WN 4	WN 5
APPARENT LOSSES PERFORMANCE INDICATORS					
Apparent Losses compared to authorized consumption (%)	223.3	135	91.8	33.7	11.6
Liters per connection per day	662.5	524.2	1124.0	277.2	128.3
LOSSES PARAMETERS					
Leakage Exponent	1.04	1.50	0.82	1.04	0.857
Night to Day Factor	0.899	0.886	0.934	0.865	0.947
Non-Revenue Water (m^3/day)	2,442.5	1,174.3	4,396.9	3,409.1	5,893.9
VOLUME OF REAL LOSSES					
Real Losses in regards to Water Supplied. (%)	29.7	61.0	55.6	52.8	25.3
Current Annual Real Losses (CARL) (m^3/year)	343,877	313,439	1,159,786	1,023,655	1,670,223
Unavoidable Annual Real Losses (UARL) (m^3/year)	38,519	13,086	30,615	56,391	318,159
REAL LOSSES PERFORMANCE INDICATORS					
Infrastructure Leakage Index (ILI)	8.9	24	37.9	18.2	5.2
Liters per connection per day	405	1426	2940	1231	419
Liters per connection per day per meter of pressure	11	40	75	34	8
m^3 per km mains per hour	2.32	2.77	3.59	1.73	0.93
PERFORMANCE GROUP	**C**	**D**	**D**	**D**	**B**

The performance of the water utilities was evaluated using the rules set by IWA (table 3)[5].

Table 3 - ILI Categories

Category	A	B	C	D
ILI - developed countries	1-2	2-4	4-8	>8
ILI - developing countries	1-4	4-8	8-16	>16

Table 2 clearly provides much more information on Non-Revenue Water, and also indicates the kind of efforts required for the water utility to become more efficient. For example, even though Water Network 1 (WN1) has the highest NRW as the percentage of the total water used (89.26%), it is still within the category C, since major part of NRW comes from administrative and not real losses (even 223.3% of authorized consumption). This setting requires quite different measures for reducing NRW as it could have been assumed from the NRW as a percentage of the total water abstraction. Comparing ILI indexes, it may be inferred that the WN 3 is in the worst shape (ILI 37.9), while the best managed water system is the one in WN 5 (ILI 5.2). The same conclusion is made if some other indicators are considered (8 liters per connection per day per meter of pressure, 0.93 m^3 per km mains per hour).

Conclusions

The non-revenue water in all water utilities studied is found to be very high: 33% in one municipality and from 64.69% to 89.26% in other four utilities. The Infrastructure Leakage Index (ILI), which is the ratio of real losses to unavoidable losses, varies widely from 5.2 to 37.9, placing one water utility under category B (potential for marked improvements), the other one under category C (poor status), whereas three water utilities are in a bad state (category D).

The study proved the applicability of the IWA methodology in B&H and high potential for using other key performance indicators in order to achieve proper management of NRW in local water utilities. These additional key performance indicators for NRW enable better analysis and more appropriate measures for the NRW reduction, what is commonly considered the biggest problem in the management of water utilities of transition and developing countries.

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