TECHNICAL PERFORMANCE INDICATORS, IWA BEST PRACTISE FOR WATER MAINS AND THE FIRST STEPS IN SERBIA

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Abstract. *Active water loss management has became one of the primary interest of the water utilities in the world. It can make significant saves and and investments in new water resources capturing can be justified only if appropriate action is done to minimize loss from the water main. There is some level of unavoidable water loss from the water main. Traditional indicator of water loss, widely adopted in the world, was % of the system input value. It always sounds well to have water loss less than some prescribed value (for instance 10%). Due to efforts of IWA Task Force in the last decade, this approach has been proven to be misleading in may cases, and new way of performance measuring and benchmarking is proposed. This paper presents the basic principles of this methodology and the results of the first step in attempt to approach Serbian water mains to the new standards.*

Key words: *Water Mains, Performance Indicators, IWA Best Practice*

1. INTRODUCTION

The level of water losses, both real and apparent, is one of the most important efficiency issues for water utilities across the world. Commonly used practice amongst water supply utilities to express water losses as a percentage of the system input volume has been proven to be unsuitable as a technical performance indicator as it does not reflect many of the influencing factors. Systems with higher system input volumes will automatically have an (apparently) lower level of water losses if expressed in percentages.

One would assume that accurate performance indicators are used for benchmarking, international performance comparison, or target setting for internationally funded projects. But unfortunately this is widely not the case - utility managers, consultants and the International Lending Institutions continue to use a very inappropriate indicator when talking about water losses.

2. IWA BEST PRACTICE WATER BALANCE

IWA Task Forces produced an international 'best practice' standard approach for Water Balance calculations (Figure 1), with definitions of all terms involved, as the essential first step in practical management of water losses [1], [2].

System Input Volume (corrected for known errors)	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption (including water exported)	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-Revenue Water (NRW)
			Unbilled Unmetered Consumption	
	Water Losses	Apparent Losses	Unauthorised Consumption	
			Metering Inaccuracies	
		Real Losses	Leakage on Transmission and/or Distribution Mains	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to point of Customer metering	

Fig. 1. IWA 'Best Practice' Water Balance

The IWA 'best practice' Water Balance is rapidly gaining international acceptance, and has already been adopted or promoted (with minor variations) by:
- DVGW (Germany), Australia (Water Services Association and Queensland Environmental Protection Agency), Malta Water Services Corporation and its regulator, South African Water Research Commission, New Zealand Water and Waste Association, American Water Works Association, and the Canadian Federation of Municipalities and National Research Centre,
- Utilities and/or consultants working in Austria, Brazil, Cyprus, Ghana, Jordan, Kazakhstan, Malaysia, Oman, Palestine, Saudi Arabia, the United Kingdom, Uzbekistan, and the many other countries.

Definitions of principal components of the IWA water balance are as follows:
- System Input Volume: the annual input to a defined part of the water supply system
- Authorized Consumption: the annual volume of metered and/or non-metered water taken by registered customers, the water supplier and others implicitly or explicitly authorized to do so. It includes water exported, and leaks and overflows after the point of customer metering
- Non-Revenue Water (NRW): the difference between System Input Volume and Billed Authorized Consumption - NRW consists of Unbilled Authorized Consumption and Water Losses
- Water Losses: the difference between System Input Volume and Authorized Consumption, consisting of Apparent Losses and Real Losses
- Apparent Losses consists of Unauthorized Consumption and metering inaccuracies

- Real Losses: the annual volumes lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering.

3. TRADITIONAL PERFORMANCE INDICTORS FOR REAL LOSSES

The following 4 traditional performance indicators are used
1. Water Losses and Real Losses as a % of system input volume
2. Water Losses and Real Losses per property per day
3. Water Losses and Real Losses per km of mains per day
4. Water Losses and Real Losses per service connection per day

Water Losses, as a percentage of system input, is easily calculated and frequently quoted and is certainly the most common indicator. Various definitions for water losses are used, in developing countries the concept of Non-Revenue Water is most generally used. Thus the indicator is not meaningful for various reasons, mainly because of the sometimes enormous levels of unauthorized consumption ('illegal connections'). The IWA best practice manual suggests its use only as a financial performance indicator and states clearly it is 'unsuitable for assessing the efficiency of management of distribution systems'.

Real Losses, as a % of system input, also suffer from deficiencies, mainly the level of (and changes in) consumption and variations in supply time (intermittent supply). Note: a system with 12 hours supply per day may easily have only 20% real losses. But what would this figure look like in an uninterrupted supply situation (all bursts would leak for 24 hours instead of twelve and thus twice as much water would be lost)!?

Real losses per property have to be rejected as the property (very often the customer) has very little to do with leakage. Frequently an apartment block with 50 apartments is counted as 50 properties even though it has only one service connection which may leak.

This leaves the question of which of the remaining two indicators is more appropriate. Leakage component analyses in water distribution systems across the world have shown that the greatest proportion of annual real losses occur on services connections, including the connecting point to the main. This applies to all systems with a connection density of more than around 20 connections per km main. Only very rural supply systems normally have a lower connection density.

The Task Force therefore recommended [2] that the basic traditional PI with the greatest range of applicability for real losses, to be referred to as the 'Technical Indicator Real Losses' (TIRL) is:

TIRL = Real Loss Volume/Service Connection/Day *w.s.p.*

TIRL is the best of these traditional indicators - but should always be calculated as 'w.s.p.' - when the system is pressurized, to allow comparisons between systems with different levels of supply. However, this indicator still does not take operating pressure into account, which is a major disadvantage. The Task Force recommended further interpretation of the calculated TIRL value for an individual system by comparing it with a calculated value for Unavoidable Annual Real Losses (UARL), using a methodology which takes account of the local factors of density of connections, location of customer meters on service connections, and average operating pressure.

4. THE CONCEPT OF UNAVOIDABLE ANNUAL REAL LOSSES

Leakage management practitioners recognize that it is impossible to eliminate real losses from a large distribution system. There must therefore be some value of 'Unavoidable Annual Real Losses' (UARL) which could be achieved at the current operating pressures if there were no financial or economic constraints. If the UARL volume for any system can be assessed, taking into account key local factors, then the ratio of Technical Indicator Real Losses (TIRL) to UARL offers the possibility of an improved Performance Indicator for real losses. In the most basic form, UARL in liters/day is

$$\text{UARL} = (18 \text{ x Lm} + 0.80 \text{ x Nc} + 25 \text{ x Lp}) \text{ x P } w.s.p.$$

where Lm is mains length in km, Nc is number of service connections, Lp is the total length in km of underground pipe between the edge of the street and customer meters, and P is average operating pressure in meters.

This equation, based on component analysis of Real Losses for well-managed systems with good infrastructure, has proved to be robust in diverse international situations [3], and is the most reliable predictor yet of 'how low could you go' with real losses for systems with more than 5,000 service connections, connection density (Nc/Lm) more than 20 per km, and average pressure more than 25 meters.

5. ILI – INFRASTRUCTURE LEAKAGE INDEX

The ratio of TIRL to UARL becomes a non-dimensional Infrastructure Leakage Index (ILI), which allows overall infrastructure management performance to be assessed independently of the influence of current operating pressure. The ILI is a measure of how well a distribution network is managed (maintained, repaired, rehabilitated) for the control of real losses, at the current operating pressure. It is the ratio of Current Annual volume of Real Losses (CARL) to Unavoidable Annual Real Losses (UARL).

$$\text{ILI} = \text{CARL / UARL}$$

Being a ratio, the ILI has no units and thus it facilitates comparisons between countries that use different measurement units. As an excellent system can be rated one with the ILI value close to 1, while system with high ILI value, for instance 10, can be rated as a poorly maintained one. Part of the problem is that people in many countries are simply not aware of the ILI - and the other part of the problem is the limited understanding and acceptance of the ILI. In this regard, many practitioners prefer not to use the ILI for one or other of the following reasons:
- the accuracy of the UARL formula is questionable;
- data required to calculate UARL are not available;
- nobody uses and understands the ILI - it is basically not accepted in the industry;
- the ILI is not needed - the classical performance indicators (like real losses per km mains per day) are sufficient;

In addition, there are another two reasons why the ILI is sometimes not used:
- 10% water losses always sounds acceptable - while the ILI in many cases highlights that the true leakage performance is far from satisfactory
- Warnings from the Water Losses Task Force that the ILI must not be used for systems with less than 25 m average pressure or less than 5,000 connections.

In spite of that, ILI technical performance indicator can be used for benchmarking water supply systems in different areas and countries. The following benchmarking criteria has been proposed by Liemberger [4].

Technical Performance Category		ILI	Litres/connection/day (when the system is pressurised) at an average pressure of:				
			10 m	20 m	30 m	40 m	50 m
Developed Countries	A	1 - 2		< 50	< 75	< 100	< 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
Developing Countries	A	1 – 4	< 50	< 100	< 150	< 200	< 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

Fig. 2. Benchmarking Criteria for Developed and Developing Countries

As can be seen from the figure 2, different ILI ranges have been provided for developing and developed countries. The proposal attempts to classify the leakage levels within the Water Utilities into four categories based on the ILI value as follows:

- Category A: Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost effective improvement
- Category B: Potential for marked improvements; consider pressure management; better active leakage control practices, and better network maintenance
- Category C: Poor leakage record; tolerable only if water is plentiful and cheap; even then, analyze level and nature of leakage and intensify leakage reduction efforts
- Category D: Horrendously inefficient use of resources; leakage reduction programs imperative and high priority

As an illustration, ILI values are presented for some water systems in England and Wales (the initiators of ILI methodology) and in Italy Fig 3.

Since the vast majority of water utilities in the developing world will have ILI values exceeding the upper limit of the Figure 2, reducing real losses to below 16 will be the starting point. As soon as utilities start to introduce active leakage control, carry out flow and pressure measurements, and improve overall data quality the bandwidth of the ILI will dramatically be reduced. Often leakage reduction will also lead to an improved supply situation and pressure increases that will make the calculation of the UARL formula more accurate.
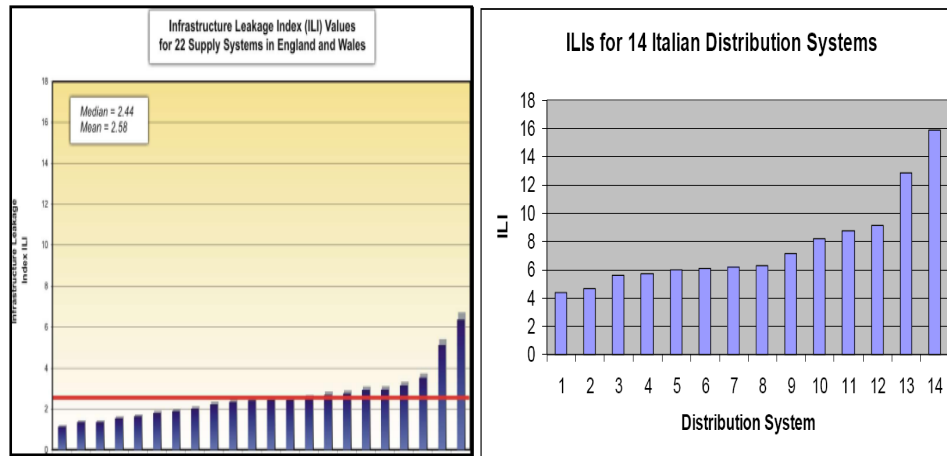
Fig. 3. ILI values for dataset of water mains from England &Wales and Italy

6. COMPARING ILI VALUES TO PERCENTAGES

If real loss expressed in % of system input volume, it sounds to one as a real potential to decrease (or even) eliminate water loss. The meaning of TIRL is to estimate unavoidable real loss level, considering very good infrastructure conditions (mentioned above) and taking into account specific conditions of any water main, and ILI should indicate ratio between volumes of the current and unavoidable losses.
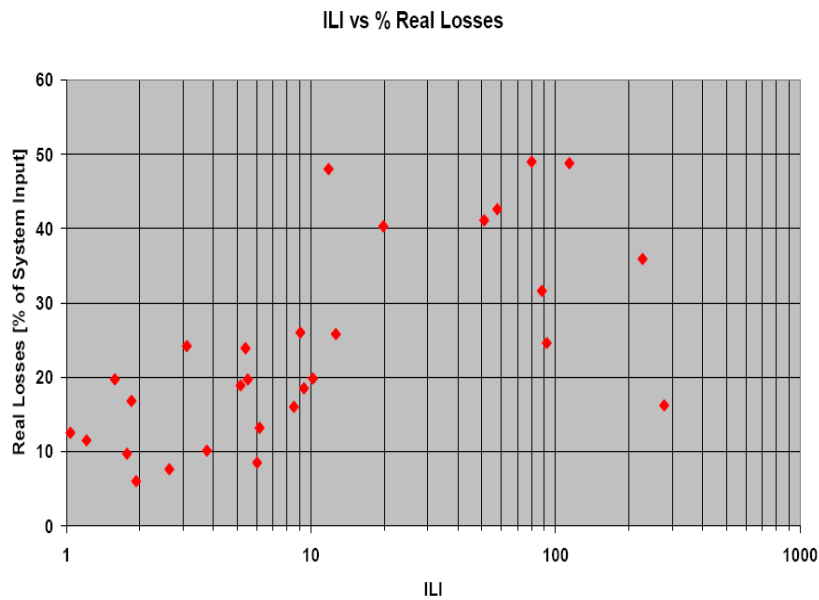

Fig. 4. ILI vs % Real Losses

Figure 4 shows the leakage management performance of 30 utilities from international data set [6] using the ILI and the respective losses expressed as percentage of total system input. It is obvious that there is no correlation, for example 50% real losses mean in one case an ILI of around 12 and in another case 114! As can be seen, real loss level of 10% is not necessarily an indication for good real loss management. Two systems with ILI value very close to 1 have more than 10% real losses, the third best ranked 20%, while the system with about 6% real loss has ILI value 2 and is the sixth best ranked, having more potential for the loss reduction than the first five systems.

7. IWA BEST PRACTICE – ILI APPLICABILITY TO SERBIAN WATER MAINS

During 2004 and 2005, upon order by the Republic Directorate for Water Resources, the assessment on municipal water utilities performance in Serbia was done. Following collected data from 98% of the questioned water mains, water supply systems in Serbia are in the most of cases composed of rather old pipes (over 40 years), made of steel, asbestos cement, while the newer parts of the mains are constructed of plastic, polyethylene and ductile iron pipes. The similar set of problems was experienced like when introducing the ILI in the developing world:
- Not always reliable information on the true network length,
- Unreliable (or no any) system input volume metering,
- Accurate number of service connections is not known - number of customers is used instead,
- Neither pressure data nor pressure loggers available. Estimated average pressure usually too high ("wishful thinking"!),
- High level of apparent losses (difficult to estimate) and therefore unreliable and inaccurate volume of real losses.

Some approximations had to be done [7]:

- Service connection lengths were often missing parameter and common value of 10 m was used for the estimation,
- Unbilled Unmetered Authorized Consumption was estimated for all utilities as 1% of System Input Volume (SIV),
- Unauthorized Consumption – Illegal connections and usage water from hydrants was estimated for all utilities as 1% of SIV,
- Metering Inaccuracies due to low bulk meter sensitivity on minimal night consumption were estimated for all utilities as 1% of SIV,
- Number of days when system is pressurized was adopted as 365 days, while the real data are different; intermittent supply decreases UARL and increases ILI value.

Using collected data, traditional and IWA best practices performance indicators were estimated for 36 water utilities. UARL average value, like as ILI value, calculated from the collected data with an error margin of 12%, does not fit to the IWA Task Force recommended 95% confidence interval.

Average Real Loss, expressed in percentage is 36%, while there were estimated some extreme values of almost 70%! The average ILI value is 11, (Figure 5).

Even though there is no correlation between these two indictors (Fig. 5 and 6), the both of them imply on bad technical condition of water mains in Serbia and high potential for improvement. The ILI values seem much better than in many other developing countries (Sri Lanka, Vietnam, …), comparing them with the highly developed systems (Great Britain, Australia, Germany, USA, …) will make one conclude that Serbian water mains are currently in poor condition, with high potential for significant real loss reduction.
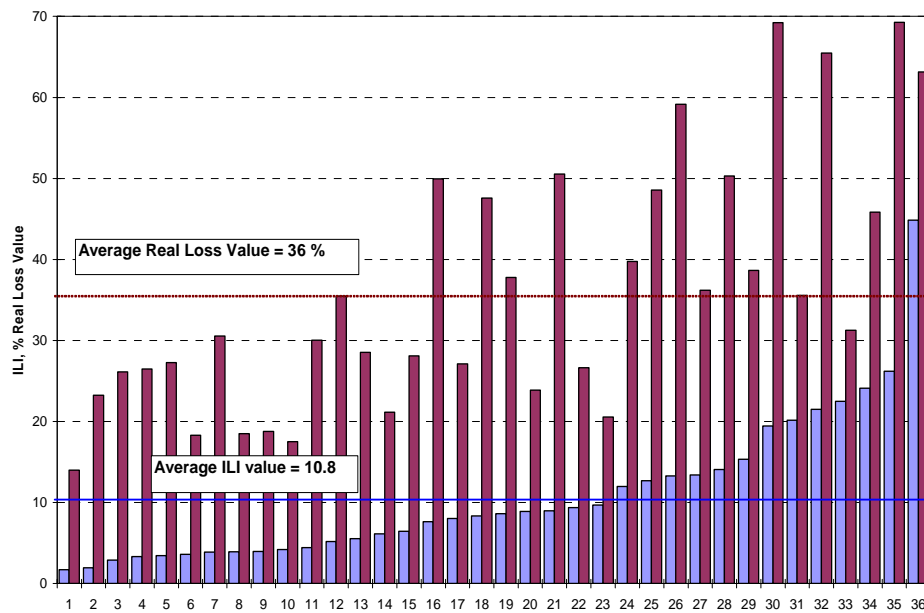

Fig. 5. % Real Water Losses and ILI in dataset of Serbian mains

In spite of problems in the initial steps of IWA best practice and UARL, TIRL and ILI performance indictors application in Serbia, this methodology can help to discover establish a new merit point of view and make water utilities to discover new facts on their functionality and potential to increase own efficiency, as water resources are not always so plentiful in Serbia (in fact many small water mains face serious problems both with insufficient water resources and high level of leakages from water mains).

New steps on the national level must be done to prescribe comprehensive systematic approach to this problem and define national strategy for water loss management. Further analysis should follow in order to recommend adoption IWA performance indicators in original or modified shape.
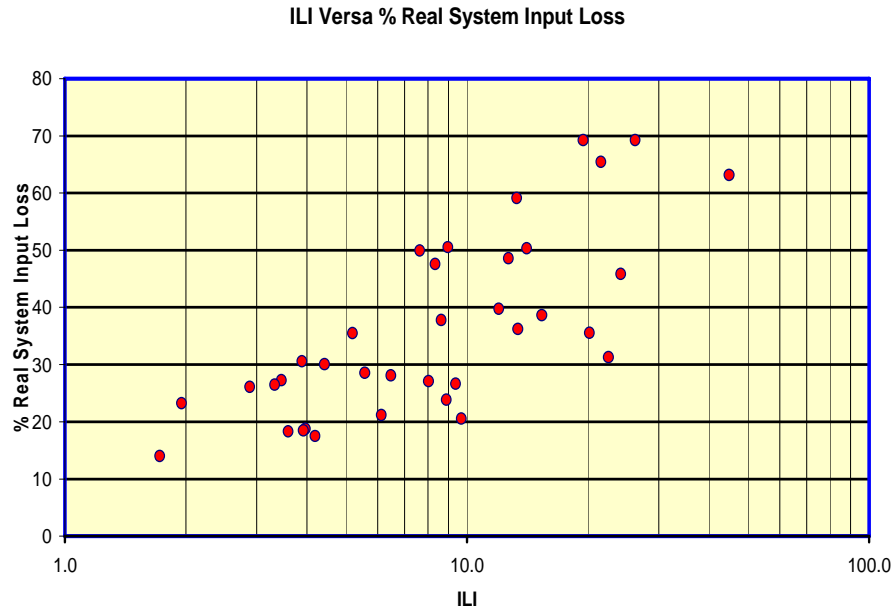
ILI Versa % Real System Input Loss

Fig. 6. ILI Versa % Real System Loss in Serbian Water Mains

8. CONCLUDING REMARKS

The ILI has, in recent years, proved to be a very useful performance indicator when benchmarking leakage in water distribution systems. Although various limits on the use of the ILI have been proposed by it's original developer to safeguard the soundness of the results, it can still provide a useful indication of high leakage even when used outside the normally accepted limits. It is certainly also a most suitable indicator for water utilities in developing countries and it is now understood that "true" ILI's of low pressure systems will always be higher than the calculated figures. This suggests that the leakage problem in developing countries is even more serious than previously anticipated.

IWA best practice water balance and methodology were used to estimate performance indictors in Serbian water utilities. In spite of lack of accurate data, the first step was done to estimate values of the IWA recommended performance indictors, but other traditional PI were calculated too, like as Real Loss %. Similar results have been found and ILI applicability can be rated as very useful tool for assessing and pointing on the real problems in Serbian water mains.

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TEHNIČKI POKAZATELJI USPEŠNOSTI, PREPORUKE MEĐUNARODNOG UDRUŽENJA ZA VODU IWA I PRVI KORACI U SRBIJI NA NJENOM UVOĐENJU

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U svetu se smatra da je aktivna politika upravljanja gubicima u vodovodnim sistemima od suštinskog interesa za normalno i racionalno gazdovanje vodnim resursima. Ova politika može doneti velike uštede, što je dokazano u praksi i ulaganje u zahvatanje novih količina vode se može smatrati opravdanim samo ako su uvedene mere aktivne kontrole gubitaka vode iz sistema.

Obzirom da se gubici ne mogu u potpunosti eliminisati, treba odrediti njihov minimalan, tj. neizbežan nivo. Tradicionalni pokazatelji gubitaka vode, široko prihvaćeni u svetu uglavnom su se bazirali na procentu izgubljene vode u odnosu na upuštenu u sistem. Uvek dobro zvuči imati manje od 10% gubitaka ukupno upuštene vode u sistem. Zahvaljujući aktivnostima radne grupe međunarodnog udruženja za vodu IWA u poslednjoj deceniji, dokazano je na praktičnim primerima da ovaj pristup sadrži puno manjkavosti i predložena je nova metodologija određivanja sveobuhvatnih pokazatelja uspešnosti rada vodovodnih sistema, kako bi svaki system mogao da proveri svoju efikasnost, a pored toga mogao i da uporedi svoje tehničke karakteristike sa drugim sistemima u okruženju i u svetu.

U Srbiji su učinjeni prvi koraci ka uvođenju IWA metodologije. Metodologija je pokazala primenljivost i na srpske sisteme vodosnabdevanja. Pokazale su se i određene manjkavosti u smislu verodostojnosti podataka koji su prikupljeni od vodovodnih sistema, zbog ograničene tačnosti i načina prikupljanja, pa je potrebno uložiti nove napore ka poboljšanju stanja vodovoda u Srbiji.