Experiences with Water Loss PIs in the Austrian Benchmarking Project

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Abstract

In the years 2003 and 2004 OVGW (Austrian Association for Gas and Water) carried out a pilot project on benchmarking in the water supply sector (Neunteufel et al., 2004). The system of performance indicators is based on the IWA system of performance indicators for water supply services (Alegre et al., 2000 and Alegre et al., 2006).

More than 70 water supply companies, which represent about 50 % of the supplied water in Austria, participated in a second project run (stage B, data from 2004) which was completed in summer 2006 (Theuretzbacher-Fritz et al., 2006).

The analysis of water losses is one part of the holistic system. This paper should give an overview regarding the experiences with the calculated water loss PIs. The factors which most influence the volume of water losses, problems in data collection and results of stage B will be discussed.

Introduction

The Austrian water supply sector is small structured. Around 3,000 water supply companies supply 8 million inhabitants in rural, urban and metropolitan areas. Based upon the international and national debates on requirements concerning the improvement of efficiency and the assurance of quality of drinking water services, the Austrian Association for Gas and Water (OVGW) has developed a mid-term strategy for setting up and carrying out benchmarking activities (Figure 1). The OVGW benchmarking activities follow a strategic approach for the successive and sustainable implementation of benchmarking instruments within the Austrian water supply sector, based upon the principles of voluntary and anonymous participation (Theuretzbacher-Fritz et al., 2007).

The pilot study in 2002 was followed by the pilot project (stage A) which was completed in summer 2004. The following stage B (2004 project) with a larger number of participants was finished in June 2006. Future projects on metric benchmarking will be organised in time intervals of three years (Kölbl et al., 2006). In the time between two metric benchmarking projects, projects on process benchmarking are carried out.

OVGW benchmarking activities are conducted at a high-quality level. A strong focus is therefore laid on aspects of comparability (clear and extensive definition of data elements, homogeneous data collection, data verification including company visits, grouping of similar enterprises, project execution by university institutes etc.) and on data security and confidentiality. Continuity is the second methodical goal – to be achieved by developing a system which can be reapplied for the future project stages and which also reflects on the international benchmarking development. Therefore, a close connection to the IWA PI system was aspired and a co-operation with the Bavarian EffWB project was strategically defined (Theuretzbacher-Fritz et al., 2007).

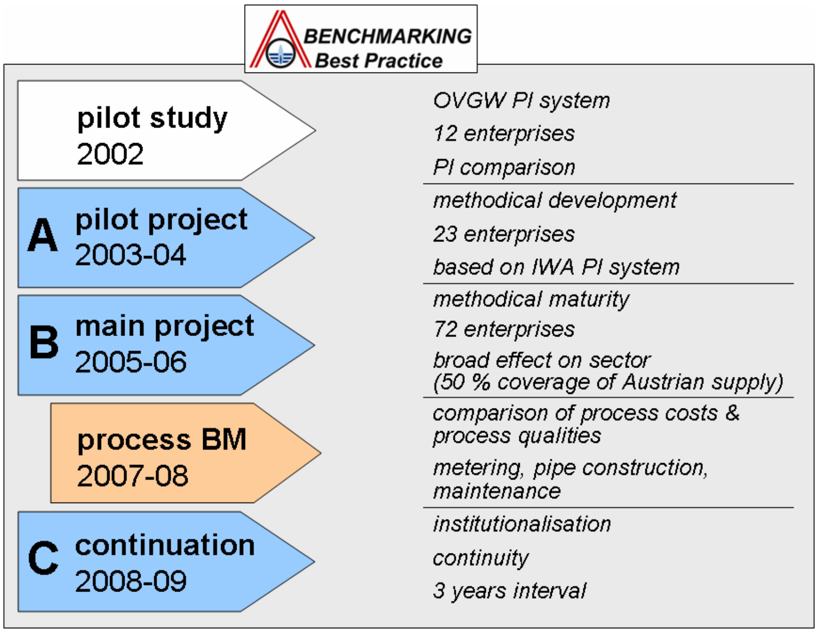

Figure 1 OVGW benchmarking strategy (Theuretzbacher-Fritz et al., 2005 amended)

Based on the five-columns-model (compare Hirner & Merkel, 2002) the OVGW metric benchmarking system is a holistic system which considers the five target categories supply safety, supply quality, customer service, sustainability and efficiency but also task fulfilment, outsourcing and organisation. The topic of water losses belongs to the category of “supply quality” (Figure 2).

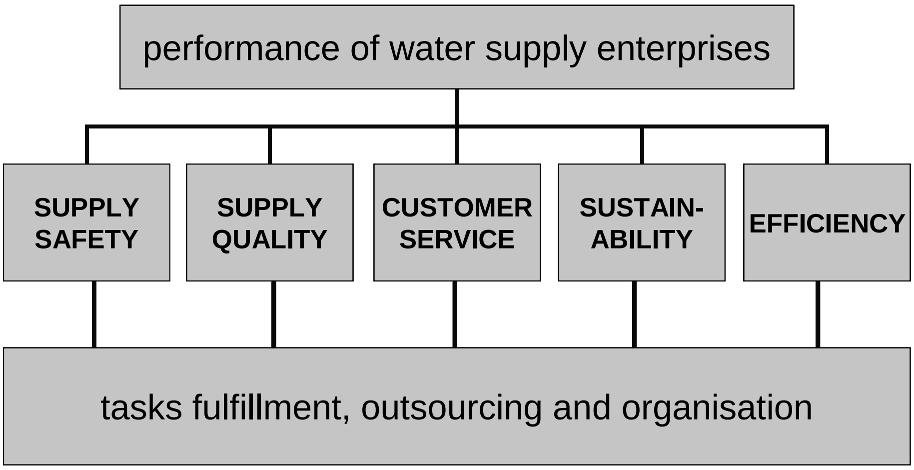

Figure 2 Target categories of OVGW benchmarking system (Hirner & Merkel 2002, amended, in Neunteufel et al. 2004)

Water Loss PIs of the OVGW system

The OVGW stage B system consists of 75 performance indicators calculated from 190 variables. In addition to these variables, 90 questions about task fulfilment and outsourcing, 75 questions about organisation, 30 questions about customer service and 90 facts as background information for high comparability complete the system.

Five of these performance indicators deal with water losses and are discussed within this paper:

- Water loss ratio (%)
- Real losses per connection and day (l/(connection*d))
- Real losses per mains length (l/(km*h))

- Infrastructure Leakage Index (ILI)
- Non-revenue water (%)

The OVGW W 63 Austrian guideline (1993) states with consideration of an overview calculation the use of the water loss PI “water loss ratio”. Many water utilities are still operating only with water losses as a “percentage” of the system input. Hence, a lot of convincing is still necessary to persuade companies to use “new” PIs like “Real losses per connection and day” or ILI.

Influencing factors

For a correct interpretation of water loss PIs, responsible influencing or explanatory factors (frame conditions) have to be considered. It is necessary to classify the field of participants in comparable groups.

Structure of the distribution system

For the Austrian project it was found that the highest influence on many water loss PIs is the structure of the distribution system. An “urbanity” criterion was created to include the network delivery rate, the service connections density and the meter delivery rate, (categories: rural, urban or metropolitan).

Another structural parameter is the function of the water supply system. It is necessary to differentiate between direct supply and bulk supply. In general, water losses in bulk supply systems are much lower than in systems with direct supply. This is a result of the non-existence of service connections, a minor complex structure of the network and therefore an easy option to practice leakage monitoring and active leakage control.

Average age of networks

On the basis of experiences in the Austrian pilot project, which showed that the context information used for “average mains age” (number CI53 of IW-system) is too general and not appropriate to evaluate the existing mains failure rates and water losses, an new index was developed - the Average Network Age Index (NAX). This weighted index considers the average age and the length-share of different pipe materials used in the network. A differentiation of different pipe diameters was forgone to keep the data acquisition for this index affordable. In accordance with several water utilities, a reference age was defined for each material, while bearing in mind that many factors influence service lives (construction quality, soil and water conditions, static and dynamic forces etc.). However, NAX is used within the benchmarking project as an explanatory factor and therefore the inaccuracy is of relative matter and can more or less be neglected. NAX (categories: young, medium or old) was identified as a factor exerting a big influence on water losses and mains failure rates (Theuretzbacher-Fritz et al., 2007).

Leakage Monitoring and Active Leakage Control (ALC)

The existing practices of leakage monitoring (including night flow monitoring and district meter areas – DMA), active leakage control as well as the speed of repair are also very important influencing factors on leakage performance. The amount of investment in ALC often depends on the costs of water production and the amount of water available.

The technologies used of participants are very different. Whereas some utilities, even small ones, have a permanent leakage monitoring for different district meter areas, others don’t even know their exact annual system input because there are no flow meters at springs.

Costs of water production and distribution

Costs of water production and distribution depend on available amount, quality (treatment necessary or not) and types of resources (natural springs with gravity pipes or wells) as well as on the average pumping height. In some cases where there are very low costs of water production and distribution, the speed of repair is noticeably higher than the repair times of companies with higher costs.

Data collection

For data collection, the IWA water balance was used, amongst others (Table 1). This water balance is used in many countries all over the world e.g. Australia, Germany, Canada, New Zealand, South Africa and by the American Water Works Association (Liemberger, 2006).

Table 1: IWA water balance (e.g. Farley & Trow, 2003)

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorised Consumption</td><td rowspan="2">Billed Authorised Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility`s Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to Piont of Customer Metering</td></tr>
</table>

Many water utilities, especially smaller ones, were not accustomed to using this type of water balance before participating in the OVGW benchmarking project. The reason for that is probably another type of water balance described in the OVGW directive W 63 (1993). This directive is the current standard for calculating water losses in Austria but it will be revised within the next few months.

To get information about reliability and accuracy of data for each single value the data quality was acquired (Table 2).

Table 2 Categories for data quality

Category	*Reliability*	*Accuracy*
A	very reliable	< 5 %
B	reliable	5 – 25 %
C	unreliable	25 – 100 %
D	very unreliable	> 100 %

In some cases the system input of natural springs is not metered and it is necessary to estimate these data. It was also a great challenge to estimate unbilled unmetered consumption. Only a few utilities have detailed information about unbilled unmetered consumption e.g. for fire fighting, washing streets, spilling sewers or watering public gardens. Another characteristic of many Austrian water utilities (particularly those with natural springs) are running wells in the distribution system. These running wells are almost always non-metered so their discharge needs to be estimated. If data of sporadic discharge measurements with buckets are available, it has to be born in mind that the network pressure in the night usually is higher because of lower demand, which causes a higher discharge at running wells.

Another problem is the estimation of the average network pressure. Depending on the structure of the distribution system (homogenous topography or hilly), the lack of pressure data is often in a range of plus or minus 1 bar. The average network pressure is one of the most influencing parameters for calculating ILI-values.

Estimating apparent losses is also quite difficult. Except single utilities theft of water e.g. at hydrants is no problem. In general, customer metering inaccuracies were only estimated due to the lack of any serious investigations into the problem.

The average length of service connections is needed for the calculation of the Infrastructure Leakage Index. Only utilities with GIS-systems are able to deliver exact data, but only estimated values are available from most participants. Because of these difficulties in data collection the data quality of such estimated values sometimes is only "C".

Another element of uncertainty is the period-end accrual of system input and customer meter readings (e.g. Gangl et al., 2006). Whereas system input data usually can be quoted for a key date without any problem, customer meter readings extend over a longer period from some weeks in smaller water companies up to the whole year in very large utilities. These data need to be confined to the key period. Inaccuracies resulting from customer meter reading periods were not considered for the current project.

Results

Theuretzbacher-Fritz et al. (2006) and Neunteufel et al. (2006) describe the stage B results in relation to the five target categories: supply safety, supply quality, customer service, sustainability and efficiency. In this paper selected results for water losses are presented. In the following figures reduced box plots are used. The grey boxes show 25 % and 75 % percentiles of the data. The numbers within the little white boxes show the number of utilities displayed in the figure and the black lines represent the median values.

Water Loss Ratio

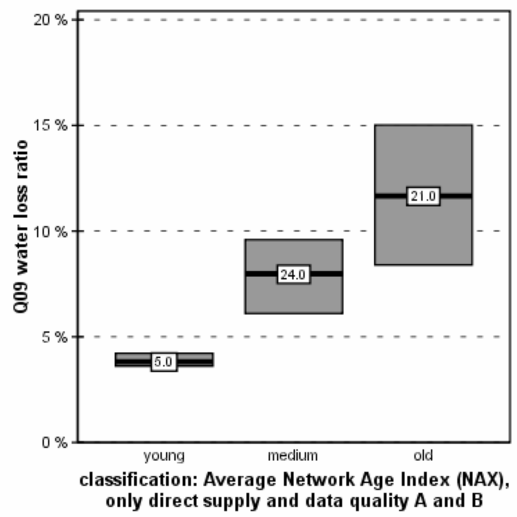

Figure 3 Water Loss Ratio

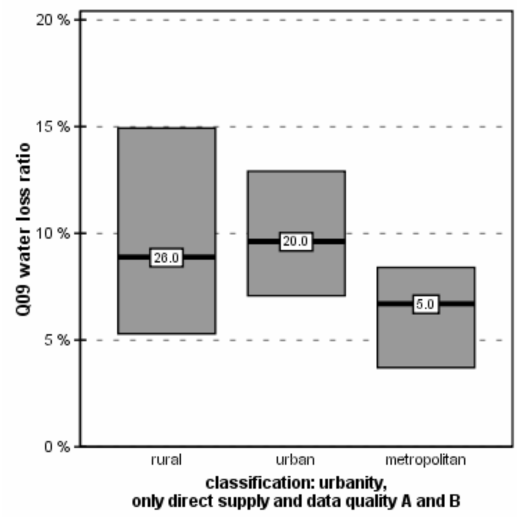

Figure 4 Water Loss Ratio

This performance indicator should act as a first reference value for discussing water losses. On closer examination, and together with other water loss PIs, it becomes clear that the water loss ratio alone is an insufficient indicator for interpreting the volume of water losses for a single utility.

The average network ages as well as the structure of the distribution systems have been identified as the factors exerting the biggest influence. The tendency of increasing water loss ratios due to network age is noticeable within all the different structures of distribution systems (rural, urban and metropolitan). It was also discovered that an increasing effort in active leakage control leads to a reduction in water losses (median decreases from 11 % to 7 %).

Real losses per connection and day

Usually a large amount of leakage occurs at service connections. Figure 5 shows the real losses per connection and day (l/connection/d) for rural, urban and metropolitan water suppliers. The increase in the median from rural to metropolitan networks probably goes back to complex influences in cities e.g. buildings, traffic and other infrastructure networks (Kölbl et al., 2006). With increasing average network age the median value (without grouping) is about 70 l/d in young systems and about 140 l/d in older systems (no figure).

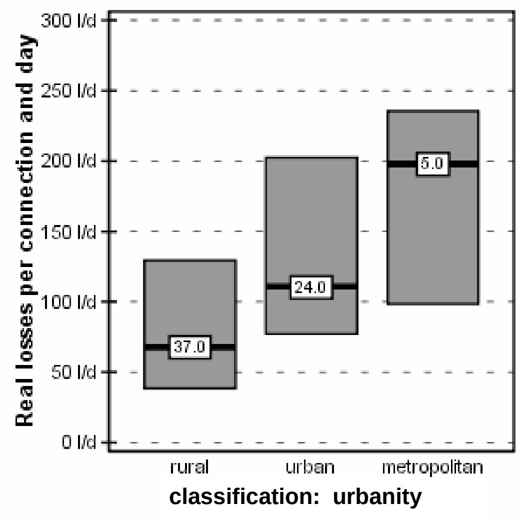

Figure 5 Real losses per connection and day

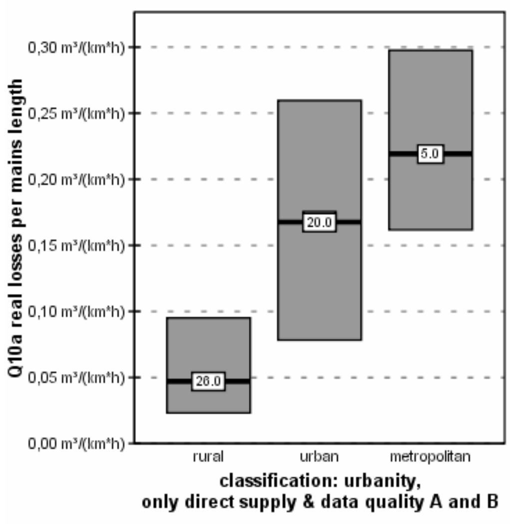

Figure 6 Real losses per mains length

Real losses per mains length

Beside the average age of the network, the structure of the distribution system is the most important influencing factor for this performance indicator. With increasing service connection density as well as with increasing network delivery rate, the losses per kilometre mains length are increasing. The "urbanity" as an indicator for the population density takes these influencing factors into consideration (Figure 6).

With increasing urbanity external influences like traffic, construction sites of other underground infrastructure, ground settlements etc. are also increasing. Hence, urban and metropolitan networks usually show higher losses per mains length than rural networks. Considering the network age, the median value in rural networks has increased from 0.02 $m^3/(km*h)$ in young systems to 0.06 $m^3/(km*h)$ in old systems. In urban networks the median value has risen from 0.06 $m^3/(km*h)$ up to 0.20 $m^3/(km*h)$ and for metropolitan networks, an increase from 0.16 $m^3/(km*h)$ up to 0.30 $m^3/(km*h)$ was found (no figure).

The influence of active leakage control is also interesting. Whereas in rural networks a decrease of median values from 0.05 $m^3/(km*h)$ with less active leakage control to 0.04 $m^3/(km*h)$ at high ALC-Level was noticed, in urban networks a reduction of the median values from 0.20 m³/(km*h) to 0.08 m³/(km*h) was detected. In metropolitan networks the median value at low ALC-level is about 0.30 m³/(km*h) and at high ALC-level the losses are about 0.16 m³/(km*h), (no figure).

Compared with the relatively strict standard values of DVGW W392 (2003) in Table 3, about 50 % of participating rural networks show low water losses. The main part of urban networks is classified as networks with medium or high water losses and the metropolitan ones also tend to high water losses within this classification.

Table 3: Standard values for real water losses per mains length in water distribution networks in m³/(km×h) according to DVGW W 392 (2003)

evaluation of water losses	*structure of distribution network*		
	area 1 (metropolitan)	*area 2 (urban)*	*area 3 (rural)*
low water losses	< 0.10	< 0.07	< 0.05
medium water losses	0.10 - 0.20	0.07 - 0.15	0.05 - 0.10
high water losses	> 0.20	> 0.15	> 0.10

Infrastructure Leakage Index

Compared to other water loss PIs like “real losses per mains length” or “real losses per connection and day”, the Infrastructure Leakage Index (ILI) also considers essential influencing factors like average network pressure and service connection density (Theuretzbacher-Fritz et al., 2006).

$$ILI = CARL / UARL$$

CARL = Current Annual Real Losses [litre/(connection * day)]

UARL = Unavoidable Annual Real Losses [litre/(connection * day)]

$$UARL = \left(18 * \frac{Lm}{Nc} + 0,8 + 25 * \frac{Lp}{Nc} \right) * P$$

Lm = length of mains [km]

Nc = number of service connections

Lp = length of service connections (from property boundary to measurement point) [km]

P = metre of average service pressure [m]

Thus ILI represents a quite complex indicator which has not been common in the Austrian drinking water sector up to now. ILI has been integrated into the OVGW stage B benchmarking system for the purpose of testing and first experiences are positive, even if this highly aggregated indicator seems to be too complex for some participants in the first instance.

Figure 7 and Figure 8 show ILI values for different structures of distribution systems and for networks of different average ages. Rural systems show lower ILI values than urban and metropolitan ones and of course, older networks show higher ILI values which indicate higher water losses. ILI values close to 1.0 represent networks which are well maintained and in a very good state.

Compared with international ILI values these results are excellent. Many water utilities in international regions do not reach ILI values close to 1. According to Liemberger (2006), well managed utilities in Western Europe, North America and Japan will probably have ILI values under 10. In Eastern Europe, ILI values can lie between 20 and 40. Values up to 100 are not uncommon in Central Asia.

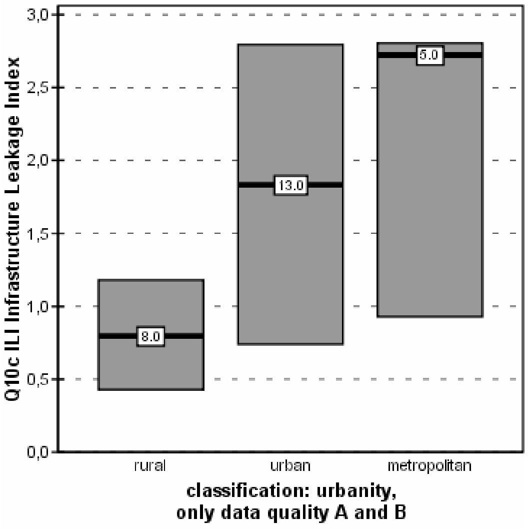

Figure 7 Infrastructure Leakage Index

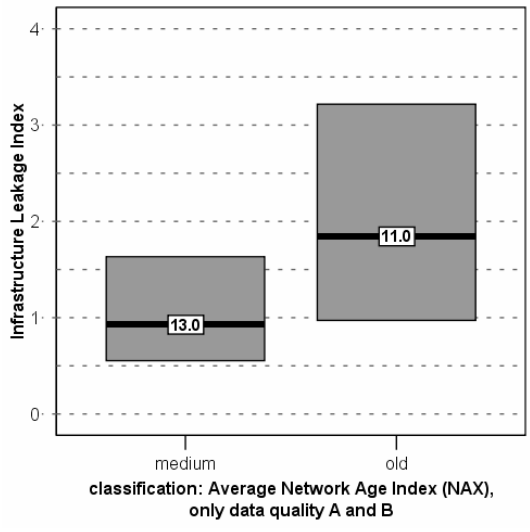

Figure 8 Infrastructure Leakage Index

Eleven Austrian ILI values are lower than 1.0 which means that the current losses are even lower than the unavoidable minimum losses. To investigate if these values represent very well managed networks or if there are other reasons, e.g. data quality of input parameters, additional analyses of all values lower than 1 were carried out. The free calculation software WB-EasyCalc was used for this purpose, courtesy of Liemberger & Partners. The individual accuracy was estimated for each input parameter (e.g. system input of each resource, system pressure, length of service connections etc.). The main influencing factors were the accuracy of the system input and pressure.

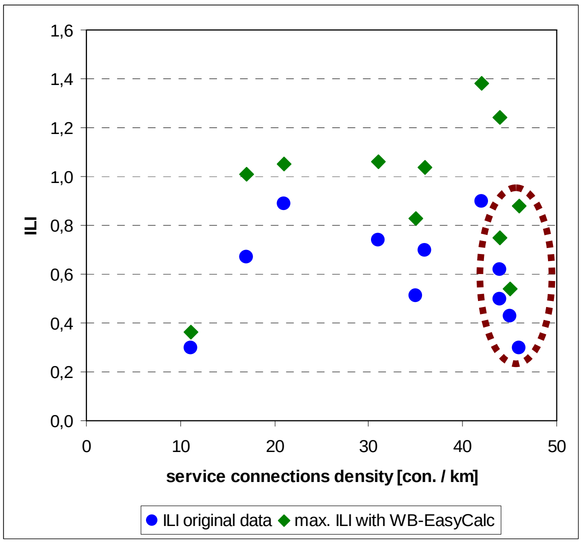

Figure 9 Infrastructure Leakage Index in subject to service connections density

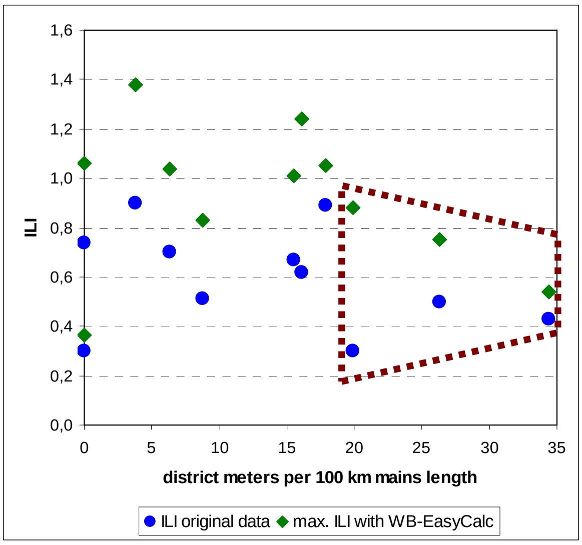

Figure 10 Infrastructure Leakage Index in subject to density of district meters

Maximal and minimal ILI values were calculated on the basis of these individual data qualities. Figure 9 and Figure 10 show original ILI values as well as maximum values calculated with WB-EasyCalc. The maximum values of six of these eleven utilities lie above 1.0, but five values are still under 1.0. It is significant that mainly utilities with a high service connection density show these low values. One reason for these results could be due to the structures of the distribution systems. Each of the companies within the dotted marking supplies different distribution zones, which have the function of DMA`s. Therefore bursts can be detected quickly and run-times are kept short.

Non-revenue water

The total amount of unbilled water is described with this indicator. It is calculated by subtracting the billed consumption from the system input. Because billed unmetered consumption is negligible for almost all participants, only “hard facts” (measured values) are responsible for the quality of this indicator.

As Figure 11 shows, non-revenue water increases with the availability. The lower the costs for water production and distribution (e.g. natural springs without treatment effort and without pumping), the smaller the incentive to reduce water losses or unbilled consumption. Localising and repairing small burst costs a lot of money. So at first glance it seems more attractive to save this money. But with an aging network this loss of substance becomes indirectly cost-effective.

The large difference between values of water loss ratio and non-revenue water results from unbilled consumption. The problem of running wells etc. was discussed in the Data collection chapter.

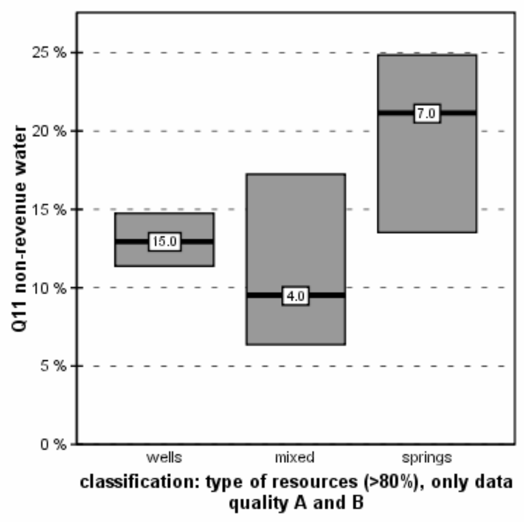

Figure 11 Non-revenue water

Conclusions

Experiences during the OVGW benchmarking project have shown that an adequate database is necessary for interpreting leakage values of single water companies as well as for comparing the water loss PIs of different water supply companies. This includes both water balance data of good quality and enough background information to characterise the structure of the distribution system.

When evaluating leakage values of single utilities, the consideration of different performance indicators is required. It can be shown that the “water loss ratio” alone, which is still the most common water loss PI in the Austrian water sector, is an insufficient indicator for interpreting leakage data. Therefore the additional consideration of “real losses per mains length” and “real losses per connection and day” is essential.

The Infrastructure Leakage Index considers essential influencing factors like average network pressure as well as density and average length of service connections. So this aggregated indicator gives a good overview of the leakage situation. The first test of ILI within the Austrian benchmarking project was successful; nevertheless, further convincing is necessary to implement this indicator into the daily operational management of water supply utilities.

Other methodical results are the need to estimating the data quality of each single input parameter of the water balance but also various improvements in data collection (100 % metering of system input, metering running wells, more pressure monitoring etc.).

When considering factual results, the structure of the distribution system and the average network age are the two most influencing factors. In general, rural networks have lower leakage values than urban and metropolitan ones. Water losses increase as a network gets older. It has been shown that the amount of non-revenue water increases with the availability of water.

The results also show the importance of leakage monitoring and active leakage control. Those companies that put in more effort in these tasks achieve much better water loss results than others. Compared with international water loss values the project results are very good in general, although a high potential for improvement was found in some companies.

Further investigations

Currently the focus of the Austrian OVGW benchmarking project is on process benchmarking. One topic deals with the process of "water loss management". The aims of these analyses are comparisons of costs, qualities and benefits of different tasks of water loss management like leakage monitoring, leak detection etc. and the embedding of these tasks into the operational management.

In 2008 the next metric benchmarking project – stage C, databases 2007 - will follow. This will give the stage B participants the possibility to compare the results and find out if measures have been successful.

Further convincing is necessary to increase the data quality (e.g. by installation of meters at delivery points of unbilled consumption), to use "innovative" performance indicators like ILI, to implement leakage monitoring etc.. Another requirement is to investigate how to solve the problem of period-end accruals of customer meter readings. Beside statistical solutions, new technologies like telemetry are also conceivable.

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