Minimising water leakages from the water distribution system

In a nutshell

SUMMARY
It is best practice to: • carry out a detailed water balance of the water distribution system and manage water pressure, avoiding high levels; • analyse the water distribution network and divide it into adequate district metering areas to detect water leakages by means of manual or automatic acoustic water leakage detectors; • respond promptly and adequately to the identified faults and leakages of the network; • establish a database to list and geo-reference all technical installations, the age of pipes, types of pipes, hydraulic data, previous interventions, etc.
Target group
Public administrations responsible for supplying potable water in their territory.
Applicability
This best practice is applicable to new and existing water distribution networks.
Environmental performance indicators
• Percentage of water loss out of the system input volume (%) • Infrastructure Leakage Index (ILI): calculated as current annual real losses (CARL) / unavoidable annual real losses (UARL) [1]
Benchmarks of excellence
The Infrastructure Leakage Index is lower than 1.5

[1] The current annual real losses (CARL) represent the amount of water that is actually lost from the distribution network (i.e. not delivered to final users). The unavoidable annual real losses (UARL) take into consideration that there will always be some leakage in a water distribution network. The UARL is calculated based on factors such as the length of the network, the number of service connections and the pressure at which the network is operating.

Description

The management of water losses of municipal water distribution networks is an important element of sustainable water supply. The loss of water - expressed as percentage of system water input - can be significantly varying in developed countries between 2 and 62 % (EC, 2007; EUREAU, 2011; SWAN, 2011, City of Berlin, 2014).

Basically, water loss management consists of four pillars: I -active leakage control, II - pressure management, III - speed and quality of repairs, and IV - pipe and assets management (Figure 1).

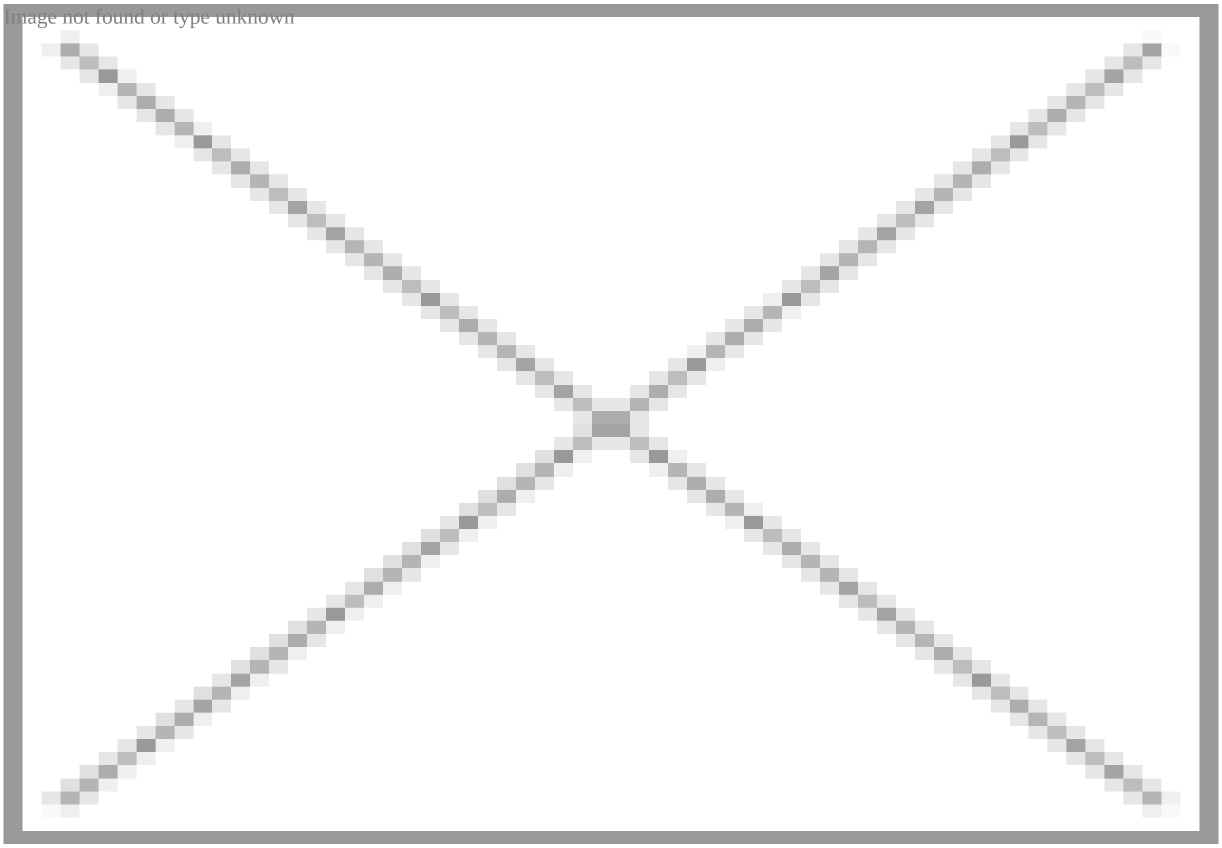
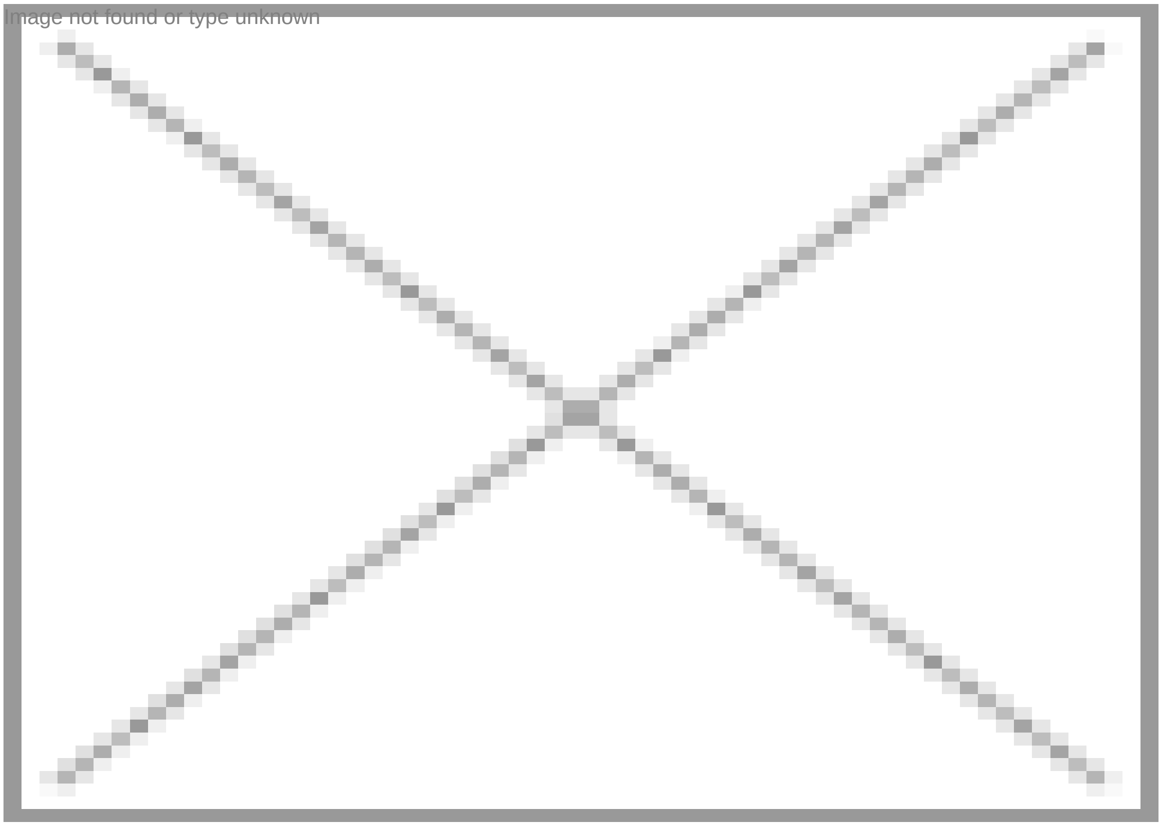


Figure 1: The four basic pillars of managing real water losses (Lambert, 2003; Lambert, 2012); the ILI is calculated as the ratio of the current annual real loss (CARL) and the unavoidable real loss (UARL), (Lambert/Hirner, 2000; Lambert, 2003; Lambert, 2012; DVGW W392, 2013)

The pipeline and assets management as the **first pillar** requires a detailed and accurate water balance according to international standard (Table 1).

Such a water balance provides the required overview of the water distribution network which can be illustrated in form of a Sankey diagram (Figure 2).

Table 1: Water balance of a public water supply system according to best practice (Lambert/Hirner, 2000; Lambert, 2003; DVGW W392, 2013)



*Difficulty may be experienced in completing the water balance with reasonable accuracy where a significant number of customers are not metered. In such cases, authorised unmetered consumption should be derived from sample metering of sufficient numbers of statistically representative individual connections of various categories, and/or by measurement of inflows into discrete areas of uniform customer profile (with data adjusted for leakage and diurnal pressure variations as appropriate).

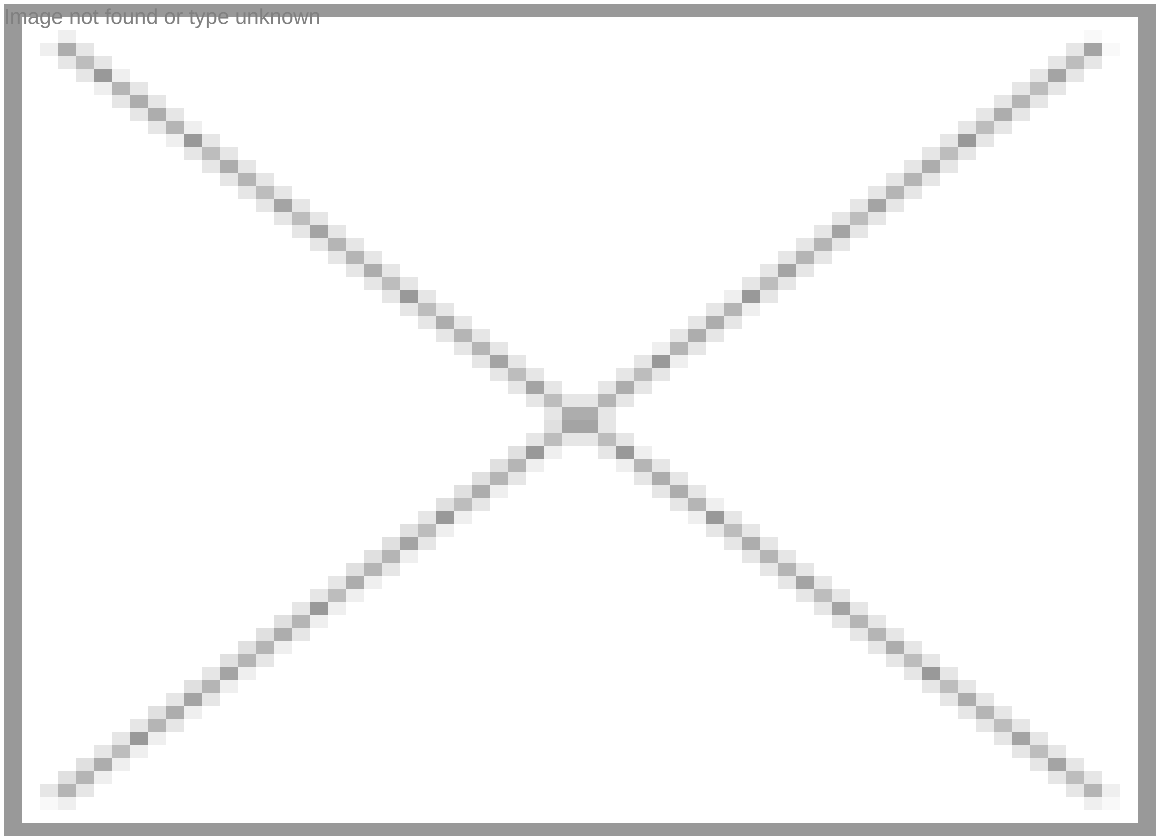


Figure 2: Example of a Sankey diagram illustrating the water balance of a water distribution network (DVGW W392, 2013),

NB: On an annual basis, the ‘real water loss’ is called current annual real loss (CARL), and the unavoidable annual real loss (UARL) is distributed among the different real losses

However, this is not sufficient to have the required more detailed understanding of the network. For this purpose, the network must be analysed and divided into adequate district metering areas which can also be called leakage monitoring zones. Figure 4 shows an example of the network of the city of Freiburg with about 220,000 inhabitants in the very South-West of Germany. Each of the 18 zones as well as the flow of the water distributed from the water tanks is equipped with continuous flow measurement (magnetic-inductive flow meters which are regularly calibrated). With the data, a water balance of the different zones is established. This enables the detection of sharp consumption increases within a zone, specifically by means of the minimum night flow measurement between 2 and 4 am (according to experience, the flow in this time period is lowest (Lambert/Hirner, 2000; Xu et al., 2014; Debiasi et al., 2014)) and is considered as the baseline consumption. Thus, the area of leakages can be identified. Then, the precise location of the leakage has to take place (see the pillar concerning active leakage control).

In addition, a database is required where all technical installations are listed and georeferenced by means of a geographic information system (GIS) (Diersche et al., 2014), and where the damage statistics, the age of the pipes, the hydraulic data (such as diameter, depth position and flow capacity), type of material, pipe conditions etc. are contained (Heinzmann, 2004).

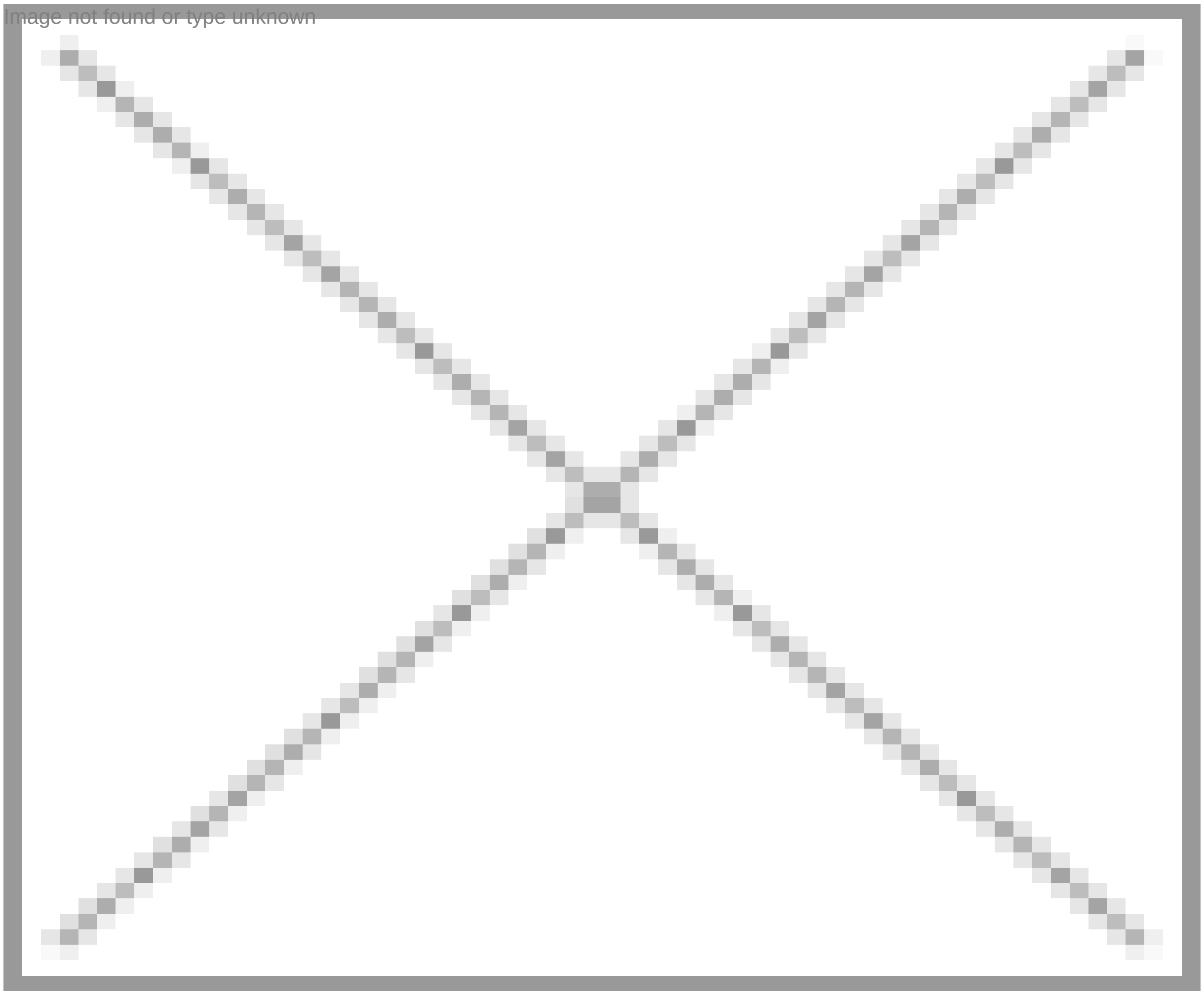


Figure 3: Overview of the 18 leakage monitoring zones (metered district areas) of the city of Freiburg/Germany (Diersche et al., 2014)

There are cities where the division of the whole network into zones is difficult, such as Berlin/Germany. There, the alternative is to have a dedicated rehabilitation strategy. On the basis of the careful analysis of network and leakage data, statistical evaluations and forecasts are established. Since 35 years, all damages/leakages of the piping network are documented and processed, and, in combination with economic considerations, such as repair and renewal costs, the annual extent to replace existing pipes by new ones is determined. For this purpose, specific software, such as PiReM is used. As a consequence of this strategy, the leakage rate is on a very low level.

The **second pillar** (indicated in Figure 1) is active leakage control to apply timely if elevated or high minimum night flows are detected. This includes the use of techniques to precisely locate a leakage by means of automatic and manual acoustic leakage detection systems (see Figure 4 and more details under operational data) or step testing (hydraulic analysis in a metered district area at minimum night flow). The use of hydraulic models can support the identification and localisation of leakages (Debiasi et al., 2014; Nicolini et al., 2014; Xu et al., 2014) but cannot be used as the only measure to detect leakages.

It is important to have an annual budget available enabling systematic active leakage control (Lambert/Taylor, 2010).

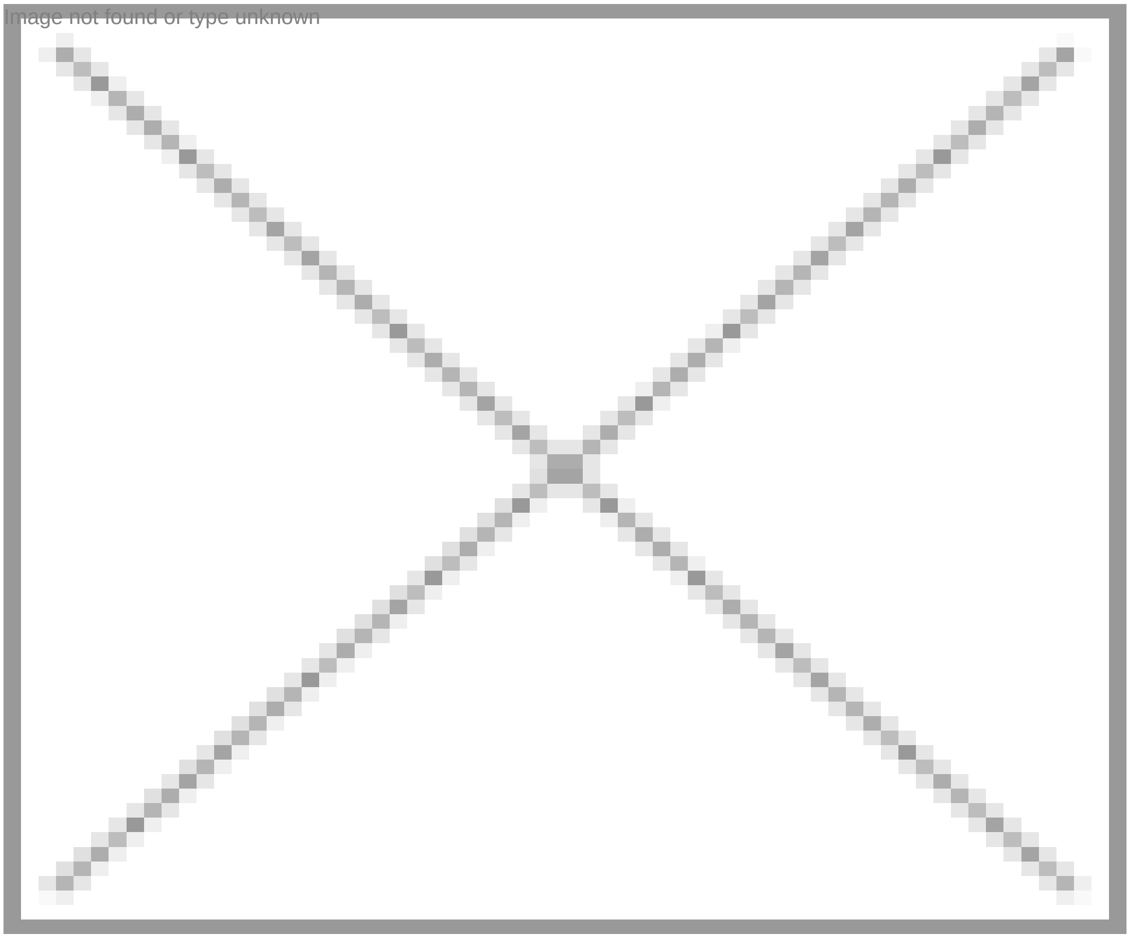


Figure 4: Automatic and manual leakage detection by means of acoustic listening sensors, noise loggers including correlators (see more details under operational data)

Another key aspect of managing water leakages is pressure management (Figure 1) which is still often underestimated, also in developed countries (Kingdom et al., 2006) although its benefits have been recognised for over 40 years (Thornton, 2003; Xu et al., 2014). For large systems, the assumption of a linear relationship between pressure and leakage rate is an acceptable simplification (Lambert/Hirner, 2000; Thornton, 2003). Consequently, each metered district area should be operated at ‘adequate’ but not excessive pressure by means of transient control, network sectorisation and pressure reducing valves (PRVs) to reduce and modulate pressure in the network (Thornton, 2003; Thornton et al., 2008; Lambert/Taylor, 2010; Mutikanga et al., 2013).

The **third pillar** concerns the timely response to all identified faults and leakages on utility infrastructure (instant high quality repair) with own personnel of the municipality or third party contracts or a combination of both. This also includes the availability of optimised resources for maintenance work as well as the adequate budget.

Linked to the third pillar, the **fourth one** is to establish a database to list and geo-reference all technical installations, the age of pipes, types of pipes, hydraulic data, previous interventions, etc.

Post meter leakages are not mentioned here but are described in the best practice on water metering.

Environmental benefits

Water losses of only 2-5 %, expressed as a percentage of system input, can be achieved. After reunification in 1990, in the Eastern part of Berlin, implementing the measures described, water losses were reduced from 25% to 4-5 % (Heinzmann, 2004). However, from the technical point of view, this environmental performance indicator alone is not appropriate (see the text below for ‘appropriate environmental indicators’) but provides a reasonable indication from the ecological point of view.

For the Infrastructure Leakage Index (ILI), introduced in Figure 1, best achieved values are below 1.5 (Lambert/Hirner, 2000; Lambert/Taylor, 2010).

The benefits of water leakage control go beyond the water saved itself. Associated benefits include the reduction of energy consumption and greenhouse gas emissions. The energy consumption for pumping and treating 1 m3 of water is 2–42 MJ and varies depending on the source of water. Surface water and groundwater need 2–3 MJ of energy to treat 1 m3 of water (Friedrich, 2002; Racoviceanu et al., 2007; Mo et al., 2011). Recycled water or imported water needs 3–18 MJ/m3 of energy (Lyons et al., 2009; Stokes and Horvath, 2009), while the number for desalinated water is 42 MJ/m3 (Stokes/Horvath, 2009). The reduction of energy consumption is accompanied by a decrease of greenhouse gas emissions. According to (Stokes/Horvath, 2009), under U.S. (California) conditions, around 60 g of CO_2 are emitted for each 1 MJ of electricity consumed in the process of producing and distributing imported (piped-in) water (N.B. this number is based on a mostly natural gas-fuelled electricity grid and may vary depending on the energy mix of a country).

Side effects

There are no environmental cross-media effects when implementing this best practice.

Applicability

The technique described is applicable in existing and new water distribution networks and can be retrofitted or applied to any existing water distribution network.

It requires personnel with adequate education and a budget sufficient to implement and to operate the system in order to minimise water losses of municipal water distribution networks.

Economics

Firstly, the management of water losses is associated with economic benefits because less water has to be abstracted, treated and distributed. This does not only include the costs for the water as such but also for chemicals, energy and staff.

Secondly, the early detection and well-done repair of a leakage can prevent considerable damages. In worst cases, the costs for such damages may exceed the costs for a pro-active leakage detection system, e.g. the described automatic acoustic leakage detection system.

There is always a certain background level of leakage that is unavoidable, and the cost of detecting and repairing all leaks may make it prohibitive. Unavoidable annual real losses (UARL) are therefore commonly calculated, and these are a function of the number of service connections, the length of mains pipes, the length of private pipes and the average operating pressure (Lambert, 2003). In the UK, the approach was developed to determine the point at which leakage reduction benefits outweigh the cost of leakage repair. When externalities are included into these costs, this point is known as the Sustainable Economic Level of Leakage (SELL) (OFWAT, 2007). However, the analysis of the SELL approach revealed that there are many uncertainties in estimating the economic level of leakages and the SELL mechanism does not promote efficiency and innovation (OFWAT, 2012).

Driving forces for implementation

The advantages of leakage detection and repair are manifold. Leaks cause health risks by contaminating piped water, decrease the quality of service through pressure losses, damage roads, buildings and other infrastructure and increase the chance of further damage to pipes through erosion. Repairing leaks leads to water, energy/GHG and financial savings. Reduced energy use also entails lower operating costs, which also benefit from reduced chemical input, reduced maintenance requirements and staff costs.

Reference organisations

Berlin/Germany; Freiburg/Germany, Hamburg/Germany; Münster/Germany; Copenhagen/Denmark, Amsterdam/Netherlands, Rotterdam/Netherlands; Melbourne/Australia; San Jose/USA, Singapore/Singapore – these cities practice an efficient management of water losses and do achieve very low level of water loss, expressed as percentage of system input volume or as Infrastructure Leakage Index (ILI). They represent best practice examples.

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