

Sustainable reduction of water loss in urban water distribution systems

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Water loss - rehabilitation

Introduction

Under technical, economic and ecological aspects the fight against water loss becomes more and more important for water supply companies. In Germany, most of the water distribution systems in the cities were constructed between the middle and the end of the last century. With an average pipe age of 45 years, the average annual rehabilitation rate of water distribution systems is about 1%. For this reason, water pipes must have a durability of at least 100 years. In highly developed industrial countries, the pipe systems have become much older and vulnerable to damage. This results in an increase of the water loss in this case, if no efficient constructional and operational measurements are undertaken.

With the available technologies such as noise measurement and the correlation method, the detection of leakages is unproblematic. The actual problem is to identify developing leakages very early and to detect them geographically. In this context, EnBW developed a system for monitoring water distribution systems.

Damage rates and tolerable water loss

Even though the technical durability of soil-covered pipes could last many decades, these parts of the water supply system will become more and more susceptible to damage. The damage rate in distribution systems increases with age. Aggressive soils, soil movement dependent on frost and traffic, construction activity and last but not least dynamic pressures caused by water consumption lead to a strain for the pipe systems. Depending on pipe materials and fittings used this leads to an increase of leakages during the decades which will affect the operation of the system.

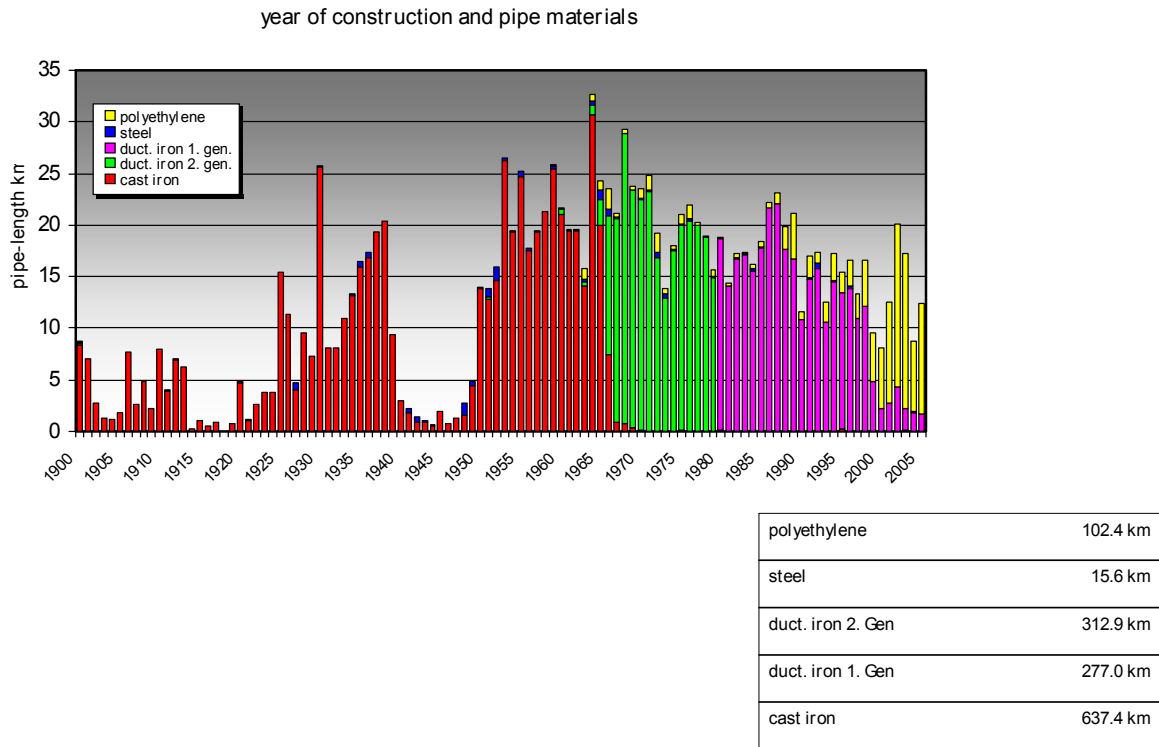


Figure 1: rehabilitation / material and age-structure of the water distribution system of Stuttgart (2006)

The water distribution system of EnBW in Stuttgart contains 50 % cast iron pipes which are laid predominantly in clay soil. Because of these soil conditions, the damage rate in Stuttgart increases during frost and in dry seasons. The damage rate of cast iron pipes is - under normal conditions - 3 damages / (km x month). In dry seasons and seasons with frost, these will increase up to 10 damages / (km x month). During the last 10 years the damage rate increased from 0.19 to 0.24 damages / (km * p.a.) for cast iron pipes and from 0.05 to 0.07 damages / (km * p.a.) for ductile iron pipes.

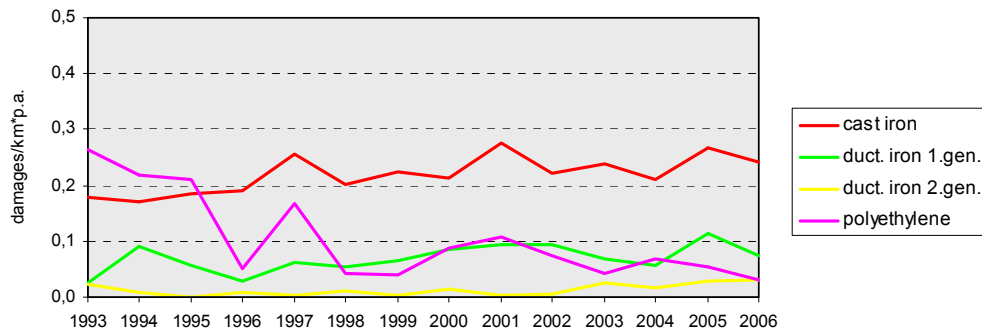


Figure 2: rehabilitation / development of damage rates (pipes)

Table 1: benchmarks for damage rates of pipes in water distribution systems (DVGW W400-3)

| definition of damage rates | damage rates | |
|----------------------------|--|--|
| | principal and local mains (damages per km and year) | service pipes (damages per km and year) |
| low | ≤ 0.1 | ≤ 5 |
| average | > 0.1 to ≤ 0.5 | > 5 to 10 |
| high | > 0.5 | > 10 |

The water loss of a water supply company is caused primarily by leakages in the pipe system. Other influences such as loose fittings and joints and water meters cause permanent loss. In Stuttgart, all these influences have an extension of about 2 - 3 l / (min x km).

By singular or periodical inspections of the pipe systems water loss can be decreased only for a short time. Because of the constant development of damages or leakages in a pipe system, a long term reduction of water loss can only be achieved by permanent monitoring measures. In this context, the monitoring of inflow(s) has to be proved as the most efficient and economic method.

During the last years, the total water loss in the distribution system of EnBW in Stuttgart, with a system length of 1,534 km, was about 4 Mio. m³ /p.a. After the reduction of this amount on the low loss from loose fittings and joints and the influence of water meters, the amount of real water loss in the distribution system itself will be approx. 2 Mio. m³ / p.a. (8 %) and the specific water loss will be at 0.15 m³ / (h x km) respectively.

Table 2: characteristic benchmarks for specific real water losses for distribution systems in m³ / (km x h) (DVGW W392)

| range of water loss | intervals of inspection | structure | | |
|---------------------|-------------------------|-------------|-------------|-------------|
| | | large city | urban | rural |
| low | max. 6 years | < 0.10 | < 0.07 | < 0.05 |
| average | 3 years | 0.10 - 0.20 | 0.07 - 0.15 | 0.05 - 0.10 |
| high | 1 year | > 0.20 | > 0.15 | > 0.10 |

In the year 2005 about 850 leakages were recorded in the Stuttgart distribution system. On the basis that the average loss of a leakage will be approximately 1 m³/h, the detection of an average leakage will take at least 0.27 years or approx. 100 days.

Even if this is only a statistical consideration, these calculations show that water loss can be reduced efficiently if the duration of leakages last could be shortened.

Monitoring methods for pipe systems

Using the available technologies, leakages can be identified from the following characteristic physical properties:

- leakage noise arising at the leakage and
- continuous outflow at the leakage which will interfere with water consumption.

Due to the fact that the measurable leakage noises dependent on the pipe material only occur in the direct surroundings of the leakage, the available technologies are only applicable for the detection of the leakage itself or to contain the leakage area (noise

loggers) but not for the early detection and localization in bigger networks or network districts.

This aspect is especially important for systems constructed with polyethylene pipes, because this pipe material is highly noise-absorbing.

The continuous water outflow at the leakage will cause an increasing water inflow in the pipe system. A monitoring of the inflow (flow rate) enables an evaluation, if new additional leakages occur - depending on the size of the pipe-network or network district.

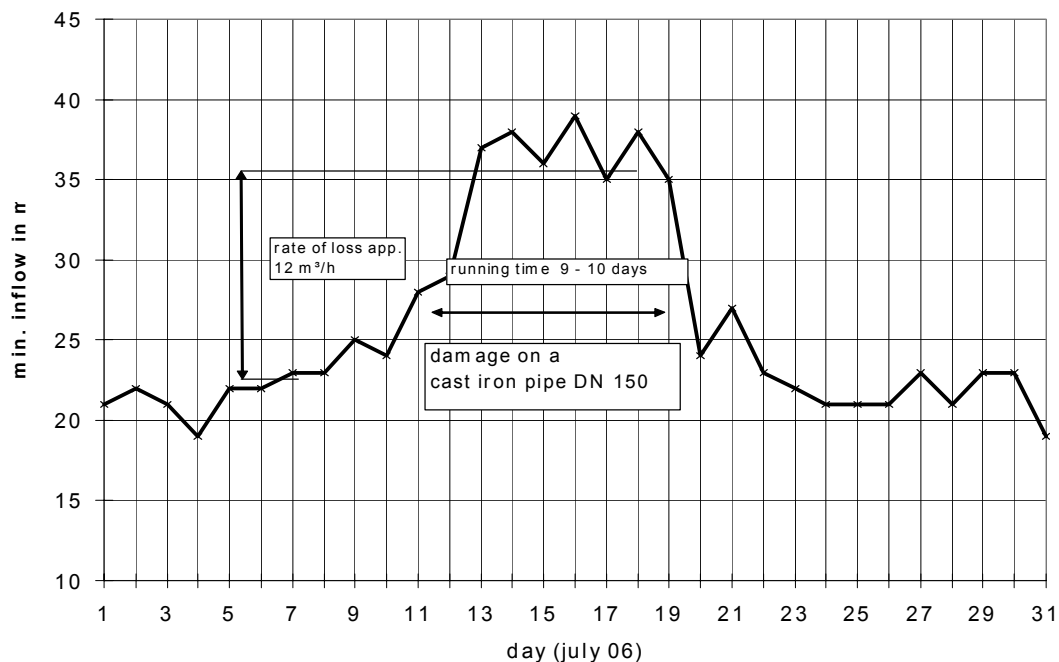


Figure 3: measurement of water loss / identification of a leakage by measurement of minimum night inflow (9,700 inhabitants, 38 km network length)

Dependent on the malfunction messages of a monitoring system, advanced measurements to isolate and to detect the leakages could be carried out using the approved acoustical technologies. The first active element in a chain of monitoring of a pipe network is the permanent measurement of the zone inflow(s).

Installation of measuring facilities for a pipe network monitoring

The outlets of each water reservoirs or source have to be equipped with applicable measuring facilities for the flow rate. Therefore usually inductive flow meters will be used; in case of bigger pipe diameters ultrasonic flow meters can also be installed. Each metered hour values will be transmitted to and recorded on the scada system using the company's telecontrol network. If a telecontrol network is not available, the measurement data can be recorded on a local installed data logger. If required, the data can be transmitted using the telephone network or by radio communication. Using these techniques, it is possible to monitor the water consumption (inflow) continuously.

In small zones (networks) this kind of leakage monitoring works without any problems, because the effort for the detection of a leakage is based on a manageable network district.

If a leak should occur in a bigger zone, with a pipe length of 170 km for example, these single leakages will not be identified on the basis of a central inflow

measurement because of considerable fluctuations of night consumption. Furthermore the effort for the location and detection of the leakage in such a big zone is exceedingly high.

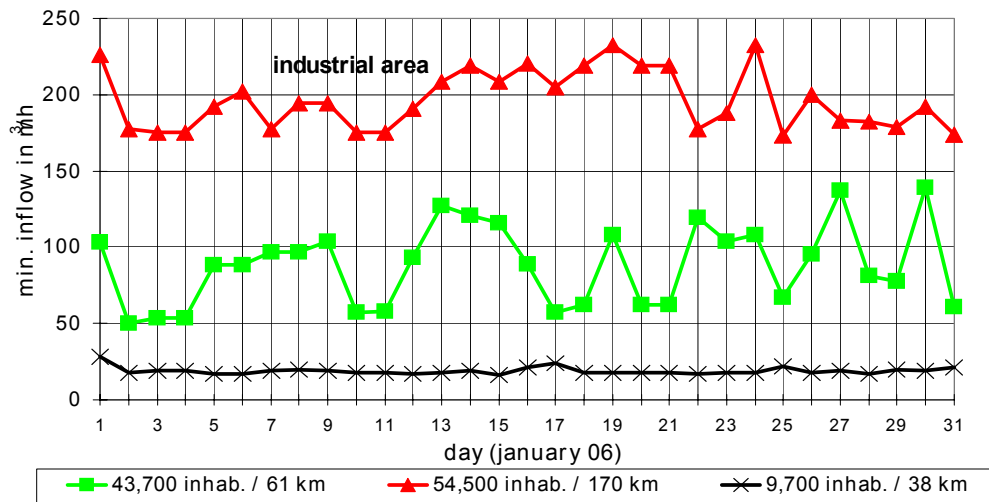


Figure 4: water loss / minimum night inflow in water supply systems of different sizes

For the practical operation of zone monitoring it is necessary to install the measuring facilities for smaller network districts. In this context, all outlets of water reservoirs and pumping stations in Stuttgart have been equipped with flow meters.

Furthermore, in all bigger zones, manholes with flow meters have been constructed in appropriate hydraulic positions in order to realize smaller districts.

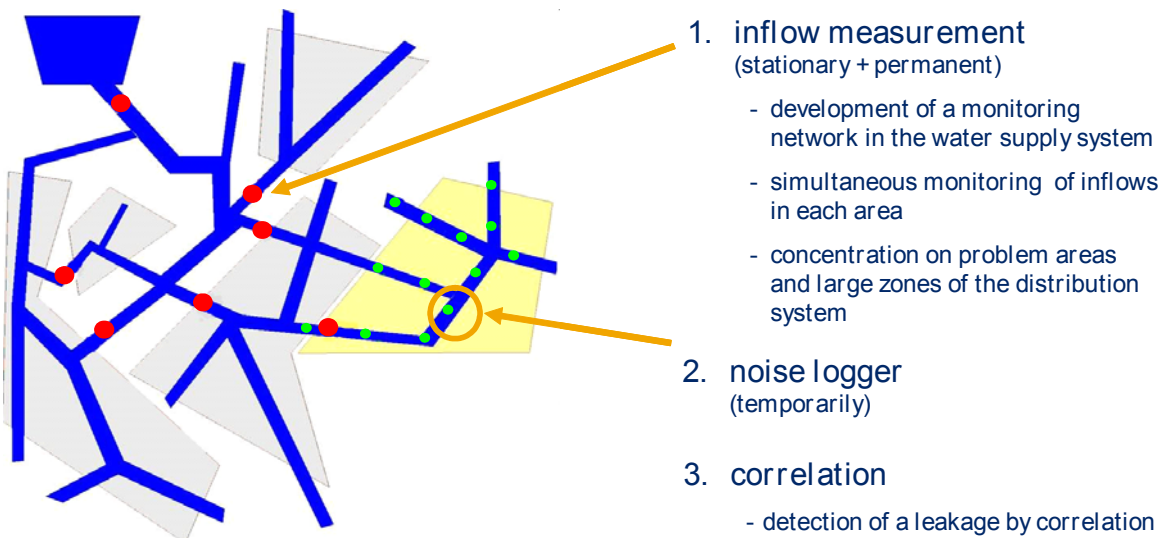


Figure 5: water loss / philosophy of district metering

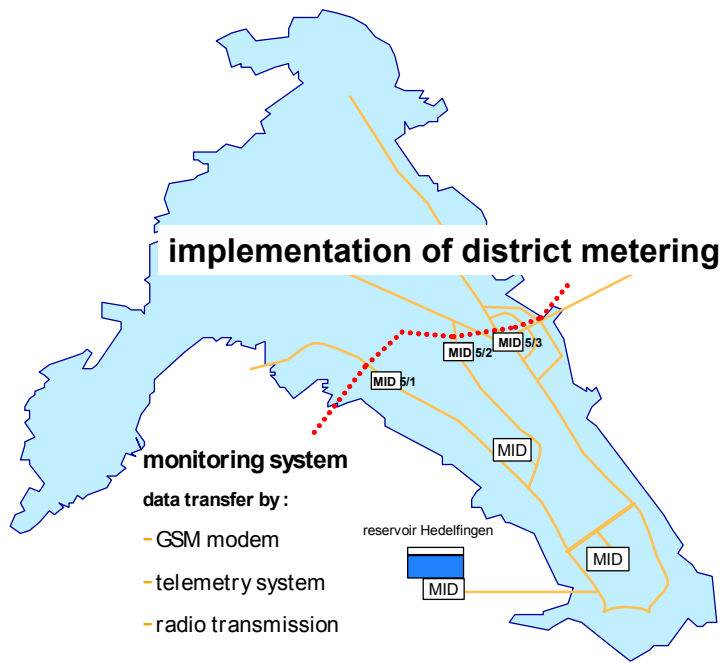


Figure 6: water loss / example for implementation of district metering

Since 2005, EnBW has used an integrated system based on a clamp-on ultrasonic flow meter. This system can be installed directly on the pipes without the necessity of a manhole - the data are transmitted by GSM. This system has to be proved as the most efficient and economic method of measuring flow rates.



Figure 7: water loss / EnBW-system 'Leak Control'

Strategically rehabilitation of water supply systems

The application of an appropriate strategically rehabilitation programme is essential for a safe and largely faultless operation of a pipe network with tolerable damage and water loss rates. In this context, the statistical analysis of damages and the application of the HERZ-method, which is based on the pipe material and age structure of the pipe network, are approved.

Using the HERZ-method, the life-expectancy of each pipe material has to be estimated as shown in figure 8.

| pipe material | life expectancy | | | | | | life ex. | 100% | 50% | 10% |
|-------------------|-----------------|----|----|-----|-----|-----|----------|------|-----|-----|
| | 40 | 60 | 80 | 100 | 120 | 140 | | | | |
| cast iron | | | | | | | 60-120 | 60 | 90 | 114 |
| duct. iron 1.gen. | | | | | | | 40-100 | 40 | 70 | 94 |
| duct. iron 2.gen. | | | | | | | 100-140 | 100 | 120 | 136 |
| steel | | | | | | | 60-100 | 60 | 80 | 96 |
| polyethylene | | | | | | | 40-80 | 40 | 60 | 76 |

Figure 8: rehabilitation / acceptance of physical life relating to pipe material

The determination of the rehabilitation volume (in km p.a.) is based on calibrated expected service life of pipe materials.

Figure 9 shows the determination of rehabilitation volume of EnBW's water supply system in Stuttgart. The actual rehabilitation rate is 12.5 km p.a. (0.81 %) and will rise to 15.3 km p.a. (1.0 %) in 2017.

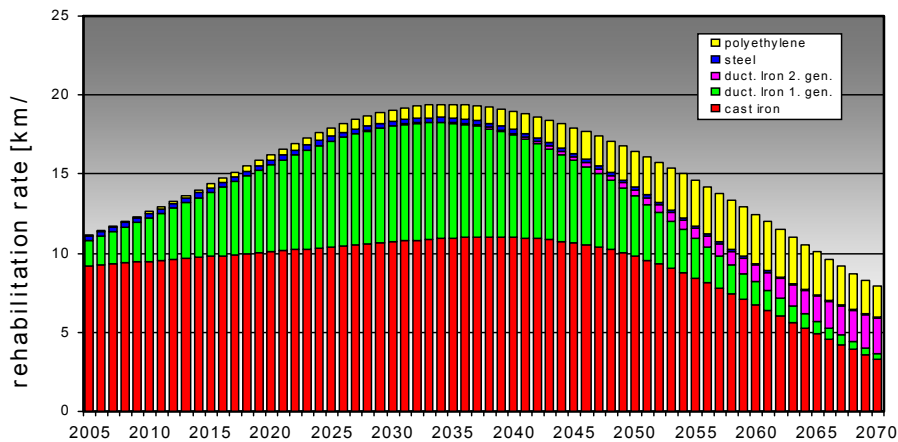


Figure 9: rehabilitation / determination of rehabilitation rate

The following step will be the identification of single measurements and the assignment of priorities. In this context the pipe material - / pipe section - specific damage rates have to be calculated. After a plausibility check and consideration of external influences (e.g. sewers, gas pipes etc.) the process leads to a ranking of projects.

Through concerted replacement of defective pipes or pipe sections a decrease of expensive damages and disturbances is to be expected. In the medium period (5 -7 years) a lowering of repair cost of approximately 30 % is expected.

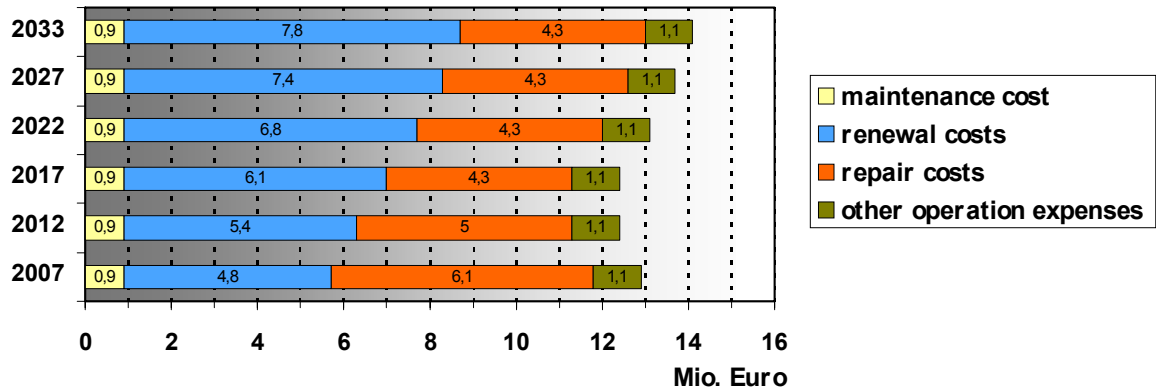


Figure 10: rehabilitation / expected compensation effect

Summary

The continuous measurement of inflow to water supply zones or to zone districts respectively allows identification of leakages. As a precondition, zones or zone districts, which have to be monitored, have to be selected in such a way that they are not too large - to keep the variations in night consumption in a tolerable range. The limit of an appropriate size would be at approx. 5,000 inhabitants or a pipe length of 15 km.

Because of the early detection and location of leakages and the strategically rehabilitation of vulnerable pipes and network districts liable to damage, the specific water loss rates in Stuttgart could be decreased permanently to an amount of approx. 0.15 m³ / (h x km). The experience and the know-how developed at EnBW could be passed on to other water supply companies.

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