Improving efficiency of water supply systems through water loss reduction measures

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Introduction

• Water is the most important resource for human.
• But water is one of most wasted resource on earth.
• One example: water distribution network.
• Non-Revenue Water is a crucial issue. European countries: 7% to 50% Water Loss in Water Utilities.
• NRW management is a complex issue...
Official data (LT) – water losses %

Average of total water loss - 30%

Level of water loss, %

Real water loss
Commercial water loss
Water volumes (mio m\(^3\)/year), LT

- Authorised consumption: 92 mio m\(^3\)/year
- System input: 130 mio m\(^3\)/year
- Total water loss: 38 mio m\(^3\)/year
- Apparent loss: 8 mio m\(^3\)/year
- Real loss: 30 mio m\(^3\)/year
Why reduce water losses?

Hole ø = 6 mm
Pressure = 50 m
» Leakage = 43.2 m³/d

Olympic size swimming pool
V = 2,500 m³
» Filled in less than 2 months

Per capita consumptions = 136 l/cap/d
Q = 317 x 136 l/cap/d = 43.2 m³/d
» Water for 317 persons
How to count water losses
Evaluation in percentage

*Kaunas case*

- 1992 – losses only 11%
- 2013 – losses event 29%

... but, lost water ????

- 8,3 mln. m³/year
- 6,1 mln. m³/year
Changes in water consumption
Basic terms and definitions

**Water losses**: The volume of water lost between the point of supply and the customer due to various reasons.

- **Real losses**
  - Volume of water lost between the point of supply and the customer meter due to physical leaks from mains, pipes and valves and due to tank overflow.

- **Apparent losses**
  - Volume of water lost due to other factors, such as unauthorised consumption, metering inaccuracies and data handling errors.
Real water losses

- Very high flow rates
- Small flow rates
- Very long runtimes
- Short runtimes

Diagram showing:
- Background leakage
- Unreported leakage
- Reported leakage

Graphs indicating:
- Awareness, Location, Repair
- $t_0 =$ occurrence of leakage
Importance and need for water loss management

- Reduced operational & capital costs
- Increased service life of water distribution systems
- Reduced health risks
- Increased security of supply
- Improved customer satisfaction
- Reduced ecologic stress
- Less infrastructure damages & repair efforts
Strategies for Water Losses
Pressure management

- Pressure management = Adjustment and control of water pressure in water supply systems to an optimum level.
Types of district metered areas
Operation and maintenance of DMAs

- Pressure
- Customer use
- Flow rate (m³/h)
- Minimum night consumption
- Background leakage
- Burst leakage
- Time (days)
Pressure management

- Pressure reduction eliminates excess pressures systematically:
  - Number of pipe breaks directly depends on pressure rate
  - Pressure management is tackling the problem right at the source and does not relocate it within the system
  - Reduction of supply pressure leads to reduction of water losses at every leak in the district metered area (DMA).

Non visible leakage, low flow, not detectable by acoustic sensors
Non visible leakage, detectable by acoustic sensors
Visible leakage, level detectable
Comparison between diaphragm and plunger valve

**PRESSURE MANAGEMENT CONSTRUCTION KIT**

- **Diaphragm valve**
  - Self actuated
  - Interesting for pipe sizes < DN300
  - No power supply required

- **Plunger valve**
  - Precise control characteristic
  - Maintenance free
  - Cavitation free
  - Especially interesting for pipes ≥ DN300
Modulation type – time-based

- **Time-based** - allows higher downstream pressure $P_2$ to be set for daytime and lower pressure at night when consumption decreases.

<table>
<thead>
<tr>
<th>Setting</th>
<th>Time (hh:mm)</th>
<th>Pressure (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set 1</td>
<td>0:00</td>
<td>25</td>
</tr>
<tr>
<td>Set 2</td>
<td>5:00</td>
<td>30</td>
</tr>
<tr>
<td>Set 3</td>
<td>7:00</td>
<td>40</td>
</tr>
<tr>
<td>Set 4</td>
<td>12:00</td>
<td>38</td>
</tr>
<tr>
<td>Set 5</td>
<td>20:00</td>
<td>30</td>
</tr>
</tbody>
</table>
Development of Water Utility Compass

• Holistic and easy-to-use Excel Tool to support calculation, WU-efficiency assessment, identification of measures and action planning.

• Baseline data: data input, calculation of IWA water balance and performance indicators.

• Includes error estimations and calculation (95% confidence limit).

• Situation analysis: water utility efficiency assessment.

• Based on a self-assessment questionnaire.

• Action plan: strategic objectives, pre-selected measures, reporting.

• Learning: general information, benchmarks.
Baseline data

<table>
<thead>
<tr>
<th>System Input Volume</th>
<th>Authorized Consumption</th>
<th>Billed Authorized Consumption</th>
<th>Billed Metered Consumption</th>
<th>Revenue Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.074'753.0 [m²*a⁻¹]</td>
<td>2'371'064.0 [m²*a⁻¹]</td>
<td>2'370'064.0 [m²*a⁻¹]</td>
<td>2'365'864.0 [m²*a⁻¹]</td>
<td>2'370'064.0 [m²*a⁻¹]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Billed Unmetered Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>4'200.0 [m³*a⁻¹]</td>
</tr>
<tr>
<td>25.0 [m³*a⁻¹]</td>
</tr>
</tbody>
</table>

**Real Losses**

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>Unit</th>
<th>Indicator value</th>
<th>Error [%]</th>
<th>Performing grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILI - Infrastructure Leakage Index</td>
<td>[-]</td>
<td>1.4</td>
<td>23.6</td>
<td>A</td>
</tr>
<tr>
<td>PMI</td>
<td>[-]</td>
<td>1.3</td>
<td>2.0</td>
<td>average</td>
</tr>
<tr>
<td>Real Losses per service conn. per m pressure (w.s.p.)</td>
<td>[I<em>conn⁻¹</em>d⁻¹*m H₂O⁻¹]</td>
<td>3.5</td>
<td>23.0</td>
<td>B</td>
</tr>
<tr>
<td>Real Losses per service conn. (w.s.p.)</td>
<td>[I<em>conn⁻¹</em>d⁻¹]</td>
<td>208.4</td>
<td>22.9</td>
<td>B</td>
</tr>
<tr>
<td>Losses per main</td>
<td>[I<em>km⁻¹</em>d⁻¹]</td>
<td>3214.1</td>
<td>22.9</td>
<td>good</td>
</tr>
</tbody>
</table>

**Input:**

Estimated value: 25% error

Metered value: 2% error

**Computed values:**

\[ V_t = V_x + V_y \rightarrow E_t = \sqrt{(V_x \times E_x / 1.96)^2 + (V_y \times E_y / 1.96)^2} \times 1.96 / V_t \]

\[ V_t = V_x \times V_y \rightarrow E_t = \sqrt{E_x^2 + E_y^2} \]
Situation analysis: Questionnaire & Assessment

<table>
<thead>
<tr>
<th>Issues / Questions</th>
<th>Self-Assessment</th>
<th>Efficiency Level</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Your grade</td>
<td>1 (poor)</td>
<td>4 (good)</td>
</tr>
<tr>
<td>9. Apparent Losses</td>
<td>Your goal</td>
<td>2 (fair)</td>
<td>5 (excellent)</td>
</tr>
<tr>
<td>9.1 Meter Installing</td>
<td>4</td>
<td>We do not expand our meter park; Unmetered areas remain unmetered.</td>
<td>We install new meters at unmetered connections and take care to calibrate and install them correctly.</td>
</tr>
<tr>
<td>9.2 Meter Accuracy Testing</td>
<td>5</td>
<td>We install some meters in unmetered areas and generally calibrate and install them correctly.</td>
<td>For most of the unmetered connections we install new water meters. Calibration and installation of the meters are mainly correct.</td>
</tr>
<tr>
<td>9.3 Fraud: Illegal Connections, Meter Tampering, Bypasses</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.4 Meter Reading and Data Transfer</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performing grade [1-5]</td>
<td>3.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Action Plan

1. Define strategic objectives (up to 10)

<table>
<thead>
<tr>
<th>Number</th>
<th>Category</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6. Pressure Management (PM)</td>
<td>Focus on pressure management improvements</td>
</tr>
<tr>
<td>3</td>
<td>4. District Metered Areas (DMA)</td>
<td>Structure the network properly</td>
</tr>
</tbody>
</table>

2. Select measures from a list pre-filtered ones (Over 250 measures)

<table>
<thead>
<tr>
<th>ID</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>275</td>
<td>Regularly calculate apparent losses performance indicators</td>
</tr>
<tr>
<td>276</td>
<td>Regularly calculate real losses performance indicators</td>
</tr>
</tbody>
</table>

3. Resulting action plan draft

<table>
<thead>
<tr>
<th>What</th>
<th>Details</th>
<th>Responsibility</th>
<th>Deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective 1</td>
<td>Focus on pressure management improvements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure management</td>
<td>Adjust the pressure in the network by using boosters and PRVs accordingly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure management</td>
<td>Increase the coverage of DMAs using pressure management and perform intensive functional testing of the system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure management</td>
<td>Perform pressure management on the whole system and test it regularly and intensively</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active Leakage Control (ALC)</td>
<td>Use pressure variations to localize leakage and water loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective 2</td>
<td>Streamline water balance calculations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance Indicators</td>
<td>Regularly calculate apparent losses performance indicators</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance Indicators</td>
<td>Regularly calculate real losses performance indicators</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective 3</td>
<td>Structure the network properly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMA</td>
<td>Check boundary valves. Try to adapt DMA borders to natural boundaries. Use suitable meters and PRVs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMA</td>
<td>Keep track of the type of customers in the DMAs and creates requirement lists for each type of customer.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
WU-Compass // Self-Evaluation Report // Alytus Water Utility (LT)
WU-Compass – Alytus Water Utility (LT)

• The holistic decision support system allows to prioritise and set up the action plan considering the 14 categories.

• Five categories for water reduction were selected, where the water utility has the weakest efficiency and the highest potential for improvement:
  - Category 4. District Metered Areas (DMA);
  - Category 5. Active Leakage Control (ALC);
  - Category 9. Apparent losses;
  - Category 10. Human Resources;
  - Category 11. Equipment and budget.
Category 4. District Metered Areas (DMA)

• Install appropriate size meter to measure the inflow to the DMA;
• Install logging equipment for continuous flow monitoring;
• Establish some DMAs and start analysing the data;
• Check boundary valves. Try to adapt DMA borders to natural boundaries. Use suitable meters and PRV's;
• Keep track of the type of customers in the DMAs and create requirement lists for each type of customer;
• Night step-testing (reducing the size of the area by closing valves);
• DMAs with minimum night flow measurement and calculation.
Data from Water Balance, Alytus WU (2011)

Annual water losses, m³/yr.

- Real Losses: 618,219
- Apparent Losses: 85,500
- Unbilled Authorized: 970

Annual saving potential Eur/yr.

- Real Losses: 150,480
- Apparent Losses: 55,816
- Unbilled Authorized: 1,707

- WU-Compass Tool helps the user to find appropriate measures.
- Find relationship of water loss components.
- Clarify the individual situation.
- Water Utility found the tool really useful.
## Performance Indicators (2011 – 2015)

<table>
<thead>
<tr>
<th>Performance Indicators</th>
<th>Value 2011</th>
<th>Value 2015</th>
<th>Grade 2011</th>
<th>Grade 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure Leakage Index (ILI)</td>
<td>2.8</td>
<td>1.4</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Pressure Management Index (PMI)</td>
<td>1.3</td>
<td>1.3</td>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td>Real Losses per service connection ([l/conn./d])</td>
<td>435</td>
<td>208</td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>Losses per main ([l/km/d])</td>
<td>6’530</td>
<td>3’214</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>Percentage of Non-Revenue Water</td>
<td>22.9</td>
<td>13.8</td>
<td>D</td>
<td>C</td>
</tr>
<tr>
<td>Apparent Losses per service connection ([l/conn./d])</td>
<td>60</td>
<td>36</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Apparent Losses Index (ALI)</td>
<td>0.7</td>
<td>0.5</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>
Conclusions

• Perfect project.
• Good cooperation.
• New ideas.
• Cross-connection.