Water Management Initiative (WMI)

NRW Measurement – Best Practice

Dec 3, 2018
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• The Need for Standardization
• IWA Water Balance
• Why Percentages are misleading
• Appropriate performance Indicators
• International Perspective
The Need for Standardization

- **Issue:** many different definitions in use: absence of standard accounting “tools”, terminology, indicators

- **Challenge:** agree on one standardised set of definitions for Water Balance components to:
  - define common terminology and indicators
  - allow performance improvement and target setting within the utility (formerly process benchmarking)
  - allow performance assessment between utilities (formerly metric benchmarking)
Why is calculating the water balance so important??

• Provides a framework for assessing a utility’s water loss situation
• Reveals gaps and shortcomings in the availability / reliability of data and level of understanding
• Creates awareness of problems and issues
• Directs necessary improvements

Understanding the Water Balance is a **MUST** for prioritizing actions and investments and for setting targets and benchmarks
Water Balance - Key Messages

• Water Balance is an important tool for understanding inflow, consumption, losses

• However, there are problems:
  – most utilities lack needed information
  – no information on nature and location of leakage

• Water Balance to be improved with two other methods:
  – Real loss component analysis
  – Leakage measurements in the system
## International Water Association (IWA) Standard Water Balance

<table>
<thead>
<tr>
<th>System input volume (SIV)</th>
<th>Billed authorized consumption</th>
<th>Billed metered consumption</th>
<th>Billed unmetered consumption</th>
<th>Revenue water (RW)</th>
<th>Non revenue water (NRW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authorized consumption</td>
<td>Billed authorized consumption</td>
<td>Billed metered consumption</td>
<td>Billed unmetered consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unbilled authorized consumption</td>
<td>Unbilled metered consumption</td>
<td>Unbilled unmetered consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water losses</td>
<td>Apparent (commercial) losses</td>
<td>Unauthorized consumption</td>
<td>Billing &amp; customer meter inaccuracy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Real (physical) losses</td>
<td>Leakage/overflows at storage tank</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage on transmission and distribution mains</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage on service connections up to point of customer meter</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ NRW = (SIV - RW) \, m^3 \]

......and using %

\[ NRW = \left( \frac{(SIV - RW)}{SIV} \right) \times 100\% \]
Simplified form of Standard IWA Annual Water Balance

NRW equation reported

Based on Total Supply

\[
NRW = \frac{\text{Produced} + \text{Imported} - \text{Billed} - \text{Exported}}{\text{Produced} + \text{Imported}}
\]

Produced + Imported = Total Supply

..in IWA terminology is **System Input Volume (SIV)**

What is the problem with this?!

…..Let’s see…….
Two cases same billed and supplied water but different NRW%

\[
NRW = \frac{(Produced + Imported) - (Billed + Exported)}{Produced + Imported} = \frac{(90+10)-(30+10)}{90 + 10} = \frac{60}{100} = 60\%
\]

\[
NRW = \frac{(Produced + Imported) - (Billed + Exported)}{Produced + Imported} = \frac{(90+60)-(30+60)}{90 + 60} = \frac{60}{150} = 40\%
\]

20% reduction on NRW – How come?!
### NRW components

#### International Water Association (IWA) Standard Water Balance

<table>
<thead>
<tr>
<th>Authorized consumption</th>
<th>Water exported</th>
<th>Non revenue water (NRW)</th>
<th>Water supplied (WS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Billed authorized consumption</td>
<td>Billed metered consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Billed unmetered consumption</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>Unbilled metered consumption</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NRW as % of WS** = \[
\frac{(Produced + Imported) - (Billed + Exported)}{Produced + Imported - Exported}
\]
NRW as % of Net Water Supply

NRW = \frac{(Produced + Imported) - (Billed + Exported)}{Produced + Imported - Exported} = \frac{(90 + 10) - (30 + 10)}{90 + 10 - 10} = \frac{60}{90} = 66.7\%
Is NRW measure enough to understand the problem?

NRW expressed as a % of System Input Volume does not work and might be misleading due to one or a combination of the following:

– Different supply time
– Different consumption levels
– Different pressure levels
Take supply time into consideration

When the System is Pressurized (w.s.p.)

Example:

- Supply time: 12 hours / day
- Annual physical losses: 5 Mm$^3$
- Service connections: 20,000
- Physical losses: $685 \text{ l/serv. conn. /d}$

  $(5 \text{ Mm}^3/20,000 \text{ serv. conn. /365 \ d})$

The Performance Indicator for Physical Losses needs to be calculated as follows:

- $[685(\text{l/serv. conn. /d})/12 \ (h)] \times 24(h) = 1,370 \text{ l/serv. conn. /d}$ (w.s.p.)
How misleading could % be?
Taking Supply Time into Consideration

<table>
<thead>
<tr>
<th>Serv. Conn./Day</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liters/day</td>
<td>10 h/d</td>
<td>3 h/d</td>
<td>12 h/d</td>
<td>7 h/d</td>
<td>20 h/d</td>
<td>11 h/d</td>
<td>20 h/d</td>
<td>9 h/d</td>
</tr>
</tbody>
</table>

**Legend:**
- Blue: Water Losses (l/serv.conn./d)
- Red: Water Losses "normalised" (l/serv.conn./d)
How Consumption affects %

Example 1
Length of network: L
No of connections: Nc
Customers: C
Pressure: P
• SIV: 100,000 m$^3$
• Consumption: 80,000 m$^3$
• NRW: 20,000 m$^3$
• NRW: 20% of SIV

Example 2
Length of network: L
No of connections: Nc
Customers: C
Pressure: P
• SIV: 200,000 m$^3$
• Consumption: 160,000 m$^3$
• NRW: 40,000 m$^3$
• NRW: 20% of SIV
How to express NRW......
...... at different consumption levels

Scenario 1

- Same water network system in terms of population, connections, average pressure, network length
- And same NRW ratio
- But different consumption levels i.e. different RW

- S (Supply)
- RW (l/c/d)
- NRW
- L Losses (l/connection/d)
- Good

Scenario 2

- 2S
- 2RW (l/c/d)
- 2NRW
- 2L (l/connection/d)
- Bad

NRW = (S-RW)/S
S = RW/(1-NRW)

Correct NRW performance indicator (PI) ➔ Losses/connection/day
Leakage Increases with Pressure

The most appropriate general equation for simple analysis and prediction of relationships between pressure ($P$) and leakage rate ($L$) in distribution systems

$$\left(\frac{L_1}{L_0}\right) = \left(\frac{P_1}{P_0}\right)^{N_1}$$

$L_0$ = Initial leakage rate (volume/unit time)
$P_0$ = Initial pressure (meters)
$L_1$ = New leakage rate (volume/unit time)
$P_1$ = New pressure (meters)
$N_1$ = Exponent $N_1$

$N_1$ exponent varies with type of leak, and also with pipe materials

*Fixed area discharge:*
Circular hole drilled in pipe: $N_1$ typically 0.5

*Variable area discharge:*
Split in flexible pipe: $N_1$ typically $\geq 1.5$
How to express NRW......
...... at different pressure levels

Scenario 1

- Same water network system in terms of population, connections, average pressure, network length
- Same consumption and same NRW ratio
- But different average pressure (P) levels

- RW (l/c/d)
- S (Supply)
- NRW
- L Losses (l/connection/d)
- High pressure (30m)
- L in l/connection/d/m P
- Good

Scenario 2

- RW (l/c/d)
- S
- NRW
- L (l/connection/d)
- Low pressure (10 m)
- 3L in l/connection/d/m P
- Bad

NRW = (SIV - RW)/SIV
SIV = RW/(1 - NRW)

Correct NRW performance indicator (PI) ➔ Losses/connection/day/m pressure
### So... how to correctly express NRW Performance Indicators?

<table>
<thead>
<tr>
<th>Objective</th>
<th>Volume per year</th>
<th>M3/ connection</th>
<th>M3/ km system</th>
<th>% of system input</th>
<th>% of water supplied</th>
<th>Infrastructure Leakage Index (ILI) with pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set target and track performance, for an individual system</td>
<td>Yes for large systems</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes, only if all justifiable pressure management completed</td>
</tr>
<tr>
<td>Technical performance comparisons of different systems</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Draw general conclusions from single or multiple system</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes, together with other context factors</td>
</tr>
</tbody>
</table>

*Source: EU, 2015*
## Comparison of leakage performance indicators

<table>
<thead>
<tr>
<th>Performance indicators for real losses</th>
<th>Continuity of supply</th>
<th>Length of mains</th>
<th>No. of service connections</th>
<th>Location of customer meters on services</th>
<th>Average operating pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of volume input</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>% of water supplied</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Litres/service connection/day</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>m3/km of system/day</td>
<td>No</td>
<td>Yes</td>
<td>Possibly</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Infrastructure Leakage Index (ILI)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Source: Lambert et. al., 1999*
The physical loss matrix

<table>
<thead>
<tr>
<th>Technical performance category</th>
<th>ILI</th>
<th>Physical Losses in Litres/connection/day when the system is pressurized at an average pressure of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10 m</td>
</tr>
<tr>
<td><strong>High Income countries</strong></td>
<td>A1</td>
<td>&lt; 1.5</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>1.5 - 2</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>2 - 4</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>4 - 8</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>&gt; 8</td>
</tr>
<tr>
<td><strong>Low and Middle Income Countries</strong></td>
<td>A1</td>
<td>&lt; 2</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>2 - 4</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4 - 8</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>8 - 16</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>&gt; 16</td>
</tr>
</tbody>
</table>
Low and Middle Income Countries:  
Guide to further action

- **ILI<4:**
  - **Good:** further loss reduction may be uneconomic; careful analysis needed to identify cost effective improvements

- **ILI= 4 – 8:**
  - **Potential for marked improvements:** consider pressure management, better active leakage control practices, and better maintenance

- **ILI 8 – 16:**
  - **Poor:** tolerable only if water is plentiful and cheap; even then intensify NRW reduction efforts

- **ILI>16:**
  - **Terrible:** inefficient use of resources; NRW reduction programs imperative and priority
Recommended Operational Performance Indicators

• Physical Losses
  – Liters/connection/day (w.s.p.)
  – Liters/connection/day per meter pressure (w.s.p.)
  – Infrastructure Leakage Index (ILI)

• Commercial Losses
  – % of Authorized Consumption
  – Liters/connection/day

• NRW
  – NOT % of system input volume;
  – Liters/connection/day (w.s.p.)
  – Value of NRW as % of operating cost
### Key NRW performance indicators
#### International Perspective

<table>
<thead>
<tr>
<th>PERFORMANCE INDICATORS</th>
<th>“Low and Middle Income” countries Acceptable performance</th>
<th>“High Income” countries Good performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-Revenue Water</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water not yielding revenue as percentage of SIV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial loss as a percentage of Annual Operating Cost without depreciation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expressed as liters/service connection/day (w.s.p.)</td>
<td>500</td>
<td>250</td>
</tr>
<tr>
<td><strong>Commercial Losses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>As a percentage of Authorized Billed Consumption</td>
<td>15%</td>
<td>10%</td>
</tr>
<tr>
<td>As volume in liters/service connection/day</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td><strong>Physical Losses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liters/service connection/day (w.s.p.)</td>
<td>350</td>
<td>150</td>
</tr>
<tr>
<td>Infrastructure Leakage Index</td>
<td>12</td>
<td>4</td>
</tr>
</tbody>
</table>

12/6/2018

Water Management Initiative (WMI)
Prioritised Actions and Investments

- Billed metered consumption
- Billed unmetered consumption
- Unbilled metered consumption
- Unbilled unmetered consumption
- Unauthorized consumption
- Customer metering inaccuracies, billing and accounting error
- Leakage on transmission and distribution mains
- Leakage and overflows at reservoirs
- Leakage on service connections up to metering point
Thank You!