Non-Revenue Water

Understanding and working proactively with Non-Revenue Water

Beat the leak

Combating Non-Revenue Water starts by mapping both how and how well your water resources are being utilized

Non-Revenue Water is a well-known global problem that results in large volumes of water being lost. It is a very real challenge faced by the majority of water utilities as a consequence of increased urbanization, higher demand, increased prices and aging distribution networks.

There are different approaches to mapping the extent of the problem and to how it can be reduced. Often however, the complexity of the subject is underestimated because of the different types of water loss, each of which needs to be dealt with differently.

Non-Revenue Water will never be completely eliminated, since there will always be a certain amount of authorized non-revenue consumption, which cannot realistically be removed. In addition, there is a natural lower threshold for the lowest achievable level of water loss, which is economically cost-effective. To get as close as possible to that threshold, it is necessary to prioritize the work in preventing water loss. This can be done by categorizing the losses in the distribution mains, so that utilities can assess the methods that can be used, and determine which initiatives can be put into place to fight water loss as effectively as possible.

One tool for evaluating water loss is the water balance created by the International Water Association, which focuses on categorizing water losses. In the following text, we describe how utilities can work with the individual elements in the water balance tool, and we recommend useful comparison methods. In addition, we take a closer look at the challenges of the traditional approach to measuring water losses and the advantages of looking at water loss in a more balanced way.

The utilization of water resources can be mapped by:

- Calculation of the water balance
- Estimation of the water loss
- Assessment of the water loss

What is Non-Revenue Water and what does it mean?

Non-Revenue Water (NRW) is an internationally known term which can be defined as:

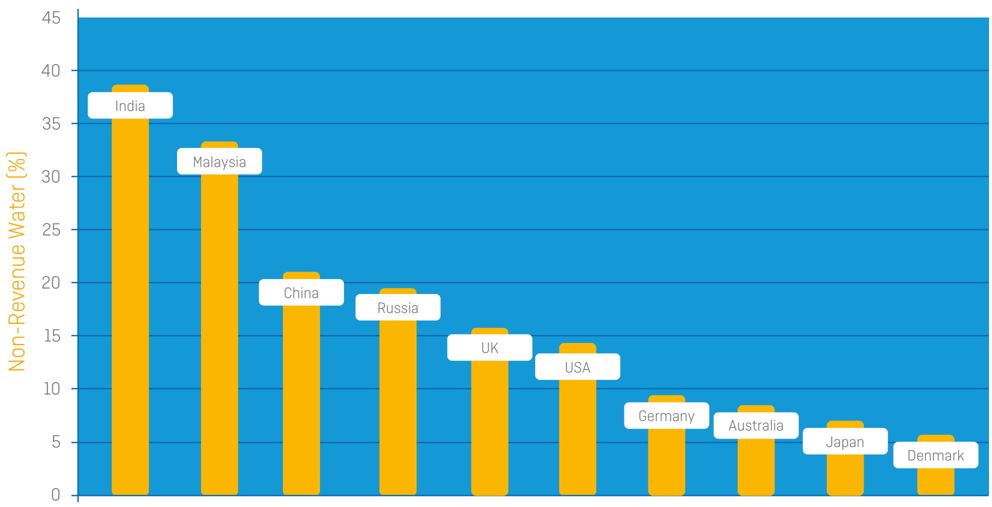
Water that is pumped into the distribution network but not invoiced, and so does not generate revenue for the utility.

In other words, Non-Revenue Water is the difference between produced water and billed water. It is water that is lost as a result of bursts due to pressure surges, inaccurate meter readings, leaks or burst resulting from a high pressure, aging infrastructure, illegal connections to the network, theft, etc.

The consequence of a high level of Non-Revenue Water is both loss of earnings and higher operational costs for the utility. It entails a significant financial drain, which for example, is expressed by the fact that the energy used to pump out Non-Revenue Water is pure waste. In addition, leaks necessitate expensive repairs of the infrastructure as well as a potential need for expanding the capacity.

According to the World Bank, globally, the level of Non-Revenue Water is between 30 and 35%. In some areas it is as high as 50–60%.

Overview of Non-Revenue Water levels in selected countries



(Source: IBNET; GWI; Frost & Sullivan)

Water balance – first step in dealing with water loss

By breaking down the amount of water that leaves the utility into smaller parts, it is possible to work with Non-Revenue Water in a more structured and effective way.

The International Water Association (IWA) has developed an international best practice method for calculating the water balance, which is the first step in dealing practically with water loss. The table illustrates how the different forms of water loss can be categorized, and the method is used to determine where the efforts should be focused to achieve the greatest impact.

We have interpreted the table for the purpose of making it more manageable and tangible. In the following text, we go through the individual elements in the table, looking at how you can actively work with them.

International Water Association (IWA) is a self-governing, non-profit organization, whose mission is to function as a global network for professionals working in the water industry, and to promote standards and best practice in the sustainable management of water resources. IWA has around 10,000 individual members, with 500 corporate members around the world and management members in about 80 countries.

To learn more about IWA, go to www.iwa-network.org/

IWA's water balance

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption
			Billed Unmetered Consumption
		Unbilled Authorized Consumption	Unbilled Unmetered Consumption
			Unbilled Metered Consumption
	Water Losses	Apparent Losses	Unauthorized Consumption
			Metering Inaccuracies
		Real losses	Leakage on Transmission and Distribution Mains
			Leakage and Overflows at Utility Storage Tanks
			Leakage on Service Connections up to Metering Points

System Input Volume

The volume of water pumped into the network by the utility over a given period of time. The amount includes both produced and purchased water. The system input volume can be divided into authorized consumption and water losses, respectively.

Authorized consumption is made up of Billed Authorized Consumption and Unbilled Authorized Consumption

Billed Authorized Consumption consists of Billed Metered Consumption and Billed Unmetered Consumption.

Billed Metered Consumption is the consumption that is metered by water meters and for which the consumers are subsequently billed.

This should be the simplest part of the table, but there are different sources of error depending on the metering setup. Manual readings and meter reading methods that are used in some countries are characterized by uncertainties and a potential high number of errors. The more people are involved in the reading, the greater the risk of error. To acquire a true basis for comparison, it is important that the method of reading is the same for all meters. Modern remote reading systems make it possible to carry out synchronous readings down to an hourly basis.

Billed Unmetered Consumption typically relates to, for example, construction sites and homes without meters, which are invoiced based on an estimated standard consumption. In many countries, the practice of billing water consumption at a fixed price and without metering continues to be widespread. This increases the uncertainty about water consumption and thus water losses.

The greater the uncertainty there is about the actual water consumption, the more difficult it is to combat water loss on an informed basis.

For example, if a household is billed for a consumption that is significantly higher than the actual consumption, the utility might believe that the water loss in the distribution network is less than what is actually the case. By installing meters in all of the homes, as much as possible of the unmetered water volume becomes metered with the benefit that the invoicing is more correct for all parties.

Unbilled Authorized Consumption consists of the unbilled unmetered consumption and unbilled metered consumption.

Unbilled Unmetered Consumption is the water that is used for fire fighting, in public sprinkler systems and for purging pipes etc., but which is not metered.

This consumption is authorized – and thus also accepted. However, it is important to subsequently register the water volume (at the very least as an estimate). Otherwise, this consumption volume is included in the table as water loss. By devising routines and agreements with local firefighting services and others who have access to unbilled water on the estimation of their consumption, you avoid trying to reduce water loss that does not need to be reduced.

Unbilled Metered Consumption is the water that is used for fire fighting, public sprinkler systems and purging of pipes etc, and which is metered.

Water Losses consist of Apparent Water Losses and Real Losses

Water Losses are the part of the water balance, which is normally used for benchmarking against other utilities.

Apparent Losses consist of Unauthorized Consumption and Customer Metering Inaccuracies.

Unauthorized Consumption is the volume of water that is lost because of theft, illegal connections to the mains, instances where the meter is removed, etc.

The development of smart meters and the widespread use of smart metering means that unauthorized consumption is constantly decreasing because there is much more transparency in the water supply. However, the risk of manipulation is higher with older mechanical meters than with modern electronic meters. Modern meters send an alarm if the water flows backwards, in cases of attempts to manipulate the meter, or if the meter is dry because, for example, it has been removed. In this way, theft is detected immediately – not only when the annual reading is being carried out or in connection with a visit to the consumer's address.

Customer Metering Inaccuracies is the water that is lost because of erroneous readings carried out by the consumers or because of inaccurate meters.

Experience shows that mechanical meters measure too little over a whole life cycle, because they become worn and sluggish over time while the start flow becomes increasingly higher. Modern electronic meters have a much lower start flow than mechanical meters. In addition, they maintain their precision longer, because they are static and do not contain any moving parts meaning that they are resistant to wear and sediments. However, attention should be given to static meters' ability to maintain a correct zero point in relation to flow, as this can affect their precision.

Depending on which meters are used, there can be a large potential in this area, in the form of water that can be removed from Non-Revenue Water and subsequently quantified in the billed water category, by the utility replacing its meters.

Smart meter is a term for intelligent meters that are able to provide feedback on the operational status at the consumers' residences and in the distribution network. In addition, the remote reading can be carried out automatically and will therefore keep the utility updated on the situation in the mains. Smart metering solutions thus provide a full overview of the distribution network and its state.

Metering itself does not solve the problem of Non-Revenue Water, but with smart metering the utility acquires knowledge about their mains, which makes them able to make well-informed decisions about the most efficient way of working with the mains and with asset management.

In addition to the household meters, it is also important that the larger district meters are highly accurate, as this has an impact on the uncertainty concerning the volume of water pumped into the system. In many countries it is not required that the pumps are type approved or re-verified.

Digital readings of the household- and district meters not only ensure that the readings are 100% correct, but also that they are carried out at the same time.

Real Losses consist of Leakage on Transmission and Distribution Mains, Leakage and Overflows at Utility Storage Tanks, and Leakage on Service Connections up to Points of Customer Metering.

Leakage on Transmission and Distribution Mains is water that is lost from parts of the distribution network that are in poor condition as a result of stress, excessive operating pressure and pressure surges.

An efficient way to calculate the loss from leakages is to look at the night-time consumption. Analysis of the night-time consumption cover water consumption in the system during the hours with the lowest demand, and it can then be assumed that this comes from leakages. With smart metering, the utility can get an even clearer picture of the real leakage levels, because the actual consumption is known at all times. By extracting this value from the total night-time consumption, the water loss can be calculated. Thus, the analysis does not need to be limited to the nighttime hours, but can be made whenever needed.

Being able to register that water is being lost in the distribution mains is one thing. Being able to identify where it is happening is much more difficult as only 10% of leaks are visible while the majority are underground leaks[1]. The time between the leak being detected and it being remedied is a crucial factor when it comes to the extent of the losses. Acoustic measurement is a method that helps to locate leaks. Using sectioning, finding leaks becomes much more efficient, because the area of the distribution network where the search takes place is minimised. This is why district metering areas (DMAs) have been introduced. In addition to household meters, larger district meters have been installed to measure the volume of water for a segregated area of the distribution mains. This means that the volume of water being pumped into each section can be compared with the volume of water being used by the consumers in that section on an ongoing basis.

One of the most costly elements in the work involved in reducing leakages and bursts is the repair and replacement of bad pipes. In addition to the cost of materials, there are also resources associated with the excavation of streets, re-routing traffic and re-establishing infrastructure. This is why it is crucial for the utility to prioritize its efforts in accordance with which ones will provide the most value in relation to reducing the total number of leaks.

Asset management is the work in assessing the state of the components in the distribution mains for the purpose of optimizing the investment strategy. In other words, it deals with replacing the right pipe at the right time.

The oldest pipes may not necessarily be the pipes that are in the worst condition. They cannot be assessed by age or type of pipe alone. The more parameters (e.g. the pipes' age, pressure effects, flow temperature, etc.) that are included in the asset management analysis, the more precise the mapping of the state of the distribution mains from the utility out to the consumers. Smart metering makes many of these parameters automatically available, which means it is possible to assess which parts of the mains need to be renovated first.

In Copenhagen the annual average water loss is 8.05%, despite the fact that 20% of the pipes are over 100 years old, and 69% are over 60 years old. The result is achieved using comprehensive knowledge of the mains, so the pipes that are replaced are the ones that need to be replaced and not solely because they are the oldest.

(Source: Allan Broløs and Charlotte Hansen, HOFOR A/S)

Pressure management makes it possible for the utility to reduce the total number of leaks and bursts, because an optimal operating pressure reduces the “stress” on the pipes. There is a direct correlation between the operating pressure and the amount of leaks.

A 10% reduction of the average pressure leads to a reduction in leakage of 10-20%, and water loss can thus be reduced significantly[2].

With increased knowledge of the pressure in the distribution mains, it is possible to optimizethe pressure, lower the energy consumption and the amount of leakage. The utility also gains detailed knowledge of pressure surges that can lead to bursts.

Leakage and Overflows at Utility’s Storage Tanks are water losses from the utility’s own reservoirs or storage tanks. The total number of reservoirs and tanks varies from country to country. There are fewer options for regulating the pressure than in a pump-controlled system. This has a negative impact on water losses, since the pressure cannot be regulated for the actual consumption.

Leakage on Service Connections up to Point of Customer metering often happens before the billing meter and is therefore included in the water loss calculation. It is more difficult to detect a leak in this part of the distribution mains since the utility often only has limited access to both the service connection and the meter, sometimes is usually placed inside the house. The repair of the leak can also be challenging, since the consumer must personally pay for the repair of the leak and the utility must document the water loss.

If the meter is instead placed in a well at the property boundary, the utility has easier access to it, and water loss from the service connection can be registered as consumption at the consumer’s address. Any challenges with access to the consumer’s address can be solved using a display in the house or access to water consumption via a smartphone app or a similar device.

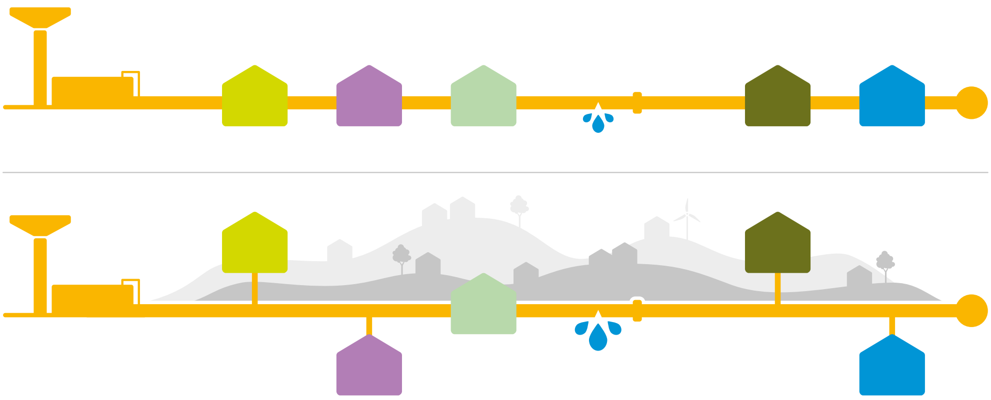
Estimation of water loss in accordance with regulation and benchmarking

Water loss is traditionally calculated as a percentage of the water volume pumped into the system. The advantage of a percentage is that it is easy to understand. However, there are several issues involved with comparing water loss solely as a percentage across utilities, since they do not have the same conditions in relation to for example, operating pressure, or consumer behavior, which is illustrated below.

So in effect, a percentage is unsuitable for use as a comparison of water loss across utilities or as a trend for the individual utility.

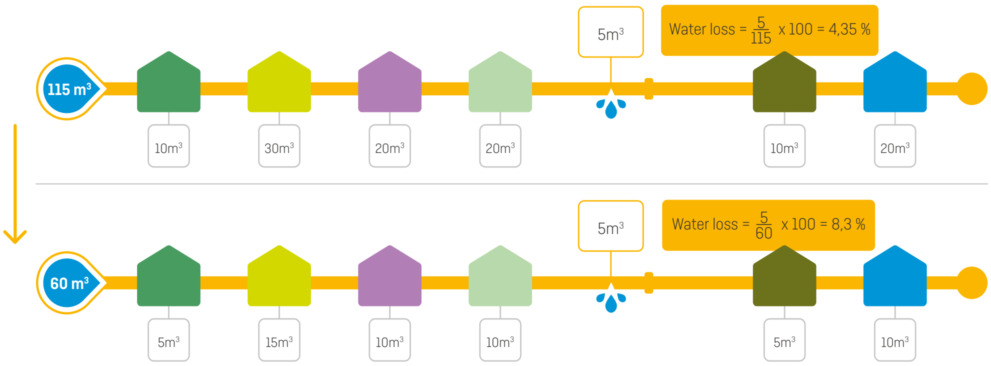
Operating pressure

If a utility for example, maintains a low average water pressure in the mains, its water loss will be relatively small, since the lower pressure results in less leakage. But topological conditions may force some utilities to maintain a high operating pressure compared with other utilities, which in terms of percentage, leads to a higher leakage level.



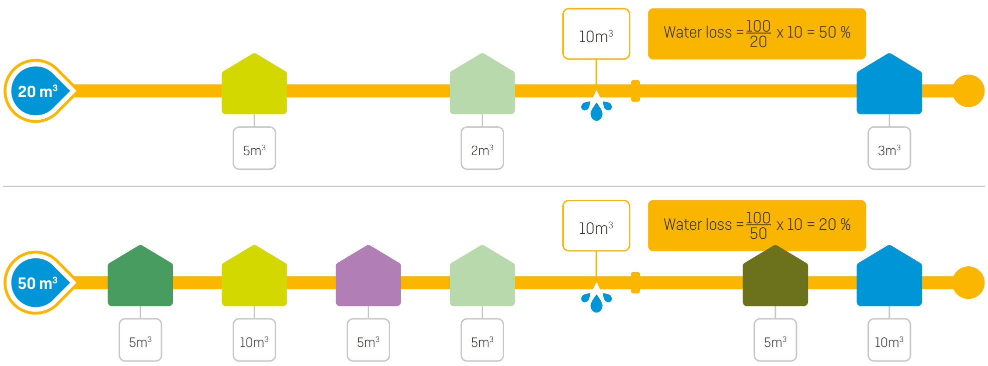
Consumer behavior

A utility that, for example, succeeds in reducing consumer water consumption through public awareness campaigns, will experience a water loss percentage that increases in line with the consumers using less water. This is because the leakage level is not necessarily affected by the reduced consumption and therefore will constitute a relatively larger share of the water pumped into the system.



The size of the distribution mains in relation to the total number of consumers

The size of the distribution mains and the total number of consumers provides a different expression for water loss. For example, a utility with large, extensive distribution mains and few consumers will have a high percentage of leakage in contrast to a utility with a small distribution mains and many consumers.



The Infrastructure Leakage Index (ILI) provides a more nuanced basis for comparison between utilities

For a more accurate picture of water loss, utilities should consider it based on the Infrastructure Leakage Index (ILI).

The calculation of ILI is based on the utility's operational data and is a more nuanced and accurate basis for benchmarking, since it takes different parameters into consideration. Using ILI, it is possible to make comparisons across for example, consumer behavior, population density and different types of utilities. However, ILI is also more complex to calculate, since it requires a larger data basis.

Infrastructure Leakage Index (ILI) is an expression of the water loss and it is calculated by dividing the annual real losses (CARL – Current Annual Real Losses) by the lowest technically achievable annual losses (UARL – Unavoidable Annual Real Losses), i.e. the water loss that is unavoidable.

ILI = CARL/UARL

CARL is calculated by subtracting the unauthorized consumption from the total water losses.

CARL = total water losses – unauthorized consumption

UARL is calculated on the basis of:

- **LM:** Length of mains (km)
- **Ns:** Total number of service connections (mains to property line)
- **Lp:** Average length, property line to meter (metres)
- **P:** Average pressure (metres)

UARL = (18 x LM + 0.8 x Ns + 25 x Lp) x P l/24 hours

To learn more about ILI, go to www.leakssuite.com/concepts/uarl-and-ili/

Assessment of ILI

What is a good ILI? The table below shows that, in developed countries, an ILI of 1-2 (A) is very good, and no more efforts should be made to reduce the amount of water loss, as this will not be economically expedient considering the possible results. An ILI of 2-4 (B) is acceptable, but there is room for improvement.

An ILI of 4-8 (C) is only acceptable, if the water resources are both abundant and inexpensive, although the water loss should still be analyzed in more detail and intensive efforts made to reduce it. An ILI higher than 8 (D) is an indication of an extremely inefficient use of the water resources. A reduction in water loss is therefore absolutely necessary and should be the utility's highest priority.

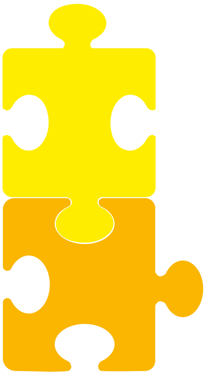
The majority of developing countries have an ILI higher than 16, so achieving an index score of under 16 will be the goal in the first instance. After that, the work will continue, e.g. the reduction of leaks, measurement of flow and pressure, improvement in the data quality will mean that the ILI will be reduced.

Assessment of the ILI level in developed and developing countries, respectively.

Technical presentation category		**ILI**
Developed countries	A	1-2
	B	2-4
	C	4-8
	D	>8
Developing countries	A	1-4
	B	4-8
	C	8-16
	D	>16

(Source: Liemberger, 2005, http://www.miya-water.com/user_files/Data_and_Research/miyas_experts_articles/15jun2010/Recommendations%20for%20Initial%20Non-Revenue%20Water%20Assessment.pdf)

Summary



Non-Revenue Water covers different types of water losses, each of which must be tackled differently. Based on the IWA water balance, the amount of Non-Revenue Water can be divided into different categories. With a focused effort, it is then possible to reduce real water losses. And by identifying, measuring and calculating the amount of water that constitutes the apparent losses, the amount will generate revenue for the utility rather than be an expense.

Next, it is not possible for the utility to manage and work proactively with its water resources, if it does not know how much water is lost, and how the water is lost.
To gain an accurate picture of water loss, it is therefore advisable to calculate the water loss based on ILI rather than the traditional percentage.

Source material:

[1] http://www.miya-water.com/facts-and-definitions/facts-about-water-loss

[2] www.studiomarcofantozzi.it/w/wp-content/uploads/2015/03/Whitepaper_English.pdf

Think forward

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