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A methodology to estimate leakages in water distribution networks based on inlet flow data analysis

Gianfredi Mazzolani[a], Luigi Berardi[b], Daniele Laucelli[b], Riccardo Martino[c], Antonietta Simone[b], Orazio Giustolisi[b,*]

[a]*Acquedotto Pugliese, Bari, 70125, Italy*
[b]*Politecnico di Bari, Dept. of Civil Engineering and Architecture, Bari, 70125, Italy*
[c]*Università di Napoli "Federico II", Dept. of Civil, Architectural and Environmental Engineering, Napoli, 80125, Italy*

Abstract

Water loss control and reduction is a major issue in Water Distribution Network (WDN) management worldwide. In many WDNs, the infrastructure monitoring in terms of flow/pressure measurements through the network, is not implemented yet and only few data (e.g. measurement of WDN inflow) are available to estimate the current leakage rate. Cheap and easily applicable procedures are needed to estimate current water losses in WDNs aimed at understanding the actual magnitude of the phenomenon and planning interventions. This work presents a simple methodology, inspired by the analysis of WDN inflow data records collected in several real water distribution networks, which permits to assess leakages based on the seasonal fluctuation of water consumptions. The methodology is tested on two synthetic case studies based on the Apulian WDN, which hydraulic status is simulated by an advanced WDN model that includes a realistic pressure-dependent background leakage model. The analyses of case studies verifies the effectiveness of the methodology under fully controlled WDN configurations (e.g. neglecting measurement inaccuracies that might happen in real WDN and/or possible alterations of asset conditions over the analyzed period). The resulting estimates of leakages proved to be accurate under the analyzed condition, thus making the methodology promising for next applications on real WDNs.

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* Corresponding author. Tel.: +39-080-596-3672.
E-mail address: orazio.giustolisi@poliba.it

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1. Introduction

Reducing leakages in WDNs has a huge economic impact [1] since it means to reduce the waste of water and energy resources, decrease cost of treatment and pumping, cut third party damages and, ultimately, reduce greenhouse gas emissions. All strategies and "best practices" (e.g. [2]) aimed at controlling and reducing leakages require the preliminary assessment of the current rate of real losses (i.e. leakages) in order to set possible targets for reductions, select effective technical actions (e.g. pressure control strategies and asset renewal/rehabilitation plans) and allocate economic resources. The methodologies to estimate current real losses are usually classified as top-down or bottom-up approaches (e.g. [3][4]). In top-down approaches, the measure or estimates of different components of the system water balance are used to derive leakages. For this reason, the reliability of top-down leakage estimate depends on the reliability of water consumption metering/assessment. Accordingly, the top-down leakage estimate usually refers to long analysis periods, depending on the water metering collection mode. Nowadays, data collection might take from hours (e.g., permanent automatic meter reading systems (AMR)), few weeks (e.g. for walk by Off Site Meter Reading (OMR)) or even months when few manual consumption readings per year are carried on. Therefore, top-down approaches are useful for drawing annual water balance but can be hardly useful to detect leakage increase during the year.

In bottom-up approaches, the assessment of leakages is based on the analysis of flow and/or pressure data monitored through the WDN. For this reason such approaches are considered more "data hungry" and time consuming, since they require the most accurate and up-to-date data as possible. The analysis of the Minimum Night Flow (MNF) is probably the most adopted bottom-up technique worldwide, permitting to estimate real losses by subtracting the expected legitimate water consumption from the recorded system inflow (e.g. [2][5]). Indeed, MNF permits to verify/integrate water balance and is the only viable option when no customers' consumption metering is available. Actually, the MNF leakage estimate has been used in conjunction with the Fixed and Variable Area Discharge (FAVAD) concept [6][7] in order to take into account the pressure-leakage dependence. Nonetheless, this poses the need for monitoring pressure through the WDN, besides collecting water inflow observations.

A different bottom-up methodology proposed by Buchberger and Nadimpalli [8] exploited the statistical analysis of flow data to estimate water losses. Besides the originality of the proposed approach, the main drawback of such methodology stems from the need of high-resolution flow data sampling (10, 5 or even 1 second), which is not technically affordable by the "smart" meters, increasingly adopted by water utilities, that transmit data sampled every 10-30 minutes using long-life batteries. In addition storing such large amount of data would be not justified by other WDN management purposes.

Unfortunately, in many WDNs worldwide, the only available information is the water flow sampled at WDN inlet points, while no flow/pressure gauges are installed within the network. In such circumstances, top-down approaches permits to estimate Non Revenue Water (NRW), based on the difference between WDN inflow data records and the authorized (and billed) water consumption, that includes both apparent losses and real water outflows (i.e. leakages). Moreover, these WDNs show high NRW rates (even higher than 50% of total inlet water volume) and the reliable estimate of current leakage rate would support prioritizing the allocation of resources for rehabilitation/renewal works and/or for implementing higher resolution flow/pressure monitoring systems within the WDN.

This contribution proposes a bottom-up methodology for leakage assessment, where the parameters of a hydraulic consistent model are estimated using WDN inflow data only, following a data assimilation [9] approach. Differently from other methodologies, the analysis can be carried on off-line, thus not requiring real-time transmission of data streams, and the sampling interval can range from few minutes to one-hour, thus being readily usable in most WDNs. Results of leakage assessment are immediately verified using recorded data, while the methodology permits to easily update leakage assessment (on-line) as soon as up-to-date data are available. In addition, the comparison of leakage estimates relating to different periods (e.g. previous years) can be used to detect the increase of leakage rate and/or verify the effects of leakage reduction actions. As such, the proposed methodology lend itself to verify/control other leakage assessment methods based on either top-down or bottom-up approaches.