A new approach to estimating household night consumption at DMA level

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Abstract

The most widely used method for assessing real water losses in a district metering area (DMA) involves measuring minimum night flow and estimating what fraction of it is not ascribed to real losses. It may be further broken down into authorized household consumption, authorized non-household consumption and non-authorised uses. Household consumption is in general the most relevant and harder to estimate component. It is very much context-dependent and very few studies are published outside of the UK. This paper summarises the results achieved in a recent study carried out in two Portuguese municipalities, and describes a set of simplified rules developed to predict DMA night household consumption. These rules depend on the number of households and on their social-demographic and billing features. Once household night consumption is estimated, it can then be deducted from to minimum nigh flow monitored in a DMA or part of a DMA, contributing to a more accurate estimate of real water losses. The results obtained show significant differences from case to case, but in most cases lower values than the published UK references. This is believed to show that residential night consumption is rather context-dependent and that real losses may in fact be higher than estimated so far in this region.

Keywords: household night consumption, water losses, telemetry, DMA

Introduction

One of the established approaches to assessing real water losses at DMA level consists of measuring minimum flow during the night period and split it into different normal night uses (*i.e.,* household and non-household), exceptional night use and background losses (UK Water Industry, 1994; Warren, 2002) . During the night, normal use is generally reduced comparatively to the rest of day, and therefore flows typically have the highest percentage of leakage. Previous studies have concluded that establishing rules to estimate household night consumption is specific to each water utility, since it can be rather dependent on social-demographics (*e.g.,* property type, household size, daily habits, etc.), technical (*e.g.,* pressure) and climate factors (Warren, 2002). Therefore, general rules to estimate household night consumption might not adequately reflect specific consumption habits and supply conditions of a water distribution system. In Portugal, for instance, the absence of similar studies at national level led to the generalised application of simplified rules developed for the United Kingdom. However, aspects such as a more heterogeneous type of properties, different social-demographic characteristics, generalised household metering, and much lower utilization of domestic tanks can strongly limit the application of these rules at national level. Nevertheless, installation of telemetry systems at household level, besides providing more accurate information on billed consumption, can provide detailed

instantaneous consumption data in a water distribution system, making it possible for a water utility to obtain a better knowledge about water uses (Loureiro, 2010).
This paper focuses on the analysis of consumption during the night period to establish simplified rules to estimate night household consumption (*i.e.*, water uses and plumbing losses) at DMA level, for two municipalities in Portugal. The analysis followed the consumption analysis methodology proposed by (Loureiro, 2010). The rules obtained depend on the number of households and on their social-demographic and billing characteristics. Once household night consumption is estimated, it can then be deducted from the minimum nigh flow monitored in the DMA or DMA sector, contributing to a more accurate estimate of real water losses.
The potential of consumption modelling, using detailed telemetry data available in a water utility, was also demonstrated when predicting household night consumption at DMA level, providing more accurate estimates of real water losses.

Methodology

The procedure adopted is based on a general methodology proposed by (Loureiro, 2010). It comprises four stages: i) selection of monitoring areas, specification and installation of water meters and telemetry systems; ii) data processing, iii) model building; and iv) prediction of household night consumption regarding context factors.

In the first stage, water meters were installed at street-level or service connection-level, involving a reduced number of households (around 30) in residential areas. Whenever individual residential telemetering is not available, this option may be considered –it is less costly and easier to implement than installing individual meters, but still allows for the identification of most individual water uses occurring during the night period. Key requirements are that a detailed leak detection and repair is carried out beforehand and that all non-residential uses are either excluded from or fully monitored during the campaigns. In these cases, this option avoided the need for replacing existing household meters (in most situations existing meters are not compatible with telemetry systems). Water meters were selected in order to measure accurately night consumption without introducing significant pressure drop to householders. The telemetry system was specified in order to collect, store and send detailed consumption and pressure data.

The second stage of the methodology involved: i) a set of tasks typically adopted in data processing of large volumes of data: descriptive analysis of data, data cleaning to detect and eliminate outliers due to problems with data acquisition or abnormal consumption (*e.g.*, significant leaks); ii) identification of the actual minimum night consumption period (MNCP) where the analysis of household night consumption would focus; iii) separation of plumbing losses from household uses in the period of analysis; and iv) data reduction by splitting consumption into water use events (*i.e.,* individual water uses such as bath, use of taps, dishwashing, etc.).

In the third stage, distribution fitting was carried out to estimate the parameters that better describe the characteristics of consumption events (*i.e.*, occurrence rate, intensity and duration). Based on the estimated parameters, a simulation model was built to predict household night consumption to a large number of households, from consumption data collected at street or service connection level, was developed.

In the fourth stage, rules to predict household night consumption (*i.e.,* water uses and plumbing losses) at DMA level, regarding the respective number of households and explanatory factors (*i.e.,* social-demographic and billing factors) were established and tested. Social-demographic data from the most recent national census survey and billing data were collected to build set-dependent variables and test relations with household night consumption. This stage involved also a comparative analysis with existing studies (UK Water Industry, 1994; Warren, 2002).

Results

Eight monitoring areas were selected at street- or at service connection-level from as many different DMA in the municipalities of Oeiras and Amadora, in the Greater Lisbon area. Combined meters – the combination of a Woltman meter with a nominal diameter 50 mm and a rotating piston meter with a nominal meter 20 mm – were selected. Consumption was monitored at 1-minute time steps during nine months, between August 2009 and April 2010. Two types of dwellings were included in the study: apartments and detached houses (Table 1). The number of households in each study area was between 20 and 33, and where the meters were located at street level, the network pipes were in good conditions, with total length less than 500 m (*i.e.,* leakage at network level was minimal).

Table 1 – Characteristics of monitoring areas

Monitoring area	Type of dwelling	Meter location	Number of households	Number of service connection	Length of public pipe
ALF-sc	apartment	Service connection	21	1	(n.a.)
ZA-s	apartment	street	31	4	59 m
BA-s	detached house	street	28	17	252 m
FC-s	detached house	street	23	15	271 m
FN-s	apartment	street	32	2	33 m
NO-s	detached house	street	28	24	429 m
QMP-s	apartment	street	33	2	11 m
SA-sc	apartment	service connection	20	1	(n.a.)

Note: n.a. – not applicable

After simulation of minimum night consumption values, to a large number of households with the same characteristics of each monitoring area, it was found that linear regression gave a good fit, for a number of households between 500 and 5000 (with a coefficient of determination r^2>0,95). These linear regression ($\beta_0 + \beta_1 \cdot N$, where β_0 and β_1 are linear regression parameters and N is the number of households in a DMA) allow for estimating the mean value for minimum night consumption (without household-plumbing losses) for areas with similar characteristics but with a large number of households (Table 2).

In order to use Table 2 to estimate household night consumption at DMA level, it is necessary to have the following DMA data: number of households, billed consumption per household tariff and minimum night flow (at 15-minute time step). Due to the reduced number of monitoring areas available to correlate consumption with social-demographic characteristics, only billed consumption per household tariff was considered as a criterion to select a simplified rule.

Billed consumption is usually readily available at a water utility, in opposition to census or survey data about households, and previous studies (Warren, 2002) have shown that, besides property type and occupancy, daily mean consumption is directly correlated with night consumption. After estimation of household night consumption due to water uses, a constant value for household-plumbing losses was adopted (0,4 l/household/h). This value corresponds to the mean value of plumbing losses obtained in monitoring areas ALF-sc and SA-sc (*i.e.*, areas with meters located at street connection level, where plumbing losses are the main component of water losses because leakage on public network pipes is negligible). After assessing the household night consumption (*i.e.*, water uses and plumbing losses), this component can be subtracted from the minimum night flow in the DMA, providing an accurate estimate of real losses (in the cases where non-household and exceptional night use are negligible).

Table 2 – Simplified rules to estimate household night consumption

Monitoring area	Billed consumption (%)			Simplified rule (parameters)	
	1st tariff	2nd tariff	3rd 4th tariffs	β_0	β_1
ALF-sc	0,60	0,40	0,00	-215,20	0,81
ZA-s	0,68	0,32	0,00	-144,60	0,53
BA-s	0,52	0,41	0,06	-235,68	0,79
FC-s	0,42	0,34	0,23	-93,00	0,41
FN-s	0,83	0,17	0,00	-56,41	0,34
NO-s	0,24	0,34	0,43	-119,37	0,47
QMP-s	0,59	0,38	0,03	-89,74	0,39
SA-sc	0,52	0,47	0,01	-61,87	0,34

Table 3 compares the results obtained for household night consumption (column [6]) (including plumbing losses) with estimates provided by previous studies (UK Water Industry, 1994; Warren, 2002) (columns [7] and [8]). It is shown that these estimates are higher than those obtained in this study. Published studies estimate household night consumption based on the mean value during a fixed period of time, whereas the simplified rules obtained in this study aimed at providing an estimate for minimum household night consumption (mean value), considering the MNCP identified for each area, which is then combined with minimum night flow in the DMA. Whenever detailed flow data at DMA level (at 15-min time step) were available, this approach allowed for more accurate estimate of real water losses, since it provided an estimate of minimum household night consumption taking into account the variability of MNCP between sectors.

Table 3 – Prediction of household night consumption at DMA level

	(in this study)					*UK water industry (1994)*	*Warren (2002)*
DMA	House holds	Minimum night flow	household night use consumption	Plumbing losses	household night consumption	household night consumption	household night consumption
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(-)	(-)	l/h	l/h	l/h	l/h	l/h	l/h
ALF	4918	11000	3751,17	1967,20	5718,37	8360,6	8606,5
ZA	4278	7300	2103,49	1711,20	3814,69	7272,6	6417,0
BA	1925	5040	1283,64	770,00	2053,64	3272,5	3368,75
FC	2175	7540	799,15	870,00	1669,15	3697,5	3806,25
FN	3172	3680	1029,19	1268,80	2297,99	5392,4	4758,00
NO	847	12590	277,45	338,80	616,25	1439,9	1948,10
QMP	3505	8710	1266,10	1402,00	2668,10	5958,5	6133,75
SA	4930	8690	1622,71	1972,00	3594,71	8381,0	8627,50

Conclusions

Predicted household night consumption for several DMA in two municipalities in Portugal show significant differences from case to case, with most values lower than the estimates that would have been obtained using UK references. This means that real losses may in fact be higher than estimated so far for the two municipalities. The potential for consumption modelling, using detailed telemetry data available in a water utility was also demonstrated to predict household night consumption at DMA level. It provides more accurate estimates of real water losses, compared to more general approaches. Simplified rules should be obtained for the largest possible number of monitoring areas in a water utility in order to cover a large variety of households with different consumption habits and consolidate the set of explanatory variables to be used in the selection of simplified rules The methodology developed and successfully applied proved to be adequate, robust, flexible and general enough to be applicable elsewhere for similar objectives.

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