Using measured microcomponent data to model the impact of water conservation strategies on the diurnal consumption profile

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Abstract A recent collaborative research project by the Water Research Centre (WRc), involving 13 water companies and the UK Environment Agency, has yielded further information on the microcomponents of water use in domestic properties in the UK. Investigating the uncertainty and diurnal variations of the data has allowed the investigation of demand reduction strategies at household and supply area levels. The paper expands on these issues and discusses how this approach can be used to help plan and manage water supply in the future.

Keywords Demand forecasting; demand management; domestic water use; end-use analysis; microcomponent

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Introduction

The domestic consumption of water consists of a number of ‘microcomponents’; for example, the use of washing machines or dishwashers, personal washing by bath or shower, toilet use, and the use of internal or external taps. Measurement of these microcomponents provides reliable information on the way in which domestic consumers use water in the home. Water service providers in the UK are required to use knowledge of microcomponent use in demand forecasts for efficient planning and operation.

WRc has provided companies with a means to measure microcomponents since 1998 using the Identiflow® technique (Kowalski, 2003). The first major collaborative study in 2000 provided microcomponent information on 250 households across the UK. Since then, the WRc has working with water companies and the UK Environment Agency (UK EA) to measure microcomponents under normal demand and seasonal peak demand conditions, on the adoption of end-user metering, and following a number of demand management initiatives. This has resulted in a pool of measured data microcomponent water use data on over 500 properties in the UK.

A recent collaborative research project (Kowalski *et al.*, 2005) set out to:

- investigate and understand the variability in microcomponent data, including temporal trends and regional differences, in order that micro-component data can be used more widely;
- help companies target ways to reduce network and resource stress through analysis of diurnal peak(s) in normal (off-peak) and peak demand periods;
- improve the understanding of the impact of water conservation measures on total consumption and the diurnal consumption profile including daily peaks.

Investigating the variability in microcomponents of water use

Microcomponent data from the data pool of 500 properties were combined with socio-economic data and lifestyle indicators from the UK 2001 Census, CACI (ACORN socio-economic classification), and WRc/water company archives. A comparison with the national stock of households in England using Census and ACORN data was conducted to assess the validity and representativeness of the data sample to be analysed. The dataset was found to contain a good spread of occupancy and house types, but favoured properties in the south-east of England for historical reasons. In addition, flats and single-occupancy households were under-represented, largely owing to the greater practical difficulties in monitoring flats. None of the households in the sample were metered consumers. However, metered consumers currently only account for about 12% of the total distribution input (25% of households) compared with 56% of distribution input consumed by unmeasured households (Ofwat, 2004a,b).

These data were tested against the consumption profiles of the microcomponent dataset to look at which factors influence domestic consumption in the UK. This exercise identified a number of factors which drive the components of water use in the UK and allowed the assessment of variability and statistical uncertainty in volumes consumed, ownership and frequency of use for various microcomponents.

Regression analysis was used to determine the key factors influencing off-peak consumption. These included day of the week (working weekday or weekend/holiday), occupancy, house type (flats or terraced, detached, semi-detached houses) and ACORN socioeconomic group.

Owing to its more volatile nature and a limited dataset, seasonal peak consumption cannot be assessed using regression analysis. Instead, comparative analysis of the largest consumers with the norm identified a number of factors which identified features about those consumers likely to use considerable volumes of water on warm, dry days. Perhaps unsurprisingly, our study indicates that these consumers are likely to be in the wealthiest socioeconomic group, own a detached property and possess a garden sprinkler.

Diurnal variations in microcomponents of water use

The study also looked at the microcomponent dataset to derive the diurnal variation in water use at the microcomponent level. Consumption on working weekdays and weekends/holidays were compared at various times of the year when normal and peak demand for water would be expected. This allowed a model to be developed which, together with information on house types, numbers of properties, socioeconomic class and occupancy rates, allows the simulation of demand for water supply zones and other metered areas of the water network.

The model allows a range of diurnal profiles to be simulated according to the season and day of the week (Figures 1 and 2). Note the influence of external tap use on warm, dry weekdays in summer (Figure 2) compared with normal demand days at other times of the year (Figure 1).

Analysis of the data has allowed the project to investigate the microcomponents which contribute most to the diurnal peak. This is a necessary first step to assess the impact of water conservation and efficiency measures on the daily peak(s) and the rest of the diurnal profile. Without such knowledge the alleviation of network hydraulic stress or supply limitations, through efficient targeting of key microcomponents, is likely to be less effective.

Modelling the impact of demand reduction strategies

The analysis of the microcomponent dataset has enabled the project to investigate and model how different demand management measures impact demand, at the microcomponent and area levels. The model developed to simulate the diurnal demand pattern of areas of the water supply network was extended to investigate the impacts of different demand reduction strategies on each of the microcomponents for that area. This offers the advantage that, once the simulated demand profiles for that area have been validated

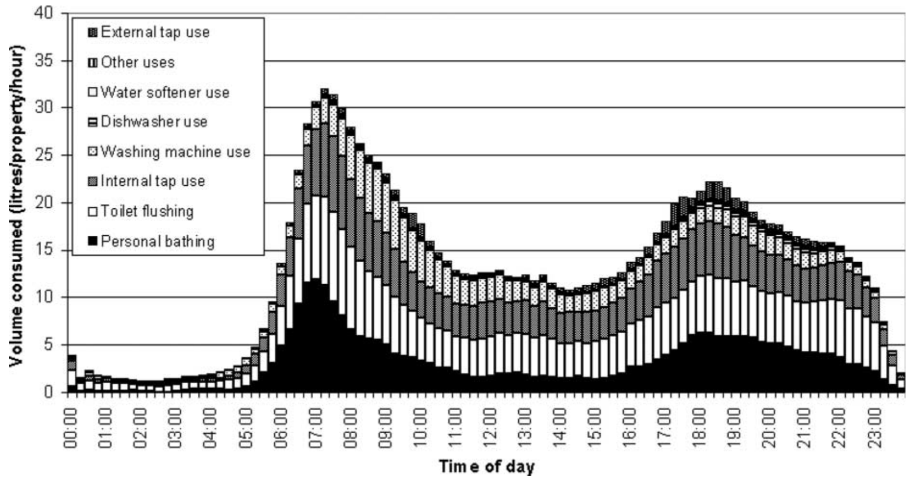

Figure 1 Rest of year weekday diurnal profile

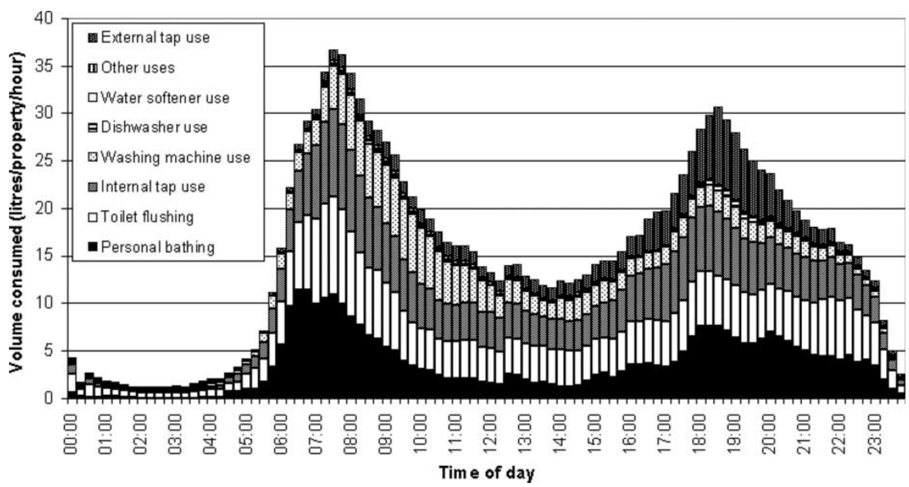

Figure 2 Summer peak weekday diurnal profile

using district/zone meter data, various demand management strategies can be applied to realistic effect on the diurnal demand profiles. Thus estimates of the water savings by area and by microcomponent can be realised.

Table 1 presents a simplified example of the inputs which can be used for this simulation, e.g. the example assumes that there is no difference in strategy impact between ACORN A and other ACORN socioeconomic groups.

In the case of the example shown in Table 1, conservative estimates of the water savings of cistern displacement devices have been applied for Strategy 1, and a negative reduction (increase) of 5% in the number of flushes has been simulated owing to the increase in the number of ‘double flushes’ required. In the area simulated, only 5% of the households have a CDD installed but this is projected to increase to 50% by the end of the water efficiency campaign.

The second strategy simulated in Table 1 was a free water butt offer by the water company to encourage rainwater collection for garden watering. Strategy 2 assumes no reduction in water volume used each time the garden is watered. Instead it assumes

Table 1 Examples of simulated demand reduction strategies

	Strategy 1	Strategy 2	
	CDD* promotion	Free water butt offer	
***Impact on*:**	***Toilets***	***External taps* ****	***Internal taps***
Reduction in volume per use (%)	30	0	0
Reduction in frequency of use (%)	−5	25	2
Current uptake of strategy (%)	5	10	10
Projected uptake of strategy at target date (%)	50	50	50

*CDD = cistern displacement device.
** By means of hosepipe, garden sprinkler, etc. connections.

that, by using rainwater collected in the water butt, the number of times potable water is used for garden watering and other external uses reduces by 25%. A small frequency reduction in use of internal taps, e.g. to fill watering cans from the kitchen tap, is also simulated.

The impact of the above strategies on the diurnal profile is shown in Figure 3. Although the simulated differences in demand appear small in Figure 3, the application of the

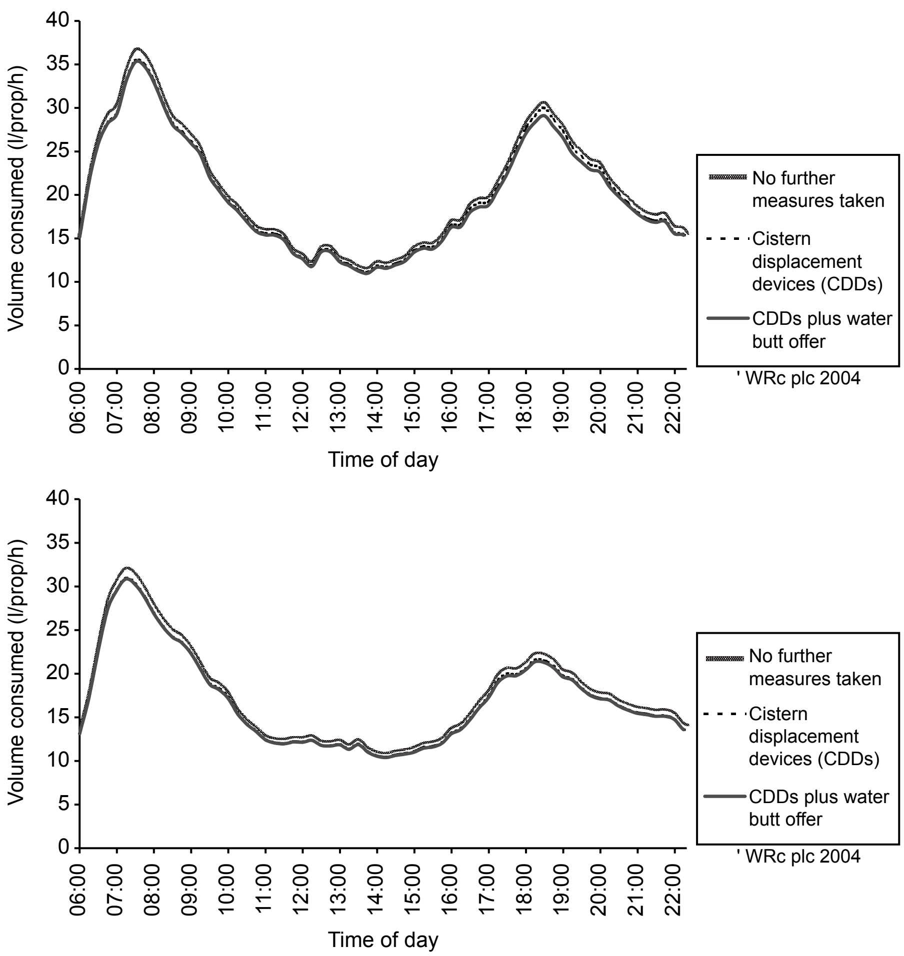

Figure 3 Effect of water butts and/or cistern displacement devices (CDDs) on diurnal peak consumption: (a) Summer peak week day: and (b) rest of year week day

strategies shown in Table 1 actually results in a simulated daily demand reduction of over 5%. This reduction is larger at peak times, and is clearly dependent on the demography of the area studied.

Given the extent to which garden watering influences afternoon peak use in the UK on warm, dry days, a targeted approach to those consumers likely to consume large amounts of water on those days would deliver real benefit, not least in managing the delivery of water to consumers during peak periods.

Toilet flushing contributes over 30% of the mean daily consumption on normal days, and is responsible for a similar proportion during the morning peak period. A saving of 30% per flush through the use of cheap and easy-to-install cistern displacement devices would offer a significant water saving and further reduce the network or resource stress during diurnal peak periods.

The simulation tool formed part of the collaborative research output and was designed in consultation with the project group of water companies. As such, project contributors can specify the model inputs and adapt model outputs to satisfy their own requirements.

Key findings

The Identiflow microcomponent dataset used in this study is reasonably representative of the national stock of properties and ACORN socioeconomic groups in England. Some property types and socioeconomic groups are under-represented and these have been identified for future work. The dataset has been analysed to provide explanations for the variation in microcomponent consumption. Characteristics that most influenced water use were occupancy and whether the household was in ACORN socioeconomic group 'A' (the wealthiest grouping) or not.

Water use patterns can also be divided into four distinctly different 'season-day' time periods: 'weekdays' and 'non-weekdays' for each of 'summer peak days' and 'rest of year'. Consumption on days which are *not* summer peak days can be explained by a regression equation which explains over 40% of the variation in consumption. Summer peak consumption is more difficult to predict given its more volatile nature. This study has shown that potentially large water users during the peak period are likely to be ACORN group A, own a detached property and a garden sprinkler.

There is a large diurnal variation in microcomponents between the four season-day time periods. The variation in microcomponents at district meter area/water supply zone level can be modelled; a spreadsheet simulation tool has been created to facilitate this. The main difference between water usage on summer peak days and the rest of the year is external tap use. Toilet flushing is the dominant water use during the night period, followed by the use of washing machines and dishwashers.

Future implications

UK water utilities will continue to need information on the constituent components of domestic water consumption in terms of appliance ownership, frequency of use and volume per use of appliances. Such information is available from the existing dataset as averages for all unmeasured customers, with broad subdivisions by ACORN (A or not A), number of occupants, dwelling type or region.

If volume per use data were available for specific sub-types / models of appliance, this would give a clearer picture of both the present and the future, when combined with the information on the mix of appliance sub-types currently being used (this would be specific to an area); and the possible rate of uptake of water-efficient appliances. The rate of uptake might be quite rapid for the cheap and simple devices but slow for replacement of major, costly household items such as washing machines. The effect on water consumption would depend on both the rate at which households replace appliances, and the incentives or disincentives in the UK market for choosing water-efficient appliances.

A relatively large number of properties has been monitored and analysed (447), but some types of household are under-represented in the dataset compared with the national position. These are

- metered properties;
- flats;
- ACORN groups E, F, O, P, Q.

However, the properties monitored may be a good representation of the set of all *unmetered* households if it is true that most flats are metered (either individually or as blocks of flats). The ACORN groups E, F, O, P and Q all contain a high proportion of flats. It is noted that low occupancy/high density dwellings form one of the cornerstones of the UK Government's Sustainable Communities initiative (ODPM, 2003).

The aims of future UK work in this area are likely to include:

- Maintaining the integrity and validity of the dataset with regular monitoring;
- extending monitoring to metered properties and other under-represented groups;
- improving information on appliance sub-type or models to assess their impact on future demand;
- measuring and assessing the effect of water demand management measures.

The work has reinforced the usefulness of microcomponent data in understanding how domestic water is used. It has also improved our understanding of water use during diurnal peak periods. The work has provided a basis for modelling the effectiveness of demand management measures. This information will inform the demand forecasting and investment planning process carried out by water service providers, and assist operational and contingency planning during times of high demand.

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