A SYSTEM FOR IMPROVED ASSESSMENT OF DOMESTIC WATER USE COMPONENTS

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A SYSTEM FOR IMPROVED ASSESSMENT OF DOMESTIC WATER USE COMPONENTS

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Abstract:

Recent work by WRc has successfully demonstrated a cost-effective technique for measuring the components of domestic water consumption. The technique involves the capture of relatively high-resolution flow data and uses novel software incorporating a decision tree algorithm to deconstruct a flow-time graph into constituent water uses (microcomponents). Using examples from a number of recent studies conducted for different UK water companies, this paper discusses the merits of the WRc technique and its importance to demand forecasting and assessment of water efficiency schemes.

Introduction

The domestic consumption of water consists of a number of '*microcomponents*'. Typically these are use of appliances such as 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 (Figure 1).

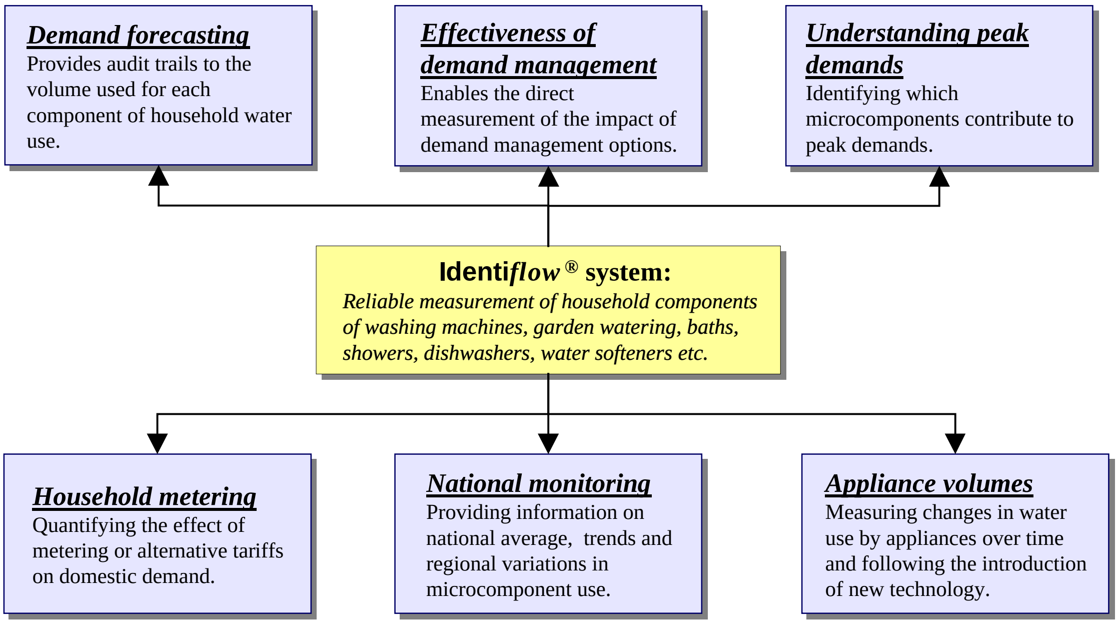

Figure 1 Applications of microcomponent use information

The current demand estimates used by the UK industry commonly originate from work by Herrington (Herrington 1995) who examined the change in water use components as a result of climate change. These components were based on the best available data at the time which were often in limited supply or subjective. Recently the industry in the UK has driven forward the development of a method for measuring the components of household use which provides up-to-date and robust data.

The technique involves measurement of household use at the flowmeter supplying the house and a means of categorising its constituent microcomponents from these measurements. This has required the development by WRc of customised logging equipment and the development of software (Identiflow®) to identify microcomponents from the total measured flow values. Particular attention has been given to the accuracy of microcomponent classification and the ability to analyse simultaneous use of several water-using devices. The following text describes the technical developments and features of the Identiflow® system and some of the applications for which it has been used in the UK. To date, demand to over 600 houses has been analysed using this system. Two UK water companies have each recently produced key water-use statistics from a representative sample of 100 houses analysed in this way.

Development of the Identiflow system

Overview of the system

The WRc system (Figure 2) for measuring microcomponent use comprises of two main parts, namely:

- **A flow meter and logger system** which can be installed in an external meter boundary box. The meter and logger system records water consumption at a relatively high resolution;

- **Identiflow® software** with automatic facilities which identify water use '*events*' and classify them as a particular microcomponent. The software also provides interactive facilities which permit the experienced user to review and refine the analysis.

The analysis provides the characteristics of each water-use event, calculating duration, volume, average flow and maximum flow, and identifying the microcomponent. The statistical analysis provides a range of reports including device characteristics, frequency of use, volume per use, and the contribution of each device to overall demand.

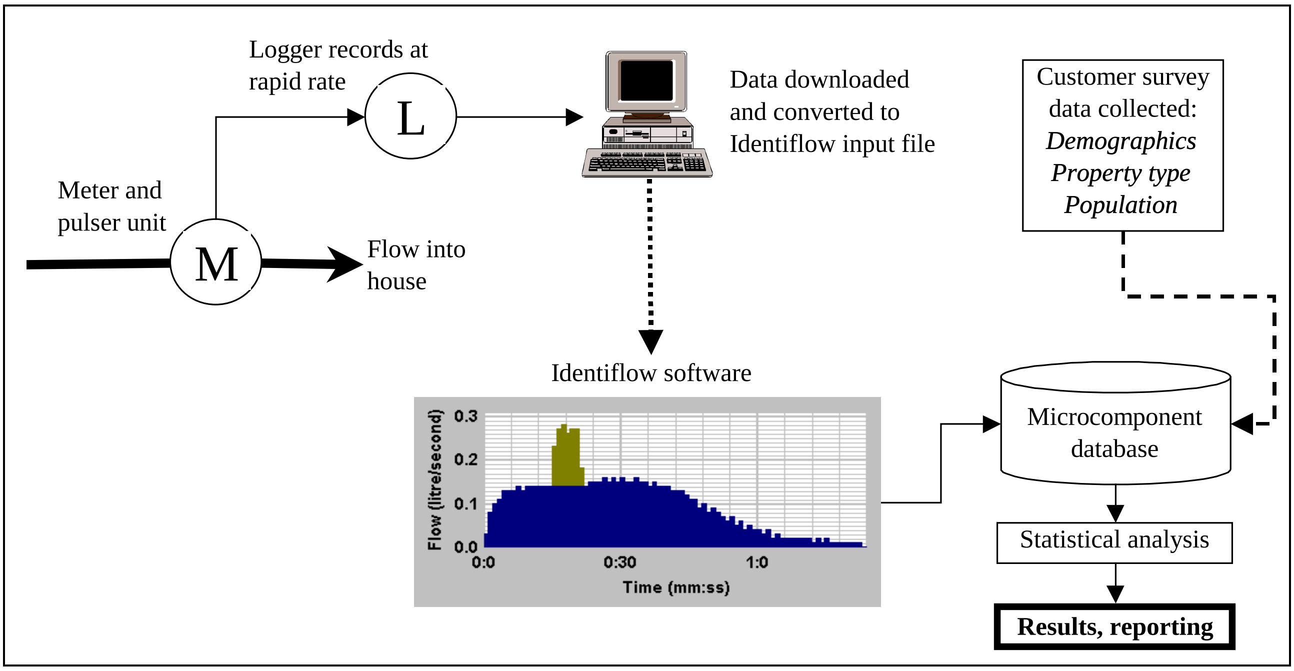

Figure 2 Identiflow® system

Technical development

Following a literature search into pattern recognition techniques, WRc consulted Imperial College, London, on possible solution methods for discriminating water-using devices from high-resolution flow data. Recognising that this was not a classical pattern recognition problem, WRc was advised that techniques employed to solve such problems were over-complicated for this new application.

WRc also investigated the use of neural networks to develop a consumption model based on key features of the flow profile. At that time, however, there was insufficient information to train the neural network and a less time-consuming method was sought. WRc therefore employed a decision tree approach which had the advantage of being simple to apply, easy to understand and readily adaptable. A simple example of a decision tree is shown in Figure 3.

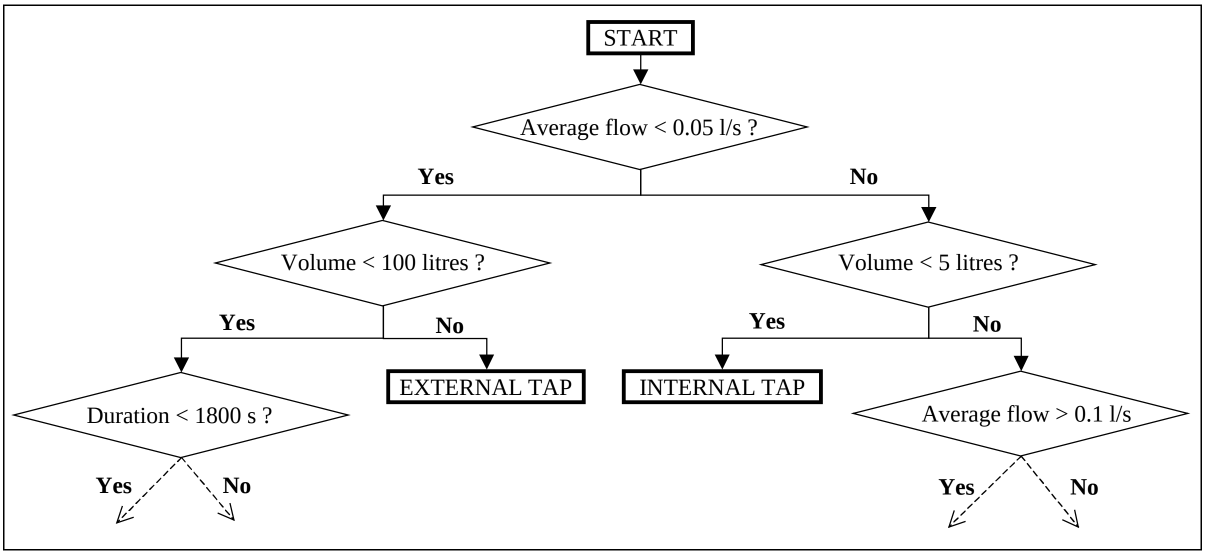

Figure 3 Simple decision tree example

Initially, a small number of properties were monitored for three weeks in order that a sufficient number and variety of water use types were collected. WRc provided a means for the consumer to record their actions electronically. This electronic diary was also stored on a data logger in order that the flow data and diary data could be compared later. This comparison yielded useful information on key discriminators which would allow us to recognise the use of water-using devices. However, in order to be more widely acceptable, the method must be:

- Applicable to a larger sample of consumers;
- Able to discriminate individual components of simultaneous device use;
- Able to classify microcomponents in a range of plumbing configurations;
- Able to take account of some variation in device characteristics, including those operated manually.

Further parametric studies followed which enabled the decision tree logic to be validated and improved. The applicability of the method was tested by logging a wide variety of housing types and plumbing arrangements. Discrimination of different water uses is more complex for households with higher occupancies (say, 5 persons or more) and where the available supply pressure is lower. Fixed-volume events (e.g. toilet flushes) have a longer duration when the pressure is lower and therefore simultaneous use of devices at such sites is more probable.

New tests were employed to reduce the reliance on decisions based on fixed-value inequalities such as those illustrated in Figure 3. This means that two devices of the same type with similar flow *profiles* but with different parametric *values* can *both* be identified correctly. In other words *shape* characteristics could be included in the model with considerable improvement to the scope of the application.

Two years of development followed and the Identiflow® software was born. The software is tested regularly, and routinely delivers success rates such as those shown in Table 1.

Table 1 Results from initial blind trials

Measure	*Region*				
	A	*B*	*C*	*D*	*All regions*
Number of events	877	667	1800	900	4244
Number of events correctly classified	760	606	1670	834	3870
% success (by number of events)	**86.7**	**90.9**	**92.8**	**92.7**	**91.2**
Total volume (litres)	5720	2722	4518	4301	17261
Volume correctly classified (litres)	4184	2104	3371	3260	12919
% success (by volume)	**73.2**	**77.3**	**74.6**	**75.8**	**74.8**

Applications in the UK

Household microcomponents (normal and peak demands)

A project was carried out in 2001 by WRc to investigate the use of the Identiflow method as a means of developing a national microcomponents monitor (WRc 2001). The trial involve monitoring around 250 properties during a period of 'normal' (i.e. non-peak) demand and assessing domestic water use at the microcomponent level.

The average *per household consumption* (phc) for all households analysed was 367.4 litres/property/day. The volume per use results were in broad agreement with common knowledge. The prevalence of newer washing machines was obvious in the sample with an average use volume of around 60 litres, much less than the consumption of machines more than, say, 10 years old. Bath events varied widely, from 50 to 150 litres, but with a mean value (around 80 litres) close to that anticipated.

Figure 4 compares microcomponent data from the WRc study with values commonly quoted by the UK Environment Agency (UK EA) which we believe to be the best estimates available in 2001. It is encouraging to note that the figures show broad agreement, and that any differences are probably accounted for by differences in demography and sample size.

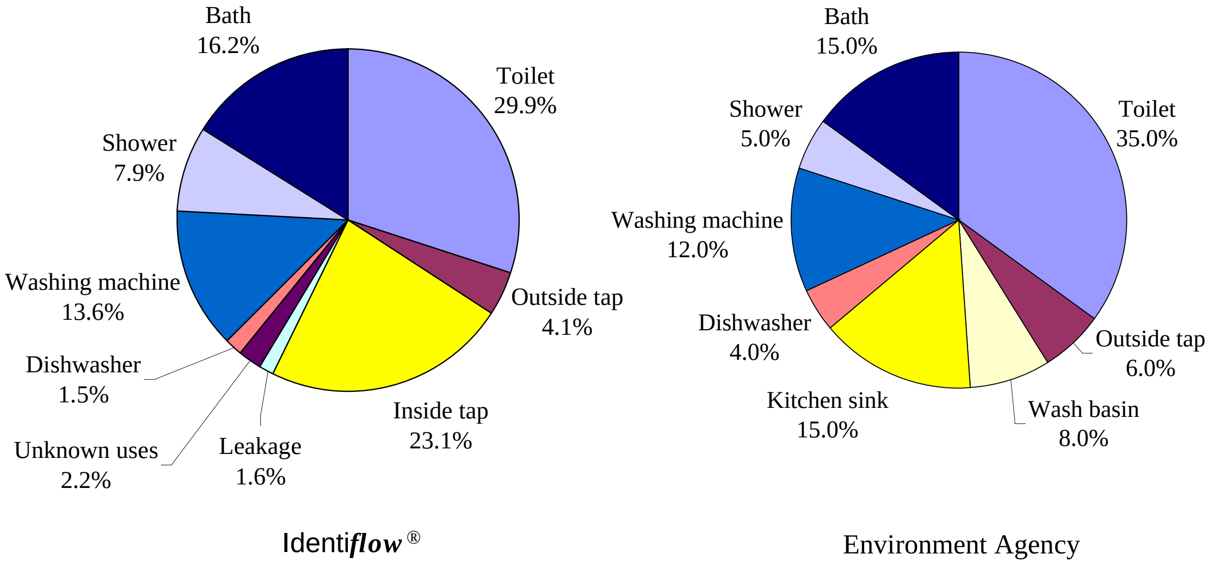

Figure 4 Agreement between WRc and UK EA studies: constituents of total consumption by microcomponent

When data are analysed at a regional level, the microcomponent volumes of use do vary between regions of the UK. Using measured values of microcomponent water use allows these differences to be quantified to a high degree of confidence.

In a parallel 'blind' study, a small sample of properties were monitored using the Identiflow system to collect flow data in the normal way. In addition, questionnaire data were collected for the same sample and compared. Figure 5 shows an example of the findings for bath use. It is clear that there can be a wide variation between actual and reported use. Indeed, in the early development phase when detailed diary and flow data were collected concurrently, almost one-third of diary-style data was unusable because there were no related flow data. *Identiflow therefore represents a significant improvement on domestic water use surveys which rely solely on questionnaire data*.

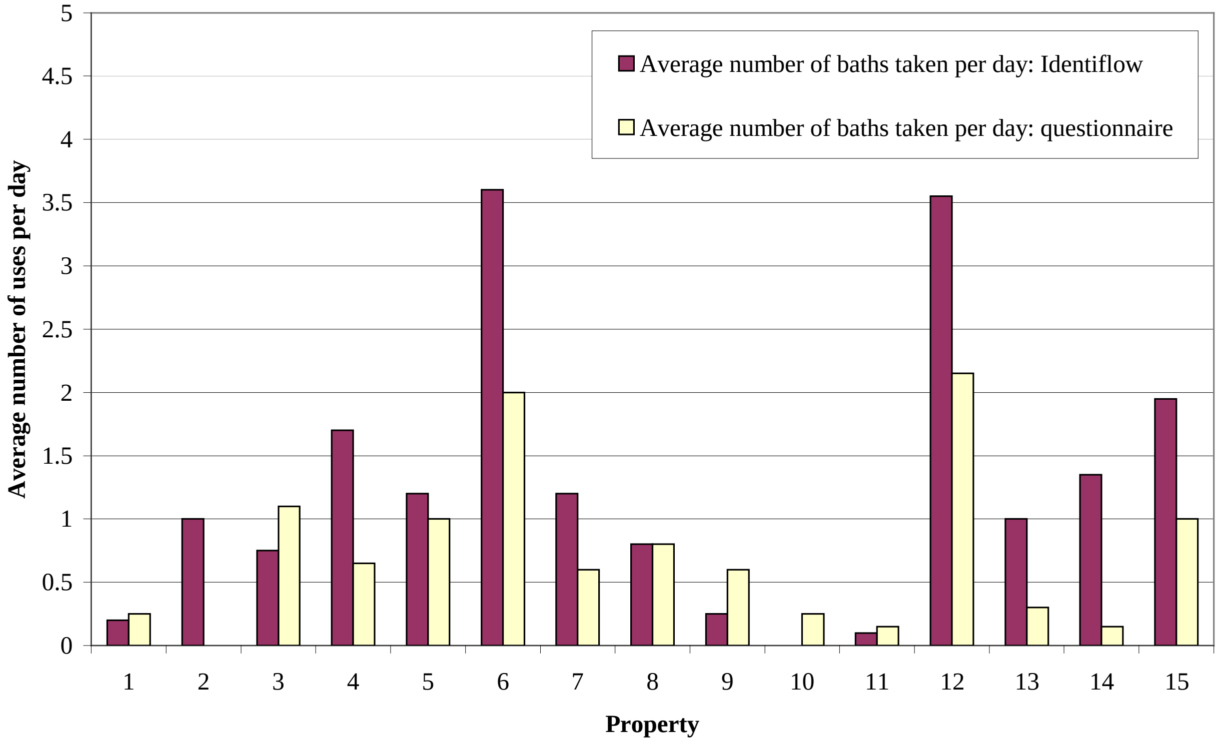

Figure 3 – Comparison of microcomponent use data from Identiflow and questionnaires

The flexibility of the technique means that it is reasonably straightforward to design investigations that can explore microcomponent use across geographical regions and within a water company's area, as well as at different times of water demand. For example, during the 2001 study (WRc 2001) a sub-set of the properties were monitored during a period of peak demand, and the results compared with the normal demand period.

Further studies have been carried out to model the variation of consumption with various meteorological factors, and to investigate which microcomponents contribute most to the variation in demand, and how they do so. Figure 5 shows a two-week period during a recent UK summer where demand for water correlates well with daily maximum temperature. With the benefit of microcomponent analysis, it is clear that the demand peak may be attributed to increased external consumption.

Figure 6 summarises the results of another study showing the change in microcomponent water use between a normal demand period during the autumn and a peak summer week. Again, external use was shown to contribute the majority of the increase in consumption in the peak demand period.

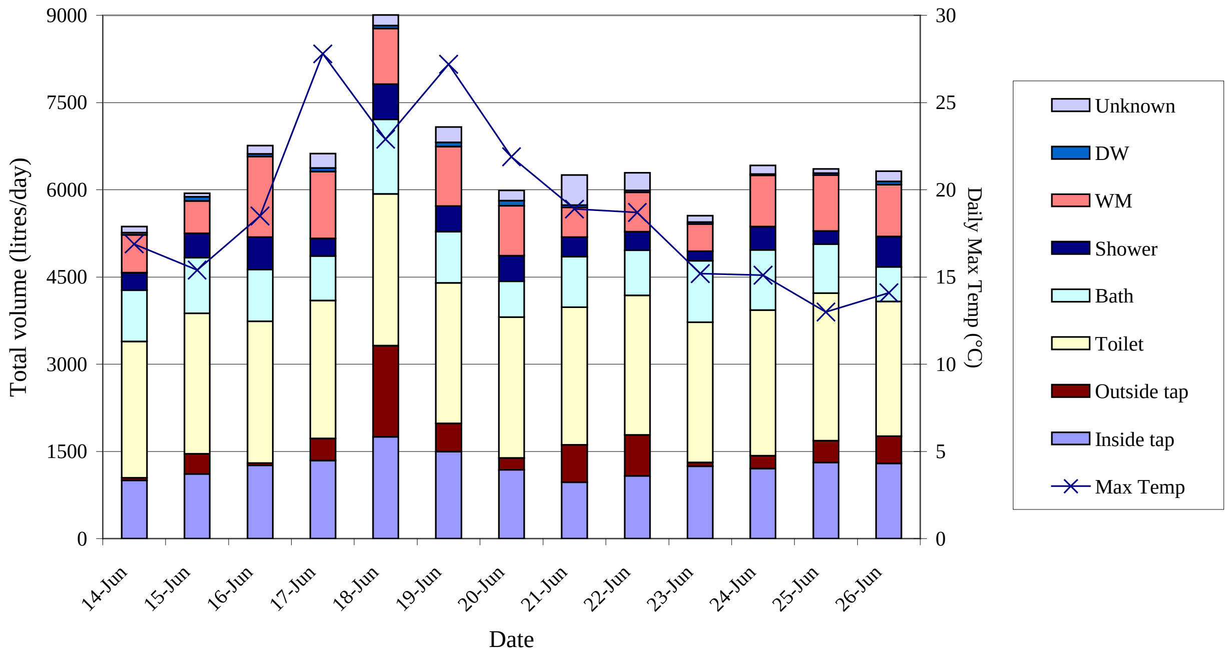

Figure 5 **Daily appliance use and maximum temperature**

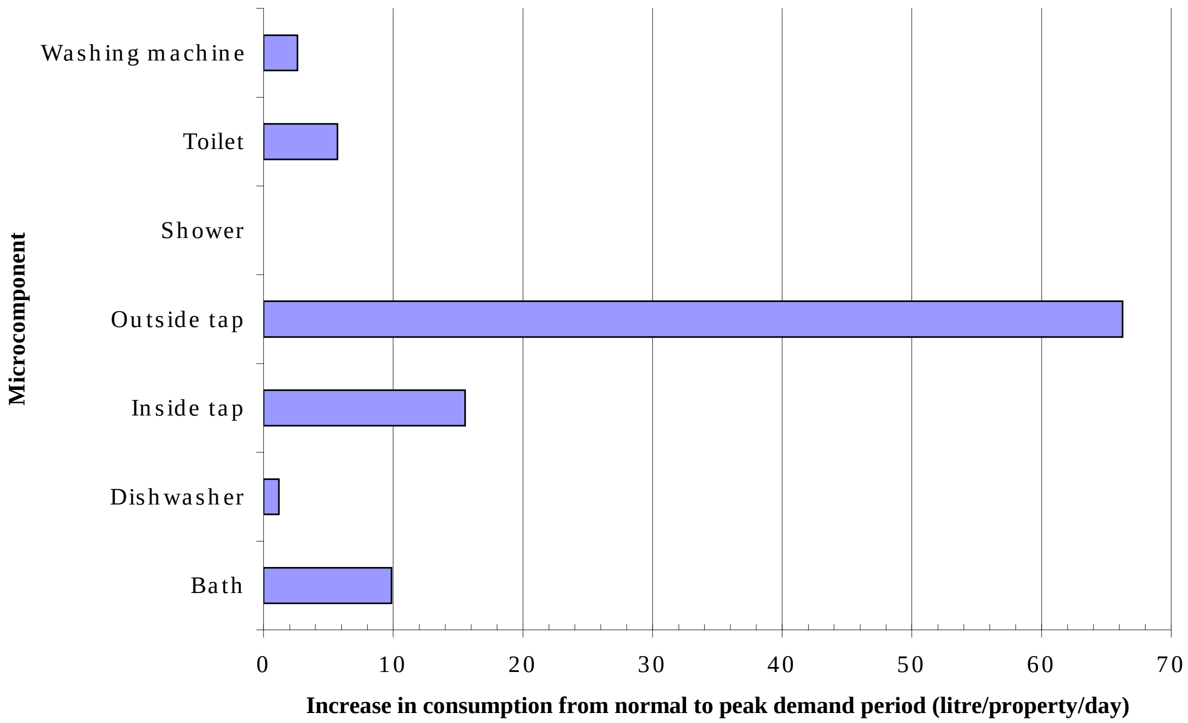

Figure 6 **Changes in microcomponent use measured using Identiflow from normal to peak demand periods**

Statistical rigour and sample size

Whilst developing a national microcomponent monitor for England (WRc 2001), WRc developed mathematical relationships between use frequencies and various household factors, such as location and occupancy, using linear regression. This analysis provided a co-efficient of variation which was used to inform an analysis of variance of microcomponent information. Following this analysis, WRc recommended a minimum sample size of 100 households in order that any results based on the whole sample would have an associated error of not more than ±10%.

Scenario forecasting

Having carried out microcomponent analysis for samples of households under normal and peak conditions, the data can then be used to carry out scenario modelling. Knowledge of current customer behaviour allied to assumptions pertaining to domestic appliance ownership, frequency of use and volume per use of appliances therefore yields useful scenario-based demand forecasts. This view was endorsed by the UK EA in its *Water Resources Guideline* to the water industry in England and Wales (UK EA 2003):

> *Micro-component analysis is the most appropriate method of examining the impacts of forecast assumptions applied to the drivers of household demand; for example, the specific effects of climate change or of water efficiency measures. Companies are required therefore to submit a base year demand broken down into micro-components.*

Summary

The Identiflow® system has now been used to identify water consumption at over 600 domestic properties across the UK. It has been used as part of large multi-company trials and individual company studies to:

- Validate and/or improve the assessment of per household consumption (phc);
- Provide a better understanding of domestic water use;
- Provide data for demand forecasting, and give improved data on normal and peak periods;
- Assess the impact of demand management and water conservation measures.

Future use and developments

In the UK, only about 20% of domestic consumers are metered and charged according to their metered consumption. Approximately 50% of the water going into supply is unmetered consumption. This implies there is considerable scope for uncertainty. Although this may be a particular problem for the UK, few countries can or will escape the effects of climate change. There is already evidence which suggests that extreme weather events are becoming more frequent, and it is therefore more important than ever to plan ahead using robust estimations of future use as well as current consumption.

In the report *A scenario approach to water demand forecasting*, (UK EA 2001) the UK EA describes in detail the method and assumptions to be used to derive forecasts of demand which underpin national strategies for the proper uses of water resources in England and Wales. The approach considers a range of socio-economic futures (the *Foresight framework*) and their predicted impact on water demand.

For domestic demand the method relies upon a microcomponent demand analysis of a ‘base year’. Adjustments are made to take account of dry year demand, based upon assumptions made concerning additional seasonal microcomponent demand (e.g. from garden watering and showering).

Specific quantification of the microcomponents of peak demand provides useful, *real* data to support demand forecasting for both water companies and the environmental regulator. Such a predictive microcomponent-based approach can be refined to produce seasonal predictions to inform investment planning and to assist operational and contingency planning for times of high demand. In addition, such specific information on microcomponents can be useful when making decisions about effective demand management and water efficiency measures.

Work is continuing on projects to integrate microcomponent data from the Identiflow® system with predictive models of future demand.

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