Establishing Meter Under Registration on Domestic Premises with Roof Tanks

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Abstract

This paper reports on a study to identify Meter Under Registration (MUR) in Oman, to be applied to the results of a survey of legitimate domestic night consumption (LDNC). Initial estimates of LDNC had been assessed from night consumption surveys carried out on a sample of over 1500 premises. However, no allowance for MUR had been applied in the interpretation of this data.

All premises in Oman are required to have a roof tank in order for customers to maintain their supply in the case of mains water supply interruptions. Regulations require that the roof tanks provide at least two days storage. It is believed that roof tanks could have a significant impact on MUR due to the long “tails” generated by the operation of the ball valve controlling the refilling of the roof tank (Rizzo & Cilia, 2005). In the case of blocks of apartments, the revenue meter will normally be located after the roof tank in which case, the roof tank will not influence MUR. It was therefore decided that a study should be carried out to review the main drivers for MUR and the likely level of MUR to be expected in Oman particularly at low flows such as those experienced at night time when a single toilet is flushed. In addition, half the premises were fitted with an unmeasured flow reducer (UFR) (Fantozzi, et al., 2009) on a bypass so that the potential of such devices to reduce MUR could be investigated.

The paper describes details of the plumbing arrangements developed for the study and the significant results established as part of the programme. It also takes the opportunity to report on the level of daily and night consumption experienced on the study area.

Introduction

As part of a programme to carry out effective leakage control management in Oman, the Public Authority for Electricity and Water (PAEW) needed to generate robust estimates of LDNC to assist in the interpretation of night flows into district metered areas. LDNC is estimated by sampling night use on a sample of properties using the existing revenue meters.

A programme was designed to investigate the potential MUR and what impact this might have on the assessment of legitimate domestic night consumption. The programme was designed to sample 50 premises with typical roof tanks, including apartments with the revenue meter after the roof tank. Other variables encompassed in the study included multiple roof tanks, different roof tank sizes, different meter manufacturers and different ages of meters. In order to assess the MUR high grade ultrasonic meters were plumbed in series with the existing revenue meters. Both meters were then logged for several weeks. Unfortunately it was fund that only 39 of the existing revenue meters could be logged.

Procedure

A high performance, non-intrusive flow meter was selected. The one selected was a $Q_3$2.5m3/hr R400 (ISO 4064_1_2014, 2014) ultrasonic meter manufactured by Diehl, known as a Hydrus meter. These meters were plumbed in series after the existing revenue meter with the intention of not changing the performance of the existing meter. A typical plumbing arrangement is shown diagrammatically and also on site in Figure 1.

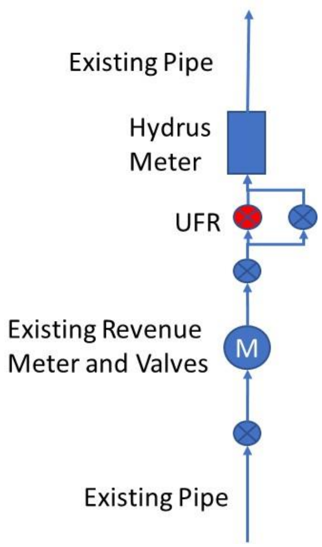

Figure 1 Typical plumbing arrangement

A low power radio network was used to collect the data from each installation and then transmit this data to a web portal on the internet. Figure 2 shows the installation of the aerial for the low power radio network and confirmation of successful transmission.

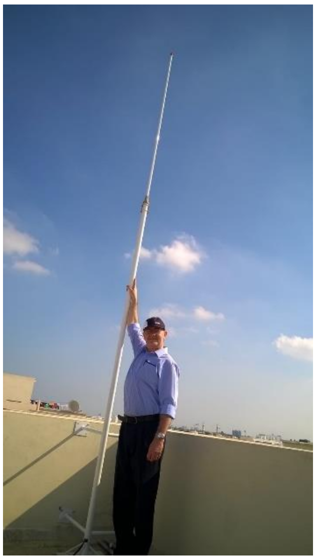

Figure 2 Installation of transmission aerial and checking successful transmission

The existing revenue meters were fitted with pulse sensors and these also transmitted to the low power radio network. A number of unmeasured flow reducers (UFR) were tested. These are manufactured on the premise that they will reduce MUR. This is achieved by stopping the flow when it is below the level of registration on the meter and then the flow is “pulsed” at higher rates that can be registered.

Results

The data on the Hydrus meters was available at 1minute intervals. This was then aggregated to 15min totals to align with the data available from the existing revenue meters. Both daily total and hourly MUR have been analysed.

Results – Daily MUR

Daily MUR for individual meters

Figure 3 shows a plot of the individual daily MUR by meter. This shows that generally MUR is very low but there are situations when it can be very high.

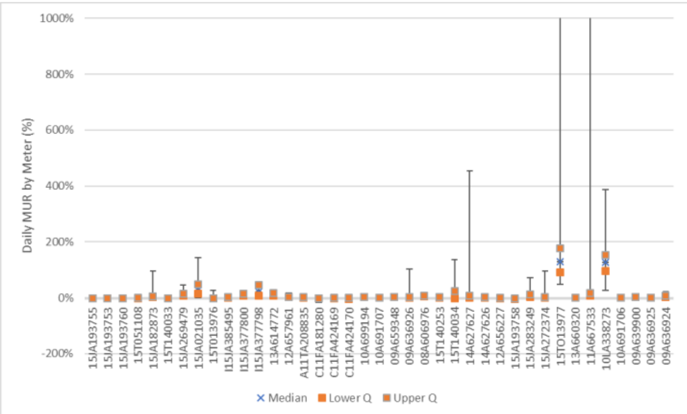

Figure 3 Individual meter daily MUR showing worst cases

The worst cases, in terms of median and range of MUR, were investigated further by comparing the 15min traces for the existing revenue meter and the associated Hydrus meter at these premises.

Figure 4 shows the trace of 15min readings for the revenue meter compared to that of the associated Hydrus meter in the case of the meter with the highest MUR on a typical day.

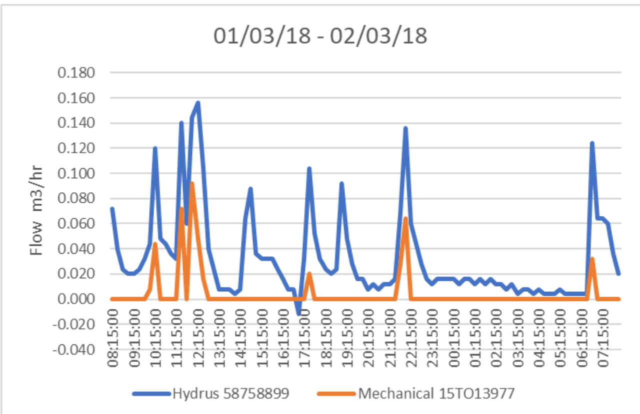

Figure 4 Daily trace for meter 15TO13977 compared to associated Hydrus meter

The trace shows that most flows during customer use are under-recorded but that this under-recording increases dramatically at low flows. There are long periods when the revenue meter is not recording any flow but the Hydrus meter shows that water is still flowing into the property. The phenomenon shown by the meter is probably due to grains of sand being stuck within the mechanical revenue meter which then impedes the rotation of the piston. This causes severe MUR as identified above.

In the case of another meter it was found that MUR changed dramatically for the period from 10th February to 23rd February. Prior to and after this period the meter performed well with MUR slightly negative. This change in MUR was investigated further by reviewing the 15min traces. It appears that a grain of sand lodged in the meter between 8:00am and 12:00 noon on 10th February and affected the meter performance in registering low flows. The grain of sand would then appear to have then been dislodged on 23rd February and the meter returned to normal performance.

Investigations were carried out to establish whether any specific relationships between MUR and some of the other studied parameters (e.g. meter age, meter manufacturer, roof tanks and the UFR) could be identified. These analyses were carried by assembling data into cohorts to reflect the parameter being investigated. It was found that the difference in MUR due to these factors was at least one order of magnitude less than the impact of sticking meters.

Variation of average daily MUR

Figure 5 shows the daily variation of the average daily MUR across all sites both with and without the sticking meters over the period of the study.

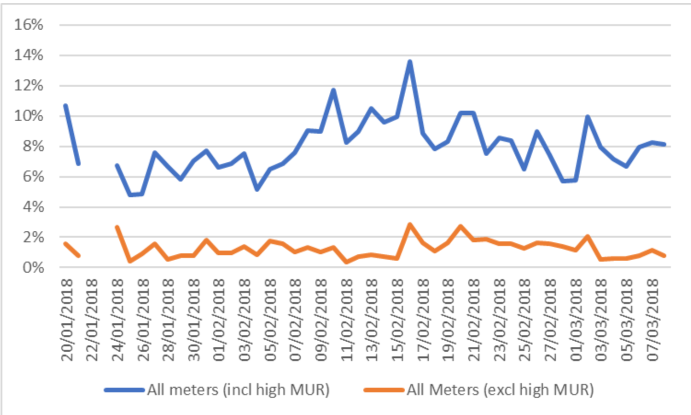

Figure 5 Graph of daily MUR during study period – with and without sticking meters excluded

The reason for the slightly higher MUR during the period from 08/02/18 to 23/02/18 was due to a meter sticking during this period as discussed earlier. When this is excluded the MUR is more consistent during the period. The median daily MUR with all the meters is 8.6% but when the 10 “sticking meters” with high MUR are excluded the median daily MUR is 1.2%. This shows that this phenomena of “sticking” meters had a significant impact on MUR. The fact that 10 meters in a sample of 39 meters have been found to exhibit this phenomenon means that it is a significant driver of MUR in Oman, despite the fact that the meters were fitted with filters.

The MUR was also evaluated in terms of l/prop/d as well as percentage terms. When all the meters were included the average MUR was 84l/prop/d but when the 10 sticking meters were excluded this dropped to 7.3l/prop/d.

Results - Hourly MUR

Analysis of hourly MUR

The previous section discussed the analysis of daily MUR. This is relevant, say, to billing where the question is whether the existing revenue meter reading is reflecting the true total volumetric consumption by the customer. When it comes to the subject of the assessment of LDNC, this is taken over a one-hour period in the middle of the night. This is currently normally established by carrying out a survey on a large sample of premises. Two readings of the existing revenue meter approximately one hour apart are taken to estimate the consumption during a 1hr period, say, between 3:00am and 4:00am. In order to make the process more practical and strike a compromise with the resources required, the readings are usually taken approximately one hour apart in the period between 2:30am to 5:00am.

Flows are significantly lower during the night with consumption being simply for flushing a toilet and washing hands. It is expected, therefore, that the MUR during the period of measuring the LDNC could be significantly higher than the daily MUR. For example, a review of Figure 4 shows that the MUR over an hour in the middle of the night can be indeterminate since the revenue meter is recording no flow while the ultrasonic meter is recording flows. The calculation of hourly MUR using % is therefore impossible and a different approach had to be taken.

Figure 6 shows the trace of the 1hr rolling average (RA) for a meter together with the associated Hydrus. The 1hr RA flow has been used rather than the 15min flow as this is relevant for the calculation of hourly MUR. The graph also shows the hourly MUR expressed simply as the numerical difference between the two flows i.e. l/hr.

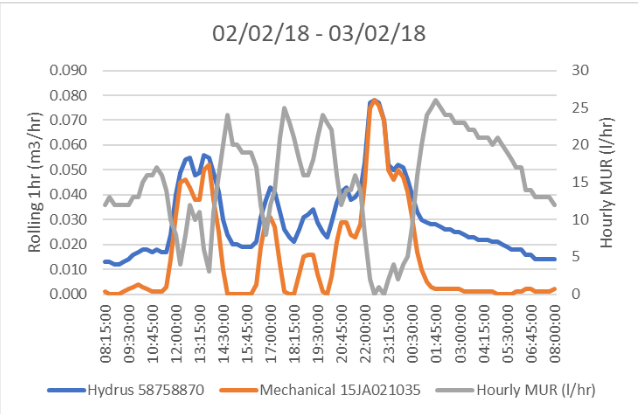

Figure 6 1hr rolling average trace for meter 15JA021035 and associated Hydrus with MUR expressed in l/hr

Figure 6 shows that the MUR when calculated in this manner ranges from 0l/hr when the customer consumption peaks at nearly 80l/hr, to 24l/hr when the mechanical meter stalls.

When more than one meter is considered then the MUR can be normalised by dividing by the number of meters and hence produce the MUR in terms of l/prop/hr.

Fixed 1hr (3:00am to 4:00am) hourly MUR

Hourly meter under registration was evaluated by calculating the rolling one-hour flows starting each quarter of an hour throughout the day for both the revenue meter and the Hydrus meter. Rather than working out the MUR for each meter as before the MUR was evaluated for cohorts. This reduced the volatility of the results significantly.

Figure 7 shows a trace of the overall night flow and the associated MUR in the one-hour period from 3:00am to 4:00am for each night from 24th January to 16th February.

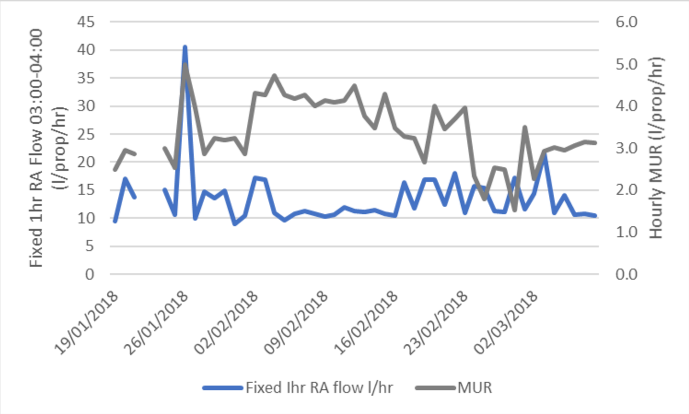

Figure 7 Trace of night flow and MUR for 1hr period 3:00am to 4:00am for all meters

The spikiness of the night flow was investigated. It was found that these spikes were due to high night flows on odd meters on odd nights. One was investigated in more detail. Figure 8 shows the trace for one of the premises where both meters were being logged.

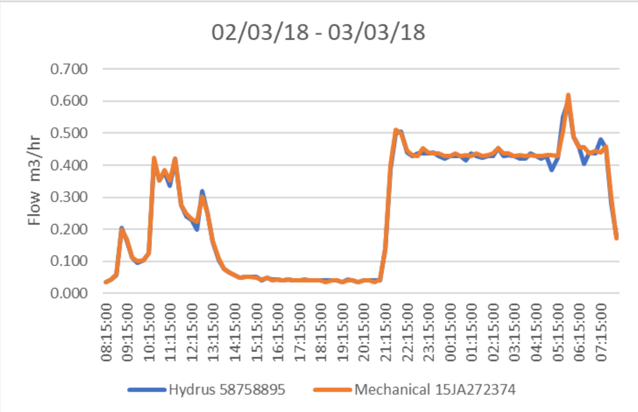

Figure 8 Daily trace for meter 15JA283249 showing high consumption on the morning of 26/01/18

Figure 8 shows that the flow was raised for approximately 10hrs from 21:30 on 02/03/18 to 07:00 on 03/03/18. The raised flow was registered precisely on both the mechanical and the Hydrus meter for the period. This would indicate that the data was real. Enquiries have ascertained that flows of this pattern have been experienced in recent trials in the UK, and these have been traced back to be due to sticking toilet cisterns.

Further investigation showed that these events occurred relatively randomly although there were some repeat events on some properties. There were approximately 25 such events out of a possible 2500 possible meter-nights i.e. a probability of occurrence of 1%. These 1% of events accounted for 22% of the night consumption during the fixed 1hr period between 3:00am and 4:00am.

Figure 7 showed that average MUR varies between about 1.6 and 5.0l/prop/hr, with an average of 3.4l/prop/hr. When the 10 “worst” meters were removed the MUR varied between 0 and 2.3l/prop/hr, with an average of 0.63/prop/hr.

Variation of fixed period hourly MUR throughout the night

An investigation was carried out to see how the hourly MUR varied according to the fixed hour that was used. Figure 9 shows the variation of hourly MUR with the period of the fixed hour, when all the meters are included.

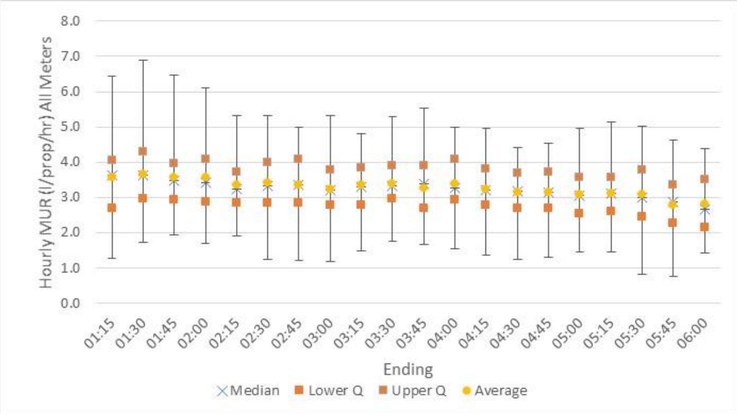

Figure 9 Variation of hourly MUR with period of fixed hour - all meters

Figure 9 shows that the hourly MUR is very consistent and stable between 01:00 and 05:30. The average MUR is of the order of 3.3l/prop/hr. When the 10 meters with the worst MUR were excluded the hourly MUR was 0.6l/prop/hr. This again shows the impact of the sticking meters on MUR.

Results - Identification of leaks

An advantage of having short interval logging, i.e. 15min, as opposed to monthly manual meter reads, is that there is sufficient clarity to identify leaks on the properties. As an example, Figure 10 shows the trace for meter 15JA272374 for a typical day. The lowest flow rate recorded was 24l/hr in just one 15min period immediately before the use event. At all other the lowest flow was 28l/hr. This could be interpreted as showing the presence of a leak.

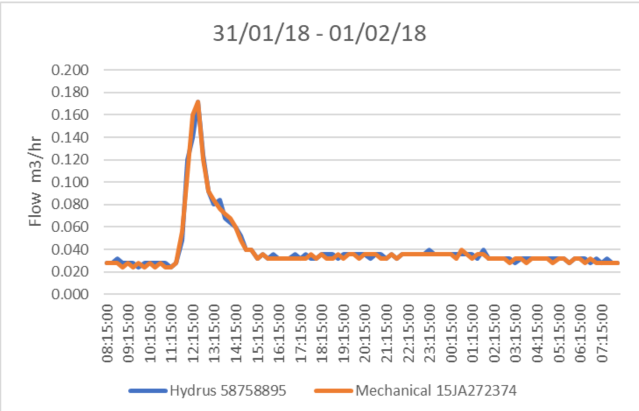

Figure 10 Trace of meter 15JA272374 showing presence of a leak on the property

However, it can be difficult to tell whether very low flows are in fact leaks or whether it indicates that the roof tank is still filling, however slowly. In Figure 10 it can be seen that the flow runs at 34l/hr for about 10hours after the use before dropping down to just under 30l/hr after about 16hrs following use. Could it have continued dropping or is there a leak?

It is common for SMART meters to use a minimum threshold, of say 0.8l/hr, in an attempt to remove the ambiguity of whether it is a leak or whether the tanks are still filling.

There are then issues of how to handle the variation across the period of record (in this case 50 days). It could be argued that the minimum should be used rather than say the median or average in order to avoid such issues, but the absolute minimum may be too rigorous and may allow through specific events such as the valve being shut off. An inspection of some nil events showed that these could not be a true reflection and must be a manual intervention. In order to remove such events a measure such at the 5%tile or 20%tile may be considered more appropriate.

The sensitivity of the results was tested for these various options. The results are shown in Table 1.

Threshold	Night Flow	Measure	Unit	Minimum	5th %tile	20th %tile
0.8l/hr	Spot 15min	Leakage	l/prop/hr	0.5	2.7	3.8
		No with leaks	% of properties	10%	28%	36%
	Rolling 1hr	Leakage	l/prop/hr	2.5	4.0	5.2
		No with leaks	% of properties	28%	36%	48%

Table 1 Sensitivity test of leakage evaluation criteria

It is suggested that the 5%tile of the spot values is probably a reasonable reflection of the true leakage position. In this case the leakage would be 2.7l/prop/hr and 28% of properties would be considered to have leaks.

This level of leakage was despite the fact that any premise where an obvious leak was discerned at the time of the initial survey was not carried forward into the study.

Results – Night Consumption

Figure 11 shows the night consumption between 03:00am and 04:00am across all Hydrus meters during the study period up to 8th March divided by the number of properties.

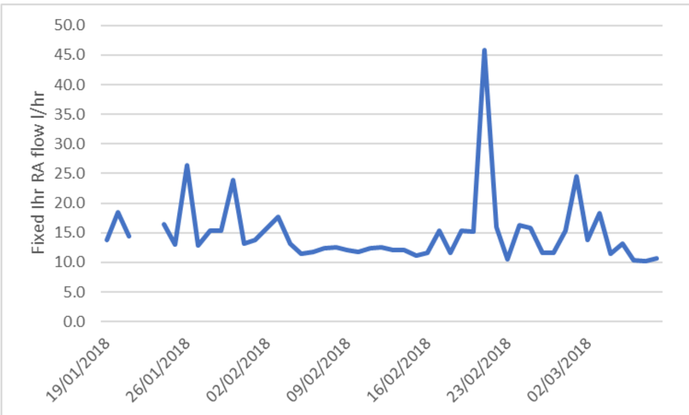

Figure 11 Night consumption per property between 3:00am and 4:00 on all Hydrus meters

As can be seen it has been relatively stable during the period of the study with an average night consumption of just over 12.5l/prop/hr. This is from the Hydrus meters and therefore would not be subject to any adjustment for MUR. The higher level during some nights (including the very high one towards the end of February) are due to what were believed to be sticking cistern valves.

Results – Daily Consumption

Figure 12 shows the average consumption on the properties during the study.

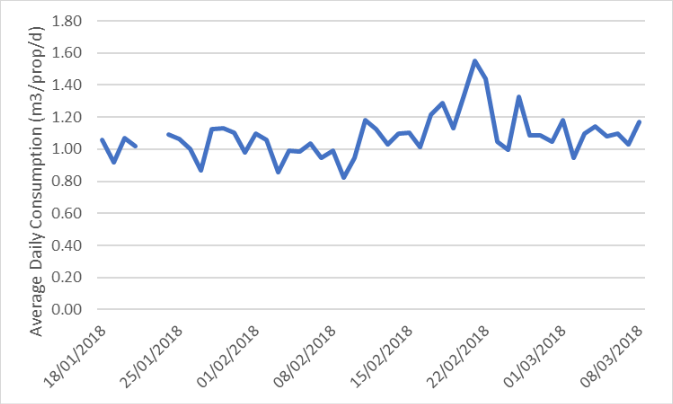

Figure 12 Average consumption per property on all Hydrus meters

This shows that the average per property consumption was fairly stable during the period and averaged 1.08m3/property per day. This implied an occupancy of about 5.5 persons per premise based on the assessed daily leakage and an assumed average per capita use of about 135l/person/d.

Results – Night consumption and use

Although the primary purpose of this study was to better understand the issues around MUR and then to quantify values of MUR within PAEW, it is useful to look at the levels of night consumption and use measured in the study area. Table 2 shows the data for the study in comparison to that generally derived in the UK.

Measure	Unit	PAEW	UK
Night Consumption (NC)	l/prop/hr	12.6	2.2
Night Leakage	l/prop/hr	2.7	0.5
Night Use (NU)	l/prop/hr	9.9	1.7
Daily Consumption	m3/prop/d	1.08	0.34
Av Hourly Consumption	l/prop/hr	44.89	13.96
NC/Av hourly Consumption	%	28%	16%

Table 2 Comparison of night consumption and use data in the study area with UK data

Table 2 shows that the night consumption in Oman looks much higher than that experienced in the UK. This appears to be driven by the filling of roof tanks that extends over the night, be it at very low flow rate but on most properties. When an allowance is made for leakage, this is reflected into the night **use** which is much higher in Oman than in the UK. However, it has to be said that the value for night consumption used in the UK was based on limited studies carried out in 1993. Recent studies being carried out in the UK are indicating that private side leakage may have been severely underestimated.

The value for the night consumption expressed as a ratio to the equivalent hourly average rate for the daily consumption is 28%. Studies in other countries outside of the UK have indicated that night consumption values, expressed as a percentage of the equivalent daily rate, of 25% are not uncommon. In fact, a recent study in Bahrain has also derived a value of 28%. The value of 28% may therefore not be unreasonable.

Conclusions

The average daily MUR was assessed as 8.6%. This value was dominated by a number of meters that were sticking probably due to the presence of sand within the mechanism of the revenue meter. When the ten worst meters were excluded from the analysis then the daily MUR dropped to 1.2%. This shows the impact on daily MUR of the sticking meters. The impact significantly exceeded the impact of the age of the meter, the meter type or whether an UFR had been plumbed into the installation.

The MUR was impacted by whether the meter was located before or after the roof tank but by significantly less than the impact of sticking meters.

Hourly MUR during the night flow period was calculated in the form of l/prop/d rather than percentage as the latter could not be derived reliably. The average hourly MUR in the middle of the night was assessed at 3.3l/prop/hr. Again, this value was dominated by the sticking meters. When the analysis was repeated without these sticking meters the average hourly MUR was 0.6l/prop/hr. The hourly MUR was reasonably constant for any fixed hour throughout the night.

Average night **consumption** on the premises included in the study was assessed at 12.6l/prop/hr.

Low flows extending throughout the day and night were identified by inspection of the flows. It was difficult to discern whether these were due to leaks or due to the roof tanks still filling albeit very slowly. Based on taking the 5%tile, in order to remove odd outlier events) of the minimum of the 15min spot values the average leakage was estimated at 2.7l/prop/hr. This means that legitimate night **use** was 9.9l/prop/hr.

It should be noted that any premises with obvious leaks at the time of the initial survey were not taken through to the study, so average leakage could well be higher.

Average daily consumption in the study area was 1.08m3/prop/d, including void properties.

When the night consumption is expressed as a ratio to the day consumption the resultant value is 0.0117l/prop/hr/l/prop/d. This equates to 28% of the daily consumption is expressed as the equivalent average hourly consumption rate.

Acknowledgements

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