Water-efficient toilets in older buildings: an investigation of potential drainline issues

A review of the performance of existing low-flow toilet installations and whole-building retrofits within Montreal's social housing stock

April 2015

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Disclaimer: This project was partially funded by Canada Mortgage and Housing Corporation (CMHC), but the content of this publication is the responsibility of ÉCOHABITATION and CMHC makes no representations of any kind with respect to the content of the publication

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OMHM – Office Municipal d'habitation de Montréal (Montreal social housing body)

LCD – Liters of water used per capita per day

EXECUTIVE SUMMARY

Though the replacement of 13L flush toilets with newer low-flow models that flush with 4.8L or less is a promising strategy for reducing water waste in Canada, some concern exists that smaller flush volumes could cause drainline blockage in existing buildings with older plumbing configurations and pipe materials. This study sought to examine these concerns by quantifying the drainline issues encountered in plumbing service calls placed by residents of Montreal's 21,000 social housing units over a 4-month period. The drainline issues reported were quantified and categorized according to toilet flush volume.

In parallel to the monitoring of service calls, two buildings were selected to undergo complete toilet retrofits. At approximately the midpoint of the monitoring period, one 8-story apartment tower and one 4-story converted heritage building underwent near-complete toilet replacements, with 12 or 13L toilets supplanted by 4.8L models. Service calls in both cases were closely monitored before and after the replacement in order to quantify performance issues encountered. Finally, residents were surveyed to gauge their level of satisfaction with the new toilets.

Results of the study show no significant difference in the prevalence of drainline blockage issues between low-flow 4.8L and full-flush 12/13L toilet installations throughout the study sample. Data suggests that drainline blockage is no more likely in low-flow toilet installations, even in existing buildings of advanced age. In the two buildings that underwent full toilet replacement, no drainline (or toilet) blockage issues were reported following the conversion to 4.8L low-flow models, and survey results indicate general satisfaction with the more efficient toilets.

Terminology used

Low-flow is used to designate toilets that are designed to flush with 6L of water or less. In the case of this study all of the low-flow toilets discussed are designed to flush with 4.8L of water.

Full-flush is used to designate toilets that are designed to flush with 12L or more.

Older building is used as a generalized term to designate buildings constructed more than 20 years ago, and that have not undergone plumbing upgrades since that time. Most of Montreal's social housing stock is composed of buildings constructed between 1969 and 1994.

Drainline blockage refers to situations where the horizontal drainline portion of a toilet's plumbing connection becomes completely clogged with paper and/or other materials, causing the toilet to malfunction.

2_ BACKGROUND

i. Research objectives

The objective of the research was to investigate popularly-held conceptions that low-flow toilets function poorly when retrofitted into existing buildings with older plumbing configurations and pipe materials. Recent building code updates that seek to reduce water waste by limiting toilet flush volumes have been met with some negative reactions from professionals who worry about the capacity of low-flow toilet fixtures to clear the drainline in older buildings with non-ideal plumbing configurations. These concerns largely stem from anecdotal reports of blockage problems encountered in such cases, but research is required to substantiate and quantify these claims and, if necessary, investigate the root cause of the problems encountered in this type of installation. The aim of the current research is to quantify drainline performance issues encountered in both full-flush and low-flow toilets installations in existing buildings of varying age, as well as to monitor the overall performance of toilets in two older residential buildings before and after being retrofitted with low-flow models.

ii. Context

The research was carried out within the City of Montreal's social (subsidized) housing building stock, which comprises 20,810 apartments classified as 'low-rent' and 1,699 apartments classified as 'affordable' located throughout the island of Montreal. Although new construction continues today, the vast majority of Montreal's social housing building stock was constructed between 1969 and 1994, and the organization estimates that over 80% of its buildings are at least 20 years old, while approximately 55% are over 30 years old. This range in building age makes the Montreal social housing stock an ideal testing ground for low-flow toilets and their relationship with plumbing configurations and pipe materials common in buildings of varying age.

iii. Partners

The study was carried out by Écohabitation and GGB Associates, with substantial contributions from the Office Municipal d'Habitation de Montréal (OMHM), the city's social housing management organization. The authors would especially like to recognize the important contribution of M.Serge Lapointe, plumbing director for the OMHM.

3_ METHODOLOGY

i. Research design

The research design for the study uses a multi-pronged approach to evaluate the performance of low-flow toilets in existing buildings. The principal tasks involved in the research were:

1. Secondary data analysis to estimate the percentage of low-flow toilets currently installed in Montreal's social housing stock.

2. Monitoring of toilet-related plumbing service calls received by the OMHM plumbing department over a four-month period. During each visit made over the course of the study period, OMHM plumbers completed a service call incident report detailing the toilet model involved, the problem encountered, and its resolution. Incidents were then classified based on:

    a. The source of the problem reported (toilet blockage, leakage or other)

    b. The type and flush volume of toilets involved (full-flush 12/13L toilets vs. low-flow 4.8L flush models)

    c. In the case of blocked toilets, the location of the blockage reported (toilet body vs. drainline)

    d. The probable cause of blockage (human error vs. technology performance)

3. Monitoring of two existing OMHM buildings retrofitted with low-flow toilet models for the purposes of the study. Two buildings were selected by the project partners to undergo complete toilet replacement at the midpoint of the monitoring period. The buildings were selected based on their advanced age (pre-1980 construction) and in order to represent two common building layouts within the social housing stock (one high-rise apartment tower and one low-rise complex). In the span of a few days, each building's residential units were retrofitted with 4.8L toilets to replace the existing 13L models. Monitoring of service calls before and after the retrofit was complemented by the distribution of a user survey at the end of the study period to gauge user response to the new toilets. Metering data was also collected before and after the retrofit in order to estimate water savings achieved.

ii. Timeline

The study was carried out during the winter of 2014-2015. The monitoring period for service calls was late-November 2014 until March 31, 2015, and the toilet retrofit work was performed in late-January/early February 2015. The approximate timeline of the major tasks involved in the study is as follows:

Table 1 : Study timeline

Task	Start date		End date	Duration
Data analysis to quantify toilet installations	November 1, 2014		November 8, 2014	1 week
Monitoring of service calls	November 20, 2014		March 31, 2015	4 months and 10 days*
Retrofit work	1)	January 26, 2015	January 29, 2015	3 days
	2)	February 10, 2015	February 11, 2015	2 days
Collection of metering data	January 15, 2015		April 9, 2015	12 weeks
Survey administration	April 20, 2015		April 27, 2015	1 week

*Original 4-month monitoring period was extended slightly to include early report submissions received from OMHM plumbers

4_ RESULTS

i. Prevalence of efficient toilet models in Montreal public housing stock

The OMHM does not keep records of toilet models installed in its residential units, so it is difficult to determine with precision the exact number of social housing units that are currently fitted with low-flow toilet models. However, some information is known about the order history for the various toilet models installed in OMHM units over the years. Data from the organization's toilet order history were extracted in order to estimate the proportion of toilets currently installed that are low-flow.

The OMHM began installing 6-Litre flush low-flow toilet models in new installations and retrofit projects in 2008 as part of an organization-wide orientation toward improving the environmental performance of its building stock. However, early experiences with the chosen low-flow model were negative, and numerous performance issues led the organization to discontinue the installation of this toilet model in new and existing units. In the years since

2008, close to 100% of these 6L toilets have been manually converted to flush with 12L of water, effectively reverting them to full-flush toilet models.

After this early negative experience, the OMHM was careful in selecting a new low-flow toilet model for widespread installation. In May 2012, the first orders were placed for a (Water Sense certified and MaP-tested) 4.8L toilet model. In the years since, this model has been installed in most new build, renovations, and toilet replacement projects throughout the OMHM building stock. Today, it is estimated that 4.8L low-flow models make up just under 5% of all toilets installed in OMHM residential units across Montreal.

Table 2 : OMHM toilet type prevalence

Number of OMHM residential units	20810
Average number of toilets per unit	1.06
Number of toilets installed (all types)	22005
Number of low-flow toilets installed (4.8L)	1076
Percentage of all installed toilets that are low-flow	**5%**

ii. Analysis of service calls

a) Service calls related to toilet blockage

During the period of study, the OMHM plumbing department responded to a total of 97 service calls from residents complaining of toilet performance issues. Of those service calls, 90 (93%) were related to blocked toilets or drainlines. These cases are the focus of this study.

Other issues encountered included leaks, cracks, toilets loose on their base, leaking seals, and in one case, scale build-up that was interfering with toilet function. These non-blockage problems are considered outside of the scope of this study as they are primarily related to improper installation, wear and tear, or other factors unrelated to toilet flush volume.

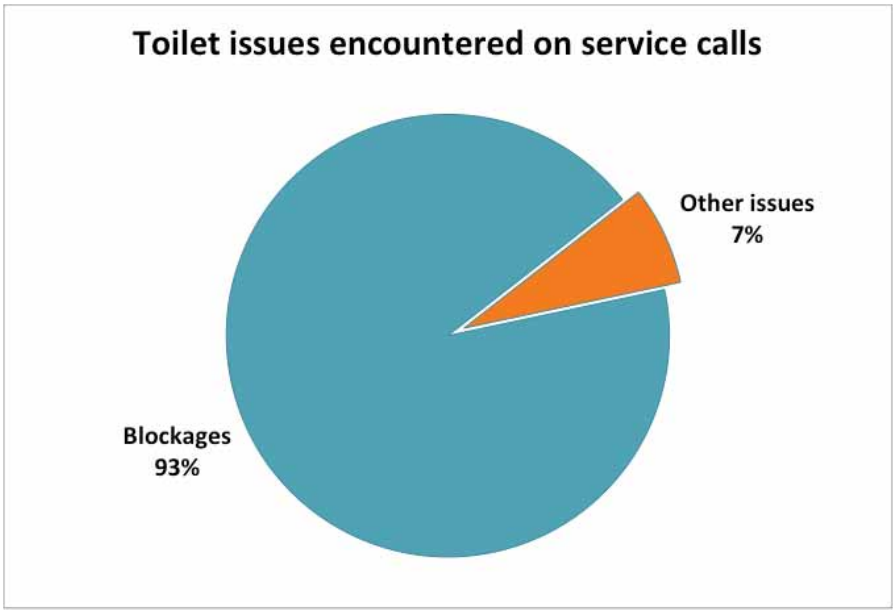

Figure 1

b) Blockage issues related to human error

Because this study seeks to examine the relationship between flush volume and drainline performance, blockage issues related to human error (improper use) must be filtered out. Service call reports indicating that the cause of toilet or drainline failure was linked to improper use were separated from the data under analysis in order to isolate only those cases directly related to flush volume. Although human error is always a possible source of toilet failure, no reliable link can be established to relate these cases with toilet flush volume or drainline performance.

Of the 90 service call reports related to toilet blockage, 15 (17%) were attributed to improper use. The reasons for toilet malfunction in all of these cases was flushing of items not intended to be disposed of in the toilet: items found included rags, toothbrushes, electrical wires, knives, and in one case, a melted plastic ashtray and pieces of burnt wood. It is important to note that in three instances 'excessive toilet paper' was identified as the cause of blockage. These cases were included in the study because the researchers consider toilet paper, whatever the amount, to be a condition of 'normal' toilet use.

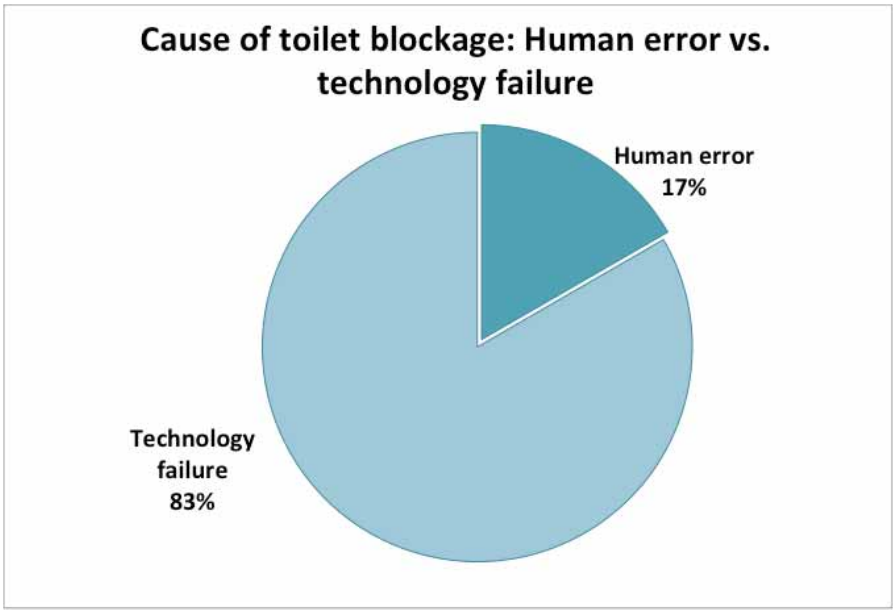

Figure 2

c) Performance issues potentially related to toilet flush volume

After filtering out reported toilet issues caused by human error and those unrelated to toilet blockages, we are left with 75 service calls to analyze. Considering that the OMHM building stock includes over 22000 toilets, and the monitoring period covers one third of a calendar year, this amounts to a technology failure rate of less than 0.4% per year. Based on these results, the toilets installed in the OMHM's building stock seem to have a good overall performance rate.

It is important here to recognize the limitations of the study in relation to toilet model, since the OMHM, as a centralized housing management agency, installs only a few models of toilet as a matter of policy. Although some service call response forms were returned with the toilet brand line left blank, the toilet installation and order history of the organization indicates that all of the toilets encountered in the study were one of three models: an older-model 13L toilet, the 6L toilet modified to flush with 12L, and the newer 4.8L low-flow toilet. However, the principal aim of this study is to estimate the effect of toilet flush volume on drainline performance, and not to evaluate different toilet models. The constancy in toilet model is helpful in this regard, because the potential differences in performance among varying models of toilet of similar flush volume can be disregarded.

It is also worthwhile to acknowledge the increased risk of performance issues when toilets are modified to flush with more or less water than originally designed. The 6L toilets modified to flush with 12L of water may reasonably be expected to have a higher failure rate

than toilets installed as per the manufacturer's instructions. If the study size were larger, it would be possible to justify the omission of these toilets from the study. However, given the size limitations of the study and considering that the principal focus of the research is the effect of flush volume on drainline clearing and not toilet type, these cases were included in the analysis.

Of the 75 normal-use related blockages reported during the monitoring period, 9 (12%) were encountered in the low-flow 4.8L toilet models. The remaining 66 (88%) were observed in full-flush models. In both cases, the toilet prevalence rates (percentage of each type of toilet installed in OMHM units) are within the sampling error range of the observed rate of blockage. In other words, each type of toilet generated reports of blockage at a rate comparable to its respective prevalence within the OMHM social housing stock. It must be noted that the small sample size of reported incidents (0.4% of the total number of toilets owned by the OMHM) led to a wide margin of error for this small study (10.6% with a confidence interval of 95%).

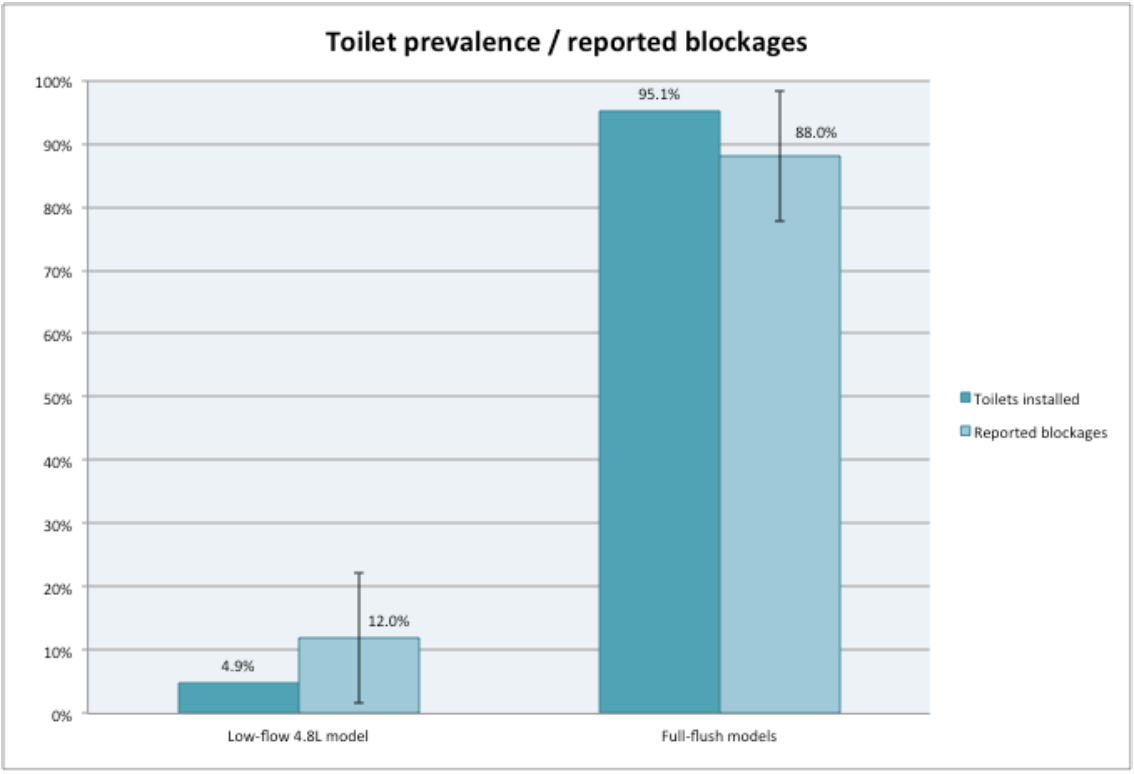

Figure 3

d) Location of blockage issues: drainline vs. toilet

The main objective of the research is to identify potential conflicts between low-flow toilet models and existing plumbing configurations in older buildings. Although low-flow toilets themselves have been widely tested to demonstrate their ability to clear the bowl with less water, the capacity of smaller flush volumes to keep drainlines clear has been hotly contested. The concern of some plumbing professionals and government officials is that smaller flush volumes will fail to clear the drainline, leading to a buildup of material and eventually complete clogging of horizontal pipe sections in plumbing configurations originally designed to work with larger flush volumes.

In order to quantify this risk, OMHM plumbers responding to service calls were asked to identify the location of materials that were causing toilets to block. Their responses were separated into two categories: blockage within the toilet body and drainline blockage. Overall, 27% of blockages were attributed to drainline clogging, while the rest (73%) were clogged toilets. Of the 21 cases where the drainline was identified as the location of the clog, just 2 (9.5%) involved a low-flow toilet, and the rest were full-flush, 12/13L models.

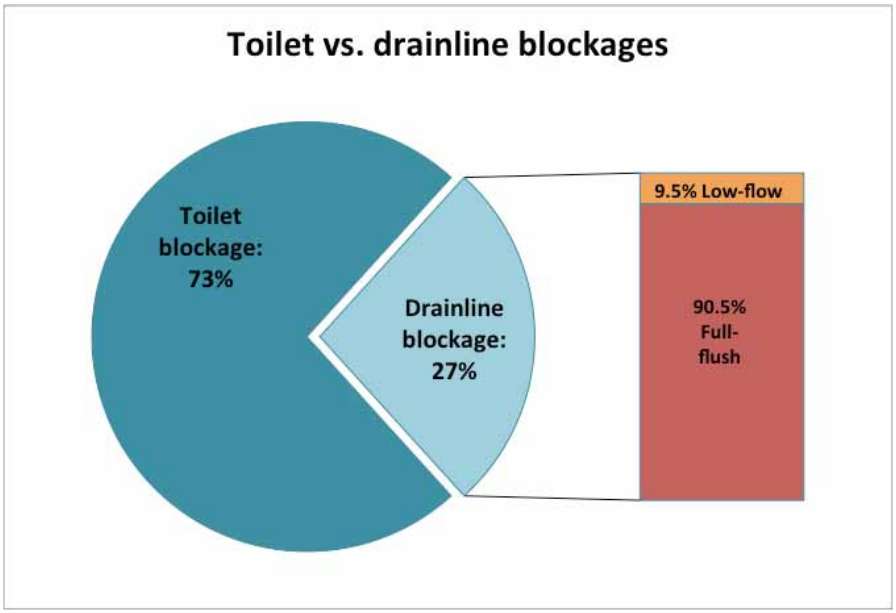

Figure 4

Of all the cases of blockage reported during the study period, 22% of low-flow incidents and 27% of full-flush incidents were attributed to drainline clogging. The rest of the reported incidents were cases of clogging within the toilet body, and therefore unrelated to the plumbing configuration, age of construction, or pipe material. Considering the sampling error,

the rate of drainline blockage in low-flow toilets was not observed to be significantly different from that of full-flush models.

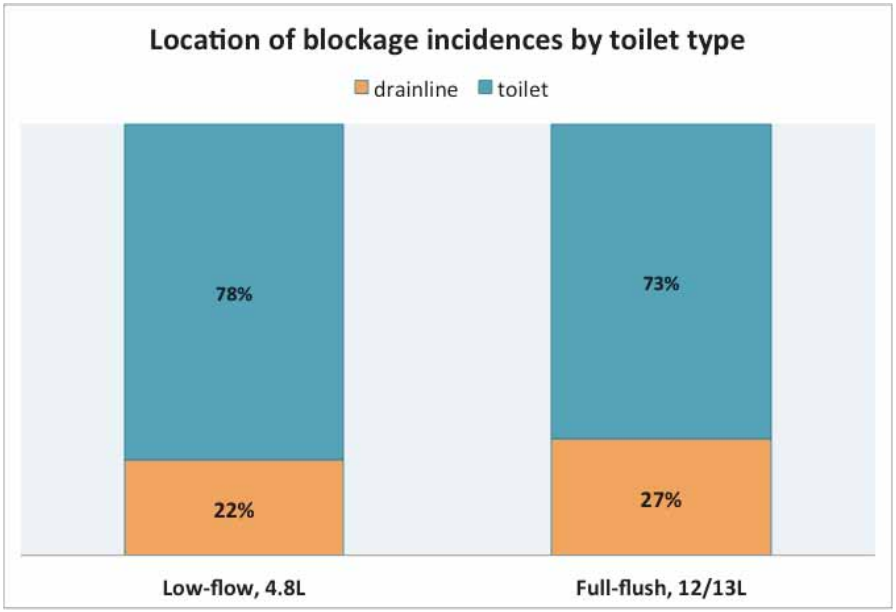

Figure 5

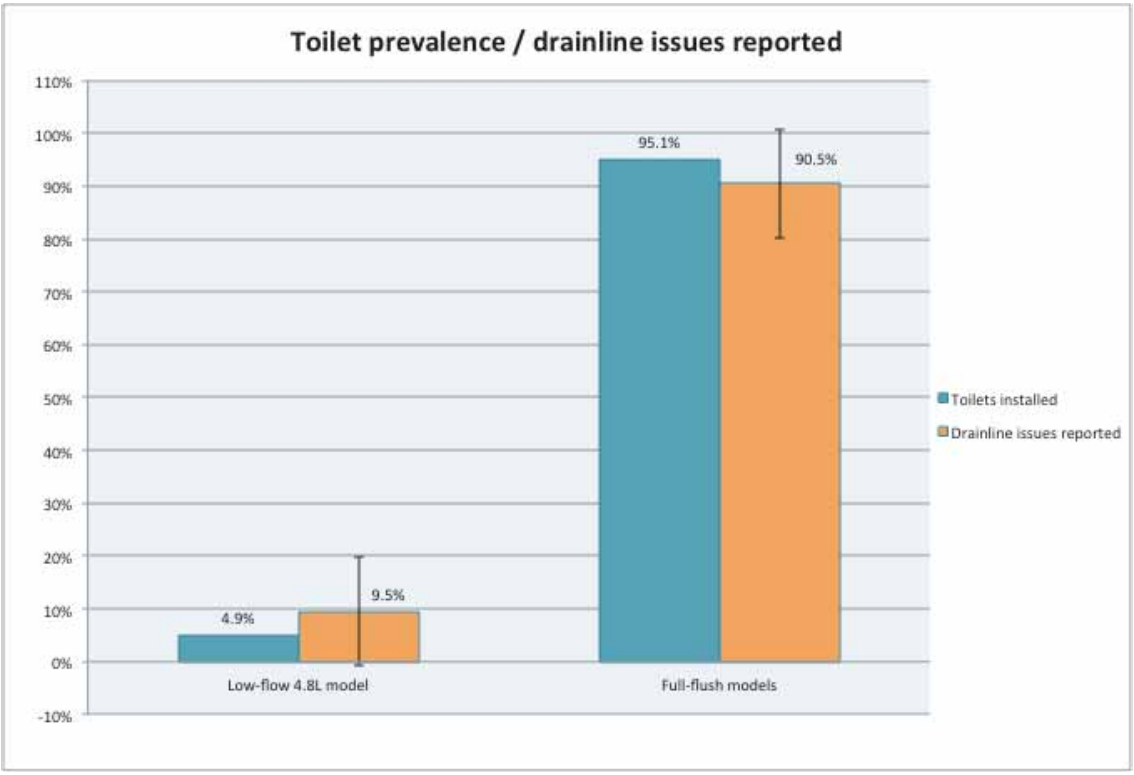

Figure 6

e) Summary of results

Table 3: Summary of results

Summary table	#	Total reports	% of total
Service reports	97	97	100%
Blockages	90	97	93%
Low-flow blockages	11	90	12%
Full-flush blockages	79	90	88%
Human error	15	90	17%
Blockages without human error	75	90	83%
Low-flow blockages without human error	9	75	12%
Full flush blockages without human error	66	75	88%

Percentage of above (blockage without human error)			
Total drainline	21	75 (+4)*	27%
Low-flow drainline	2	7	22%
Full flush drainline	19	76 (+4)*	27%

* 4 reports indicated both toilet and drainline blockages, so these were counted in both categories

ii. Retrofit projects

a) Building description

Two buildings were selected for whole-building toilet retrofits. In order to zero in on the potential for drainline problems with older plumbing, the primary selection criterion was building age (minimum building age suggested was 30 years). The two buildings chosen were favoured because their units all previously featured full-flush 13L toilets, and because they represented different building typologies (one 8-story apartment block and one 4-floor converted heritage building). The buildings chosen were:

1. 2355 rue Delisle
Year of construction: 1973
Floors: 8
Units: 96
Occupants: 175
Average occupancy: 1.82 pers/unit

Image: Alarie Photo / OMHM

2. 3985 rue Masson
Original year of construction: 1920 (school)
Renovation and residential conversion: 1980
Floors: 4
Units: 21
Occupants: 23
Average occupancy: 1.1 pers/unit

Image: OMHM

Prior to the replacement date, all of the toilets installed at both 2355 Delisle and 3985 Masson were full-flush 12 or 13L models. At 2355 Delisle, toilet replacement work began on the 26th of January and concluded on the 29th. Of the 96 toilets in the building, 81 were replaced during these three days. At 3985 Masson, toilet replacement work began the 10th of February and wrapped up the next day. In that case, 16 of 21 toilets were successfully replaced. In both cases, the reasons for non-replacement were either 1) designation of the unit as accessible to handicapped residents (where toilet height is an accessibility criteria) or 2) occupants could not be reached in time.

b) Toilet-related service calls

The buildings in the study were monitored for toilet-related service calls before and after toilet replacement. One service call was received from a resident of 2355 Delisle before the retrofit, complaining of toilet blockage in a converted 12L full-flush model. No service calls were received from either building in the two months following the toilet retrofit.

c) Metering results before/after retrofit

Although Montreal's residential buildings are not metered, the research team thought it would be valuable to benefit from this opportunity to measure the water use of the two study buildings before and after the toilet retrofit. The city of Montreal agreed to donate two meters, and these were installed roughly 2 weeks (in the case of 2355 Delisle) and 3 weeks (in the case of 3985 Masson) before the start of toilet retrofits. The metering results show an impressive decline in overall building and per capita water use before and after the toilet replacement: a 41% reduction in both average daily whole-building water demand and liters/capita/day (LCD) at 2355 Delisle (where 81 of 96 toilets were replaced) and a 17% reduction in both values at 3985 Masson (where 16 of 21 toilets were replaced). The results observed translate to water savings of 168 LCD at the Delisle site and 69 LCD at the Masson site following the toilet replacements. Note that the metering data obtained while toilet replacement work was underway are excluded from these calculations.

See next page for metering results. Meter data was averaged to yield mean values of daily water demand for the period between readings. The graphs below show the evolution of whole-building water demands (left axis) and liters per capita per day (LCD) consumed (right axis) over the 9 weeks that metering data was collected. LCD results are based on an occupancy rate of 1.82 persons/unit at 2355 Delisle, and 1.1 persons/unit at 3985 Masson.

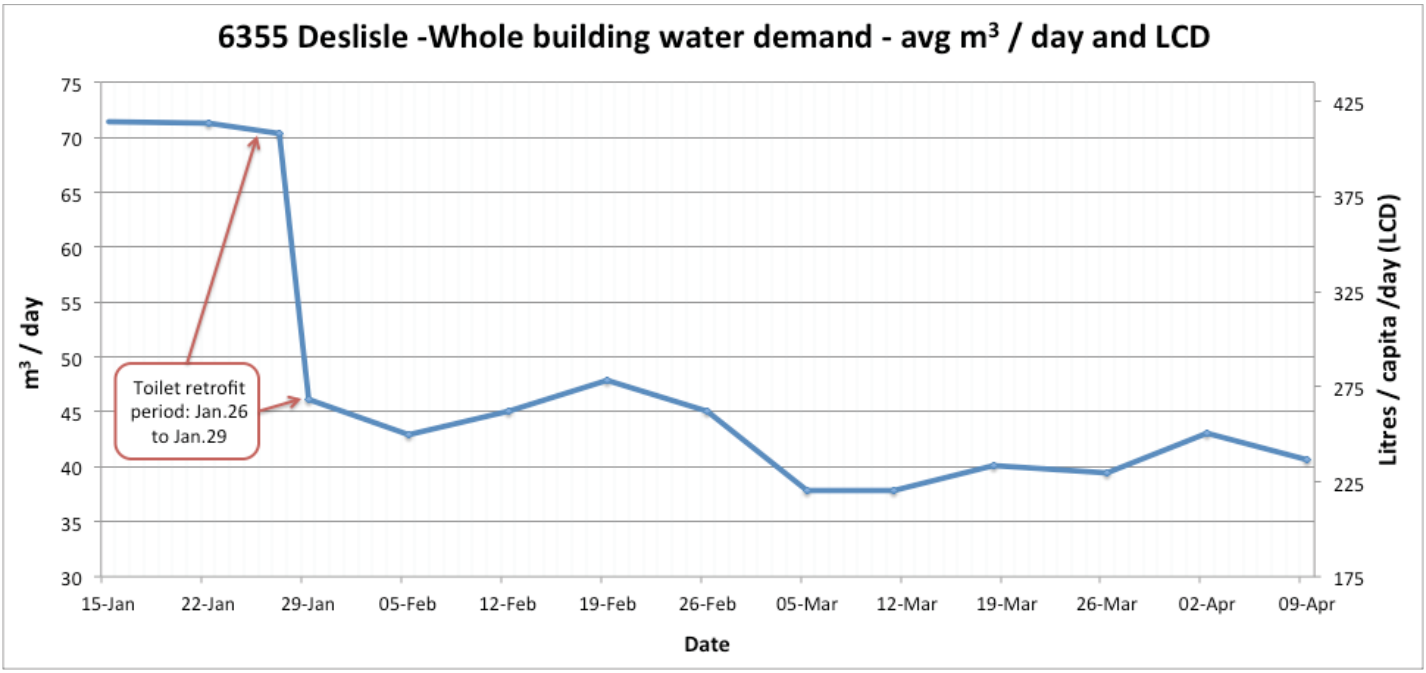

Figure 7

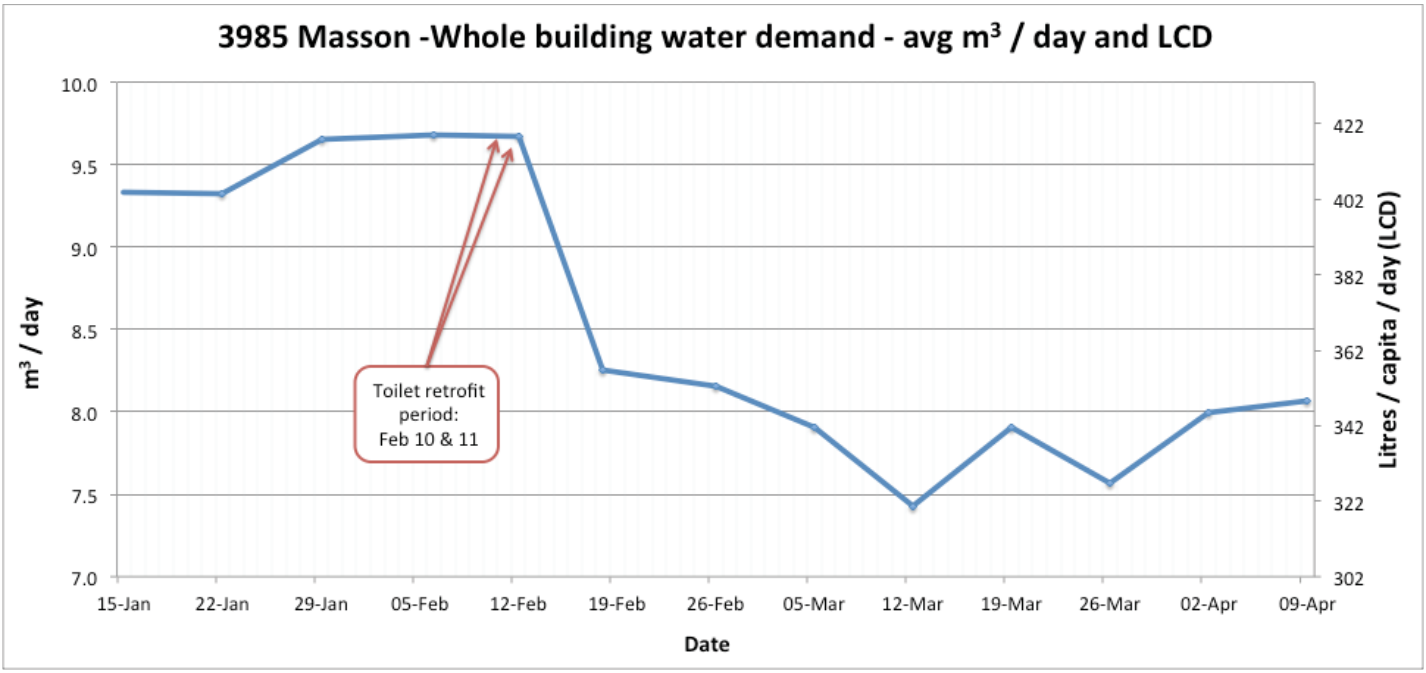

Figure 8

d) Survey data

Following the 4-month study period, surveys were distributed to all the residential units in both buildings where toilets had been replaced. The survey asked respondents to mark one of five boxes (strongly disagree / disagree / neutral / agree / strongly agree) for each of the following three statements:

1. The new toilet is easier to use than the old toilet
2. The new toilet flushes better than the old toilet
3. The new toilet requires less cleaning than the old toilet

And finally,

4. Declare their overall satisfaction with the new toilet (strongly dissatisfied / dissatisfied / neutral / satisfied / strongly satisfied):

The response rate for the survey in the two buildings was 49%. Five surveys had to be removed from the sample because they failed to check only one box per question, and one other was removed because the respondent indicated that their toilet had not been changed. Overall, the surveys displayed a high degree of general satisfaction with the new toilets installed, with the two positive categories (strongly agree/strongly satisfied and agree/satisfied) together garnering between 54-60% of responses to each question, and the two negative categories (strongly disagree/strongly dissatisfied and disagree/dissatisfied) totalling 21-25%.

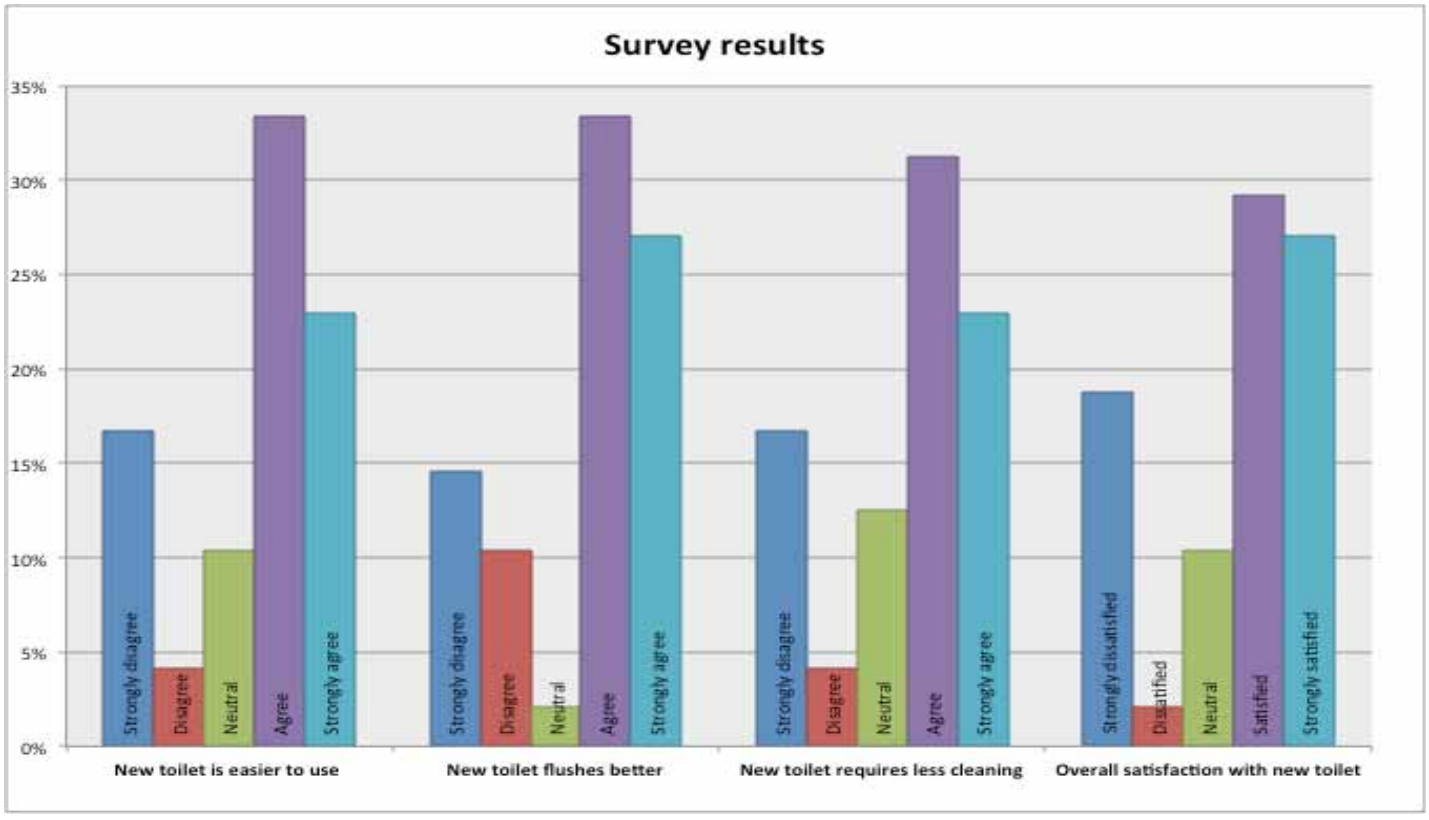

Figure 9

5_ CONCLUSIONS

Toilet flushing represents a large proportion of water use in residential buildings. The widespread replacement of "standard" toilets that flush with 13L of water or more with newer low-flow models that flush with 4.8L or less is thus a very promising strategy for reducing water demands in the residential sector. In this study, overall water savings of up to 41% were observed in two apartment complexes retrofitted with low-flow toilet models. This result reinforces the significant water-saving potential of the widespread installation of low-flow toilets.

The potential for drainline blockage with smaller flush volumes is commonly used as an argument against requiring the installation of low-flow toilets, especially in relation to retrofit projects in older buildings. The objective of this study was to investigate the actual frequency of drainline blockage when low-flow toilet models are installed in existing buildings of varying age. The Montreal social housing stock was deemed an ideal testing ground for this research as it includes hundreds of older buildings and over one thousand units already retrofitted with low-flow toilets.

Results from 4 months of toilet performance monitoring in over 22000 social housing units suggest that the relative frequency of both general toilet malfunction, and specifically drainline clogging, are not statistically different for low-flow and full-flush toilets, even in older buildings. Failure rates observed did not deviate from the estimated installation rate of each toilet type. In the small sample observed, drainline clogging issues were in fact less likely to be the source of toilet malfunction in low-flow 4.8L toilets than they were in full-flush 12/13L models, though the overall values for each were not statistically different. This result is reinforced by observations from whole-building toilet retrofit projects, where the widespread replacement of 13L toilets with 4.8L models in two pre-1980 apartment complexes did not lead to any reported performance issues.

Over the course of the study, low-flow toilets performed as expected when installed in existing buildings, and they were met with generally positive reviews from users surveyed. This information should prove useful for cities and housing bodies like the OMHM that are keen to promote water-saving initiatives within the residential sector. Though this study is limited in size, results suggest that the widespread installation of water-efficient toilets can produce very significant water savings without sacrificing performance or user satisfaction.

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