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### *Residential Waste Flow Reduction With Low-Flush Toilet Fixtures*

by

Robert L. Siegrist

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# RESIDENTIAL WASTE FLOW REDUCTION WITH LOW-FLUSH TOILET FIXTURES

by

Robert L. Siegrist

Residential waste flow reduction is gaining increased recognition as an important element of an effective water pollution control program. Alleviating overloaded sewage treatment facilities, reducing operational requirements and costs, and rendering innovative and alternative treatment systems more feasible, have all been recognized as potential benefits of reducing wastewater flows.

Strategies to achieve residential waste flow reduction are numerous and varied [1-9]. Consumer education to yield improved water-use habits, the use of water-saving devices, fixtures, and appliances and wastewater recycle systems are several alternatives that can be used to produce waste flow reductions. Of these, the use of water-saving devices, fixtures and appliances appears to offer the greatest potential at present. Furthermore, since the major component of residential wastewater emanates from water-carriage toilet usage (Table 1), significant waste flow reductions can be achieved with the use of water-saving toilet devices and fixtures.

As alternatives to the conventional flush toilet, an extensive array of innovative toilet systems are under various stages of development and/or application [3-5,7,9,14-20]. While many of these alternatives are receiving vigorous promotion, to date only limited field investigations have been conducted. As a result, the performance characteristics of many have not been adequately delineated. In many cases, a perspective buyer or regulatory official has been forced to judge the suitability of a system based on insufficient information.

To enhance the existing data base, a field study was initiated at the University of Wisconsin to evaluate the performance of several alternative

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The author is Robert L. Siegrist, P.E., Specialist, Department of Civil and Environmental Engineering, Small Scale Waste Management Project, University of Wisconsin-Madison. March, 1980.

Table 1. Average Residential Waste Flow Characteristics<sup>a</sup>

Activity	Gal/Use	Uses/cap/day	Daily Flow	
			Gal/cap/day <sup>b</sup>	%
Toilet Flush	4.3	3.5	16.2	35
Bathing	24.5	0.43	9.2	20
Clotheswashing	37.4	0.29	10.0	21
Dishwashing	8.8	0.35	3.2	7
Garbage Grinding	2.0	0.58	1.2	3
Miscellaneous	-	-	6.6	14
Total	-	-	45.6	100

<sup>a</sup> Based upon the results reported in [1,10-13]. The results shown are the means of the individual study averages.

<sup>b</sup> Gal/cap/day may not equal gal/use multiplied by uses/cap/day due to difference in the number of study averages used to compute the means shown.

toilet systems. The fixtures under study are very low-volume water carriage toilets which are similar in appearance and function to the conventional water closet, but provide for flush volume reductions as high as 90 percent. The objectives of the study are to identify the magnitude of water savings and waste flow reductions afforded, delineate installation requirements for new and existing dwellings, delineate operation and maintenance requirements, identify the potential for long-term user acceptance, determine potential health hazards, and estimate system costs. This paper contains a discussion of the research accomplished to date including preliminary results.

## MATERIALS AND METHODS

### Toilet System Characteristics

Three commercially manufactured low-flush toilet systems were selected for evaluation in this study. The characteristics of the toilets as determined from the manufacturer's literature and communications are outlined in Table 2, with a photograph of each shown in Figures 1 to 3. The three units selected for study were chosen for a variety of reasons including the

following: 1) their application was suitable to single family residences, 2) they were similar in appearance and function to a conventional toilet, thus requiring minimal habit changes, 3) they offered a spectrum of flushing modes, 4) they appeared to require minimal operation and maintenance, and 5) their costs were not unrealistically high.

#### Study Residence Characteristics

Contacts were made with regulatory and public information agencies to locate at least three residential dwellings interested in participating in this study. Efforts were made to include "typical" dwellings with normal water-using fixtures and one or more children in the residing family. After delineating the characteristics of any interested residences through written questionnaires, three primary study sites were chosen, possessing the characteristics detailed in Table 3. An additional two study sites have also been selected to enable installation and monitoring of the Microphor and Ifö fixtures at a second dwelling. The discussion presented in this paper, however, deals only with the three primary study sites.

#### Toilet System Installation

Installation of the toilet systems was accomplished by local plumbers according to the standard instructions provided by each manufacturer. Each installation was observed by project personnel to characterize the installation requirements. Additional communications with the installers of each unit were also utilized for this purpose.

Table 2. Characteristics of the Low-Flush Toilets Under Study\*

Characteristic	Toilet		
	Microphor	Monogram	Ifö
Flushing Mode	Water Assisted by Compressed Air	Water Assisted by Macerator Pump	Water
Flushing Actuation	Depress/Release Lever	Depress/Release Button	Lift/Release Handle
Resource Requirements:			
Water	0.5 gal/use	0.35 gal/use	1.6 gal/use 0.8 gal/use
Power	Yes	Yes	No
Application Considerations	<ul style="list-style-type: none"> <li>• Compressed Air Req'd.</li> <li>• Standard Rough-in</li> <li>• Water Pressure 20-50 psi</li> </ul>	<ul style="list-style-type: none"> <li>• Power Supply</li> <li>• Standard Rough-in</li> <li>• Water Pressure <math>\geq 20</math> psi</li> </ul>	<ul style="list-style-type: none"> <li>• Non-Standard</li> <li>• Rough-in</li> <li>• Drain Line Slope <math>\approx 3\%</math></li> </ul>
Maintenance	Service Compressed Air Source	Grinder Replacement @ 2-5 yrs	-
Development State	Fully Developed	Prototype	Fully Developed
Manufacturer	Microphor, Inc. Willits, CA.	Monogram Industries, Inc. Venice, CA.	Ifö Sanitaire AB Sweden
Approximate Cost**	\$410 plus compressor	\$1000 <sup>†</sup>	\$240-365

\* Based on manufacturers' literature and communications with manufacturer by project staff.

\*\* Shipping cost additional to cost presented.

<sup>†</sup> Prototype cost shown. Manufacturer's predicted production model cost is approximately \$500.

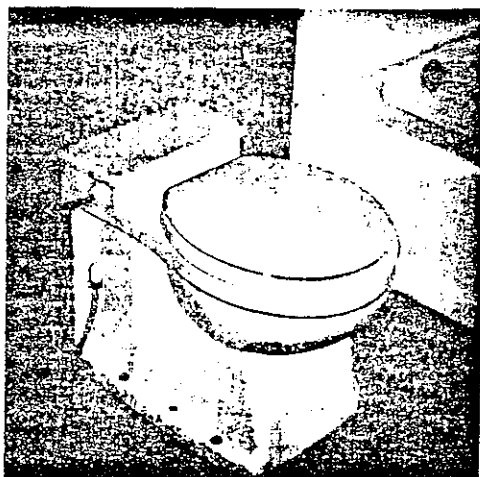


Figure 1. Microphor Low-Flush Toilet

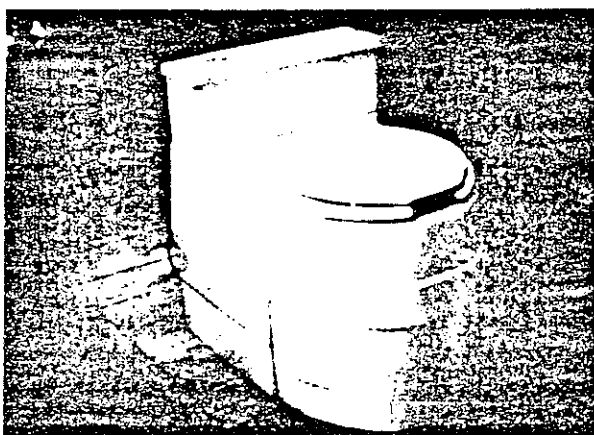


Figure 2. Monogram Low-Flush Toilet

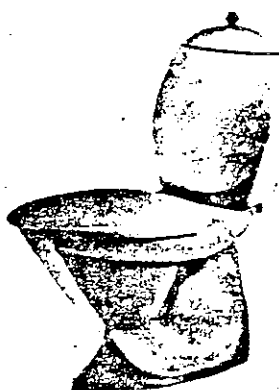


Figure 3. Ifö Low-Flush Toilets  
(6L model on left, 3L model on right)

Table 3. Characteristics of Study Residences

Characteristic	Toilet Unit		
	Microphor	Monogram	Ifö
Site I.D.	1	2	3
Installation	New	Retrofit	Retrofit
Residents			
Adults	2	2	2
Children(Age)	2(4,5)	2(5,8)	1(<1)
Floors	2	1	2
Toilets	2	1	2
Automatic Clotheswasher	Yes	Yes	Yes
Automatic Dishwasher	Yes	No	No
Garbage Disposal	No	No	No
Water Supply	Well	City	Well
Waste Disposal	Holding Tank	City	Septic Tank

#### Waste Flow Reductions

The waste flow reductions achieved through use of the low-flush toilets were determined from water use characterization data collected at each of the sites. This determination was based on the assumption that interior water use was essentially equal to wastewater flow, and was accomplished in one of two ways at each site. For the retrofit installations (sites 2 and 3), water use characterization was accomplished for at least 60 days prior to installation of the low-flush toilets to obtain background data. The water use data collected after installation, was compared to this background data to determine the waste flow reduction actually achieved. For the new-fit installation (site 1), the collection of background data was not possible. An accurate estimate of the waste flow reduction achieved was made using toilet usage data directly measured at the site by comparing the measured waste flow to the waste flow that would have existed if a conventional water-carriage toilet had been in place during the study period.

Characterization of the water use and wastewater flow at each site was accomplished through several means. To measure total water use at each site,

a water meter (Badger Recordall Model 15) was installed on the incoming water supply to the home. The standard register on this meter was modified to provide an electrical switch closure after each 5 gal increment of water use. This was accomplished by connecting a small bar magnet onto the register dial needle and positioning two proximity reed switches (SPST) above it at the 2.5 and 7.5 gallon dial positions. As water was used, the dial needle rotated, and as it passed by each proximity switch, the switch was temporarily closed by the magnet on the needle. This switch closure activated an electrical impulse counter and one channel on a four-channel, strip-chart recorder (Cole Parmer Instrument Co., Model 8364-30). This modified register was tested in the laboratory and field, and found to record flow within 0.5 percent of a similar unmodified register.

Toilet usage was monitored continuously at each site. At sites 1 and 2, a flow-indicating switch (Gems Delaval, Model FS-200, 0.5 gpm actuation) was installed in the water supply line serving each toilet. Each time a toilet was flushed, water flow through the switch caused a switch closure which activated an electrical impulse counter and a second channel on the strip-chart recorder. At site 3 a float switch (Gems Delaval, Model LS 1700) was installed in the toilet tank. Each time a toilet was flushed, the toilet-tank water level dropped, resulting in the temporary closure of the float switch which activated an electrical impulse counter and a channel on the strip-chart recorder.

Toilet water use was measured indirectly by combining the toilet usage data collected with the measured flush volume of each toilet. At sites 1 and 2, the volume of water utilized in flushing was measured with a water meter (Badger Recordall Model 15) installed in the water supply line to the toilet(s). Periodic measurements from the toilet water meters were combined with the toilet usage data from the event counters and chart recorder to determine the flush volume. Each toilet was also calibrated periodically using the toilet water meter to confirm the flush volume determined. At site 3 each toilet was calibrated using the main water meter to identify the volume/flush.

Exterior water use was recorded by the residents at each site on data sheets provided.



### Wastewater Quality Impact

In an attempt to identify the potential impact of flow reduction on wastewater quality, grab samples were periodically obtained from the septic tank at site 3. This was accomplished by submerging a 1 L polyethylene sample bottle (with cap on) into the tank through the manhole over the inlet end at a location approximately 2 ft from the inlet and to a depth of 1.5-2.0 ft beneath the liquid surface. After submergence, the bottle cap was removed and a sample was collected. All samples were transported back to the University of Wisconsin where analyses were performed for physical, chemical and microbiological parameters according to procedures outlined in Standard Methods [21]. As with the water use monitoring, this sampling was performed before and after installation of the low-flush toilets.

### Toilet System Operation and Maintenance

The toilet usage at each site was monitored continuously as described previously. The operation of the mechanical components of the Microphor and Monogram toilet systems were also monitored. Each operation of the air compressor serving the Microphor unit and the macerator pump in the Monogram system was recorded by an electrical impulse counter and an elapsed time indicator. Power use by each system was recorded through a separate kilowatt-hour meter. Any maintenance performed either by the residents or by project staff was recorded in a maintenance log.

### User Reactions

The comments and reactions of the residents at each site to the low-flush toilet systems were recorded on data sheets provided. Further information was gained through discussions with them during periodic site visits.

### Site Preparation

The monitoring equipment was installed during July, 1979. Installation of the Microphor toilets was accomplished during July, 1979. Installation of the Ifö toilets at site 3 occurred in early October, 1979. Installation of the Monogram toilet at site 2 is in progress at this time.

## RESULTS AND DISCUSSION

The preliminary results generated to date in this study are presented in this section. It is emphasized that these results are only preliminary at this time. In addition, the data available for site 2 is limited as the installation of the Monogram toilet at that site is currently in progress.

### Toilet System Installation

#### Microphor Toilets --

The installation of the Microphor toilets was readily accomplished. Installation requirements for the toilet fixture itself were essentially the same as for a conventional water closet. The toilets have standard rough-in dimensions and attach to a three or four-inch diameter closet-flange fitting with wax rings or neoprene gaskets which seal the connection.

A new air compressor was purchased locally according to the specifications recommended by the toilet manufacturer. The compressor was a 1/2 hp unit with a 12-gal reservoir (Dayton Speedaire, Model 1Z280E). This unit was bolted to the floor in a closet adjacent to the second floor bathroom. Connecting the two toilets to the air compressor was accomplished using an installation kit purchased from the toilet manufacturer. The kit contained an air filter-regulator and a length of 1/4-inch diameter nylon tubing with assorted fittings. Running the necessary air lines to the individual toilets from the compressor presented no problems since this was accomplished during construction of the house.

The major difficulty likely to be encountered in installing the Microphor toilets concerns supplying the required compressed air to each toilet fixture. This is really only a problem in retrofit installations, particularly those with a toilet on a second floor.

#### Ifö Toilets --

Retrofitting the Ifö toilets at site 3 was relatively straightforward, taking a total of four man hours. A 6 L/flush unit with concealed trap was installed in the first floor bathroom. The toilet discharge was connected to the existing closet flange and the sewer using a rubber gasket provided

with the toilet, and a 4-inch by 3-inch reducer fitting and a standard wax ring gasket. The toilet fixture was attached to the floor with four, 3-inch long wood screws. Since this fixture was attached to a conventional 12-inch rough-in flange, the rear of the toilet tank was located approximately 7 inches from the wall.

The water supply to the toilet was provided using a 15-inch length of 1/4-inch diameter (ID) chrome stool supply. The water supply fitting on the toilet was 1/2-inch male pipe thread, and was located on the right rear side (viewing fixture from front) of the fixture. A 1/2-inch to 3/8-inch reducer coupling and a 3/8-inch speedy connector were used to join the water supply to the fixture.

A 3 L/flush unit was installed in the second floor bathroom. The toilet discharge was connected to the existing closet flange using a rubber gasket and a reducer fitting provided with the toilet and a standard wax ring gasket. The fixture was attached to the floor using four, 3-inch long wood screws. This retrofit was also made to a 12-inch rough-in flange, and as a result the rear of this toilet was located approximately 9 inches from the wall. The water supply to this toilet fixture was provided as for the 6 L/flush unit installed on the first floor.

The major difficulty posed in retrofitting the Ifö fixtures is the wall to toilet tank separation that results. This might be aesthetically or physically unacceptable in some applications. Alteration of the existing sewer line might be possible to avoid this separation in some retrofit applications, but this would have to be evaluated on a case by case basis. For new installation, installation of the Ifö fixtures should pose no difficulties. The rough-in dimensions are 4 inches and 6 inches for the visible trap and concealed trap models, respectively. Connection of the toilet discharge to the sewer can be readily accomplished using the rubber gasket provided with each toilet which attaches to a section of 4-inch diameter sewer pipe protruding 2 to 2 1/2 inches above the finished floor.

#### Monogram Toilets --

The Monogram toilet installation has not been completed yet, and the following comments regarding its installation have been made based upon an inspection of the unit. The discharge from the toilet should attach directly

to a standard closet flange with a 12-inch rough-in. Standard wax rings or neoprene gaskets appear suitable to seal the connection. The water supply to the toilet attaches to the fixture at the rear of the unit on the left side. The power supply required by the unit is provided through an electrical cord which exits the rear of the unit and plugs into any standard 115-volt outlet.

#### Waste Flow Reductions

The water use characterization data collected to date is summarized in Table 4. Also presented are the estimated data for the before-installation period at site 1 and the after-installation period at site 2. These estimates were made using the actual measured toilet usage data at each site and either typical toilet flush volumes as reported in Table 1 (site 1) or the low-flush fixture flush volume as measured in the Laboratory (site 2). Non-toilet water uses were assumed to remain constant in making these estimates.

The toilet usage data collected to date is also summarized in Table 4. The mean daily per capita toilet usage was measured at 2.6, 6.6, and 2.1, respectively for sites 1-3. To facilitate comparison of these results to those determined by previous investigators, the mean daily toilet usage determined for each individual home monitored in several previous investigations [1,10,11,13] was analyzed. In total, data was available for 29 homes ranging in size from two to ten residents. A statistical analysis of the data yielded the following results:

Mean toilet use .....	3.7 uses/person/day
Standard Deviation .....	2.1
95% Confidence Interval ...	2.9-4.5
Range .....	1.4-9.1

The results collected to date in this study are well within the range of previously reported data.

The average waste flow reductions achieved at each of the study sites are presented in Table 5. As shown, reductions in total daily flow varying from 15 to 34 percent were achieved. Of the flow reduction indicated in Table 4 for site 3, approximately 9 percent was due to the installation of

Table 4. Water Use and Waste Flow Characteristics\*

Characteristic	Toilet Unit					
	Microphor		Monogram		Ifö	
Data Period**	Before <sup>†</sup>	After	Before	After <sup>††</sup>	Before	After
Interior Water Use, gpd						
Days of Data	-	90	130	-	61	20
Mean	(119)	79	182	(120)	101	77
S.D.	-	55	90	-	52	51
95% Conf.Int.	-	68-91	166-198	-	88-114	54-101
Range	-	15-255	0-570	-	0-230	15-240
Toilet Usage, gal/use						
	(4.3)	0.45	2.7	0.35	4.0	1.46 <sup>#</sup>
Toilet Usage, npd						
Days of Data	-	90	130	-	61	20
Mean	-	10.4	26.2	-	6.1	6.5
S.D.	-	4.9	5.6	-	3.1	4.0
95% Conf.Int.	-	9.4-11.4	25.2-27.2	-	5.3-6.9	4.6-8.4
Range	-	3-30	0-40	-	0-15	1-16
Toilet Water Use, gpd						
Days of Data	-	90	130	-	61	20
Mean	(44.7)	4.7	70.8	(9.2)	24.4	9.5
S.D.	-	2.4	15.1	-	12	6.2
95% Conf.Int.	-	4.2-5.2	68.2-73.4	-	21-27	6.7-12.2
Range	-	1-15.7	0-108	-	0-59	1.6-22
% of Interior	(38.0)	5.9	39.0	(7.7)	24.0	12.3

\* Based on actual daily measurements unless otherwise noted below.

\*\* Referenced to installation of low-flush toilets. At site 3, faucet aerators and a reduced flow showerhead were also installed, reducing the flow rates by approximately 25-55%.

<sup>†</sup> Estimated utilizing the measured toilet usage data and a flush volume of 4.3 gal.

<sup>††</sup> Estimated utilizing the measured toilet usage data and a flush volume of 0.35 gal as measured in the laboratory.

<sup>#</sup> Actual flush volume which is average of 3 L and 6 L models based on actual differential usage at site 3.

faucet aerators and a low-flow showerhead. All flow reductions presented in Table 5, however, are those resulting solely through use of the low-flush toilets.

The waste flow reductions predicted for typical residential dwellings with low-flush toilets are outlined in Table 6. The predictions shown are based upon installation in a typical residential dwelling with four residents producing a total daily wastewater flow of 200 gpd, of which 35 percent or 70 gpd is produced through usage of two, conventional water closets. Waste flow reduction in the 30 percent range can be expected with several of the low-flush fixtures. These predictions are in general agreement with the reductions actually measured in this study.

#### Wastewater Quality Impacts

Analyses of grab samples collected from the septic tank utilized at site 3 are presented in Table 7. While limited, the data collected to date have indicated a mean increase in all pollutants measured. Based on a simple mass balance, the 24 percent reduction achieved at site 3 should have produced a concentration increase of approximately 32 percent. As shown in Table 7, the mean concentration increase actually measured varied from 4 to 90 percent. It is interesting to note that the largest concentration increase was measured for total Kjeldahl nitrogen, which is contributed primarily in toilet wastewater. Additional data is being collected to confirm the concentration increases measured to date.

Table 5. Average Water Use and Waste Flow Reductions\*, Percent

Characteristic	Toilet Unit		
	Microphor	Monogram	Ifö
Flush Volume	90%	87%	64%
Toilet Water Use	90%	87%	61%
Interior Water Use and Waste Flow	34%	34%	15%

\* Based on the results presented in Table 4. Waste flow assumed approximately equal to interior water use. The flow reductions shown, resulted solely through use of the low-flush toilets.

Table 6. Predicted Waste Flow Reductions for Typical Residential Dwellings with Low-Flush Toilet Fixtures

Characteristic	Conventional Toilet Fixtures		Low-Flush Toilet Fixtures			
	Standard (A)	Water-Saver (B)	Microphor	Monogram	Ifö (3L)	Ifö (6L)
Flush Volume						
gal/use	5.0	3.5	0.45	0.35	0.79	1.60
% Reduction from (A)	0	30	91	93	84	68
% Reduction from (B)	-	0	87	90	77	54
Daily Waste Flow*						
No reduction, gpd	200	-	-	-	-	-
Reduction, gpd	0	21	64	65	59	48
Reduction, %	0	10.5	31.9	32.6	29.4	24.0
Reduced flow, gpd	200	179	136	135	141	152

\* Reductions based on a total daily flow of 200 gpd with 70 gpd or 35% contributed by conventional toilet usage of 3.5 uses/person/day @ 5 gal/use.

Table 7. Flow Reduction Impact on Septic Tank Concentrations at site 3\*

Parameter	Units	Before Flow Reduction			After 24% Flow Reduction			Change in Mean (%)
		Samples	Mean	Range	Samples	Mean	Range	
BOD <sub>5</sub>	mg/L	5	224	94-325	2	234	213-256	+4
COD	mg/L	5	330	87-572	2	569	534-604	+72
TKN	mg-N/L	3	50	21-92	2	95	82-107	+90
Turbidity	NTU	4	56	42-80	2	89	43-135	+59

\* Based upon analyses of grab samples obtained from the septic tank at a location 2 ft from the inlet and at a depth of 1.5 ft below liquid surface.

### Toilet System Operation and Maintenance

Monitoring of the air compressor serving the Microphor toilets at site 1 yielded the following data:

Air compressor cycle length .... 2.0 minutes

Frequency of operation ..... 1:14.4 toilet uses, or  
1:1.4 days

Power consumption ..... 0.0016 kwh/toilet use

Based on this data, calculations for operation of the compressor for a period of one year were made. This analysis indicated the compressor would operate approximately 264 times, for a total of 8.8 hours and consume slightly over 6 kwh of electricity. Although supportive data has not been collected yet, cursory calculations indicate that the power consumption of the Monogram toilet will be similar. The Ifö toilets have no mechanical components and thus no power consumption.

To date, no maintenance has been required nor performed to any of the toilet fixtures, themselves. The air compressor serving the Microphor toilets has required some attention however. A relatively minor problem was encountered shortly after installation. After the 12 gal air reservoir was pressurized and the compressor shut off, the air would slowly leak out of the reservoir. All the air line connections were checked and the check valve-unloader was replaced, but the problem persisted. The cause of the problem was finally traced to vibration in the copper tubing used to connect the compressor head to the air reservoir. Installation of nylon tubing in place of the copper tubing finally solved the problem. After approximately six months of operation, the air compressor received minor maintenance from the homeowner. The oil was checked and found to be clean and at the full level. The air filter was also found to be clean.

### User Reactions

The reactions of the residents using the Microphor and Ifö toilets have been very positive. The residents have reported that the toilets have performed equal to a conventional water closet. The flushing capability has been very satisfactory. Double-flushing has not been necessary to clear the bowl and typical cleaning frequencies have been sufficient to keep the



bowl stain-free.

An adverse reaction to the Ifö toilets concerned the small volume of water retained in bowl. It was insufficient to clean a soiled diaper in the manner the residents had been accustomed to with a conventional water closet. It is likely that this reaction would be expressed of very low-flush toilets in general. A second adverse reaction to the Ifö toilets concerned the large separation distance between the rear of the toilet and the wall which results after retrofitting the unit for a conventional water closet.

### Cost Analysis

The costs to purchase, install and operate each of the low-flush toilets as well as two types of conventional water closets are outlined in Table 8. These costs are based on those actually encountered in this study and estimates from the equipment manufacturers and local plumbers. An abbreviated cost analysis was performed to identify the actual increased cost that would be incurred if the low-flush toilet fixtures were used in place of conventional fixtures to 1) reduce holding tank pumping costs, 2) remedy an overloaded soil drainfield, and 3) reduce the size of a new soil drainfield. The results of this analyses appear in Table 9. While it is recognized that the data presented are only cursory estimates, it is interesting to note that the payback period for the holding tank application was less than 2 years for all of the toilet fixtures. With two exceptions, the other two applications would require an additional investment that would not be returned as a result of waste flow reduction. However, additional benefits that might result such as any additional land area for development that would have otherwise been used for drainfield and reduced water supply costs must also be considered in a complete cost analysis.

Table 8. Estimated Low-Flush Toilet Fixture Costs\*

Cost Item	Conventional Toilets	Low-Flush Toilets			
		Microphor	Monogram	6 L Ifö	3 L Ifö
<u>Capital Cost, \$</u>					
Fixtures (2)	220	820	1000**	730	480
Ancillary Equipment					
Air compressor	-	200	-	-	-
<u>Installation Cost, \$</u>	60	150	60	70	70
Subtotal	280	1170	1060	800	550
<u>Operating Cost, \$</u>					
Power	0	0.30/yr	0.30/yr	0	0
<u>Maintenance Costs, \$</u>	?	?	?	?	?

\* Based on installation in a new dwelling with two fixtures.

\*\* Projected cost of production model toilet at approximately \$500 per fixture.

#### SUMMARY

A demonstration project is in progress at the University of Wisconsin to evaluate the performance of several low-flush toilet fixtures under field conditions. The fixtures under study are similar in appearance and function to the conventional water closet, but yield a flush volume reduction as high as 90 percent (Table 1). The low-flush fixtures have been installed in residential dwellings (Table 2) and monitoring of the performance of the toilet systems is in progress. The preliminary results generated to date are outlined below.

1. The three low-flush toilet fixtures under study have flush volumes of 0.35 to 1.60 gal per use. These volumes are 63 to 81 percent less than the 4.3 gal typically employed by a conventional water closet (Table 1).

2. Installation of all three fixtures can be readily accomplished in a new dwelling. Retrofitting the Microphor toilet may pose difficulties in running the required air supply line from the compressor to each fixture, particularly where toilets on two different stories are involved.

Table 9. Cost Analysis of Low-Flush Toilet  
Fixtures in Selected Applications\*

Application	Parameter	Toilet Fixture				
		Conv. Water- Saver	Microphor	Monogram	Ifö (6 L)	Ifö (3 L)
Base Conditions	• Increased Cost over conventional toilet, \$	0	890	780	520	270
	• Daily flow reduction, %	10.5	31.9	32.6	24.0	29.4
	• Yearly Flow reduction, gal	7665	23360	23720	17520	21535
Holding Tank	• Pumpage Cost savings @ 2¢/gal	\$153/yr	\$467/yr	\$474/yr	\$350/yr	\$431/yr
	• Payback period, yr	0	1.9	1.6	1.5	0.6
Reduced Drainfield Sizing (New)	• Drainfield cost savings @ \$1.25/ ft <sup>2</sup> , 1000 ft <sup>2</sup> req'd with no Q reduction	131	399	408	300	368
	• Net increased cost	-131	+491	+372	+220	-98
Remedy Drainfield Hydraulically Overloaded by 30% (retrofit)	• Drainfield cost savings @ \$1.25/ ft <sup>2</sup> , 300 ft <sup>2</sup> . Expansion area needed for 30% overload	- <sup>†</sup>	325	325	- <sup>†</sup>	325
	• Net increased cost	- <sup>†</sup>	+845	+735	- <sup>†</sup>	+225

\* Cursory estimates based on data presented in Table 6 and 8, and assumptions presented in this table.

\*\* For retrofit installations, the cost of installation of conventional water closets (\$280) must be added to the net increased cost to yield the true increased cost for those installations.

<sup>†</sup> Does not provide 30% flow reduction.

Retrofitting the Ifö toilets for a conventional water closet results in a separation of 6 to 9 inches from the rear of the toilet tank to the wall which may be physically or aesthetically unacceptable in some applications. Alteration of the drainage system to remedy this separation might be possible.

3. Reductions in total daily flow of 34, 34, and 15 percent have been determined for the Microphor, Monogram and Ifö toilets, respectively (Table 5).

4. A flow reduction of 24 percent at site 3 resulted in substantial increases in the concentration of measured pollutants in the contents of the septic tank at that site (Table 7).

5. The power consumption by the low-flush toilets was found to be insignificant. The Microphor toilet power consumption, due to the air compressor, was measured to be 0.0016 kwh/use. Power consumption for the Monogram toilet, due to the macerator pump, was estimated to be similar to that of the Microphor. The Ifö toilets have no power consumption.

6. User reaction to the Microphor and Ifö toilets has been very positive. The units have proven to be capable of clearing the bowl of waste materials with a single flush. No increase in cleaning frequency to keep the bowls stain-free has been reported.

7. An abbreviated cost analysis was performed for applications where the low-flush fixtures were employed to 1) reduce holding tank pumping costs, 2) remedy an overloaded soil absorption field and 3) reduce the size of a new soil absorption field (Tables 8 & 9).

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