

Enhanced Street Sweeping



Street Sweeping (courtesy of City of San Jose).

Summary

Enhanced street sweeping involves increasing sweeping frequency, targeting high trash generating areas and modernizing street sweeping equipment. Multiple sweeper designs exist including: (1) mechanical sweepers; (2) vacuum-assisted wet sweepers; (3) regenerative air sweepers; and (4) vacuum-assisted dry sweepers (Table 1). The expected lifespan of a street sweeper is 4 to 7 years. Street sweeping activities do remove significant quantities of trash from roadways, but it is unclear how much trash is prevented from entering receiving waters. Capital costs of purchasing modern equipment can range from \$100,000 to \$250,000+ (\$2005)(Schilling 2005). The potential inability to further restrict parking in urban areas may present a major limitation to increasing street sweeping frequency.

Description/Design

Street sweeping can minimize pollutant transport to receiving waters. Sediment, debris and trash are the targeted pollutants, but removal of other pollutants may be accomplished. Street sweeping may also prevent pipes and outlet structures within stormwater detention facilities from becoming clogged with debris and trash. Typically, commercial areas are swept more frequently than residential or industrial areas. For example, arterial, commercial and bike routes are swept either twice per month or weekly in the City of San Jose (City of San Jose 2007a), while residential areas are swept once a month on a day immediately following garbage collection (City of San Jose 2007b). Enhanced street sweeping involves increasing street sweeping frequency or focusing efforts in high trash generating neighborhoods. Although sweeping can be performed on any paved surface (e.g., roadways, parking lots and sidewalks), targeting high trash generating areas (commercial business districts, industrial sites, and intensely developed areas near receiving waters) and adjusting the timing/frequency of sweeping are considered enhanced street sweeping practices. Other common

IC-1 Institutional Control

Street Sweeper Designs and Practices

- Mechanical sweeper
- Vacuum-assisted wet sweeper
- Regenerative air sweeper
- Vacuum-assisted dry sweeper
- Tandem sweeping

Implementation Point

- In Street ✓
- Start of Pipe
- In Pipe
- End of Pipe
- In Creek
- Dispersed

enhanced street sweeping practices may include more frequent sweeping during August to October (City of Los Angeles 2002) or increasing sweeping before and during the rainy season (City of Los Angeles 2002). Within the Bay area, some cities may have to modify their street sweeping schedules to address the heavy leaf-fall season. For example, the City of Palo Alto sweeps streets at least weekly. However, during the fall leaf season (October through January), the City may be off schedule due to an increased work load and holidays. As a result, the City of Palo Alto recognized that weekly sweeping is impractical during these months (City of Palo Alto 2007). Street sweeping is also ideal in urban environments where space for structural stormwater controls is limited.

Currently, multiple sweeper designs exist including: (1) mechanical sweepers; (2) vacuum-assisted wet sweepers; (3) regenerative air sweepers; and (4) vacuum-assisted dry sweepers (Table 1). The expected lifespan of a street sweeper is 4 to 7 years. Vacuum-assisted and regenerative air sweepers are generally better than mechanical sweepers at removing finer sediments, while mechanical sweepers are better at removing larger debris (i.e., trash) (FHWA 2007).

Table 1. Street sweeper design and practices.

Type	Description
<i>Mechanical sweepers</i>	The most common type of street sweeper. Involves a number of rotating brushes sweeping litter into a collection chamber. A rotating gutter broom removes particles from street gutters and a water spray controls dust. The particles removed are placed in front of a cylindrical broom that rotates to carry the material onto a conveyor belt and into a storage hopper.
<i>Vacuum-assisted sweepers</i>	This design uses a gutter broom to push particles from the street into the path of a vacuum intake that transports the dirt to the hopper. The transported dirt is usually saturated with water.
<i>Regenerative air sweepers</i>	Air is blown onto the pavement and a vacuum removes the mobilized particles. They include a dust separation system. Regenerative air sweepers, which are like mechanical vacuum sweepers but use recirculated air to blast the pavement, dislodging litter before it is swept by rotating brushes towards a vacuum for pick-up. This sweeper also uses water sprays for dust suppression.
<i>Vacuum-assisted dry sweepers</i>	These units combine the elements of a tandem sweeper into a single unit. This system is useful at industrial sites where it is necessary to have complete removal of particulate matter without leakage. A continuous filtration system prevents fine particulates from leaving the unit.
<i>Tandem sweeping</i>	This practice employs a mechanical sweeper (a broom and conveyer belt system) followed immediately by a vacuum-assisted sweeper.

Performance and/or Effectiveness

There is little published data on how much trash and litter is removed by street sweeping, or on how changing sweeping operations affects trash removal (CWP 2007). During the 1980's, USEPA supported a series of studies, the Nationwide Urban Runoff Prevention Program (NURP), to determine whether street sweeping prevented sediment associated contaminants from entering the storm drain system. The general consensus was that street sweeping was not an ideal best management practice (BMP). However, improvements in sweeper technology have caused a recent reevaluation of their performance. Recent estimates are that new vacuum-assisted dry sweepers may achieve a 50-88% overall reduction in the annual sediment loading for a residential street, depending on sweeping frequency (Sutherland and Jelen 1997). It is important to note that the focus of these studies is not on preventing trash from entering waterways, but on fine sediments and their associated pollutants (CWP 2007).

Street sweeping operations do remove substantial quantities of trash from roadways. From FY 2003-2004 through FY 2005-2006, the total volume of material removed by SCVURPPP Co-permittees during street sweeping operations ranged from 57,933 cy to 82,717 cy of material. In addition, the total volume of material removed in Contra Costa County during 2001 until 2006 ranged from 26,407.6 cy to 33,984.2 cy (EOA, Inc., 2007). One percent (by volume) of the material removed was trash (EOA, Inc. 2007). As a result, street sweeping operations in Contra Costa County annually prevented on average 306.5 cy of trash from reaching local waterways.

Changes to Frequency and/or Timing

There is some evidence that suggests that the frequency of sweeping could increase the amount of litter removed. For example, street sweeping conducted two to three times daily in the commercial business district of Cape Town, South Africa removed as much as 99% of the total litter load (Marais & Armitage, 2003). On the other hand, sweeping selected streets in Springs, South Africa once a day removed approximately 83% (Armitage et al, 1998 in Armitage 2001).

Marais & Armitage (2004) developed a computer model of how street sweeping performance changes in response to frequency. Figure 1 shows that the predicted performance of street sweeping is based on the ratio of average days between street sweeping to the average days between significant rainfall events (from about 10 mm upwards). The model output¹ (Figure 1) indicated that once street sweeping drops below the frequency of significant rainfall events (the inter-event dry period), it intercepts less than half of the litter deposited in the streets (Marais & Armitage 2004). This led the authors to conclude that inter-event dry period is a critical factor in assigning street sweeping frequency.

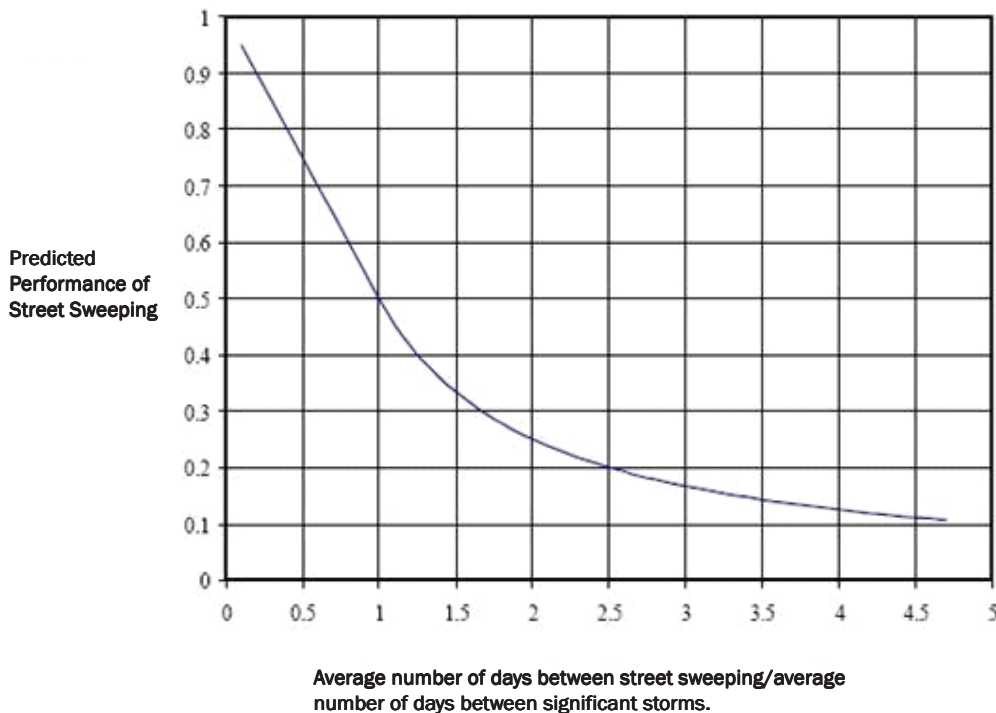


Figure 1. Modeling results for the maximum expected performance of street sweeping (Armitage 2001).

¹ This model assumes that street sweeping is able to remove all litter from the road; significant rainfall events are large enough to mobilize all litter remaining on the road; and catch basins have large enough openings to accommodate the largest pieces of litter. In reality, some litter will be inaccessible (e.g., "hidden" under vehicles), few rainfall events are large enough to carry every piece of litter to the catch basins, and the litter frequently accumulates at catch basins without falling into them even though the opening is nominally large enough.

An analysis of street sweeping data from certain cities in Alameda County, CA indicated that increasing street sweeping frequency and/or changing fixed sweeping schedules increases the volume of material removed. For example, the Cities of Hayward, San Leandro and Union City had statically significant increases in the total volume of material removed and the number of miles swept after implementing program changes. However, these changes did not lead to statically significant increases in removal rates (total volume collected vs. total miles swept) (EOA, Inc., 1999).

Some researchers have suggested that it is not simply the frequency that is critical to increasing performance, but also the timing of street cleaning. For example, an Australian study recorded the amount of trash generated within a 918.6 ft strip of a shopping center. Observations started at 5:15 AM, immediately after [daily] street sweeping operations and ended at 6:30 PM. The data indicated that the rate of accumulation of litter was highest between 8:00 AM and 5:00 PM, with litter accumulation effectively ending around 5:00 PM (Walker and Wong 1999). This schedule leaves twelve hours during which trash can be remobilized by rain or wind and potentially enter the storm drain system before the next round of street sweeping (Walker and Wong 1999).

Effectiveness Study Results

While many studies have examined the effectiveness or performance of street sweepers, the majority have focused on the removal of fine particles, sediment-associated pollutants and nutrients. A few studies have specifically examined the effectiveness of street sweepers with respect to trash or how changing the frequency/timing will impact effectiveness. Nilson et al. (1997) (cited in Walker and Wong 1999)² assessed the effectiveness of street sweeping for trash removal in stormwater. For this study, three similar streets were swept at different intervals. Catch baskets were placed in curbside storm drains to collect trash and debris missed by the sweeper. Sweeping frequency for the study streets was the following: every day, once a week and not at all. During the study, pollutants trapped in the baskets were removed and quantified weekly (Walker and Wong 1999). The results of the study show little correlation³ between the frequency of sweeping and the trash and debris load collected in the catch baskets. The study found that a considerable amount of trash and debris entered the storm drain system during intense rain, wind or both, irrespective of the nature of the street sweeping program (Walker and Wong 1999).

During its Litter Management Pilot Study, Caltrans conducted an assessment of the effectiveness of various BMPs, including street sweeping, for preventing litter from entering the storm drain system (Lippner et al. 2001). For this study, mechanical sweepers were used weekly in treatment areas and monthly (typical Caltrans schedules) in control areas. Sweepers were operated at manufacturer's recommended speed (5 miles per hour). This study used a paired watershed approach, with four study sites, each with three replicate pairs of catchment areas. Each catchment drained to a single pipe outfall, which had a monitoring net at the outfall. The testing was conducted over two rainy seasons (1998 - 1999 and 1999 - 2000). The difference between the treatment and control were expressed as a percent of the control (Table 2).

The effectiveness was expressed as the apparent reduction in litter discharged from treatment outfalls compared to control outfalls. Thus, negative values of apparent reduction indicate that more litter discharged from the treatment outfalls than from the control outfalls (Lippner et al. 2001).

Table 2. Mean apparent reduction in litter entering the storm drain system due to increased frequency of street sweeping (Lippner et al. 2001).

	Avg Collected Dry Weight (kg/ha-yr)		Avg Collected Volume (liters/ha-yr)		Avg Count (items/ha-yr)	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Control	9.4	16.8	109	104.9	15272	17208
Treatment	12.1	26.7	103.5	101.4	16066	21544
Apparent Reduction	-29%	-59%	5%	3%	-5%	-25%

² There is no information on the type of sweeper used or how long the study lasted.

³ The exact statistic is not given in the text.

Results from the study varied depending on which unit of analysis was examined (Table 2). For example, if analyzed using volume, increasing the frequency of street sweeping decreased the amount of litter entering the storm drain system. However, the opposite conclusion is drawn if analyzed solely by weight⁴ (Table 2). When all the data were pooled and statistically analyzed regardless of their units⁵, there were no significant differences between control and treatment (Lippner et al. 2001). Therefore, the results from this study do not support the idea that increasing frequency would necessarily divert more litter away from the storm drain system.

Improving/Modernizing Sweeping Equipment

Earlier studies conducted for NURP indicated that the performance of mechanical sweepers was poor for removing fine particles from roadways (USEPA 1999). The most recent technology is a vacuum-assisted dry sweeper originally developed by Enviro Whirl Technologies, Inc. A computer model developed by Sutherland and Jelen (1997) reported that this sweeper type could remove 70% of particles less than 63 μ m and up to 96% of pollutants larger than 6370 μ m (Table 3). As more chemical pollutants are associated with fine particles, managers would likely have to make a choice between removing more trash sized particles vs. more fine particle associated contaminants.

Table 3. Predicted street sweeping effectiveness for various particle sizes by technology (Sutherland and Jelen 1997).

Particle Size Range μ m	Street Sweeping Technology Effectiveness (%)				
	NURP era Mechanical	Newer Mechanical	Tandem Sweeping	Regenerative Air	Enviro-Whirl
<63	44	100	93	32	70
125	52	100	95	71	77
250	47	92	93	94	84
600	50	57	89	100	88
1000	55	48	84	100	90
2000	60	59	88	100	91
6370	78	81	98	94	92
>6370	79	70	87	92	96

Factors Affecting Street Sweeping Performance

The frequency of street sweeping is determined by need, the number of miles to be served, and local budget constraints. Sweeping programs tend to be implemented city-wide, not just in areas serviced by storm drains. Frequent, late fall sweepings are essential in areas with sustained winter rains (USEPA 1999). The performance of any street sweeping activity is in part dependent on the equipment used and the environmental and geographic conditions (e.g. wind and presence of parked vehicles). However, the performance of individual sweeping mechanisms can be a relatively insignificant factor in the overall performance of street sweeping operations unless other factors (e.g., street parking) are addressed (Walker and Wong 1999). According to Walker and Wong (1999), the performance of street sweeping programs depend more on land-use activities, the inter-event dry period, street sweeping frequency and timing, access to source areas and sweeper operation than the actual street sweeping mechanism (Walker and Wong 1999). These factors also influence the deposition, accumulation and removal rates of pollutants on street surfaces. Physical features which include the degree of catchment imperviousness and the hydraulic characteristics of street surfaces can also influence the performance of street sweeping. As a result, these factors require consideration before a thorough assessment of street sweeping for stormwater pollution control can be achieved (Walker and Wong 1999).

⁴ A correlated conclusion might be that street sweepers are better at removing large, lighter trash items (e.g., plastic bags) but worse at removing small, heavier trash items (e.g., batteries).

⁵ The pooled data from all control sites were compared to the pooled data from all treatment sites using the Wilcoxon Rank Sum Test. At the 5% level, the null hypothesis (i.e., the amount of litter collected by street sweeping twice weekly would be the same as sweeping once monthly) could not be rejected.

In practice, the performance of street sweeping for trash removal is influenced by a number of factors including: access to the street load, operator skill, sweeping speed, sweeping mechanism, time of day sweeping is conducted and weather conditions (Walker and Wong 1999). Ultimately, Walker and Wong (1999) conclude that street sweeping will continue to meet other municipal objectives (street cleanliness and aesthetics). However, there is little evidence that there will be significant improvements in stormwater quality with respect to trash resulting from changing street sweeping practices.

Costs

The largest cost associated with street sweeping is the capital costs of purchasing the equipment, which can range from \$100,000 to \$250,000+ (\$2005) (Schilling 2005). Total costs associated with sweeping operations can differ depending on the technology used (Table 4). Costs will also depend on sweeping frequency, number of cars on the street, degree of enforcement of parking regulations, volume of litter, and the types of labor and machinery employed. Fall sweeping programs in areas with significant leaf fall will also have additional costs. The standard hopper of a typical sweeper is about 3.5 cubic yards. Sweeping certain streets in neighborhoods with mature trees could quickly fill the hopper. As a result, numerous trips are required to sweep and haul collected materials away (Metropolitan Council 1994). During the fall months, Bay area cities have had to increase labor hours devoted to street sweeping.

Table 4. Estimated costs associated with two different sweeping technologies (USEPA 1999).

Features	Sweeper Type	
	Mechanical	Vacuum Assisted
Life (years)	5	8
Purchase price (\$2005)	100,000	200,000+
Operation and maintenance costs (\$2005/curb mile)	40	20
Annualized Sweeper Costs (\$2005/curb mile/year) with a frequency of:		
Weekly	2,235	1,260
Bi-weekly	1,120	630
Monthly	520	290
Four times per year	170	100
Twice per year	90	50
Annual	45	25

Pros

Street sweeping in San Francisco Bay area counties has been shown to prevent large quantities of trash from entering the storm drain system. Many cities perform street sweeping activities as part of their routine municipal activities. Therefore, optimizing some aspects of street sweeping could be done with relative ease which would result in reductions of trash to the storm drain system.

Cons

Purchasing new street sweeping equipment requires a significant investment of capital and a yearly operation and maintenance budget. Sweepers have a useful life of approximately 4 to 7 years. The potential inability to further restrict parking in urban areas may present another limitation to increasing street sweeping frequency. Additional limitations include training sweeper operators and the lack of solid evidence regarding the level of trash-related pollutant removal. Mechanical sweepers have greater requirements for maintenance than vacuum-assisted and regenerative sweepers since they possess more moving parts that require periodic replacement. Water-based sweepers require water loading, resulting in reduced operational time (Gordon and Zamist 2006). Mechanical

sweepers can create large amounts of dust, while regenerative air sweepers can be very noisy. There exists trade-offs between street sweeper types (noise, effectiveness of removal of particles of different sizes). There is little evidence to support the idea that optimizing street sweeping will dramatically reduce trash loading to the storm drain system.

References

- Armitage, N. 2001. The removal of urban solid waste from stormwater drains. www.unix.eng.ua.edu. (Access date April 2007).
- City of Los Angeles 2002. High Trash-Generation Areas and Control Measures. City of Los Angeles Department of Public Works, Watershed Protection Division. January 2002. 30 pgs.
- City of Palo Alto 2007. Regular Street Sweeping Schedules. www.city.palo-alto.ca.us/living/news/details.asp?NewsID=698&TargetID=41. (Access date August 2007).
- City of San Jose 2007a. Street Sweeping, Department of Environmental Services. www.sjrecycles.org/residents/street_sweeping.asp. (Access date August 2007).
- City of San Jose 2007b. Street Maintenance- Street Sweeping. Department of Transportation. www.sanjoseca.gov/transportation/sm_streetsweeping.htm. (Access date August 2007).
- CWP 2007. Pollution Prevention Fact Sheet: Parking Lot and Street Cleaning. Centre for Watershed Protection. www.stormwatercenter.net/Pollution_Prevention_Factsheets/ParkingLotandStreetCleaning.htm (Access date April 2007).
- EOA, Inc. 1999. Analysis of Street Sweeping Data. Prepared for Alameda Countywide Clean Water Program. June 1999. 57 pgs.
- EOA, Inc. 2007. Estimating Constituent Load Removals from Street Sweeping Activities in Contra Costa County, CA. Development of Typical Concentration Values of Concern. Prepared for Contra Costa Clean Water Program. March 9, 2007. 21 pgs.
- FHWA 2007. Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring Fact Sheet - Street Sweepers United States Department of Transportation, Federal Highway Administration. www.fhwa.dot.gov/environment/ultraurb/3fs16.htm (Access date June 2007).
- Gordon, M., and R. Zamist 2006. Municipal best management practices for controlling trash and debris in stormwater and urban runoff. www.plasticdebris.org (Access date April 2007).
- Lippner, G., J. Johnston, S. Combs, K. Walter, D. Marx 2001. Results of the Caltrans Litter Management Pilot Study. Presented At: California Water Environment Association (CWEA), 72 nd Annual Conference, Sacramento, California, April 16-19, 2000 (included in conference proceedings).
- Marais, M. & N. Armitage 2003. The measurement and reduction of urban litter entering stormwater drainage systems. Water Research Commission Report No. TT211/03, Pretoria, South Africa.
- Marais, M. & N. Armitage 2004. The measurement and reduction of urban litter entering stormwater drainage systems: Paper 2 – Strategies for reducing the litter in the stormwater drainage systems. Water SA Vol. 30 (4): 483 – 492.
- Metropolitan Council 1994. Metropolitan Council's Best Practices for Street Sweeping. Report No. 71-94-020A. www.worldsweeper.com/Street/BestPractices/metrostudy.html [Access date June 2007]. 60 pgs.
- Nilson, B., N. Silby, JR Argue 1997. An Investigation into Source Control of Gross Pollution, Submitted at the 8th National Local Government Engineering Conference. *cited in* Walker and Wong, 1999.
- Schilling, JG. 2005. Street Sweeping- Report No. 1, State of the Practice. Prepared for Ramsey-Washington Metro Watershed District (<http://www.rwmwd.org>). North St. Paul, Minnesota. June 2005. 45 pgs.
- Sutherland, RC and SL Jelen 1997. Advances in Modeling the Management of Stormwater Impacts. Volume 5, Chapter 8. W. James, Ed. Guelph Canada. ISBN 0-9697422-7-4. 12 pgs. p 179-190.
- USEPA 1999. Preliminary Data Summary of Urban Storm Water Best Management Practices. EPA-821-R-99-012 Office of Water. Washington, DC 20460 August 1999. 216 pgs.
- USEPA 1999. Combined Sewer Overflow Management Fact Sheet Pollution Prevention United States Environmental Protection Agency Office of Water Washington, D.C. EPA 832-F-99-038. September 1999.
- Walker, TA, and THF, Wong 1999. Effectiveness of Street Sweeping For Stormwater Pollution Control. Technical Report. Report 99/8. December 1999. Cooperative Research Center for Catchment Hydrology. 40 pgs.