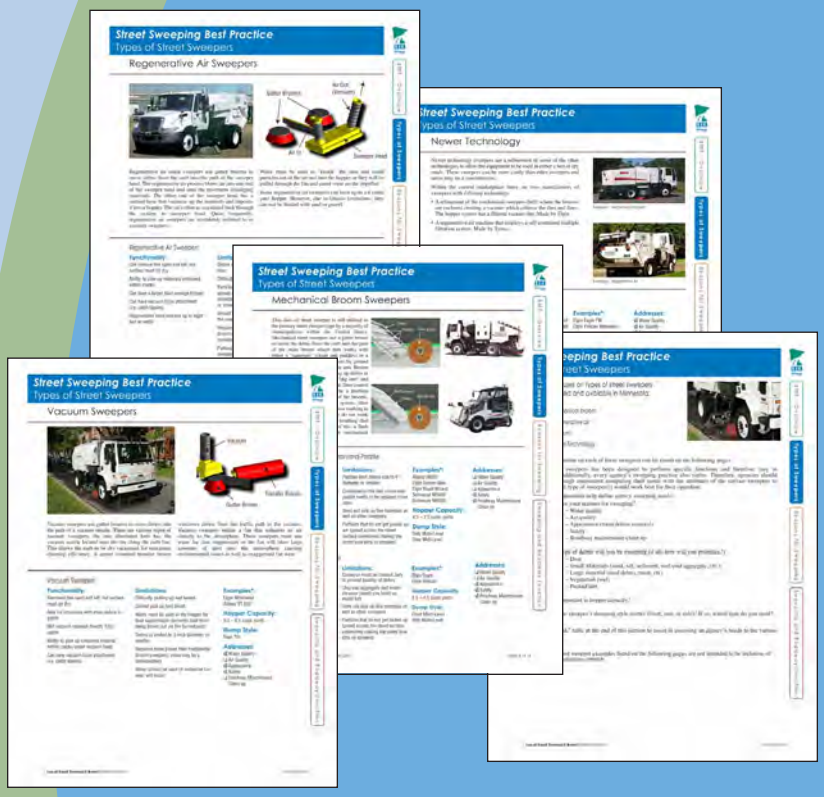
RESEARCH

2008 RIC06

Resource for Implementing a Street Sweeping Best Practice



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This resource was developed to assist agencies in implementing a street sweeping best practice. The Technical Advisory Panel decided these best practices are most useful for application in the State of Minnesota. These information sheets are designed to provide technical staff, policy and decision makers with guidance on a number of topics including: Best Practices Overview, Types of Sweepers, Reasons for Sweeping and Sweeping and Roadway Function.

This series of information sheets were put together for agencies to develop criteria to enhance the street sweeping process. The four information sheets are intended to be used as a group, highlighting the different components that should be considered when implementing/enhancing a street sweeping program.

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Implementing a Street Sweeping Best Practice
Introduction

The Minnesota LRRB has developed a series of information sheets as a resource for Implementing a Street Sweeping Best Practices. These sheets are designed to provide technical staff, policy and decision makers with guidance on a number of topics including:

1. Best Management Practices Overview
2. Types of Sweepers
3. Reasons for Sweeping
4. Sweeping and Roadway Function

In preparing this resource it is acknowledged that there are numerous research studies and reports on Street Sweeping. At the time of printing, this resource is a synthesis of the Technical Advisory Panel (TAP) consensus of the most useful information for application in Minnesota.

This series of information sheets were put together for agencies to develop criteria to enhance the street sweeping process. The four information sheets are intended to be used as a group, highlighting the different components that should be considered when implementing/enhancing a street sweeping program.

Additional copies of these sheets can be obtained at the LRRB Website: www.lrrb.org (Search: Street Sweeping)

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Implementing a Street Sweeping Best Practice
Street Sweeping Best Practice Overview

Overview

As with any other best practice, an agency needs to balance many factors in order to achieve their best practice. The information presented within this document is provided to assist an agency in developing a best practice. This information includes:

- Reasons for sweeping (air quality, water quality, safety, appearance, maintenance clean-up)
- Types of roadways to be swept
- Type of debris to be swept (dust, small particles, large particles, vegetation, packed dirt, etc.)
- Available equipment
- How the equipment can be used
- Budgets – capital, operations and maintenance costs
- Agency's approach to water quality regulations

The following pages of this overview will provide general best practice information for street sweeping pertaining to:

- Various ways of treating quality (street sweeping versus other methods)
- Capital cost of street sweepers
- Operational cost of street sweeping
- Maintenance cost of street sweeping

From a combination of the information provided within this resource, conversations and networking with peer agencies and from technical assistance from manufactures, an agency will have the information and knowledge to balance the key factors and develop a best management practice.

Various Ways of Treating Quality

Converse to some other major Metropolitan Planning Organizations (MPO), here in Minnesota, and specifically the Twin Cities metropolitan area, one important factor that has influenced street sweeping practices is the overall approach taken in addressing and treating water quality standards.

Minnesota is known for the quality of receiving waters for recreation and the propagation of fish and wildlife. Improving quality in the 1970s and 80s involved separating stormwater and wastewater from combined sewers, primarily in the Metro Area and providing extensive treatment for the latter source to maintain receiving water quality standards. As mandated by the Clean Water Act and EPAs Phase 1 (11/16/90) and Phase 2 (12/8/99) stormwater regulations, treatment methods have involved implementing best management practices (BMP) such as detention ponds, underground structural devices, street sweeping and more recently rain gardens and low impact development criteria.

While Minnesota emphasized construction of structural BMP devices, street sweeping as a nonstructural operation provides significant benefits in achieving quality not only in the receiving water, but roadway appearance, safety, potential air quality improvement and improving structural device maintenance. Implementing a street sweeping program using higher efficiency street sweepers either alone or in combination with mechanical sweepers and coupled with sweeping frequencies reflecting the amount of roadway material generated is a prudent approach for achieving quality.

Table 1 provides a suggested street sweeping program recognizing the differences in roadway material generation. Minimum street sweeping frequencies may be adjusted dependent upon the receiving water and the level of quality desired by the owner/operator or mandated by regulation.

Table 1:
Proposed Street Sweeping Frequencies[1]

Area	Minimum Frequency	Maximum Frequency
Arterials	9 times per year	16 times per year
Commercial	9 times per year	16 times per year
Light Industrial	6 times per year	9 times per year
Heavy Industrial	9 times per year	16 times per year
Residential	4 times per year	9 times per year
Central Business District[2]	Biweekly	2 times per week

[1]Schilling, J.G. 2005. Street Sweeping – Report No. 3, Policy Development and Future Implementation Options for Water Quality Improvement. Prepared for Ramsey-Washington Metro Watershed District (http://www.rwmwd.org) Little Canada, Minnesota 55117.

[2]Frequency may depend upon business community and local government expectations.

Cost Considerations

The capital cost for purchasing a street sweeper can be quite high, ranging from $140,000 to $250,000 depending upon the sweeper type (mechanical, regenerative-air, etc.) and options included. Table 2 is a modification of previous information[1] augmented by recent sweeper purchasing information from governmental units. Major options affecting the purchase price are secondary engine fuel type and size (gasoline, diesel, CNG), sweeper box material (metal type, coatings), hopper dump style, and accessories (vacuum wand, interior cab features, etc.). An equally important factor in the purchasing decision is street sweeper service life. While high efficiency street sweepers (regenerative-air and vacuum) are initially more expensive, their expected average service life range is significantly longer than mechanical sweepers due primarily to less moving parts requiring repair and replacement. Longer service life translates into lower Operation and Maintenance expense on a unit basis (dollar cost per curb-mile swept).

Table 2:
Street Sweeper Cost Data (2007 dollars)[1]

Sweeper Type	Purchase Price($)
Mechanical	$140,000+
Regenerative-air or Vacuum/ Newer Technology	$175,000 - $ 250,000

[1] Schilling, J.G. 2005. Street Sweeping – Report No. 1, State of the Practice. Prepared for Ramsey-Washington Metro Watershed District (http://www.rwmwd.org). Little Canada, Minnesota 55117.

Operator Training

Street sweepers, whether mechanical or high efficiency types, are complex machines to operate in an efficient manner. Operator training should include two important components:

1. Street sweeper operation
2. Reasons for street sweeping

While great strides have been made by sweeper manufactures with respect to touch, joy-stick and other improvements for in-cab operation, the bottom line is what's happening both within the sweeper itself and on the street that counts. A very important part of the purchase price of any new sweeper is including the cost of factory-training for operators. Street sweeper operator training should include at a minimum: daily operation checklist procedures, machine operation, trouble-shooting indicators and problems, daily and long-term preventive maintenance, minor repairs, machine and personal safety requirements. Factory-training for operators and mechanics often comprises a minimum of 32 hours of lecture and/or hands-on efforts.

While implementing factory-training in conjunction with a new sweeper purchase is a high priority, equally important is having an internal training program for new hires. While a new hire may need a commercial drivers license (CDL), at a minimum an established training program with a designated trainer(s), or documented standardized test (e.g. going through a series of maneuvers) that new operators must pass to operate the street sweeper on various roadways or alleys would be necessary to assure competence in machine operation. The training program should designate the amount of time that a trainee spends riding with and watching a trainer, the minimum amount of time spent driving accompanied by a more senior employee, and a minimum set of maneuvers that a trainee must be able to accomplish before riding alone. The training program should also include a preventive maintenance lesson provided by a sweeper mechanic.

Training should include the Reasons for Street Sweeping. Employees in targeted positions (whose interactions, jobs, and activities affect storm water quality) should be provided information regarding the requirements of a storm water management program, trash and debris control and air quality issues relating to street sweeping. Efficiency is significantly enhanced by having operators that understand machine operation and the reasons for street sweeping. A successful street sweeping program incorporates both.

Street sweeper operator training should include at a minimum:

- Daily operation checklist procedures
- Machine operation
- Trouble-shooting indicators and problems
- Daily and long-term preventive maintenance
- Minor repairs
- Machine and personal safety requirements
- Factory-training for operators and mechanics often comprises a minimum of 32 hours of lecture and/or hands-on efforts.

Preventative Maintenance

Preventive maintenance will assure that a street sweeper achieves its service life. Often street sweepers and trucks are used by more than one driver, thus it may be difficult to determine which operators may neglect periodic preventive maintenance requirements. In addition, scheduled maintenance for the operational vehicles may be overlooked because the units needing such work are cleaning the streets. An internal program which tracks scheduled maintenance also contributes to achieving sweeper service life.

Daily washing of street sweepers is imperative, especially in snow-belt states where deicers are incorporated into street debris and sediment. service life is significantly reduced as a result of corrosion of metal parts exposed to deicer chemicals

This sheet focuses on types of street sweepers commonly used and available in Minnesota:

- Mechanical broom
- Regenerative air
- Vacuum
- Newer-Technology

Detailed information on each of these sweepers can be found on the following pages.

Each of these sweepers has been designed to perform specific functions and therefore vary in functionality. Additionally, every agency's sweeping practice also varies. Therefore, agencies should conduct a thorough assessment comparing their needs with the attributes of the various sweepers to determine which type of sweeper(s) would work best for their operation.

The following questions help define agency sweeping needs:

- What are your reasons for sweeping?
  - Water quality
  - Air quality
  - Appearance (trash/debris removal)
  - Safety
  - Roadway maintenance clean up

- What type of debris will you be sweeping (if all, how will you prioritize?)
  - Dust
  - Small Materials (sand, silt, sediment, seal coat aggregate, etc.)
  - Large material (road debris, trash, etc)
  - Vegetation (wet)
  - Packed dirt

- What is the surface type/condition/cross section of pavement (smooth, uneven, alleys, etc.)?

- How important is hopper capacity (volume vs. payload)?
  - Sweeper hopper capacity is shown as a volume (e.g. cubic yards). Usable volume is often shown as less due to internal equipment restrictions. But, hopper payload capacity is limited by the truck chassis. Thus, the actual hopper payload is a function of the materials being swept. For example, leaves, grass clippings, twigs, and trash will maximize usable hopper volume capacity, while sweeping sand or a sand/gravel mixture often results in a payload capacity less than the usable volume due to the chassis limit.

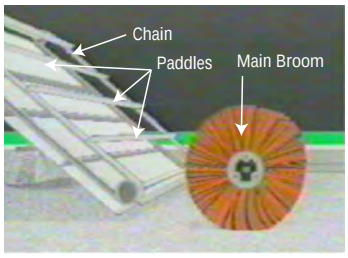
- Does the sweeper's dumping style matter (front, rear, or side)? If so, which type do you need?

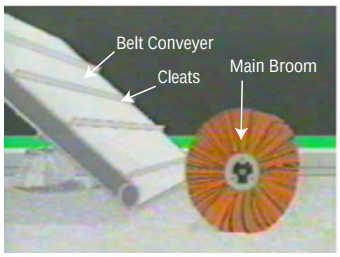
There is a "blank" table at the end of this section to assist in assessing an agency's needs to the various sweeper types.

* The street sweeper examples listed on the following pages are not intended to be inclusive of all manufactures/models

Mechanical Broom Sweepers

This class of street sweeper is still utilized as the primary street sweeper type by a majority of municipalities within the United States. Mechanical street sweepers use a gutter broom to move the debris from the curb into the path of the main broom which then works with either a squeegee (chain-and-paddles) or a conveyor belt to move debris from the ground into a hopper contained within the unit. Broom sweepers are very good at picking up debris in any weather condition and can "dig into" and remove hard packed dirt and mud. Dust control for this type of machine can be a problem because of the churning action of the brooms. The onboard water spraying system (dust control) helps to mitigate dust when working in low debris areas; however, they do not work well in heavy debris areas and resulting dust can affect air quality. Because of this, a flush truck is sometimes used with mechanical sweepers to help mitigate dust.





Mechanical Sweepers: Chain-and-Paddle

Functionality:
Effective for wet/matted leaves and digging/sweeping packed dirt

Able to sweep millings and coarse sand better than belt sweepers (no “inside” areas of buildup)

Compared to Belt Sweepers, less daily build up

Requires less power than regenerative air and vacuum sweepers

Limitations:
Paddles limit debris size to 6” diameter or smaller

Compared to the belt, chain-and-paddle needs to be replaced more often

Does not pick up fine materials as well as other sweepers

Particles that do not get picked up are spread across the street surface sometimes making the street look dirty or streaked

Examples*:
Allianz M350
Elgin Broom Bear
Elgin Road Wizard
Schwarze M5000
Schwarze M6000

Hopper Capacity:
4.5 – 7.5 cubic yards

Dump Style:
Side Multi-Level
Rear Mid-Level

Addresses:
- ❑ Water Quality
- ❑ Air Quality
- ☑ Appearance
- ☑ Safety
- ☑ Roadway Maintenance
  Clean up

Mechanical Sweepers: Belt

Functionality:
Able to pick up large debris (plastic bottles, cans, branches)

Able to pick up wet/matted and large amount of leaves better than other sweepers

Effective at “digging into” and removing packed dirt from roadway

Requires less power than regenerative air and vacuum sweepers

Limitations:
Conveyor must be cleaned daily to prevent buildup of debris

Chip seal aggregate and winter abrasive (sand) can build up inside belt

Does not pick up fine materials as well as other sweepers

Particles that do not get picked up spread across the street surface sometimes making the street look dirty or streaked

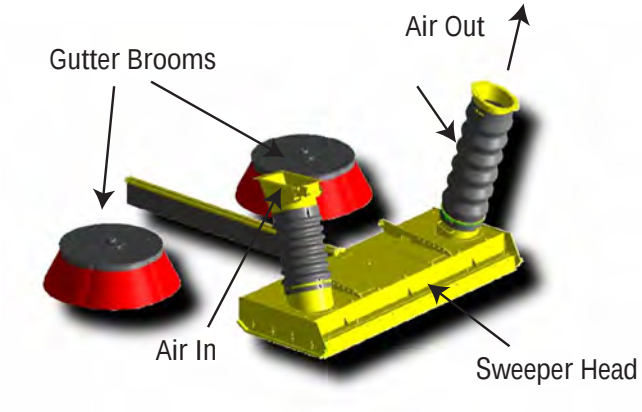
Examples*:
Elgin Eagle
Elgin Pelican

Hopper Capacity:
3.5 – 4.5 cubic yards

Dump Style:
Front Multi-Level
Side Multi-Level

Addresses:
- ❑ Water Quality
- ❑ Air Quality
- ☑ Appearance
- ☑ Safety
- ☑ Roadway Maintenance
  Clean up

Regenerative Air Sweepers



Regenerative air street sweepers use gutter brooms to move debris from the curb into the path of the sweeper head. The regenerative air process blows air into one end of the sweeper head and onto the pavement dislodging materials. The other end of the sweeper head has a suction hose that vacuums up the materials and deposits it into a hopper. The air is then re-circulated back through the system to the sweeper head, which is a distinctly different operation from a pure vacuum system.

Water must be used to "knock" the dust and small particles out of the air and into the hopper or they will be pulled through the fan and cause wear on the impeller.

Regenerative Air Sweepers

Functionality:

Can remove fine sand and silt, but surface must be dry

Ability to pick-up materials entrained within cracks

Can have a larger than average hopper

Can have vacuum hose attachment (i.e. catch basins)

Regenerative head reaches up to eight feet in width

Limitations:

Debris is limited to diameter of air out hose

Difficulty in picking up wet/matted leaves

Particles that do not get picked-up are spread across the street surface sometimes making the street look dirty or streaked

Requires more power than mechanical broom sweepers; noise may be a consideration

Should be used in above freezing temperatures only

More efficient operation on flat pavement surface

Examples*:

Allianz RT 655
Elgin Crosswind
Elgin Fury
Schwarze A7000, A8000 A9000
Tymco 435
Tymco 600 & 500

Hopper Capacity:

4.0 – 9.6 cubic yards

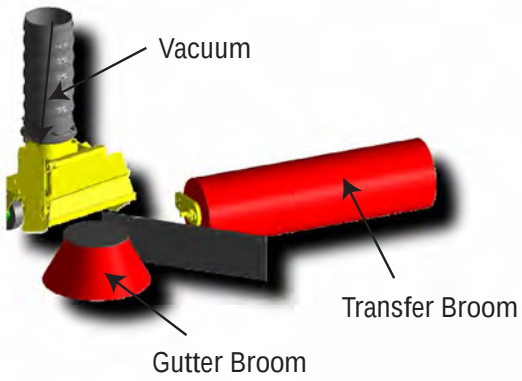
Dump Style:

Rear Tilt
Side Multi-Level
Rear Mid-Level
Rear Raker

Addresses:

- ☑ Water Quality
- ☑ Air Quality
- ☑ Appearance
- ☑ Safety
- ❑ Roadway Maintenance
  Clean up

Vacuum Sweepers



Vacuum sweepers use gutter brooms to move debris into the path of a vacuum nozzle. There are various types of vacuum sweepers; the one illustrated here has the vacuum nozzle located near the tire along the curb line. This allows the curb to be dry vacuumed for maximum cleaning efficiency. A center mounted transfer broom windrows debris from the traffic path to the vacuum. Vacuum sweepers utilize a fan that exhausts its air directly to the atmosphere. These sweepers must use water for dust suppression or the fan will blow large amounts of dust into the atmosphere causing environmental issues as well as exaggerated fan wear.

Vacuum Sweepers

Functionality:

Removes fine sand and silt, but surface must be dry

Best for situations with most debris in gutter

Will vacuum material directly from gutter

Ability to pick up entrained material within cracks under vacuum head

Can have vacuum hose attachment (i.e. catch basins)

Limitations:

Difficulty picking up wet/matted leaves

Cannot pick up tree brush

Water must be used in the hopper for dust suppression (prevents dust from being blown out via the fan exhaust)

Debris is limited to 3-inch diameter or smaller

Requires more power than mechanical broom sweepers; noise may be a consideration

Water should be used or excessive fan wear will occur

More efficient operation on flat pavement surface

Should be used in above freezing temperatures only

Examples*:

Elgin Whirlwind
Allianz VT 650

Hopper Capacity:

8.0 – 8.5 cubic yards

Dump Style:

Rear Tilt

Addresses:

- ☑ Water Quality
- ❑ Air Quality
- ☑ Appearance
- ☑ Safety
- ❑ Roadway Maintenance
  Clean up

Newer Technology

Newer technology sweepers are a refinement of some of the other technologies to allow the equipment to be used in either a wet or dry mode. These sweepers can be more costly than other sweepers and noise may be a consideration.

Within the current marketplace there are two manufactures of sweepers with differing technology:

- A refinement of the mechanical sweepers (belt) where the brooms are enclosed creating a vacuum which collects the dust and fines. The hopper system has a filtered vacuum fan. Made by Elgin.
- A regenerative air machine that employs a self-contained multiple filtration system. Made by Tymco.

The industry is continually developing new and better equipment. The reader is encouraged to research new equipment as it progresses.

Sweepers - Mechanical/Vacuum

Sweepers - Regenerative Air

Sweepers - Mechanical/Vacuum

Functionality:
Removes fine sand and silt

Able to pick up wet, matted vegetation

Able to pick up large debris (plastic bottles, cans, small branches)

Wet operation with skirts removed

Can use dry vacuum or water to suppress dust

Year round operation

Limitations:
Broom skirting limits ingestion of large amounts of leaves in the fall

More skirting parts that are prone to wear

Examples*:
Elgin Eagle FW
Elgin Pelican Waterless

Hopper Capacity:
3.5 - 4.5 cubic yards

Dump Style:
Front Multi-Level
Side Mid-Level

Addresses:
- ☑ Water Quality
- ☑ Air Quality
- ☑ Appearance
- ☑ Safety
- ☑ Roadway Maintenance Clean up

Sweepers - Regenerative Air

Functionality:
Removes fine sand and silt

Year round operation

Limitations:
Should be used on flat surface to seal sweeper head

Debris is limited to diameter of vacuum hose

Difficulty in picking up wet, matted vegetation

Examples*:
Tymco DST4 & DST 6

Hopper Capacity:
4.5 - 7.3 cubic yards

Dump Style:
Rear Tilt

Addresses:
- ☑ Water Quality
- ☑ Air Quality
- ☑ Appearance
- ☑ Safety
- ❑ Roadway Maintenance Clean up

Comparison Table

		Mechanical Broom Sweeper		Regenerative Air Sweeper	Vacuum Sweeper	Combination Sweeper
		Conveyor or Belt	Chain and Paddle			
Ability to Pick Up Debris	Dust					
	Small Materials					
	Large material					
	Vegetation (wet)					
	Packed dirt					
Hopper Capacity						
Dumping Style						
Optional Features						
Comments						

Reasons for Sweeping

There are five reasons to conduct roadway street sweeping operations. The list of reasons does not reflect the level of importance, but each may relate to one another.

- Appearance: Debris and trash removal
- Air Quality
- Roadway Maintenance Clean-up
- Safety
- Water Quality

Selecting a street sweeper requires an understanding of the five reasons, applying them to the roadway situation(s) and evaluating the right equipment for the job. For example, if appearance was the only reason, then selecting a mechanical broom machine would be appropriate. Examining "Reasons for Sweeping" is useful in the equipment selection process.

Appearance: Debris & trash removal

Roadway appearance (aesthetics) presents the public with a positive view for special areas, e.g. Central Business District (CBD). The business community may pay a greater tax or fee to offset the cost of higher street sweeping frequencies (once per week) within a CBD. More frequent sweeping is practiced by large and smaller communities in Minnesota (e.g. Minneapolis, Saint Paul, and North St. Paul). Intensive sweeping presents a pleasing environment for prospective customers, often translating into increased economic viability for a central business district or shopping center.

Inconsiderate disposal of convenient consumer products (cigarette butts, pop cans, water bottles, plastic bags, etc.) leads to street sweeping for trash removal from catch basin inlets and roadway gutters. Seasonally (fall and spring) public works operations implement street sweeping to remove accumulated leaves and debris from the gutter line. Removal of such materials is critical in preserving hydraulic efficiency of stormwater infrastructure. If catch-basins become clogged with leaves and debris, the risk of roadway flooding increases, thereby presenting a hazard to the traveling public.

Street sweeping exclusively for trash removal within large drainage areas can be an expensive proposition and should be evaluated with other measures (pollution prevention education, catch-basin inserts, and outfall trash collection devices).

Conclusion

Street sweeping for appearance (debris and trash removal) purposes and infrastructure efficiency is an important reflection upon a community's environment and a good public works practice to maintain proper infrastructure operating efficiency. It's best accomplished with either mechanical or higher efficiency sweepers.

Air Quality

There is a consistent direct relationship between high levels of fine particles in the surrounding air and health related issues:

- an associated increase in mortality rates
- respiratory infections
- the number and severity of asthma attacks
- the number of hospital admissions observed in different parts of the United States and various areas around the world

Particles less than 10 micrometers (microns - approximately 1/10 the diameter of a human hair) in diameter are known as PM_{10} and pose a health concern because they can be inhaled into and accumulate in the respiratory system.[1] There are essentially two sources of PM_{10} particles: natural sources, including sea salts, volcanic ash, pollens, and man-made sources originating from direct emissions - industrial facilities; fugitive dust sources (e.g., construction sites) and paved and unpaved road dust; and secondary particulate matter formed in the atmosphere.

Street sweeping using PM_{10} certified equipment is done to reduce the amount of particulate matter stirred-up from vehicular traffic on paved roadways. Street sweepers are certified as PM_{10}-efficient or capable of a picking-up greater than or equal to 80% of particles less than or equal to 10 microns. These types of street sweepers, especially higher efficiency models are used to limit the amount of PM_{10} stirred-up during the street sweeping process, thus improving air quality at street level.[2]

Mathematical modeling in the City of Toronto, Ontario suggests that removing 80% of PM_{10} through street sweeping will provide a 25 – 30% improvement in the City's fine particle air quality and even greater improvement is expected for pedestrians and cyclists on the City's arterial roads.[3] Sweeping for air quality control is best accomplished with higher efficiency sweepers (regenerative-air and newer technology sweepers)

Conclusion

Air quality can be impacted from fine particles stirred-up on the roadway surface. Street sweeping with higher efficiency sweepers (vacuum, regenerative-air and newer technology sweepers) may improve air quality.

[1]PM_{10} website: http://www.epa.gov/tnn/naaqs/pm/pm10_index.html

[2]In Clean Roads to Clean Air Program, City of Toronto, Ontario, Canada. http://www.toronto.ca/transportation/environment/

[3]Stevanovic-Briatico, Vesna. 2007. Clean Roads to Clean Air Program. 2007 APWA Public Works Congress and Exposition. September 10, 2007. San Antonio, Texas.

Roadway Maintenance Clean-up

Conducting street sweeping for roadway maintenance clean-up falls into two categories. The first consists of routine sweeping of roadways impacted with erosion and sedimentation from development sites. Such sweeping is undertaken on a weekly or as needed basis (following significant rainfall events) or may be required by state or local permits. Often such sweeping is conducted by contract sweeper companies hired by the developer.

The second category is street sweeping in conjunction with roadway surface maintenance (pavement management plan) involving crack sealing and/or seal coating. The roadway surface is swept prior to sealing (best accomplished by using regenerative-air or vacuum sweepers). An asphalt binder (sealcoat) is then applied followed immediately by aggregate chips. One to two days later, excess chips are swept from the roadway surface (best accomplished by using mechanical broom or regenerative-air sweepers).

Conclusion

Street sweeping for Roadway Maintenance Clean-up is conducted as a result of erosion and sediment from construction sites and/or in conjunction with ongoing maintenance involving crack and chip sealing. Either mechanical and higher efficiency sweepers would be best to accomplish these tasks.

Safety

Roadways should be kept free of debris and other materials that may impede the safety of the traveling public. Two safety issues are apparent. The first applies to vehicular traffic (especially motorcycles) approaching intersections where coarse and fine sediment materials may be left on surface causing greater braking distance, increased risk of skidding and potential loss of vehicle control. This safety issue may result from the application of abrasives (sand and deicers) during winter conditions. Winter and/or spring street sweeping resolves the issue.

The second safety issue applies to the bicycling public. Attached bikeways striped and within the curb and gutter line may accumulate debris and sediment in the absence of timely street sweeping. Such a condition may force the cyclist into the traffic lane, increasing the accident risk. Debris size is not critical because bicycle tires are fairly thin in thickness, primarily for weight and speed. Thus, even small sizes of debris may be hazardous. Bike lanes are often included on collector and arterial streets; therefore street sweeping may be a more frequent occurrence.

Conclusion

Street sweeping should be conducted to reduce safety hazards to the traveling public for both vehicles and cyclists. Mechanical and higher efficiency sweepers can accomplish these tasks.

Water Quality

Maintaining or improving water quality enhances the quality of our environment and demonstrates compliance with local and state regulatory requirements to reduce pollutant loading to receiving waters. Street sweeping is an accepted best management practice (BMP) for reducing pollutant loading into receiving waters. When street sweeping is combined with other treatment BMPs, water quality can be improved.

Source, Cause and Effects

Urban stormwater runoff contains pollutants that are most often associated with fine materials - silt and clay sediments which get washed off the roadway surface. Table 3 illustrates typical characteristics for roadway sediments. The source of the sediments can be erosion from adjacent property, roadway deterioration, and vehicle traffic. Table 3 highlights that silt and clay sediments are often an order of magnitude higher in pollutant concentrations (heavy metals, nutrients and hydrocarbons) when compared to coarser materials.

Table 3:
Roadway Soil Particles: Class, Size and Pollutant Characteristics[1]

Class Name	Material Particle Size (mm)	Lead (ppm)	Zinc (ppm)	Phosphorus (%)	PAHs (ppm)
Gravel	2.0	Range 87 – 1,230 Average 483	Range 110 – 810 Average 338	Range 0.03 – 0.18 Average 0.08	Range 2.1 – 9.2 Average 5
Medium to very coarse sand	0.25 – 2.0				
Very fine to fine sand	0.050 – 0.250				
Silt	0.002 – 0.050 [2]	Range 5,960 – 6,150 Average 6,055	Range 4,330 – 4,405 Average 4,405	Range 0.85 – .088 Average 0.86	Range none Average 11.7
Clay	< 0.002				

[1]Breault, R.F., Smith, K.P., and Sorenson, J.R., 2005, Residential street-dirt accumulation rates and chemical composi¬tion, and removal efficiencies by mechanical- and vacuum-type sweepers, New Bedford, Massachusetts, 2003–04: U.S. Geological Survey Scientific Investigations Report 2005-5184, 27 p. [Modified from Tables 2 and 4].
[2] Particle size is representative of PM_{10}

Heavy metals such as lead, zinc, other metals and polycyclic aromatic hydrocarbons (PAHs) from vehicle traffic bind onto sediments and in turn are carried off the roadway surface as runoff. Nutrients such as phosphorus and nitrogen from vegetation (grass-clippings, leaves, and twigs), lawn fertilizer, and pet waste can wash off adjacent property into the roadway gutter line.

When the runoff enters a receiving water, turbidity results - decreasing water transparency and nutrients can cause algae blooms. Coarse sands, gravel, vegetative debris and trash create detention pond sediment deltas at storm sewer outlets and loss of water depth. Sediment must be removed periodically from ponds, lakes and drainage systems.

Sweeper sediment pick-up efficiency

There are major differences in the ability of street sweepers to pick-up sediment from roadway surfaces. This important street sweeper capability should be well understood when sweeping is conducted for sediment removal and pollutant loading reduction. Table 4 depicts removal efficiencies for various sediment particles sizes with respect to mechanical versus vacuum sweepers.

Table 4:
Roadway Soil, Particle Size and Sweeper Removal Efficiencies

Class Name	Material Particle Size (mm)	Removal Efficiency (%) [mechanical broom sweeper]		Removal Efficiency (%) [vacuum sweeper]	
Gravel	2.0	Range 60 - 79%[1] 9 - 40%[2]	Average 69%[1] 21%[2]	Range n/a[1] 31 – 94%[2]	Average n/a[1] 71%[2]
Medium to very coarse sand	0.25 – 2.0				
Very fine to fine sand	0.050 – 0.250				
Silt	0.002 – 0.050 [3]	Range 16 – 48 %[1] 13 – 13 %[2]	Average 21%[1] 13%[2]	Range n/a[1] 39 – 81 %[2]	Average n/a[1] 60%[2]
Clay	< 0.002				

[1] Pitt, Robert, Bannerman, R. and Sutherland, R. 2004. The Role of Street Cleaning in Stormwater Management. Paper presented at Water World and Environmental Resources Conference 2004, Environmental and Water Resources Institute of the American Society of Civil Engineers, Salt Lake City, Utah. May 27 – June 1, 2004, Table 1.

[2] Breault, R.F., Smith, K.P., and Sorenson, J.R., 2005. Residential street-dirt accumulation rates and chemical composi¬tion, and removal efficiencies by mechanical- and vacuum-type sweepers, New Bedford, Massachusetts, 2003–04: U.S. Geological Survey Scientific Investigations Report 2005-5184, 27 p., Table 6.

[3] Particle size is representative of PM_{10}

Conclusion:

Two characteristics are clearly evident in these studies and others. First, mechanical broom sweepers are good at removing coarse sediment, but poor at removing fines (silt, clay and PM_{10}). In addition, removing the course sediment causes the remaining fine sediment to be easily washed off the roadway surface. Second, vacuum and regenerative-air (not shown here) sweepers have a greater capability to remove both coarse and fine sediments.

Thus, if water quality is an important street sweeping outcome, using a vacuum or regenerative-air sweeper would be the best option as they both have capability to remove both coarse and fine sediments.

Regulatory

Street sweeping can be a valuable BMP for compliance with stormwater permits issued by the Minnesota Pollution Control Agency (MPCA). The three pertinent general permits are as follows:

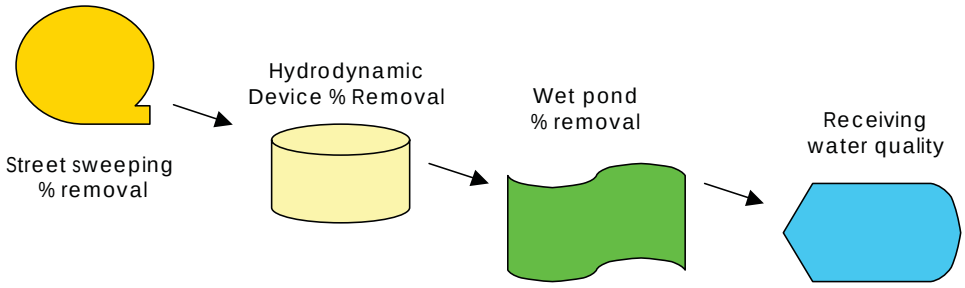
1. Multi-Sector Industrial Permit
2. Municipal Separate Storm Sewer System (MS4) Permit
3. Construction Activity Permit

Each of these permits requires preparation of a Stormwater Pollution Prevention Plan (SWPPP) by the permit holder that may spell-out street sweeping as a BMP to be implemented. In the metropolitan areas of Minnesota, Local Water Management Plans (LWMP) are prepared by local governments in conjunction with watershed plans. The LWMPs often identify street sweeping as a water quality improvement operation by the local governments.

Statewide, the MPCA identifies water bodies in violation of water quality standards and as such they become listed following the procedures of Section 303(d) of the Clean Water Act. With a water body listing, a Total Maximum Daily Load (TMDL) study is undertaken for the water body laying out an implementation plan requiring reductions in pollutant loading. If a water body violates the turbidity standard, a BMP requiring increased street sweeping frequencies could be one of a suite of actions to achieve the turbidity water quality standard.

Street sweeping can be implemented as a stand alone BMP or in conjunction with other BMPs. The latter is called a BMP treatment train. The flow chart below illustrates the treatment train.

Figure 1:
BMP Treatment Train



The treatment train concept in stormwater management is based upon the operation of a wastewater treatment facility. Pollutant removal is enhanced (solids and dissolved substances) as the wastewater or the above example stormwater moves through the system. In addition to the enhanced system treatment capability, the treatment train can be implemented to prolong maintenance cycles, thus reducing cost long-term. For example, street sweeping removes coarse and fine sands depending on equipment type, which in turn prolongs the maintenance cycle of the downstream devices (hydrodynamic devices and wet ponds). Maintenance of the latter devices can be a very costly and time consuming process.

Thus, street sweeping fits into the overall view of BMP and is an important part of the tool box for improving water quality as well as conducting optimal maintenance operations.

The maintenance practice of street sweeping is often conducted in a manner reflecting roadway function or design. Roadways are designed and built to serve two functions: provide access to property and to get from one place to another. Roadway design considers both functions to varying degrees: where property access is a priority, slower speeds and lower traffic volumes are assumed. Thus, residential areas have standard street widths, slower speeds and many property access points. Where mobility is primary, higher speeds and greater traffic volume dictate the design. Traversing and connecting various land use areas are arterials (minor and principal) which have wider street widths, higher speeds and less property accesses.

Parking lots, whether public or private, provide their own unique design challenges because street sweeping equipment used for roadways does not operate as efficiently in such facilities. Similarly, central business districts or "downtowns" present a different challenge for street sweeping due to vehicular parking obstructing efficient operations.

Thus, understanding the roadway system function and design along with associated facilities is important for conducting street sweeping in an efficient manner.

Roadway Owner / Function

In Minnesota, there are four generally accepted functional roadway classifications. The following table depicts the classifications along with general traffic volumes and speeds associated with each. The State (Minnesota Department of Transportation) and local governments (counties, cities and towns) have ownership and maintenance responsibility for the respective roadways as shown below.

Table 5:
Roadway Functional Classes and Responsible Governments

Functional Roadway Classes	***Principal Arterial*** >10,000 ADT 45-70 mph	***Minor Arterial*** 3,000 - 10,000 ADT 30 - 45 mph	***Collector streets*** 1,000 - 5,000 ADT 30 - 45 mph	***Local streets*** ≤ 1,000 ADT ≤ 30 mph
Mn/DOT	Yes	No	No	No
Counties	Occasionally	Yes	Yes	No
Cities and towns	No	Yes	Yes	Yes

The amount of pollutant load is associated with roadway functional classification. High traffic volume roadways (principal and minor arterial) translate into greater potential deposition of pollutants and materials associated with vehicular movement [brake linings (antimony, copper, zinc), tire wear (cadmium, hydrocarbons, zinc) and of course the loss of vehicle parts from wear and tear]. Lower traffic volume roadways (collector and local streets) potentially reflect lower pollutant loads associated with litter (leaves, grass clippings, twigs and branches). Pollutant loads from litter sources is seasonal in nature (fall and spring) with vegetation growth and die-off being greater within residential neighborhoods with mature vegetation versus newer subdivisions. Surrounding land use is also a contributor to pollutant loads and most often is associated with minor arterials and collector streets traversing through commercial and industrial areas.

Street sweeping frequency should reflect roadway functional classification, in part. Traditionally in Minnesota, street sweeping is performed twice per year (spring and fall) by most governments (state, county and local). Exceptions to this generalization are central business districts (CBDs) and a few local governments which conduct more intensive operations. The following table shows street sweeping frequency for various roadway and land use types undertaken by approximately 40 local governments in Minnesota versus approximately 50 local governments across the United States and Canada (www.rwmwd.org) in 2005.

Table 6:
Street Sweeping Frequency for Roadway and Land Use Areas[1]

Sweeping Frequencies	Twice per year		3 – 6 times per year		More frequently		Every 2 Weeks		Every Week	
	MN	US/ Can	MN	US/ Can	MN	US/ Can	MN	US/ Can	MN	US/ Can
Arterial Streets	58%	2%	26%	24%	5%	26%	8%	26%	3%	21%
Residential Streets	72%	18%	23%	29%	0%	27%	0%	20%	5%	7%
Commercial / Industrial areas	62%	11%	19%	28%	7%	21%	5%	17%	7%	23%
CBDs	39%	6%	25%	7%	11%	31%	9%	18%	16%	37%

[1]Schilling, J.G. 2005. Street Sweeping – Report No. 2, Survey Questionnaire Results and Conclusions. Prepared for Ramsey-Washington Metro Watershed District (http://www.rwmwd.org) Little Canada, Minnesota 55117

Summary:

- A majority (58 – 72%) of Minnesota survey respondents swept arterial - residential streets and commercial / industrial areas twice per year.
- A super majority (66 – 76%) of the U.S. and Canadian respondents swept arterial – residential streets and commercial / industrial areas from 3 – 26 times per year.
- Residential streets are less likely to be swept on a frequent basis by either group of survey respondents.

Urban vs. Rural

Street sweeping is most frequently practiced on urban roadway sections. As shown in Figure 2 below, street sweeping is conducted primarily within the attached roadway bike path (5-foot section) and gutter area along the curb line (1 – 1.5 foot). While the traffic lanes may also be swept, particularly once or twice on a seasonal basis, the majority of materials will be removed with the bike-path and curb line area.

Figure 2:
Street sweeping of bike path & curb line

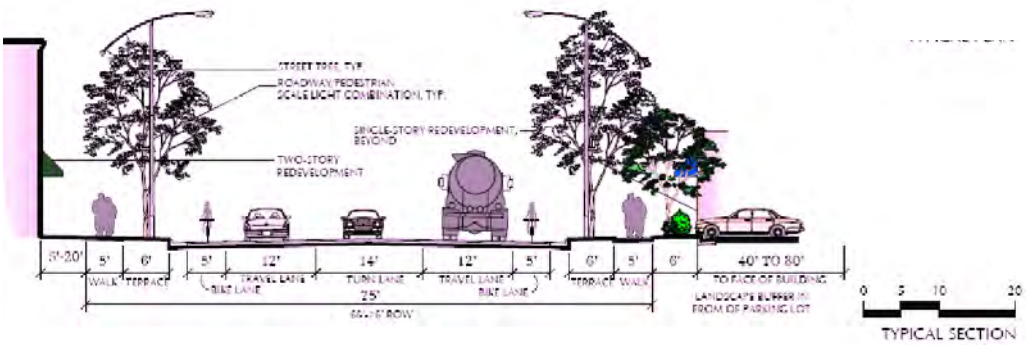
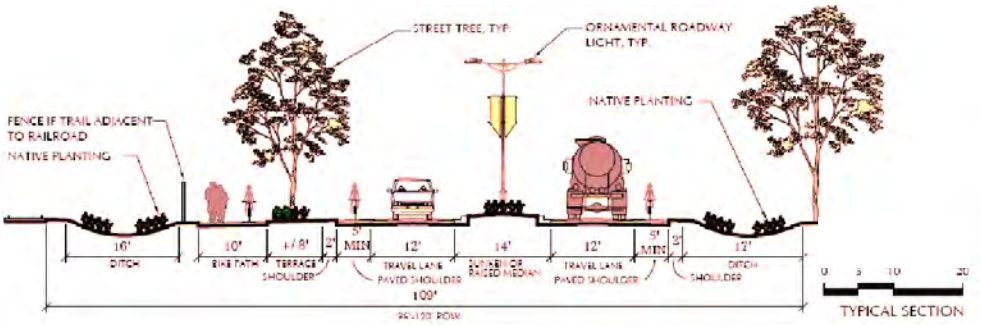


Figure 3:
Street sweeping of inside curb lane



Street sweeping of rural roadway sections is less likely primarily due to design considerations. In general, a rural roadway section does not have a curb line (curb and gutter) adjacent and supporting the traffic pavement surface. The exception may occur on inside traffic lanes where turn lanes, landscaping and/or lighting may be included in urbanized or transition areas. As shown in Figure 3 above, street sweeping may be implemented in such roadway areas. Otherwise, street sweeping of rural roadway sections would likely not be necessary on a regular basis primarily due to materials being blown or washed-off the driving surface onto the shoulder and/or deposited into the adjacent drainage ditch.

Green Pavements

Green paving systems allow infiltration of stormwater while providing a stable load-bearing surface for parking, walking and driving. These systems contain void spaces to provide infiltration of runoff into their underlying engineered porous materials and then into native soils. Porous paving systems can preserve natural drainage patterns, enhance groundwater recharge and soil moisture, and can help establish and maintain roadside vegetation. Although a good substitute for conventional concrete and asphalt, porous paving systems are typically not suitable for medium and high traffic volume applications. However, considerable research is underway investigating the use of porous pavement for all roadway applications.

There are several different types of porous paving systems, which are referred to here as 'porous concrete and asphalt', and 'permeable pavers'.

Maintenance Consideration

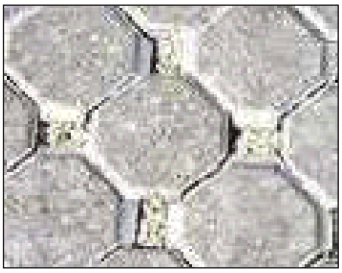
Both porous pavements and permeable pavers require sweeping; however, because of their inherent designs they require special care when sweeping. This includes not forcing materials into the "pores" of porous pavements or removing the filler materials from pavers. Currently there is not a sweeper that efficiently addresses these pavements. If using one of the sweepers listed in the "Types of Sweepers" sheet, check with the manufacture on how to best use on these pavements.

Porous Concrete and Asphalt

Porous Concrete – low volume residential street

Porous Asphalt – parking lot

Permeable Pavers



Concrete block pavers

Brick pavers