Improved Stormwater Through Street Cleaning

16th Annual EPA Region 6 Stormwater Conference
Fort Worth, Texas
Wednesday July 30, 2014, 3:45 pm

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Why Street Dust and Street Cleaning?

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Origins of Street Dust

- Soil and sediment
- Vegetation
- Motor vehicles
- Industrial emissions
- Litter
- Animal carcasses

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Environmental Contaminants in Street Dust

- Metals
- Organics
- Nutrients
- PM_{10} and $PM_{2.5}$

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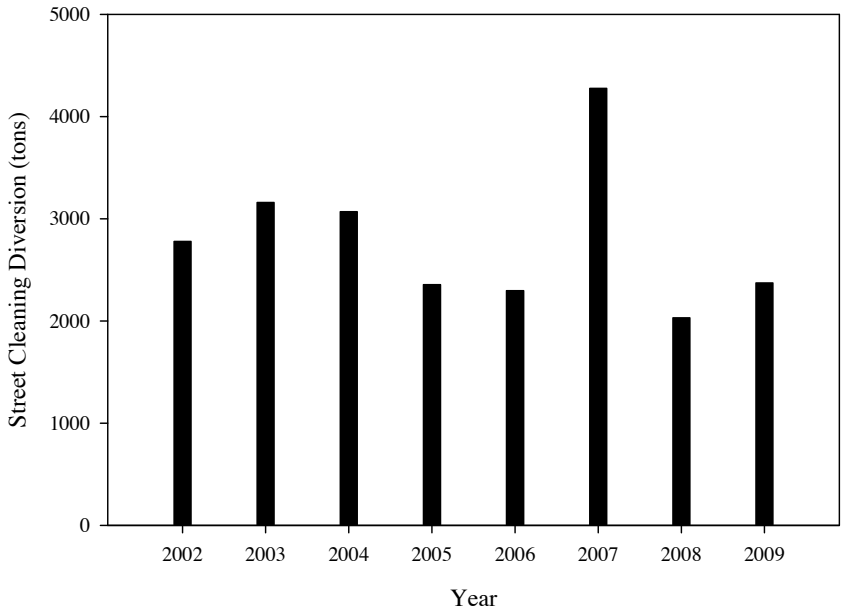
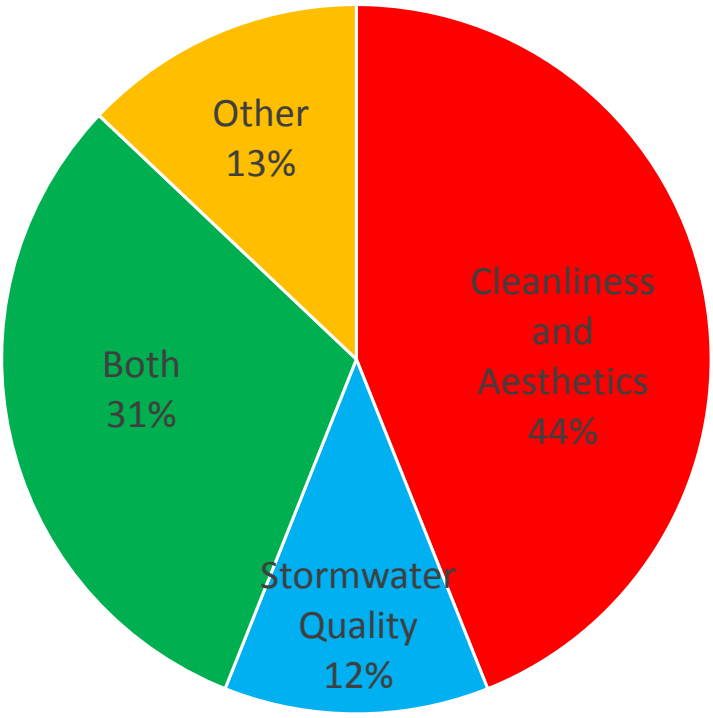
SWEEPING
SPOILS
MAY CONTAIN
HAZARDOUS
MATERIALS
OR OBJECTS
KEEP OUT
6

Mass of materials collected by street cleaning in the City of Waco, Texas for 2002-2009.



Street Cleaning Purposes

Cleanliness and Aesthetics vs Stormwater Quality



(Brinkmann and Tobin 2001)

Environmental Regulation – Water Quality

Federal Water Pollution Control Act (FWPCA) 1948

Clean Water Act (CWA) 1972

- Amended FWPCA
- Outlined regulation structure
- Set standards
- Required permits
- Established grants
- Established a planning need

National Pollutant Discharge Elimination System (NPDES)

- Point source pollution
- Non-point source pollution

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NPDES Permits

- Phase I (1990) - cities ≥ 100,000
- Phase II (1999) – suburban areas
- Notice of Intent (NOI) to discharge
  - BMPs
    - Public education and outreach
    - Public participation
    - Enforcement
    - Construction runoff control
    - Post construction runoff control
    - Pollution prevention
  - Measureable goals

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Street Cleaning Technology History and Methods

Mechanical

Vacuum

Regenerative Air

High-Efficiency Sweepers

All may use water for dust suppression

All may use gutter brooms

Mechanical Sweepers

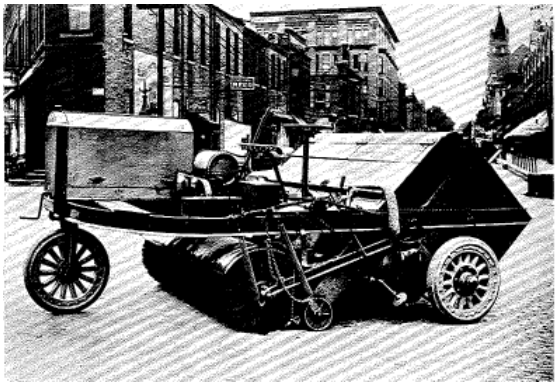
1843 – Invented in Manchester, England

1902 – New York City makes serious use of a team drawn sweeper

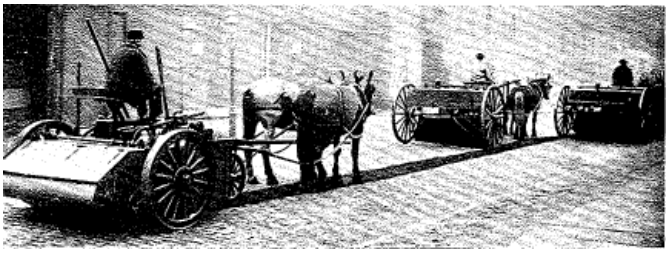
1914 – First practical and commercially successful self-propelled sweeper

2005 – About 41% of municipalities in the United States and Canada still use mechanical sweepers (Schilling 2005b)

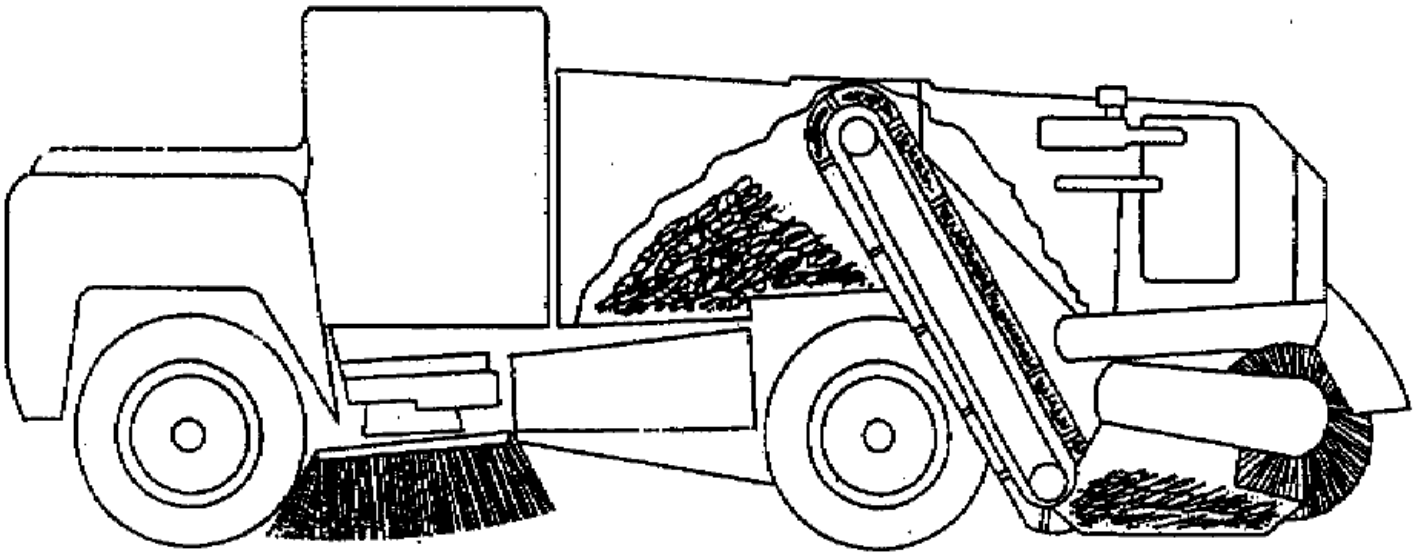
Richmann 1962



Richmann 1962



Mechanical Sweepers



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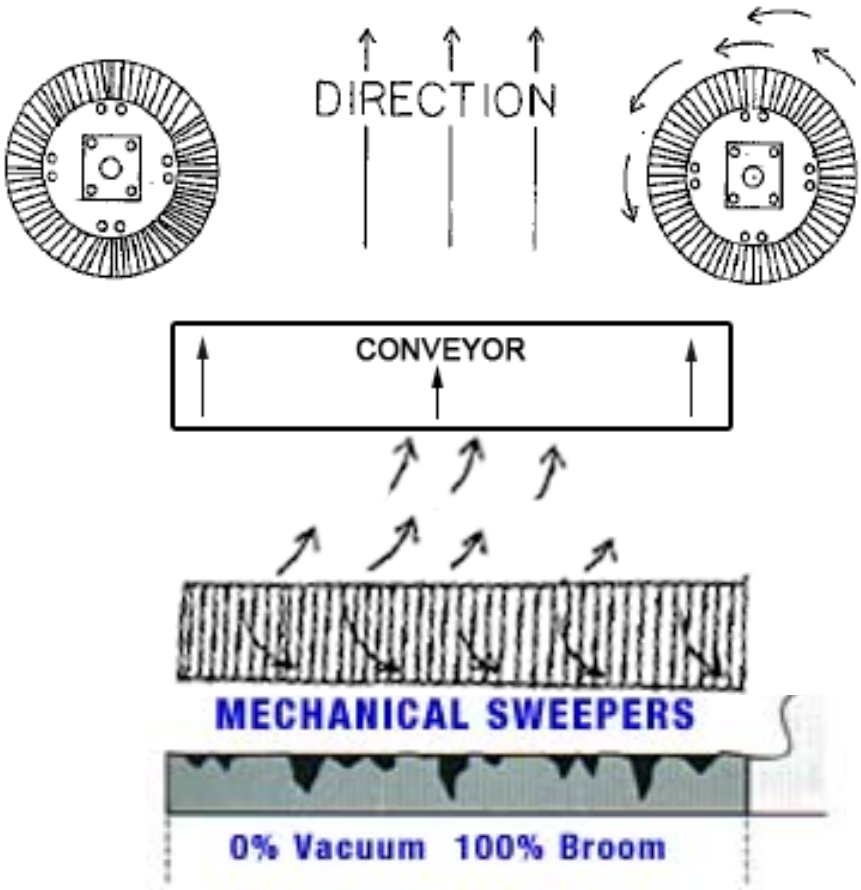
Mechanical Sweepers



Mechanical Sweepers

Advantages

Good at picking up:

- Bulky, heavy material
- Packed down material
- Wet vegetation

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Disadvantages

- Less efficient at picking up fine material
- Leaves material in cracks and uneven pavement
- Dusty
- Breaks down larger particles
- Not the best choice for the environment
- Maintenance Cost

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Vacuum Sweepers

1920s – Invented in Europe

1950s – Johnston Sweepers

1970s – Gained popularity

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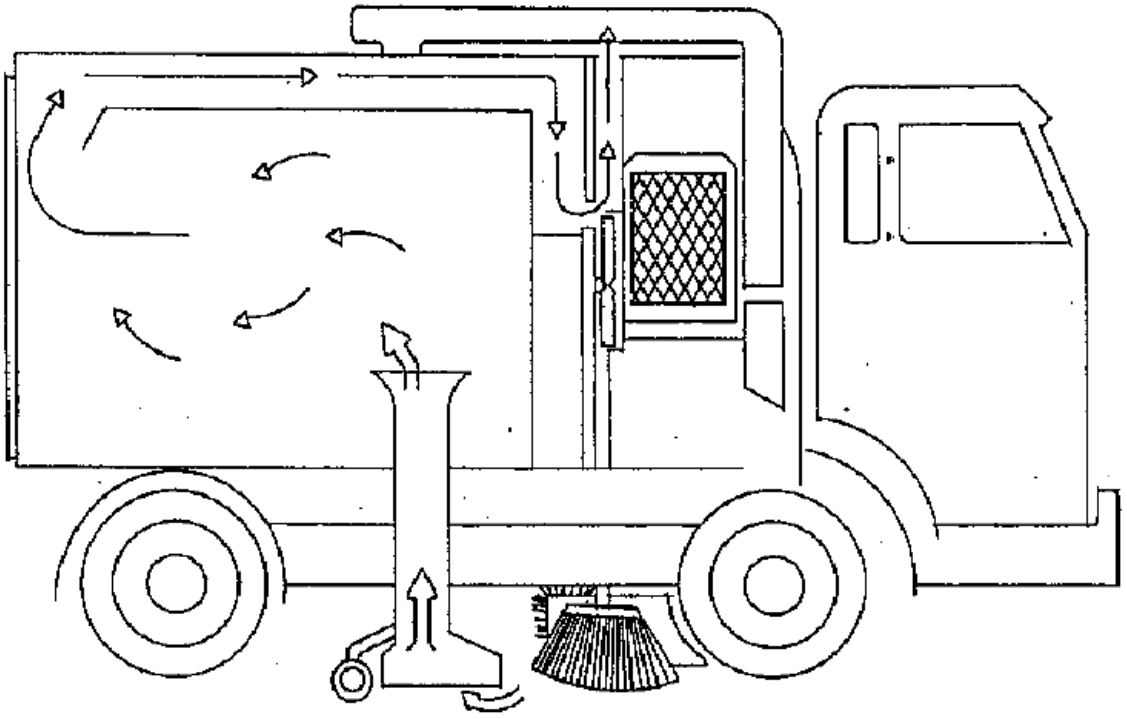
Vacuum Sweepers



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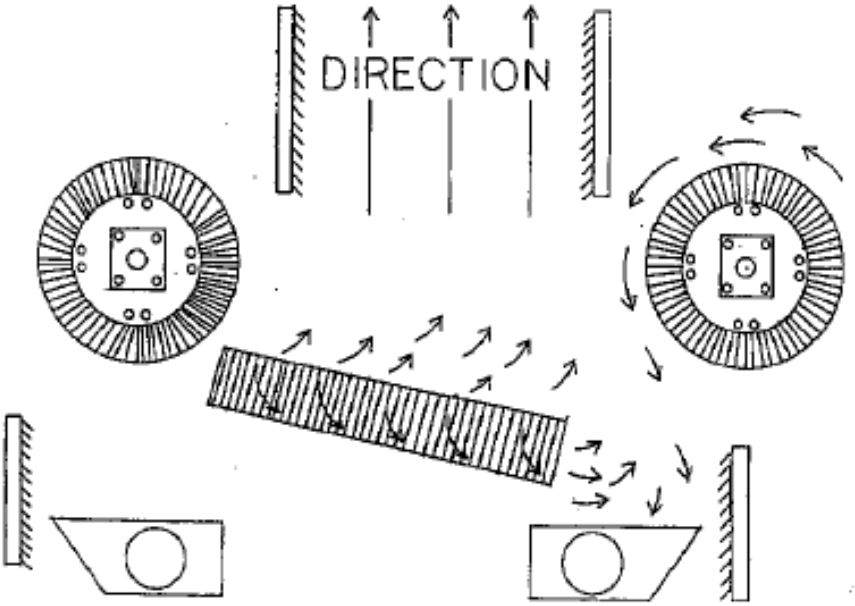
Vacuum Sweepers



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Vacuum Sweepers

Advantages

- Better than mechanical sweepers at picking up fine material within 1 meter of the curb

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Disadvantages

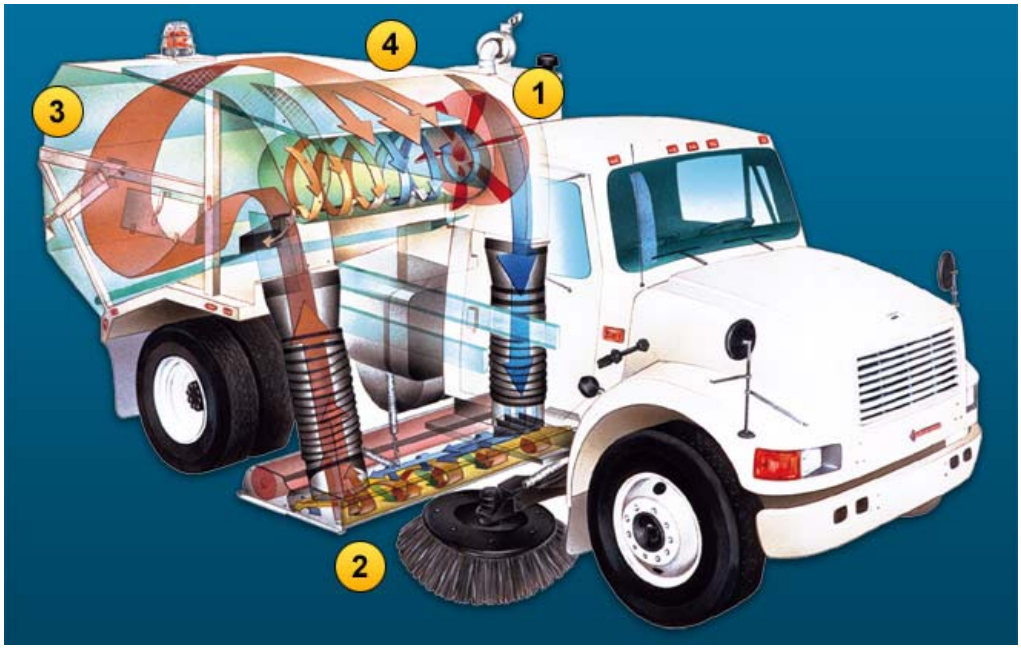
- Not as effective at picking up:
  - Bulky, heavy material
  - Wet vegetation
- Leaves material in cracks and uneven pavement
- Breaks down larger particles
- Dusty
- Exhausts air

Regenerative Air Sweepers

Mid 1960s – B.W. Young – Waco, Texas

Original Young "Air-Flo" Truck Mounted Regenerative Air Sweeper – circa 1966

Regenerative Air Sweepers



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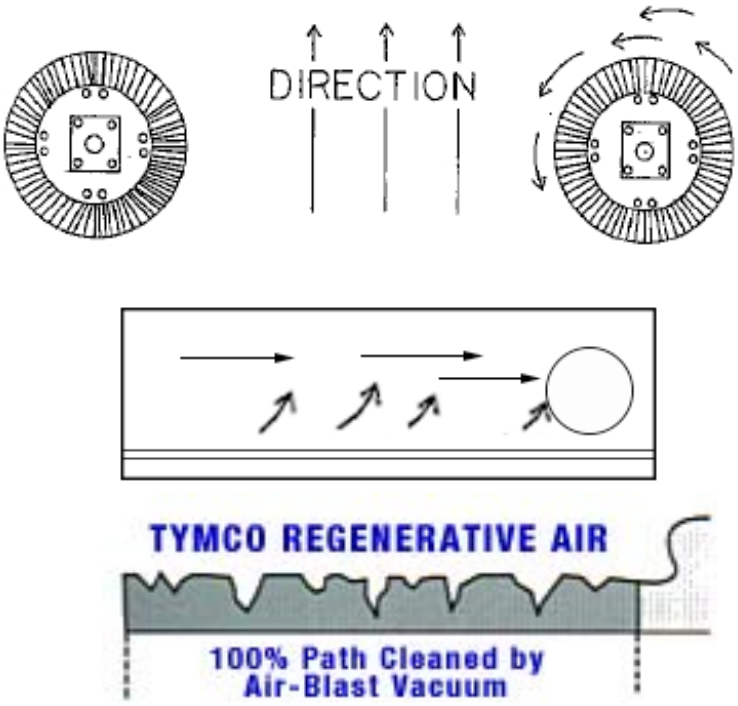
Regenerative Air Sweepers



Regenerative Air Sweepers

Advantages

- Better than mechanical sweepers at picking up fine material
- Wider path
- A deeper clean
- Lower maintenance cost

Disadvantages

- Not as effective at picking up:
  - Bulky, heavy material
  - Wet vegetation
- Uneven pavement may cause fugitive dust losses

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High Efficiency Sweepers

1997 – “High efficiency” coined by Sutherland

- Control PM_{10} & $PM_{2.5}$
- Use media filters for additional dust control
- Most are designed with the ability to sweep without water

1995 – EnviroWhirl

1970s – Some sweepers used filters – not high efficiency

1984 – TYMCO Model 600DC

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High Efficiency Mechanical

www.elginsweeper.com

www.elginsweeper.com

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High Efficiency Vacuum

http://www.henryequipment.com/1360/Details.aspx

High Efficiency Regenerative Air

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Early Street Sweeper Studies

Lee et al. (1959) - U.S. Naval Radiological Defense Laboratory
- Effectiveness of removing dry fallout material

Sartor and Boyd (1972) – US EPA – Review
- Vacuums are more efficient than mechanical sweepers
- Wide range of efficiencies (11-78%)

Early Street Sweeper Studies

Pitt (1979) – US EPA San Jose, CA “real world” study

- Established testing procedure
- Sweepers are more effective at picking up larger particles

Athayde et al. (1983) Nationwide Urban Runoff Plan (NURP)

- 1978-1983
- 28 locations
- $30 million ($106 million in today’s dollars)
- Constituent reductions never exceeded 50% in event mean concentrations

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“Contrary to Conventional Wisdom, Street Sweeping Can be an Effective BMP”

Sutherland and Jelen (1997)

- Determined that newer street cleaning technology is more effective than it was during the NURP era
- Simplified Particulate Transport Model (SIMPTM)
- TSS washoff reduction
- Single family residential streets
- Arterial streets
- Portland, Oregon

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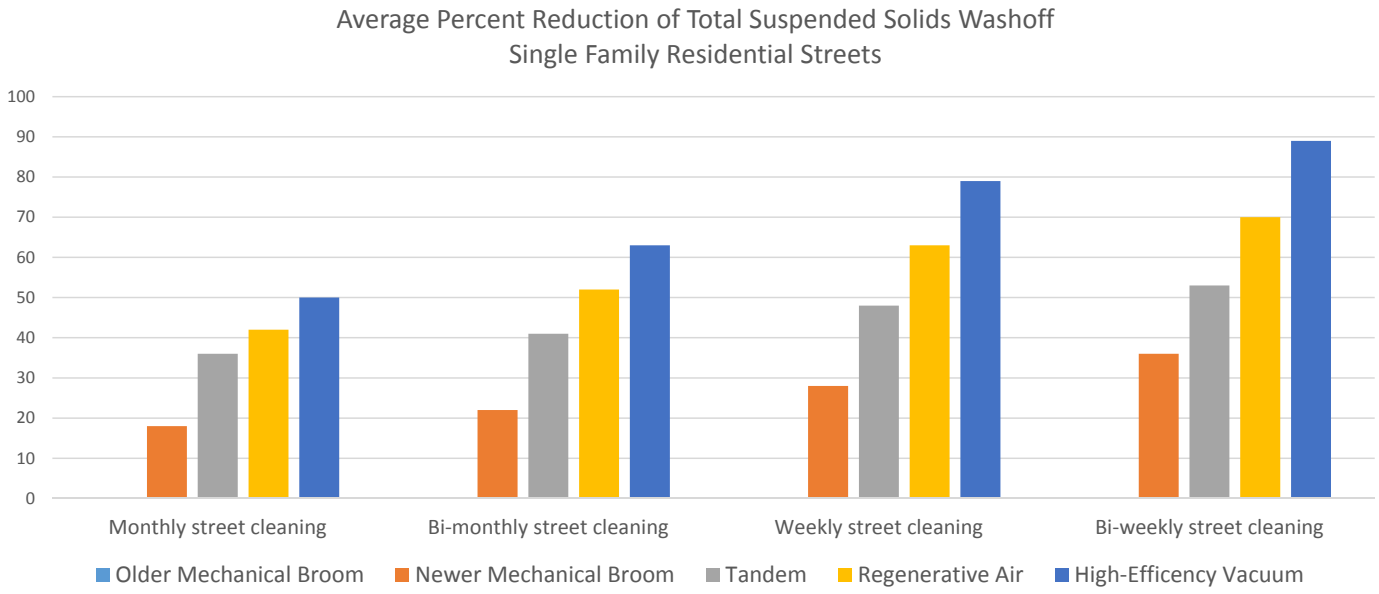
Sutherland and Jelen (1997)

(Adapted from Sutherland and Jelen 1997)



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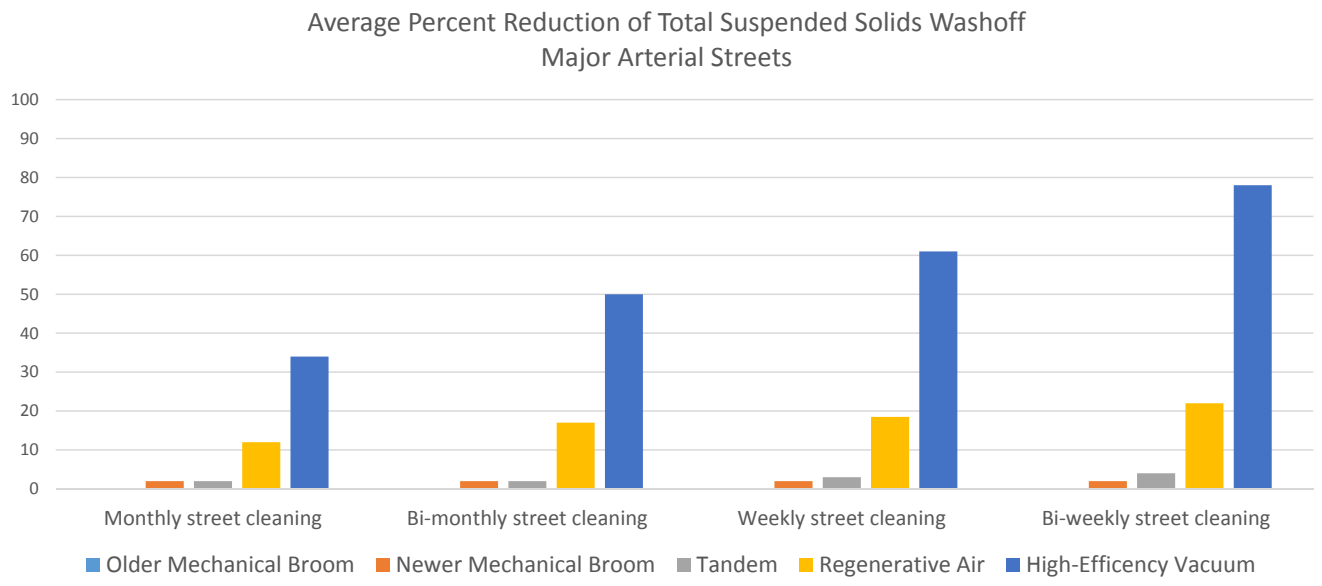

Toronto Clean Roads to Clean Air (2005)

- Routinely exceeding Ambient Air Quality Criteria and Canada-wide Standards for PM_{10} and $PM_{2.5}$
- PM_{10} – identified as a toxic substance – May 2000
  - Canadian Ministers of Health
  - Minister of the Environment
- PM causes respiratory and cardiovascular problems
- PM + Ozone = Smog
- Mechanical sweeping contributes to PM

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PM Sweeper Performance Test

- 80 x 11 m enclosed tent
- Two 2.75 x 30 m strips of calcium carbonate powder
- Mean diameter of 3 μm and total weight of about 270 kg
- Aged pavement with cracks and potholes.
- Water was not used
- Used LIDAR to measure ambient air PM

PM Performance Test

(Stevanovic-Briatico 2007)

Environmental Technology Verification Canada (ETV) Verified Sweepers

- High Efficiency Regenerative Air 1 (2005) – >90%
- High Efficiency Regenerative Air 2 (2008) – 89% (±2.1)
- High Efficiency Regenerative Air 3 (2008) – 81.8% (±3.6)
- High Efficiency Mechanical (2008) – 88.1% (±2.9)

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National Water Research Institute (Canada)

Rochfort et al. (2007)

Sweeper Type	Speed	>2,000 μm	64-2,000 μm	<64 μm
Older Regenerative Air	8-15 km/hr	0%	0%	0%
Conventional Mechanical	8-15 km/hr	58%	0%	0%
Newer High-efficiency Regenerative Air	5-8 km/hr	88%, 73%	62%	35%

USGS – Madison, WI

Selbig and Bannerman (2007)

- Mechanical
  - 5% pick-up efficiency
  - 20% reduction in average basin street-dirt yield
- Regenerative air
  - 25% pick-up efficiency
  - 76% reduction in average basin street-dirt yield
- Vacuum
  - 30% pick-up efficiency
  - 63% reduction in average basin street-dirt yield

USGS – Cambridge, MA

- Lower Charles River Basin exceeds Total Maximum Daily Load (TMDL) of phosphorous (P)

- A **Total Maximum Daily Load** (TMDL) is a limit set by an environmental regulatory agency for a given pollutant that a body of water can receive while still meeting water quality standards.

- MassDEP expects City of Cambridge, Massachusetts to reduce P contributions by more than 65%

Sorenson (2013)

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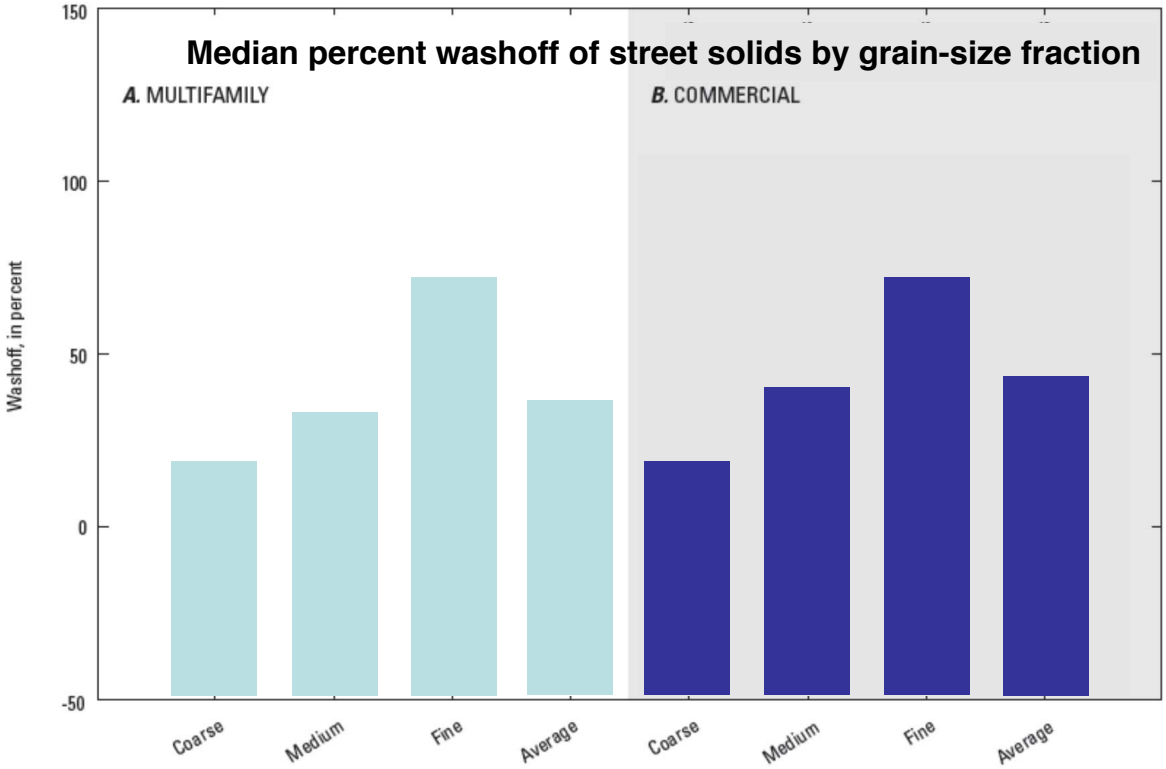
USGS – Cambridge, MA



Coarse is ≥ 2 mm
Medium is < 2 mm to ≥ 0.125 mm
Fine is < 0.125 mm

Adapted from Figure 11 (p. 25)

USGS – Cambridge, MA

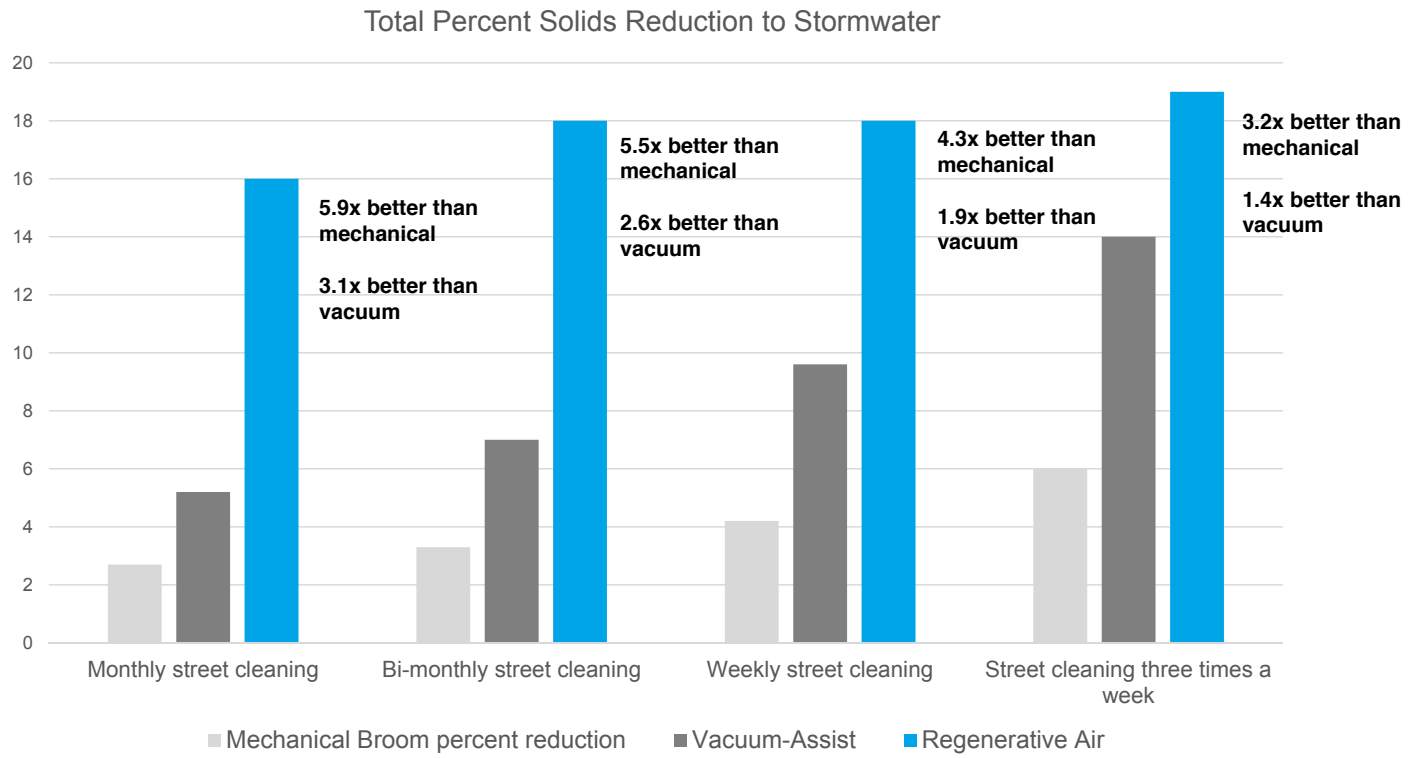
Sorenson (2013)

- High-efficiency regenerative air sweeper
  - Median removal efficiency
    - Multifamily – about 82%
    - Commercial – about 78%
  - Total Phosphorus (P) reductions

    - Multifamily – about 82%
    - Commercial – about 62%

- Source Loading and Management Model (SLAMM)
  - Compare Regenerative Air to Mechanical and Vacuum sweepers
    - Reductions of Solids
    - Reductions of P

SLAMM Results



Sweeping with a regenerative air sweeper monthly is 2.7x more effective at reducing solids than sweeping with a mechanical sweeper three times a week and 1.1x more effective at reducing solids than sweeping with a vacuum-assist sweeper three times a week.

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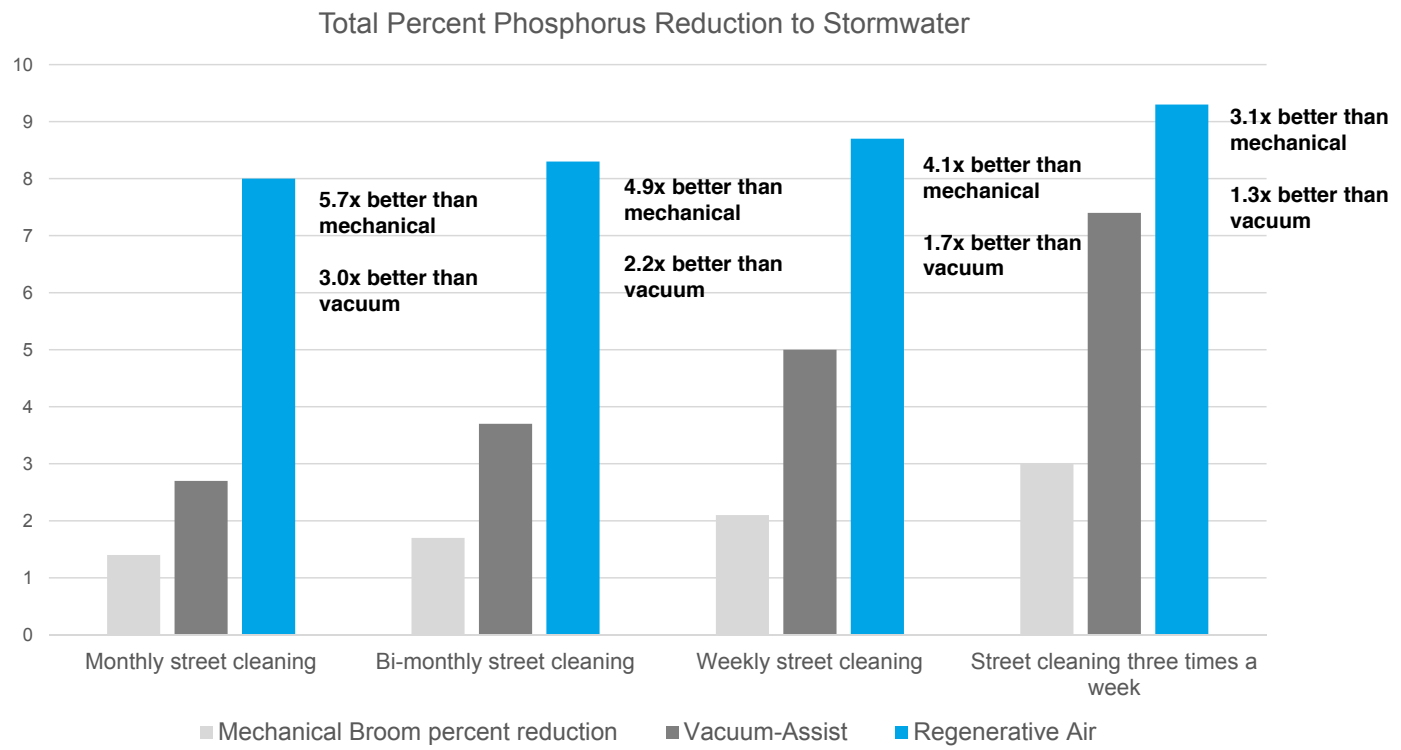
SLAMM Results



Sweeping with a regenerative air sweeper monthly is 2.7x more effective at reducing phosphorus than sweeping with a mechanical sweeper three times a week and 1.1x more effective at reducing phosphorus than sweeping with a vacuum-assist sweeper three times a week.

Conclusions

- Street cleaning can be an effective BMP
- Newer technology seems to be more effective
- How effective depends on many variables
    - climate and geology
    - cleaning frequency
    - street surface type
    - amongst manufacturers
    - testing parameters

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Q&A