Clean Roads to Clean Air Program

2007 APWA Public Works Congress & Exposition

Presenter
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Acknowledgement
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Clean Roads To Clean Air Program

Are you struggling to achieve the following with your street sweeping equipment?
- Cleaner Roads;
- Cleaner Air - Reduce Smog;
- Cleaner Stormwater;
- Year Round Performance;
- Less Downtime; and
- Low Maintenance

If you answered YES to any of these, this presentation will help you achieve these goals!!

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Background

- Toronto air quality preliminary model results indicate that a major local source of fine particulate matter (PM$_{10}$) is attributable to fine road dust;
- New street sweeper technology were reportedly capable of removing at least 80% of fine road dust;
- An 80% removal of fine road dust (PM$_{10}$) could result in 25%-30% improvement in the City’s PM$_{10}$ air quality;
- Auditor General identified sweepers as a high replacement priority for the organization;
- Sweeper fleet experiencing increased downtime for unscheduled repairs; and
- Toronto’s Wet Weather Flow Master Plan identified street sweeping as a Source Control measure.

Internal and External Stakeholders

Internal Stakeholders
Transportation Services Division
Toronto Environment Office
Fleet Services
Toronto Public Health
Toronto Water
Occupational Health and Safety
Purchasing Services
Legal Services

External Stakeholder
City of Hamilton
Environment Canada

Air Quality in Toronto

- PM$_{10}$ and PM$_{2.5}$ levels in Toronto routinely exceed the acceptable Provincial AAQC and CWS values;
- Both PM$_{10}$ and PM$_{2.5}$ are significant health concerns and year-round health hazard especially at “nose-level” on City’s arterial roads;
- 1,200 premature deaths attributable to chronic exposure to PM$_{2.5}$;
- 180 premature deaths attributable to acute exposure to PM$_{10}$;
- Fine particulates cause respiratory and cardiovascular problems.
What is Particulate Matter

- The major source of PM$_{10}$ in Toronto is an invisible fraction of “Fine Road Dust”.
- Particulate Matter (PM) + Ozone = Smog.
- “Fine Road Dust” comes from tire wear, asphalt wear, clutch and brake wear;
- PM$_{10}$ was identified as a “Toxic” substance in May 2000 by the Canadian Ministers of Health and Minister of Environment (under Canadian Environmental Protection Agency);
- Inhalable particulate matter (IP or PM$_{10}$); and
- Respirable particulate matter (RP or PM$_{2.5}$)

Where is Particulate Matter

80% of Fine Road Dust stays below 2 metres vertically

80% of Fine Road Dust stays within 5-10 metres horizontally
**Early Air Quality Modelling Results**

- New street sweeper technology such as: regenerative air, vacuums assist street sweepers are currently available and are reportedly capable of removing at least 80% of fine road dust (PM$_{10}$);
- Modelling suggested that an 80% removal of fine road dust (PM$_{10}$) will provide 25% -30% improvement in the City’s PM$_{10}$ air quality and even greater improvement is expected for pedestrians and cyclists on the City’s arterial roads.
Street Monitoring of Fine Road Dust

Objective

Obtain real-time Fine Particulate Matter, PM\(_{10}\) and PM\(_{2.5}\) measurements in downtown Toronto to determine the street level concentrations to which motorists, cyclists and pedestrians are exposed.

Figure 6a
Dec. 4 Test 1: PM\(_{10}\) Motorist Exposure ( Entire Circuit)

Average [PM\(_{10}\)] = 0.079 mg/m\(^3\)

Figure 6b
Dec. 4 Test 1: PM\(_{2.5}\) Motorist Exposure ( Entire Circuit)

Average [PM\(_{2.5}\)] = 0.066 mg/m\(^3\)
Street Monitoring of Fine Road Dust

Findings

- Toronto has an air quality problem related to Fine Road Dust (PM₁₀ & PM₂.₅);
- Daytime Street Levels of PM exceed Ambient Air Quality Criteria (AAQC) all Day;
- Problem varies with various factors:
  - Sweeping Frequency
  - Land Use
  - Traffic Volumes
  - Time of Day
  - Type of Vehicular Traffic
  - Weather;
- Confirms the need to assess the potential of “New Technology” Street Sweepers in reducing the concentration below AAQC levels;

Future Work

- Continue Monitoring Fine Road Dust Concentrations (Mobile and Stationary) and compare old and new technology street sweeper effectiveness;
- Investigate the relationship between Street Design and Building Configurations and Concentrations of Fine Road Dust;
LIDAR Test

What is LIDAR

LIDAR – Light Detection And Ranging technology, is remote sensing equipment using emitting laser light pulses to measure the fine road dust’s plume concentration and movement as the signals bounce back to a receiver.

LIDAR Test

Purpose of LIDAR Test

- Test whether we can use LIDAR as a tool to evaluate street sweeping activity;
- Obtain visual records and air contamination levels of various street sweepers technology under a number of operational conditions;
- LIDAR equipment provides the ability to track Fine Road Dust (Fine Particulate Matter, PM$_{10}$, PM$_{2.5}$) from City roads under real conditions;
Mechanical Sweeper Travels
North in East Curb Lane 11:26:43

Mechanical Sweeper Travels
North in East Curb Lane 11:26:48

Mechanical Sweeper Travels
North in East Curb Lane 11:26:58
**LI DAR Test**

**Key Findings**
- Mechanical street sweepers disturb a significant amount of fine road dust into the air;
- Street sweeping activity in itself contributes to poor air quality;
- Sweeping disturbs road dust creating an even worse re-entrainment problem;
- Cross-sectional images of the plume of Fine Road Dust generated by the mechanical sweepers were recorded with the data showing that approximately 80% of PM$_{10}$ stays below 2 metres (vertically) and stays within 10 metres (horizontally) during sweeping.

**Objectives of the CRCA Program**
- to deploy PM$_{10}$ and PM$_{2.5}$ efficient street sweepers that are capable of regular sweeping plus removing fine particular matter (PM$_{10}$ and PM$_{2.5}$) from the City’s paved roads year round; and
- to deliver the city street sweeping service in a manner that would significantly contribute to improving overall human health, air and storm water quality.

**Key Elements of the CRCA Program**
- Air quality model;
- Operational Performance;
- Maintenance and Downtime Costs;
- Protocols
  - Evaluate PM$_{10}$ and PM$_{2.5}$ efficiency
  - Evaluate operational performance;
- Implemented several studies understanding the relationship between air quality and street sweeping;
- Developed a harmonized street sweeping level of service based on established criteria (i.e. road class)
- Stormwater quality;
- Street sweepings management and disposal;
- Occupational Health and Safety review, handling and cleaning procedures;
- Monitoring air quality during street sweeping.
**Toronto Protocol Development**

**Early Concepts**
- Rule 1186 was considered but found lacking
- Used 97% sand plus 3% PM 10 “paint filler”
- Certified if 80% of either material captured
- No limit on water use
- Shrouds were allowed for dust suppression
- Used open ended tunnel and forced air concentrations
- Used a pass/fail approach

**City of Toronto Requirements**
- Use Gutter Brooms, BUT No Shrouds
- Controlled Speed
- Use No Water
- Has Dustless Capability

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**Toronto Protocol Development**

**Why Dustless**
- The critical value of determining the most effective PM sweeper is its ability to operate without putting excessive PM 10 & PM 2.5 into the air that we breathe.
- Reduce the exposure of cyclist, pedestrian and motorists using our right-of-ways
- Permits sweeping during smog days and reduces smog impacts on population

**Why Waterless**
- Capability of sweeping year-around
- Avoid toxic loads being washed down catchbasins that impact the stormwater quality and the cost of treatment

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**Toronto Protocol Development**

**Why Shroudless**
- Operational performance affected (i.e. problem picking up leaves, large debris);
- Shrouds are too easily and frequently damaged;
- Damaged shrouds affects removal and entrainment efficiency;
- Leaves a stream of silt debris next to the curb;
Toronto Protocol Development

General Test Concepts

- Controllable and Replicable Conditions Test
- Use Average of Three Tests
- Use Manufacture’s recommended speed or 8–10 km/h if absent
- Pre-Vacuum Test Surface
- Known Quantity of Test Material Applied (PM$_{10}$ Only)
- Pre and Post-Test Weight of Sweeper
- Post-Vacuum Test Surface
- Measure Removal Efficiency - “capture-and-remove-by-sweeper”
- Measure Entrainment Efficiency - “disturb-and-deposit-elsewhere”
- Not a Pass/Fail Approach

Test Track (typifies a Toronto worst case scenario)

- aged asphalt with cracks & potholes
- curbs are essential
- include sidewalks in the Test Track

Test Material

- 270 kg of Test Material
- 100% Camel White - dry ground Lime Stone - marble (CaCO$_3$)
- median diameter = 3 microns (good for PM$_{10}$ & PM$_{2.5}$)

Meteorology

- no precipitation in previous 36 hours
- wind speeds must be below 8 km/h
- track MUST be dry, relative & absolute humidity MUST be low

Vacuuming and Spreading

- Test Strips were separated into twelve quadrants for the spreading of the test material;
- Test track was divided into eight quadrants that were vacuumed and evaluated as separate areas;
  - Four quadrants for the inside of the test track
  - Two quadrants for the sidewalk portion of the test track
  - Two quadrants, outside portion of the test track

Monitoring

- Used eight monitors – four PM$_{10}$ and four PM$_{2.5}$ with two PM$_{10}$ and two PM$_{2.5}$ monitors in the centre of the track operated 20 hours/day
PM\textsubscript{2.5} & PM\textsubscript{2.5} Street Sweeper Efficiency Test Protocol

The protocol establishes a method to gauge the year round efficiency of street sweepers for their removal of PM\textsubscript{10} and PM\textsubscript{2.5} from typical Toronto urban streets and their ability to limit the amount of PM\textsubscript{10} entrained into the air during the sweeping process.

Two key methods used in the evaluation of the street sweepers:
• how much material was picked up/left behind by the street sweeper and
• how much material was entrained by the street sweeper

PM\textsubscript{10} & PM\textsubscript{2.5} Street Sweeper Efficiency Test Protocol

PM Criteria and Thresholds

- Pick-up Removal Efficiency (%) More than 90%
- Deposit on Sidewalk Efficiency (%) Less than 0.08%
- Air Contamination PM\textsubscript{10}
  • Maximum Concentration Less than 0.08 mg/ m\textsuperscript{3}/ kg
  • Total Concentration Less than 11 mg/ m\textsuperscript{3}/ kg
- Air Contamination PM\textsubscript{2.5}
  • Maximum Concentration Less than 0.02 mg/ m\textsuperscript{3}/ kg
  • Total Concentration Less than 5.0 mg/ m\textsuperscript{3}/ kg
PM\textsubscript{10} & PM\textsubscript{2.5} Street Sweeper Efficiency Test

Disco Yard: PM10 and PM2.5
Street Sweeper Efficiency Test
(Daily Activities)
(Video)

Street Sweeper - PM\textsubscript{10} Entraining Efficiency Test
Street Sweeper Comparison: Levels During Test
PM\textsubscript{10} Levels During Test
Table 1
### Table 2

<table>
<thead>
<tr>
<th>Time (20 Sec. Intervals)</th>
<th>PM$_{10}$ Levels During Test</th>
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</thead>
<tbody>
<tr>
<td>0:00:00</td>
<td>0.01</td>
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<tr>
<td>0:00:20</td>
<td>0.1</td>
</tr>
<tr>
<td>0:00:40</td>
<td>1</td>
</tr>
<tr>
<td>0:01:00</td>
<td>10</td>
</tr>
<tr>
<td>0:01:20</td>
<td>100</td>
</tr>
<tr>
<td>0:01:40</td>
<td>1000</td>
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</table>

### Table 5

<table>
<thead>
<tr>
<th>Time (24 Sec. Intervals)</th>
<th>PM$_{10}$ Levels During Test (mg/m$^3$)</th>
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</thead>
<tbody>
<tr>
<td>0:00:00</td>
<td>0.01</td>
</tr>
<tr>
<td>0:00:23</td>
<td>0.1</td>
</tr>
<tr>
<td>0:00:46</td>
<td>1</td>
</tr>
<tr>
<td>0:01:09</td>
<td>10</td>
</tr>
<tr>
<td>0:01:32</td>
<td>100</td>
</tr>
<tr>
<td>0:01:55</td>
<td>1000</td>
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</table>

### Table 8

<table>
<thead>
<tr>
<th>Time (23 Sec. Intervals)</th>
<th>PM$_{2.5}$ Levels During Test (mg/m$^3$)</th>
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</thead>
<tbody>
<tr>
<td>0:00:00</td>
<td>0.01</td>
</tr>
<tr>
<td>0:00:23</td>
<td>0.1</td>
</tr>
<tr>
<td>0:00:46</td>
<td>1</td>
</tr>
<tr>
<td>0:01:09</td>
<td>10</td>
</tr>
<tr>
<td>0:01:32</td>
<td>100</td>
</tr>
<tr>
<td>0:01:55</td>
<td>1000</td>
</tr>
</tbody>
</table>
PM10 & PM2.5 Street Sweeper Efficiency Test Results

Top Four Street Sweepers - Test Results

<table>
<thead>
<tr>
<th>Sweeper Company’s Name</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street Sweeper Technology</td>
<td>Mechanical</td>
<td>Regenerative-Air</td>
<td>Mechanical</td>
<td>Regenerative-Air</td>
</tr>
<tr>
<td>Percent Dust Removal</td>
<td>95.14%</td>
<td>95.11%</td>
<td>95.01%</td>
<td>95.00%</td>
</tr>
<tr>
<td>Total PM10 Concentration</td>
<td>6.04</td>
<td>6.04</td>
<td>6.04</td>
<td>6.04</td>
</tr>
<tr>
<td>PM10 Criteria</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg. of All Test Dates</td>
<td>18.54</td>
<td>35.38</td>
<td>7.00</td>
<td>45.62</td>
</tr>
<tr>
<td>Avg. of All Test Dates 7/24/2004</td>
<td>6.02</td>
<td>6.03</td>
<td>6.03</td>
<td>6.03</td>
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<tr>
<td>Total Concentration</td>
<td>5.44</td>
<td>5.44</td>
<td>5.44</td>
<td>5.44</td>
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</table>

Emission Comparison Mechanical VS Regenerative-Air

<table>
<thead>
<tr>
<th>Street Company’s Name</th>
<th>A</th>
<th>B</th>
<th>F</th>
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<tbody>
<tr>
<td>Street Sweeper Technology</td>
<td>Regenerative-Air</td>
<td>Mechanical</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Percent Dust Removal</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Area 1 South District per month (kg)</td>
<td>19,132.10</td>
<td>19,132.10</td>
<td>19,132.10</td>
</tr>
<tr>
<td>Area of PM10 in Silt Loading</td>
<td>12.39</td>
<td>44.00</td>
<td>na</td>
</tr>
<tr>
<td>Average Quantity of PM10 in Silt Loading</td>
<td>1,853.90</td>
<td>2,039.20</td>
<td>2,039.20</td>
</tr>
<tr>
<td>Quantity of additional PM10 left behind by Sweeper A (kg)</td>
<td>+985.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity of additional PM10 left behind by Sweeper F (kg)</td>
<td></td>
<td>+1,729.54</td>
<td></td>
</tr>
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PM10 & PM2.5 Street Sweeper Efficiency Test

Street Sweeper Comparison Video

Efficiency Test 2004

(Video)
Maintenance Review

- Toronto staff reviewed the maintenance cost of a number of different street sweeper technologies that are operated in-house and through contracted services.

- Toronto staff obtained and reviewed the maintenance costs of different street sweeper technologies from several other municipalities.

Operational On-Street Test

Key operational requirements evaluated:

- Wet road surface condition pick-up efficiency;
- Maneuverability around parked cars pick-up efficiency;
- Leaf pick-up efficiency;
- Large debris pick-up efficiency;
- Heavy silt loading pick-up efficiency; and
- Operate sweeper without gutter brooms pick-up efficiency.

Operational On-Street Test

Summary of Findings

<table>
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<th>Operational Requirements</th>
<th>Mechanical</th>
<th>Regenerative-air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maneuverability</td>
<td>14%</td>
<td>36%</td>
</tr>
<tr>
<td>Pick-up Large Debris</td>
<td>90%</td>
<td>93%</td>
</tr>
<tr>
<td>Leaf Removal</td>
<td>95%</td>
<td>96%</td>
</tr>
<tr>
<td>Heavy Silt Loading</td>
<td>95%</td>
<td>98%</td>
</tr>
<tr>
<td>Sweeping During Wet Conditions</td>
<td>82%</td>
<td>89%</td>
</tr>
<tr>
<td>Dustless Sweeping (without gutter brooms)</td>
<td>n/a</td>
<td>87%</td>
</tr>
</tbody>
</table>
Transportation Services Division
Toronto Environment Office

Operational On-Street Test

Operational On-Street Test
(Video)

Performance Evaluation

Summary of Criteria Evaluated

Daily Maintenance by Operator - Cleaning hopper; Washing Sweeper; Fueling; Cleaning filters; and Cleaning Dust Trap

Daily Mechanical Maintenance - Replacing gutter brooms; shift pick-up head; replace pick-up head broom; replace water filter; and accessibility of parts

Parts Availability - Mock-up order of warranty and outside warranty parts

Operator Evaluation - visibility; ergonomics; comfort; noise in cab; dust in cab and safety features

Stormwater Quality Evaluation

Study Objective

To assess the improvement of stormwater quality by street sweeping, one of the source controls included in the Toronto Wet Weather Flow Master Plan

Project implemented in 2004 and 2005, collaboration between Environment Canada, Toronto Water and Transportation Services Division
Transportation Services Division
Toronto Environment Office

Study Results
- New technology regenerative-air street sweepers provide the greatest environmental benefits by reducing the total mass or road deposited sediment after sweeping and dissolved metals in runoff.
- Key for street sweeping to be effective source control the following measures must be considered:
  - Sweeping prior to rainfall and as often as practical;
  - Areas with high level of pollution (such as arterial roads and industrial areas) should receive more frequent sweeping;
  - Sweepers must be clean and maintained properly;
  - Operators must be trained to achieve the best performance.

Stormwater Quality Evaluation

Effectiveness of Street Sweeping as a Stormwater Pollution Source Control

(Video)

Recommendation
Recommend “dustless” regenerative-air street sweepers as a preferred technology at this time, meeting PM$_{10}$ and PM$_{2.5}$ efficiency criteria, operational, performance and maintenance requirements.
2005 Street Sweeper RFP

First Stage
• Meet all mandatory requirements as specified in Section A and B of the Specifications
• Additional features as specified in Section C of the Specification were scored
• If mandatory requirements are met the Proponent will qualify for stage two of the process

Second Stage
• Mandatory testing and evaluation of regenerative-air street sweepers
  • the PM$_{10}$ and PM$_{2.5}$ efficiency;
  • operational requirements; and
  • performance evaluation

Results
• The City of Toronto has purchased 25 “dustless” regenerative-air street sweepers;
• In the near future Toronto will be purchasing additional sweepers in support of the City Council’s newly and unanimously endorsed combined air quality and climate change related policy;
• The evaluation process has provided a framework for the continuous development of new operational practices and procedures, ensuring that the City’s street sweeping service is delivered in a safe, environmentally sustainable, efficient and effective manner; and
• This will be a standard by which we recommend and will use for all our future sweeper purchases.

Benefits
Regenerative-Air Street Sweepers
Remove 50% More PM from City Streets

EQUALS

14 TONNES OF PM
Benefits

Summary of Sweepings Hauled (tonnes)

<table>
<thead>
<tr>
<th>Month</th>
<th>2006</th>
<th>2007</th>
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</thead>
<tbody>
<tr>
<td>April</td>
<td>274.98</td>
<td>758.00</td>
</tr>
<tr>
<td>May</td>
<td>359.14</td>
<td>683.00</td>
</tr>
<tr>
<td>June</td>
<td>325.90</td>
<td>304.22</td>
</tr>
<tr>
<td>July</td>
<td>212.46</td>
<td>172.48</td>
</tr>
<tr>
<td>Total Sweepings Hauled</td>
<td>1172.48</td>
<td>1917.90</td>
</tr>
</tbody>
</table>

Ellesmere Yard is hauling 64% more street sweepings over the previous year

Benefits

- Reduction of airborne particulate matter at street level, by at least 21%;
- Improvement in air quality will be beneficial to the general health of City's residents, workers and visitors;
- Reduces the number of cases of acute and chronic exposure of fine particulates;
- Improves stormwater quality and reduces the cost of stormwater treatment;
- Reduces maintenance costs
- Reduces downtime for unscheduled repairs
- Permits sweeping during smog days and will help to reduce smog impacts;
- Capable of street sweeping year-around and will help to improve the level of street sweeping service across the City

Municipal Requirement

Third Party Testing

- Developed a testing protocols and criteria to objectively evaluate the environmental and operational effectiveness of street sweepers now and in the future;
- ETV and PAMI were contracted by the City of Toronto to review the Protocol and witness the testing; and
- A number of municipalities have indicated support in adopting the PM Efficiency Test and criteria as a new street sweeping municipal standard
- Tymco DST-6 regenerative-air street sweeper received an Environmental Technology Verification Certificate verifying the performance claims achieved using the City of Toronto Test Protocol.
Enhancements to the CRCA Program

**Best Practices**
- Handling and cleaning of street sweepers - occupational health and safety review of procedures;
- Air quality inside cab;
- Dust trap and dust filter cleaning procedures;
- On-going monitoring and training of operators to ensure that the equipment is operated and maintained to maximize performance;
- Waste stream management including:
  - Storage of street sweeping debris in yards;
  - Manage sweepings entering catchbasins; and
  - Disposal and potential diversion of sweepings;
- Monitoring changes of PM concentrations on swept City streets;
- On-going evaluation the street sweeping frequency and street sweeper complement; and
- Incorporating PM efficient street sweepers in post construction sweeping contracts.

2008 Street Sweeper Monitoring
- To assess the effectiveness of City’s new “regenerative-air” street sweepers in improving PM$_{10}$ and PM$_{2.5}$ in Toronto;
  - Ambient Air Quality Concentrations
  - Dust Disturbance by Sweepers
- To evaluate the harmonized street sweeper level of service by geography and road classification;
- To report back to Council on
  - the effectiveness of new street sweepers;
  - resource requirements; and
  - impact to operating budget.

Clean Roads to Clean Air Program

Thank you for your interest and attention

Questions

Contact Information

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