



Clean Roads to Clean Air Program

The City of Toronto's Clean Roads to Clean Air Program was established as a concept in 2003 and realized in 2007 and 2008 by replacing the full fleet with environmentally and operationally efficient street sweepers. The CRCA Program meets the City's mandate to manage its operations in a sustainable and efficient manner and to consider the impacts to the environment and human health. The Program achieved this by establishing environmental and operational criteria and testing protocols. Also, the procurement of sweepers is innovative in that it includes the evaluation of environmental and operational performance using a third party verification process.



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Part 2: Human Health Concerns

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Part 6: Operational On-Street Test Protocol

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Toronto's Past

Prior to procuring the PM efficient street sweepers this was typical experience in the City of Toronto.

Large accumulation of street debris and fugitive road dust and environmentally inefficient street sweepers created poor air quality conditions.



Part 1:

Health Evidenced, Environmental Requirements

Environmental Health Requirements

A range of toxic metals that are of human health concern accumulate and can be found in road dust, such as cadmium, lead and arsenic.

A primary source of metal-enriched road dust is traffic.

Metals are released from non-exhaust, traffic-related sources as a result of the wear and tear of roadway surfaces and automotive parts and components such as brake linings, catalytic converters and tires.

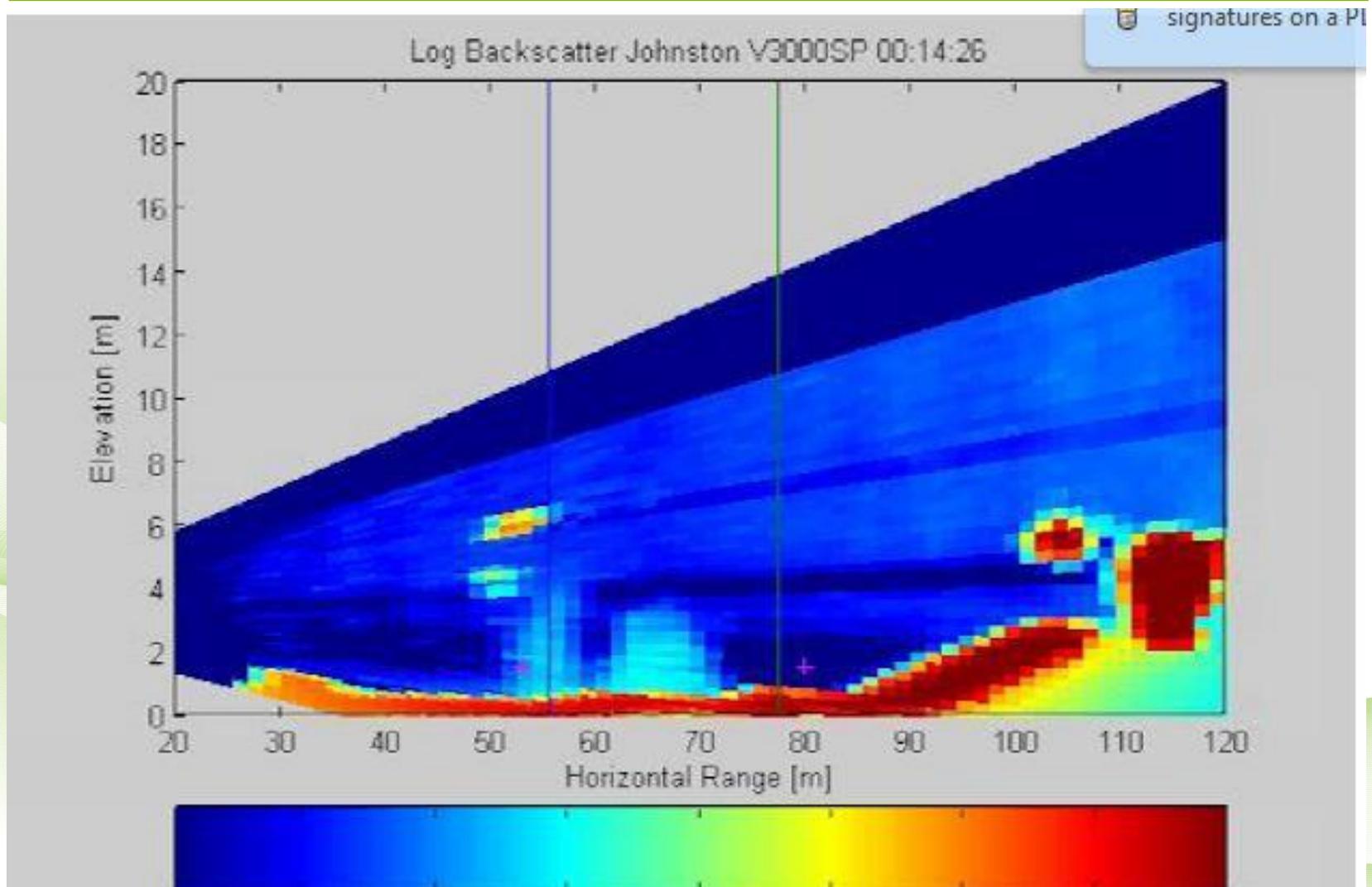
The road dust has been identified as a contributor of metal contamination to air, water and soil.

Sweepers Adding to Air Quality

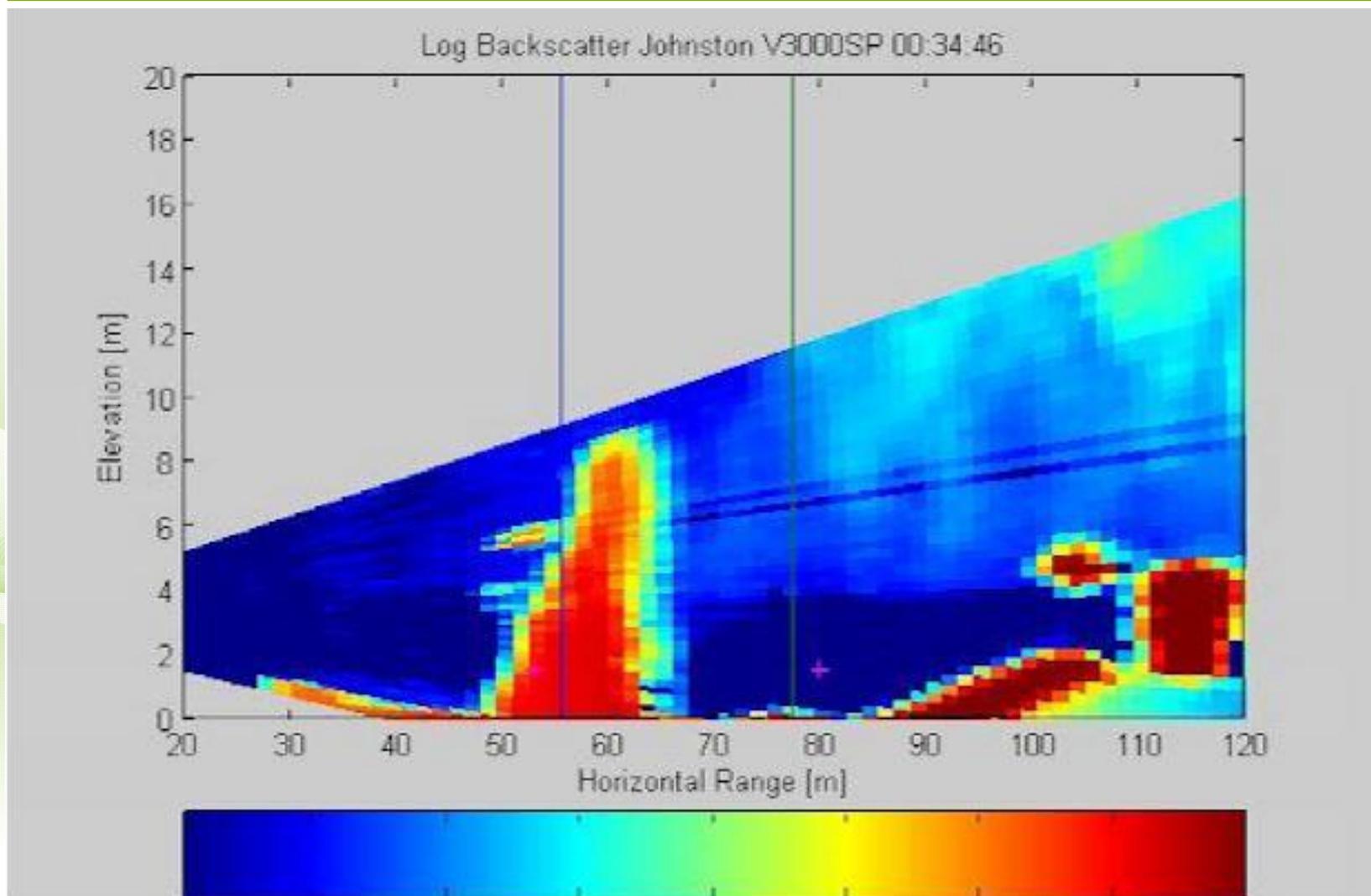
Purpose

- Obtain visual records and air contamination levels of various street sweepers technology under a **number of real operational conditions and to evaluate street sweeping activity;**
- **LIDAR** (Light Detection and Ranging) images in the next few slides showing PM concentrations:
 - Pre sweeping car passing;
 - Mechanical street sweeper sweeping; and
 - Post sweeping car passing
- **PM₁₀ and PM_{2.5} levels in Toronto routinely exceed the acceptable Provincial AAQC and CWS values**

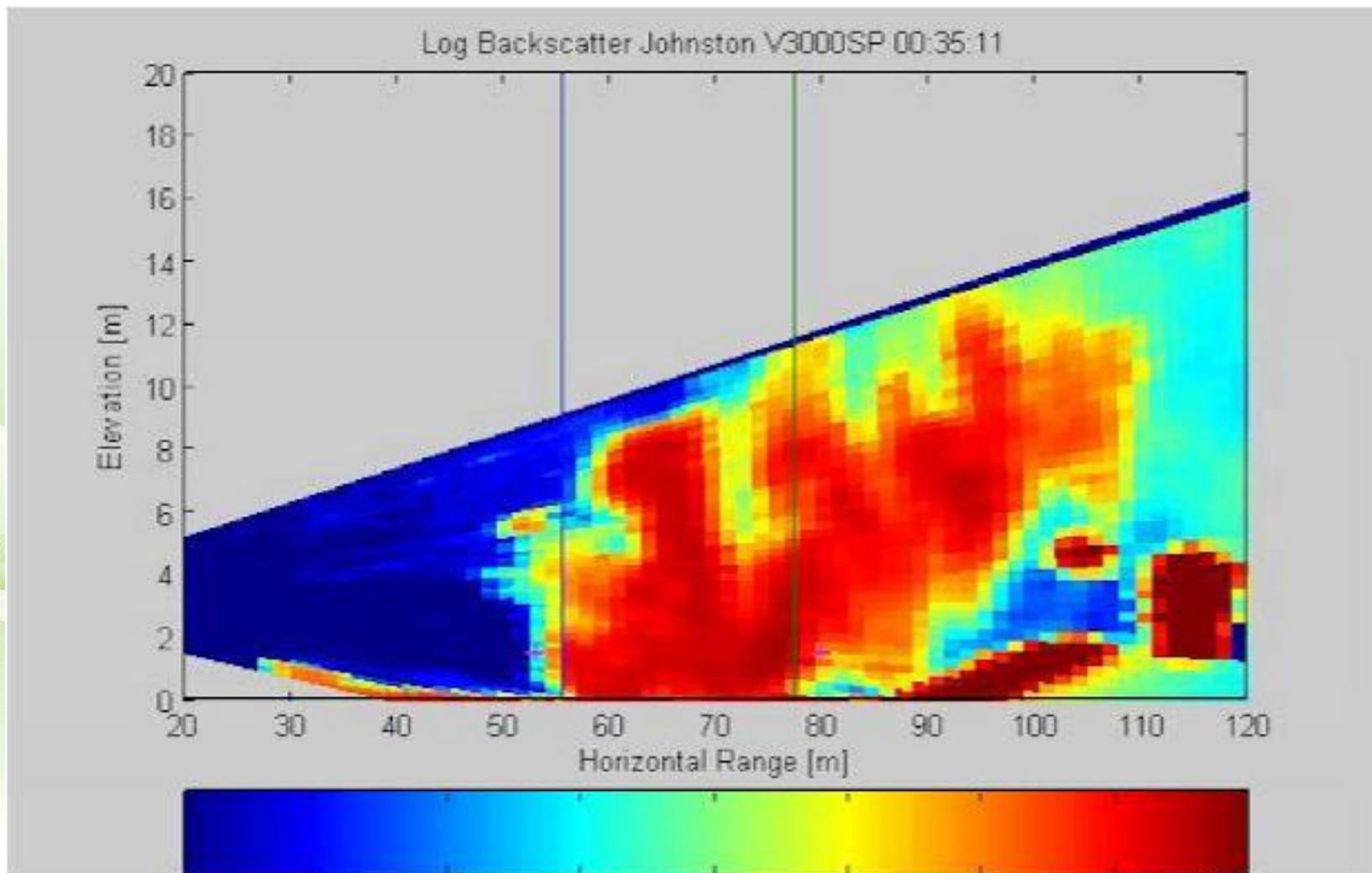
Pre Sweeping Car Passing



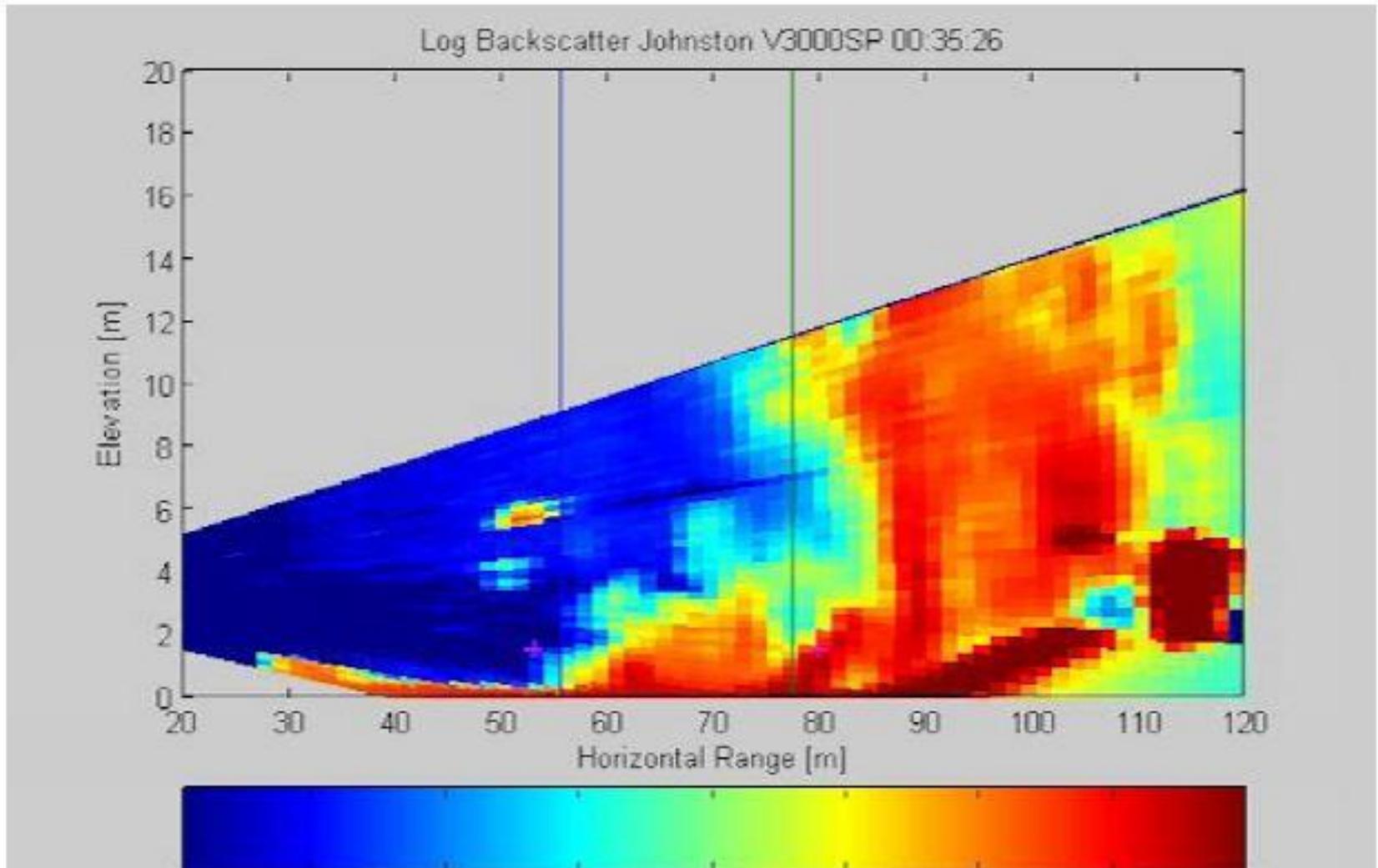
Mechanical Sweeper Sweeping



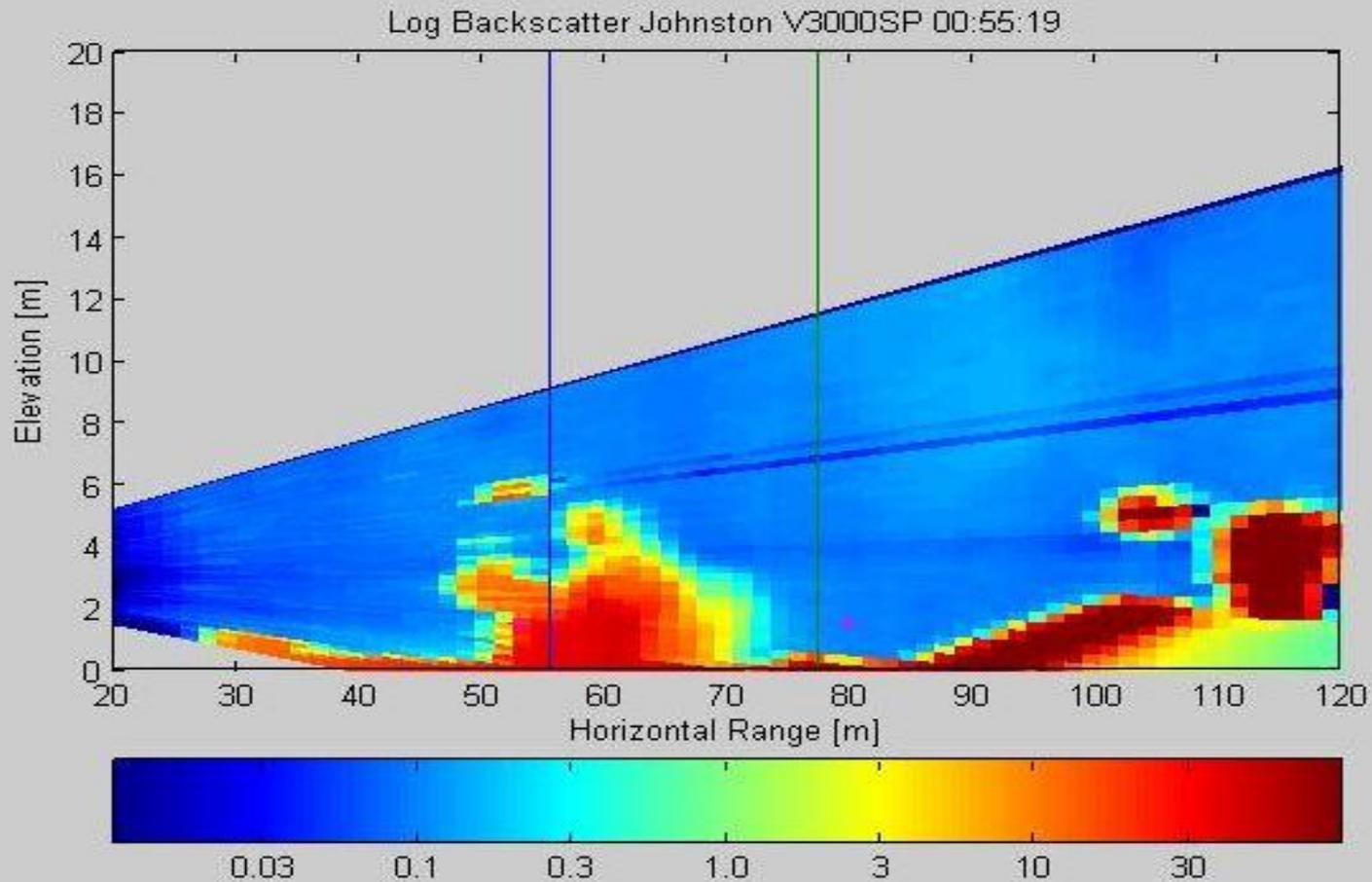
Mechanical Sweeper Sweeping



Mechanical Sweeper Sweeping

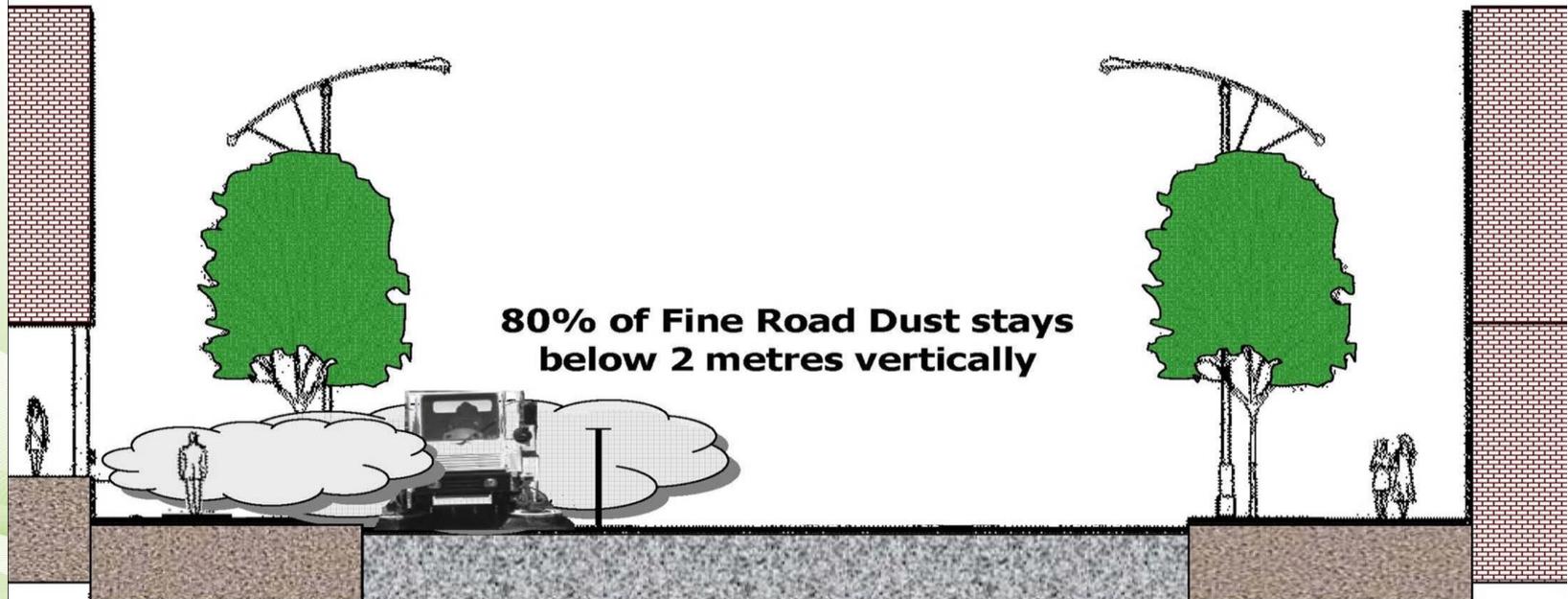


Post Sweeping Car Passing



During Sweeping & Passing Vehicles

Where Is Particulate Matter Found



80% of Fine Road Dust stays below 2 metres vertically

80% of Fine Road Dust stays within 5-10 metres horizontally

Where is Particulate Matter Found

PM₁₀ Distribution

- PM₁₀ is lifted by **moving/passing** vehicles;
- **Urban canyons & streets “trap”** movement;
- **PM₁₀ is more concentrated along major streets; and**
- **PM₁₀ is less concentrated in residential neighborhoods**

Stormwater Quality Study

- Assessing the effectiveness of street sweeping as a source control measure for stormwater included in the Wet Weather Flow Master Plan;
- Collaborated with Environment Canada and number of City divisions the project evaluated the quantity of sediment and dissolved metals in stormwater runoff;
- Pollution was tested at a site in Toronto, using three types of sweepers employed by the City;
- Test results between swept and unswept scenarios were assessed by comparing: (a) conventional sediment quality parameters, total residue mass, and particle sizes for dry sediment samples, and (b) toxicity, conventional water quality parameters, and particle sizes in wet samples.

Stormwater Quality Evaluation



Street Sweeper Technology:

Regenerative-Air

Location:

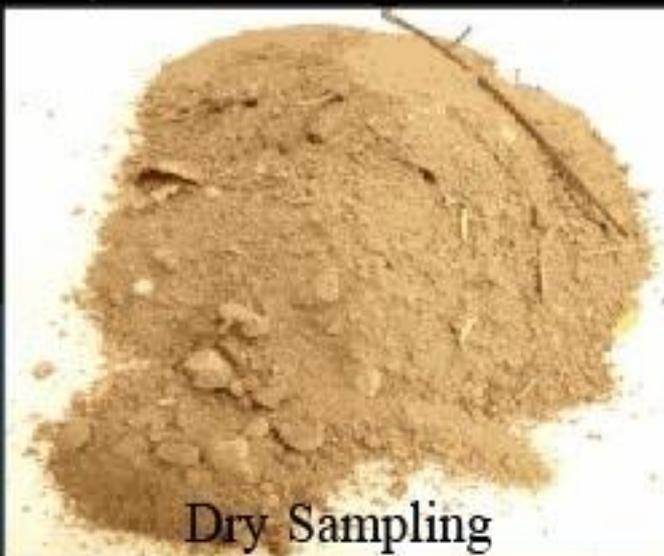
Markham Rd
(Southbound - Swept Portion)



Industrial Vacuum
(Nilfisk-Advance 2050)



Dry Sampling



Dry Sampling

Location:

Markham Rd
(Southbound - Swept Portion)



Wet sample collection
– test catchment area



Wet Sampling



Location:

Markham Rd
(Southbound - Swept Portion)

Stormwater Quality Study

Study Results

- Regenerative-air street sweepers provide the greatest environmental benefits by reducing the total mass of road deposited sediment and dissolved metals in runoff;
- The following measures must be considered for street sweeping to be effective source control:
 - Sweep prior to rainfall and often as practical;
 - Areas with high level of pollution (such as arterial roads and industrial areas) should receive more frequent sweeping;
 - Sweepers must be cleaned and maintained properly; and
 - Operators must be trained to achieve the best performance
- See full report at <https://www.cawq.ca/journal/temp/article/410.pdf>

Part 2:

Human Health Concerns

Human Health Concerns

- Both PM_{10} and $PM_{2.5}$ are **significant** health concerns and a 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

Human Health Concerns

What is Particulate Matter

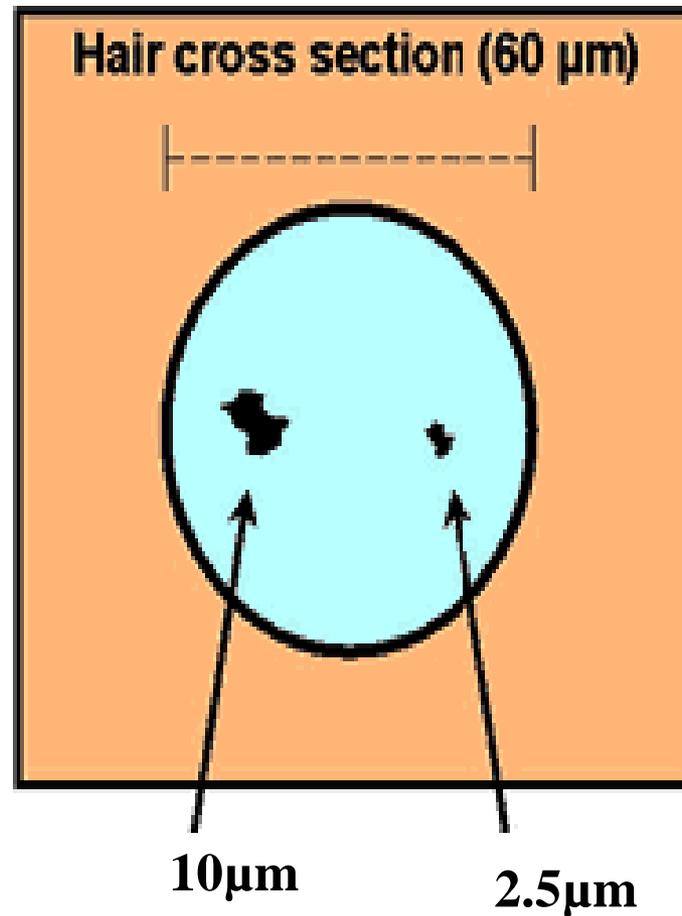
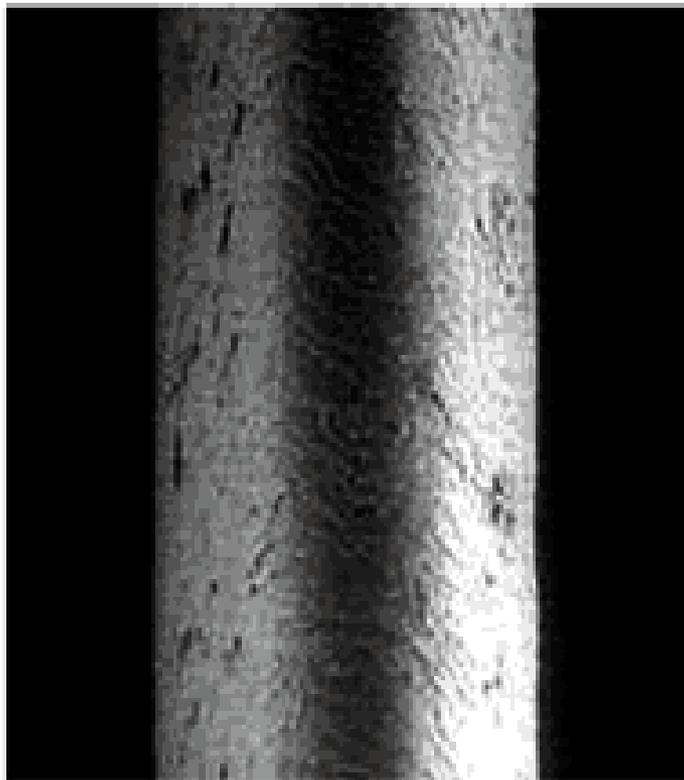
The major source of PM_{10} in Toronto is an invisible fraction of “Fine Road Dust”

“Fine Road Dust” comes from tire wear, asphalt wear, clutch and brake wear

Inhalable particulate matter (IP or PM_{10})

Respirable particulate matter (RP or $PM_{2.5}$)

Human Health Concerns



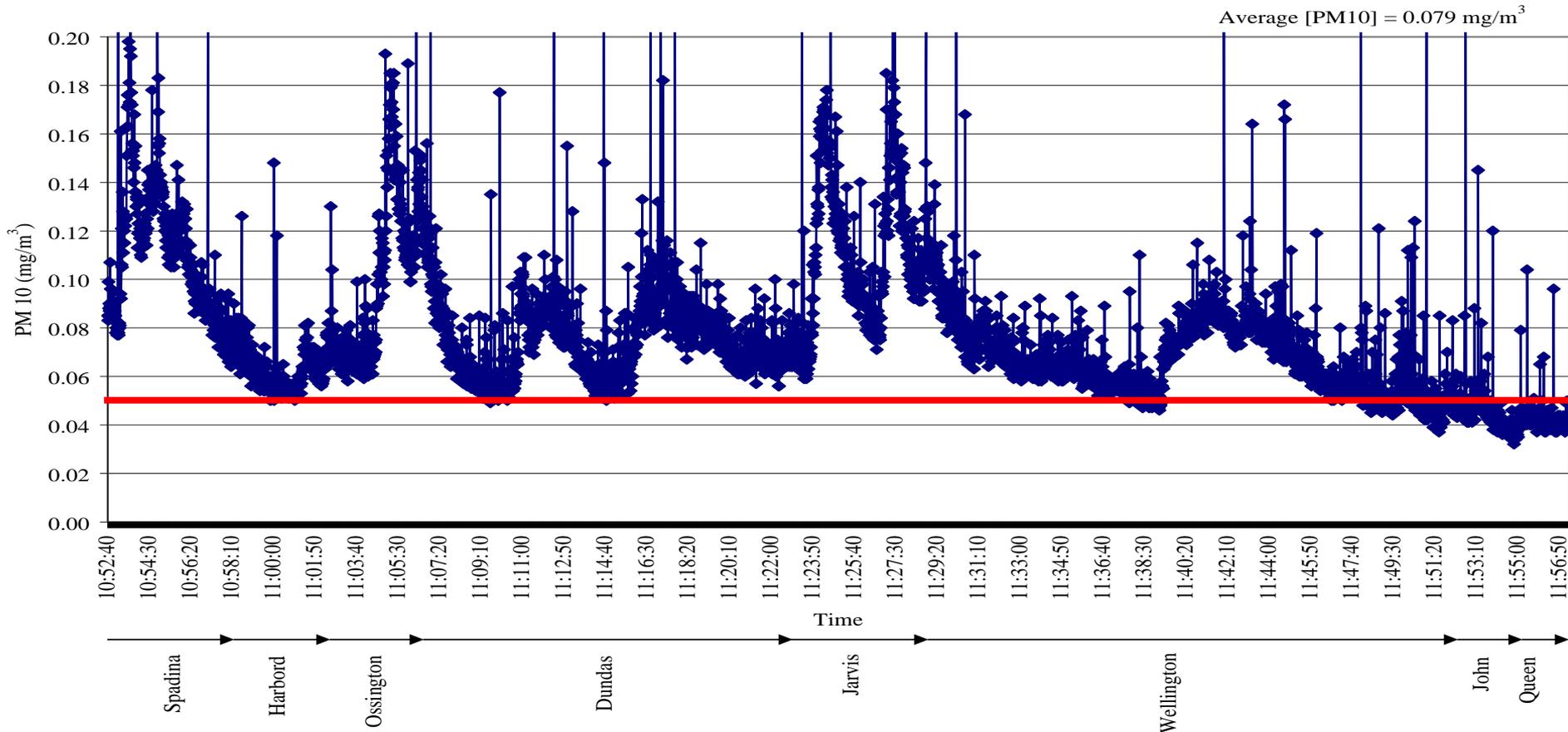
Human Health Concerns

Street Monitoring of Fine Road Dust

- In 2005 and 2006 a number of street monitoring studies were undertaken.
- Real-time PM_{10} and $PM_{2.5}$ measurements were obtained in Toronto to determine the street level concentrations to which motorists, cyclists and pedestrians are exposed.
- Graphs show the PM_{10} motorist, cyclist and pedestrian exposure levels, an acceptable level of $50\mu\text{g}/\text{m}^3$.
- Graphs show the $PM_{2.5}$ motorist, cyclist and pedestrian exposure levels, an acceptable level of $30\mu\text{g}/\text{m}^3$.

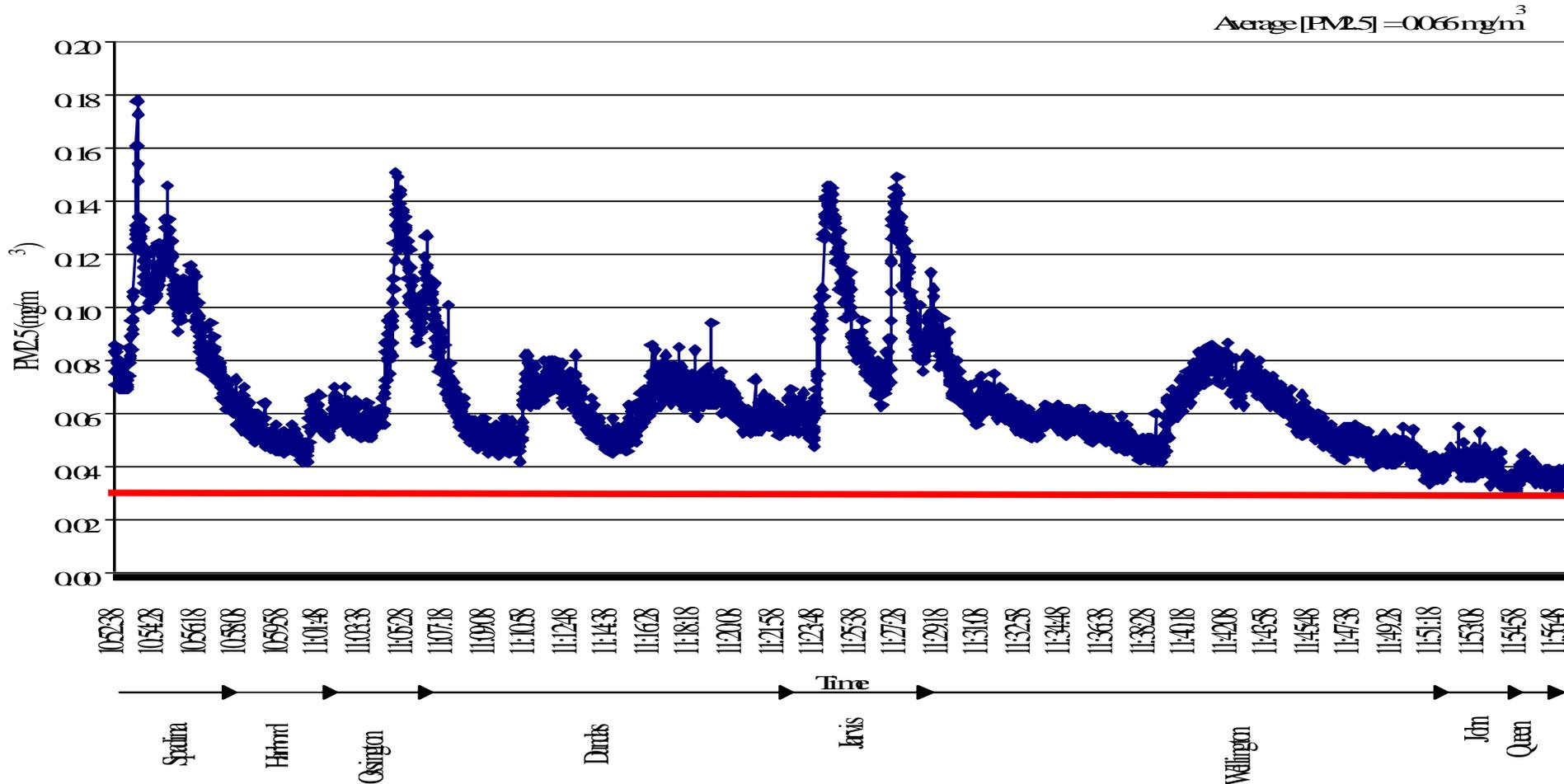
Street Monitoring of Fine Road Dust

Figure 6m
Dec. 4 Test 1: PM 10 Motorist Exposure (Entire Circuit)



Street Monitoring of Fine Road Dust

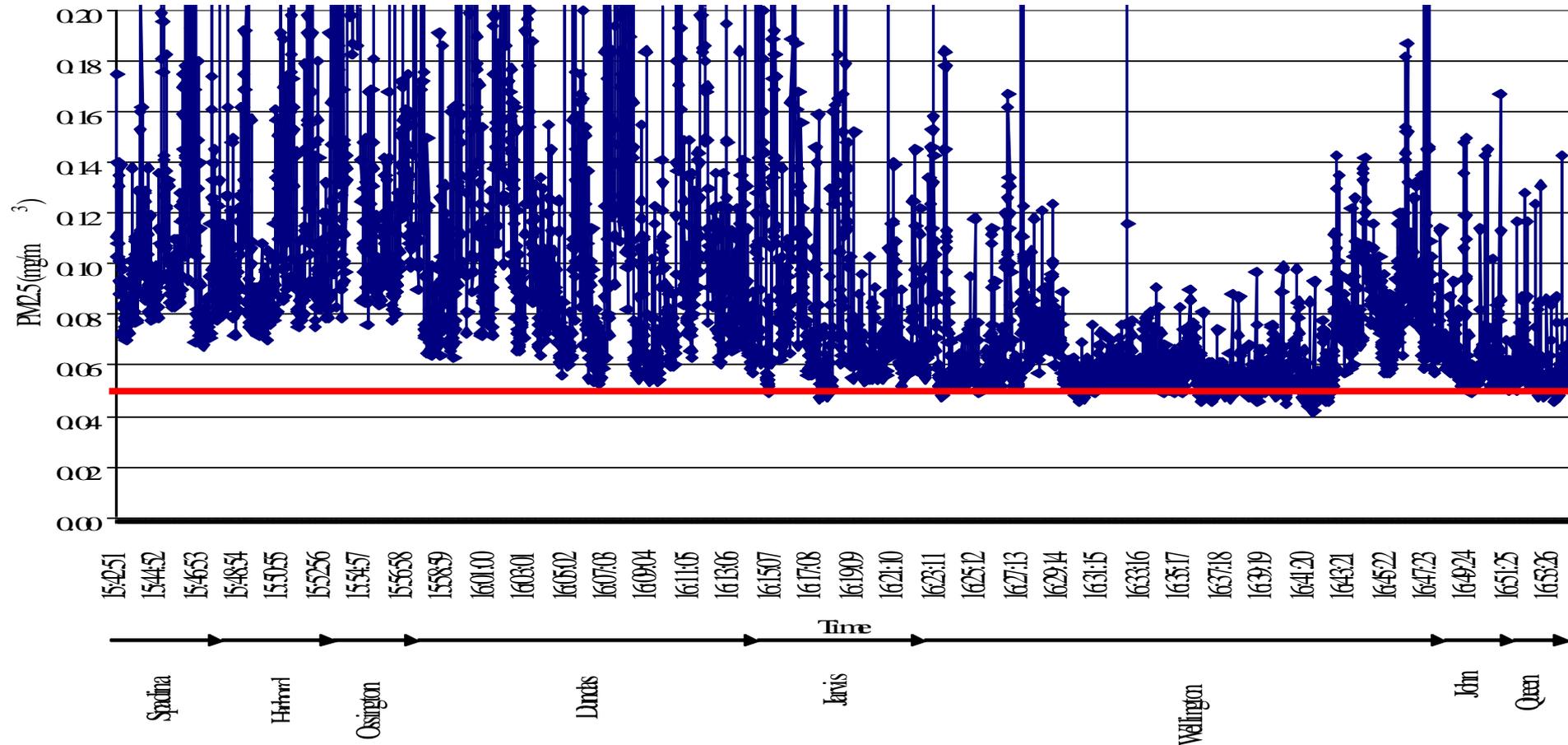
Figure 6
Dec. 4 Test 1: PM_{2.5} Matrix Exposure (Entire Circuit)



Street Monitoring of Fine Road Dust

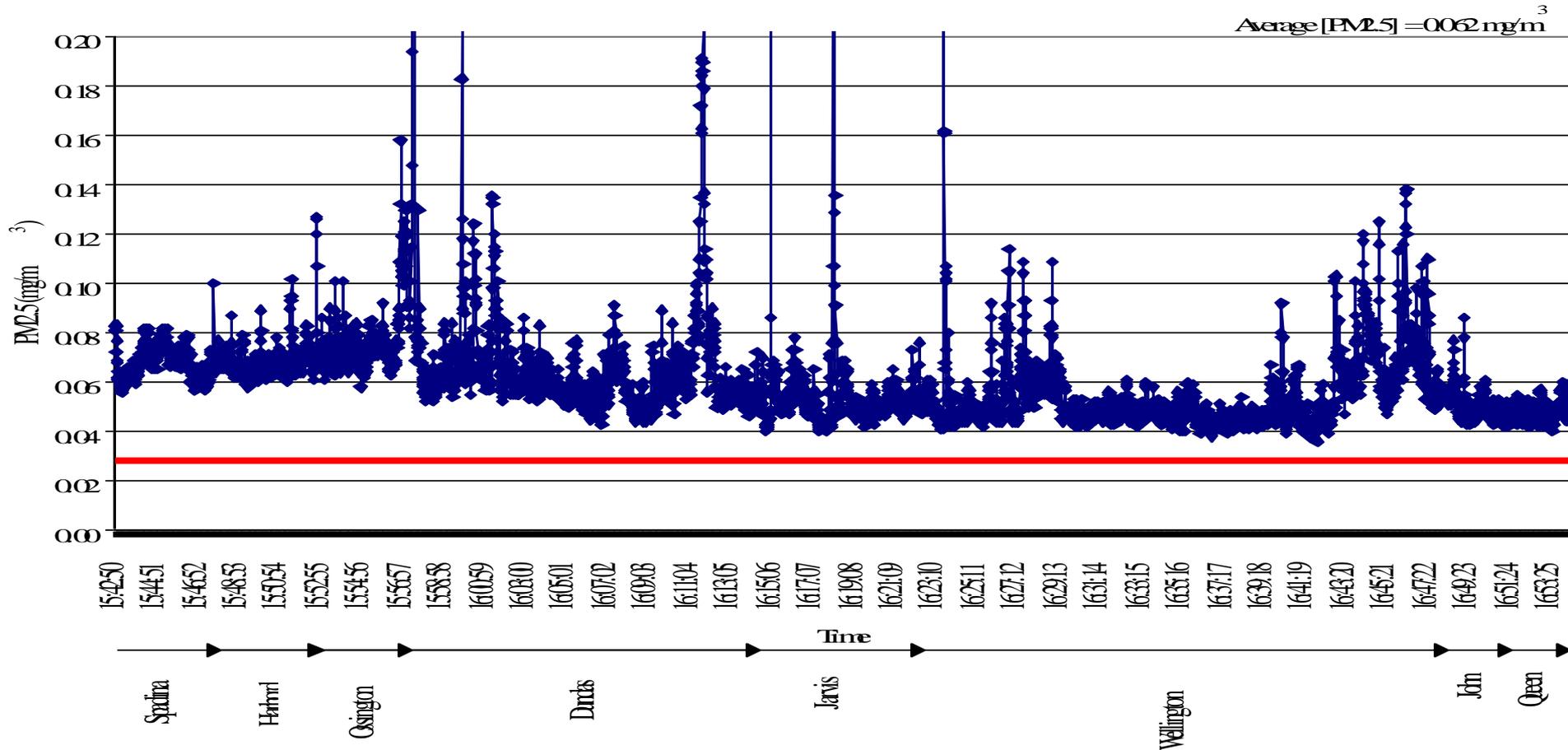
Figure 70
Dec 4 Test 2: PM10 Cyclist Exposure (Entire Circuit)

Average [PM10] = 0.099 mg/m³



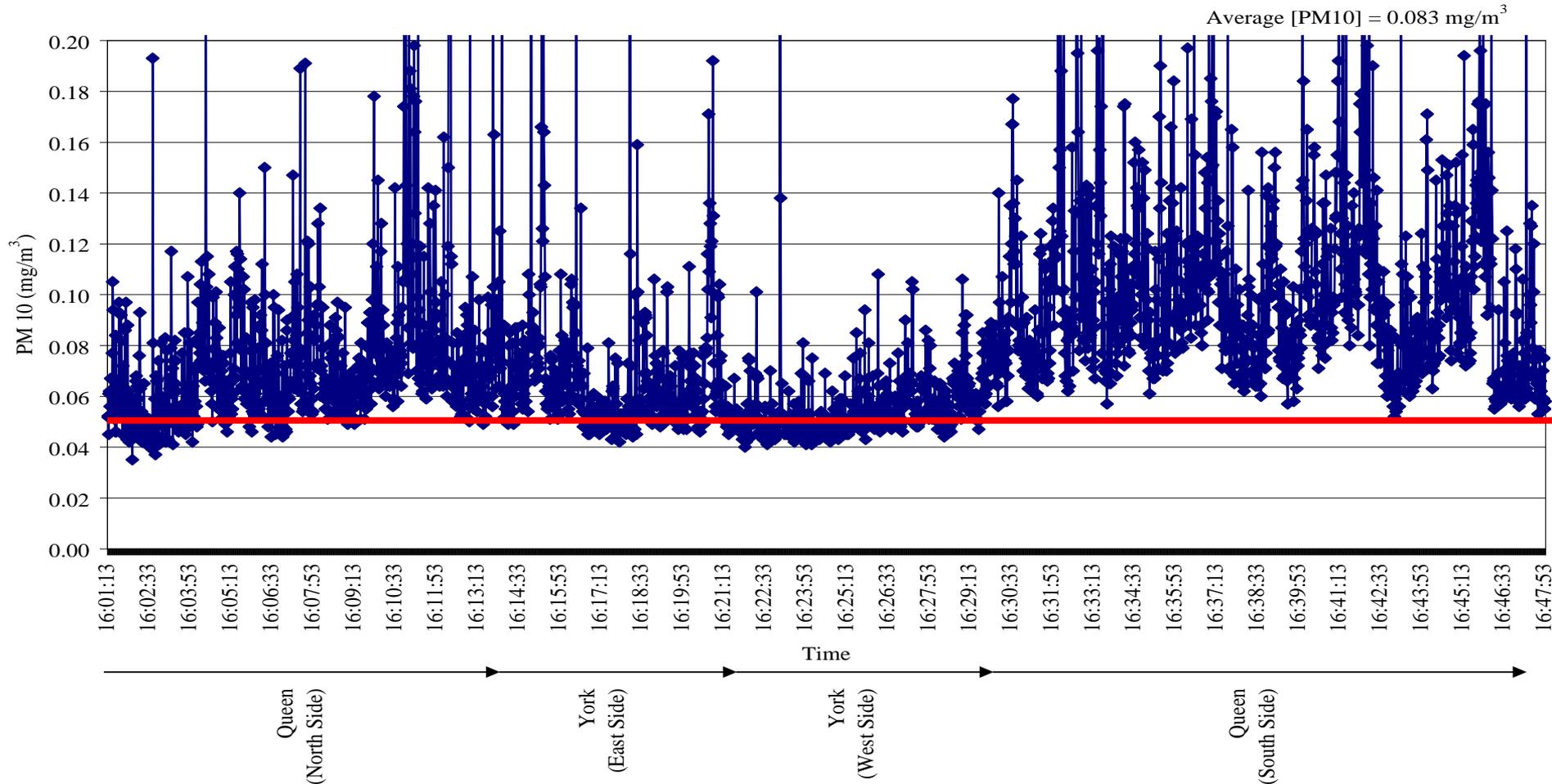
Street Monitoring of Fine Road Dust

Figure 7p
Dec 4 Test 2: PM_{2.5} Cyclist Exposure (Entire Circuit)



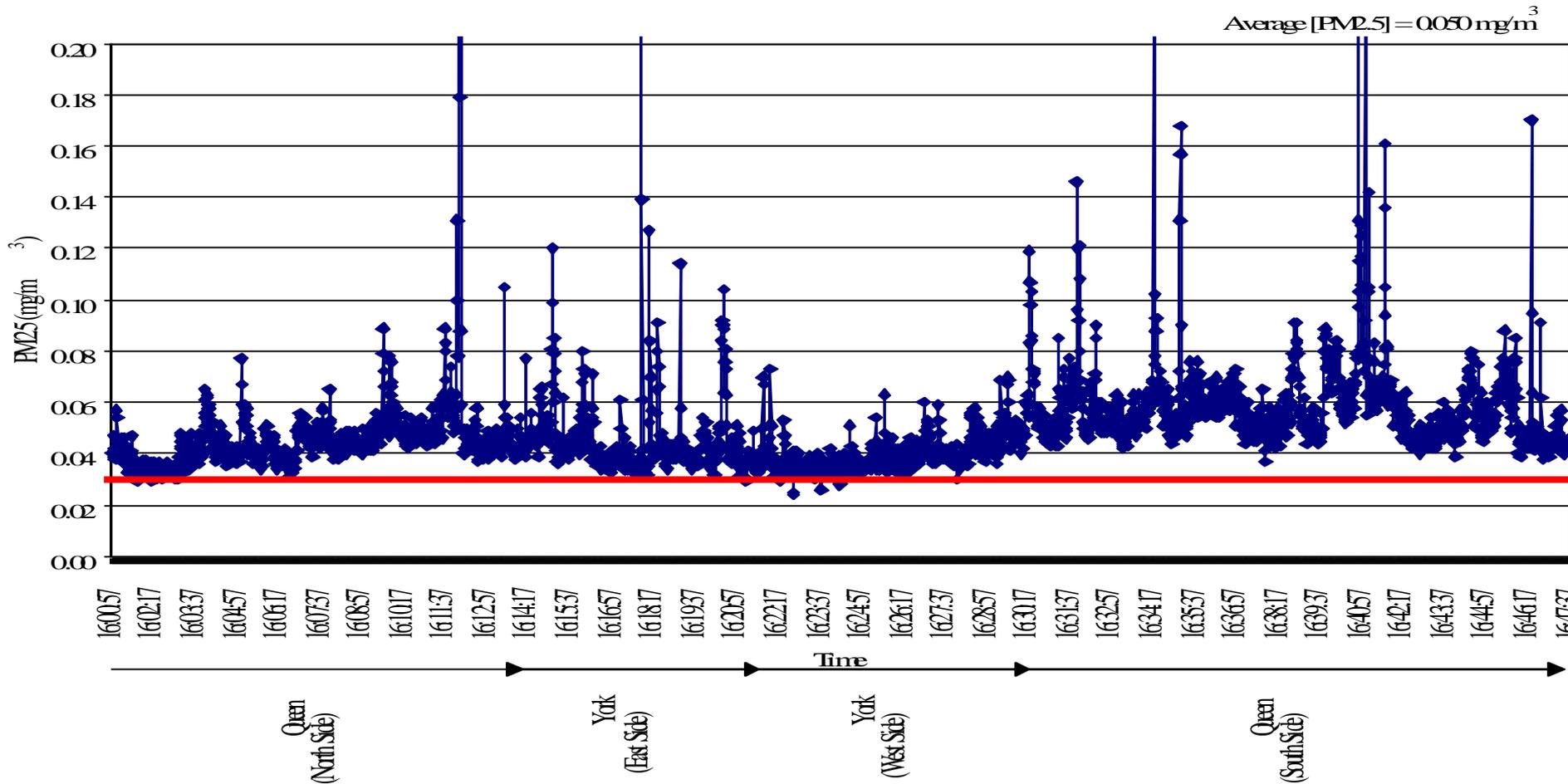
Street Monitoring of Fine Road Dust

Figure 9i
Nov. 26 Test 2: PM 10 Pedestrian Exposure (Entire Circuit)



Street Monitoring of Fine Road Dust

Figure 9j
Nov. 26 Test 2: PM_{2.5} Pedestrian Exposure (Entire Circuit)



Human Health Concerns

Street Monitoring of Fine Road Dust Results

The findings show that Toronto has an **air quality problem** related to Fine Road Dust (PM₁₀ & PM_{2.5});

- Daytime Street Levels of PM **exceed** Ambient Air Quality Criteria all Day;
- Problem varies due to a number of **factors**:
 - Sweeping Frequency
 - Land Use
 - Traffic Volumes
 - Time of Day
 - Type of Vehicular Traffic
 - Weather;
- This confirms the need to **assess the potential** of “New Technology” Street Sweepers in reducing the concentration below Ambient Air Quality Criteria levels;

Human Health Concerns

Metals in Urban Road Dust

Transportation Services participated in a Health Canada and University of Toronto led study called Distribution and Bioaccessibility of CMP Priority Metals in Road Dust.

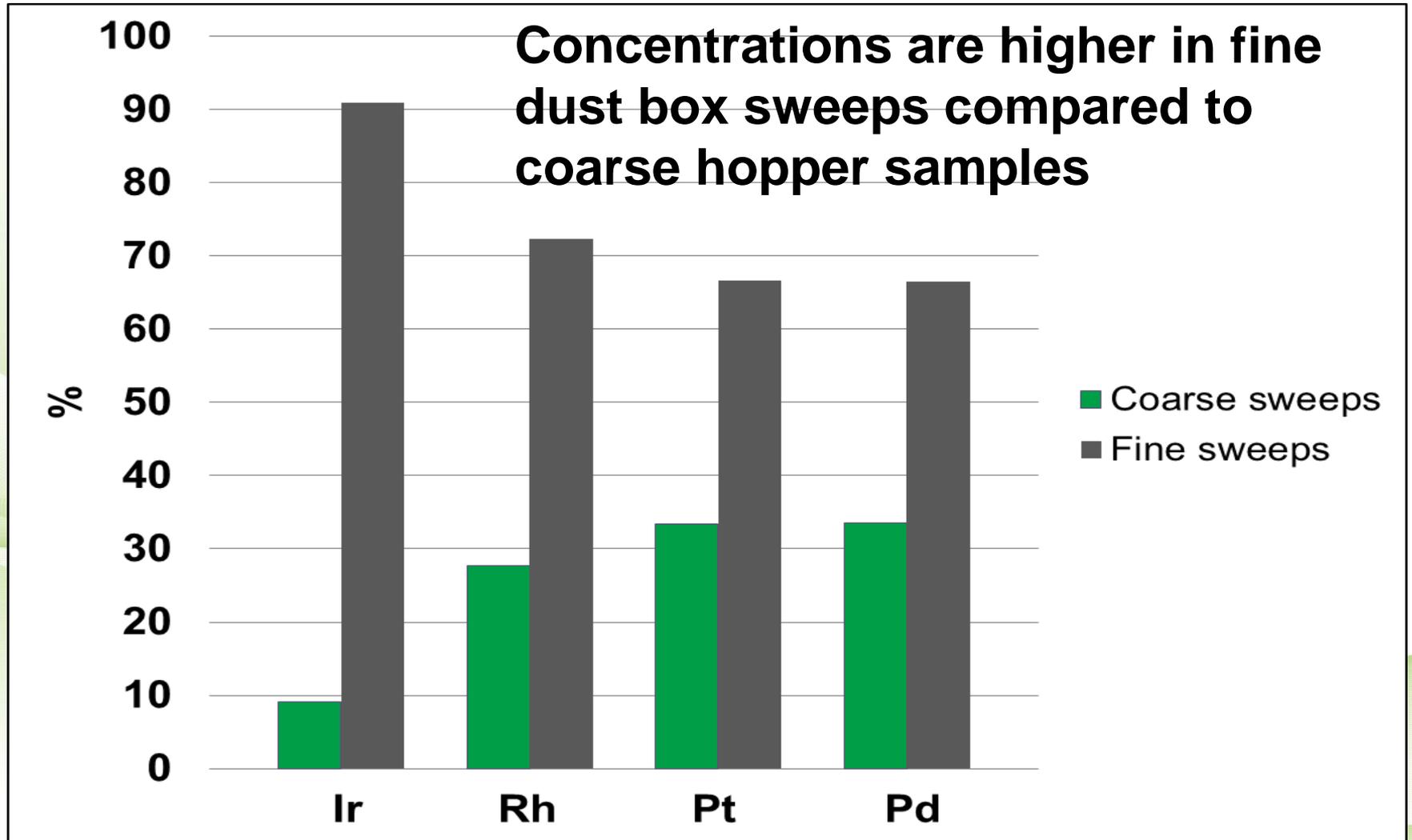
The focus of this study

- (1) assessing the bioaccessibility of metals in fine fractions of road dust using biologically-relevant methods to more accurately represent conditions in the human lung, and
- (2) to isolate fine and ultrafine particulate size fractions from road dust that are likely to be inhaled or respired by exposed individuals and travel longer distances, contributing to widespread urban pollution in both outdoor and indoor environments.

Metals in Urban Road Dust

- The re-suspension of fine road dust is a contributor of metal contamination to local urban air and water sheds;
- Elevated amounts of toxic elements such as cadmium (Cd), arsenic (As) and lead (Pb) are found in road dust;
- Automotive catalytic converters are emitting in traffic exhaust: platinum (Pt), palladium (Pd), rhodium (Rh), osmium (Os), iridium (Ir) and ruthenium (Ru);
- More data on the concentration of metals in road dust needs to be undertaken in order to understand exposure in urban settings on how the public is being exposed when travelling in the ROW and penetrating indoor environments.

Metals in Urban Road Dust



Part 3:

Why Operational Requirements

Why Operational Requirements

Municipalities struggle to achieve the following with their street sweeping equipment:

- Cleaner Roads
- Safer Roads
- Year Round Performance
- Quantifiable and Objective Evaluation
- Continual Improvement
- Less Downtime
- Low Maintenance

Part 5:

Clean Roads to Clean Air Program

Clean Roads to Clean Air Program

Objective

- to deploy PM₁₀ and PM_{2.5} efficient street sweepers that are capable of regular sweeping plus removing fine particular matter (PM₁₀ 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

The CRCA Program established a process to objectively measure and evaluate the operational and environmental performance of street sweepers.

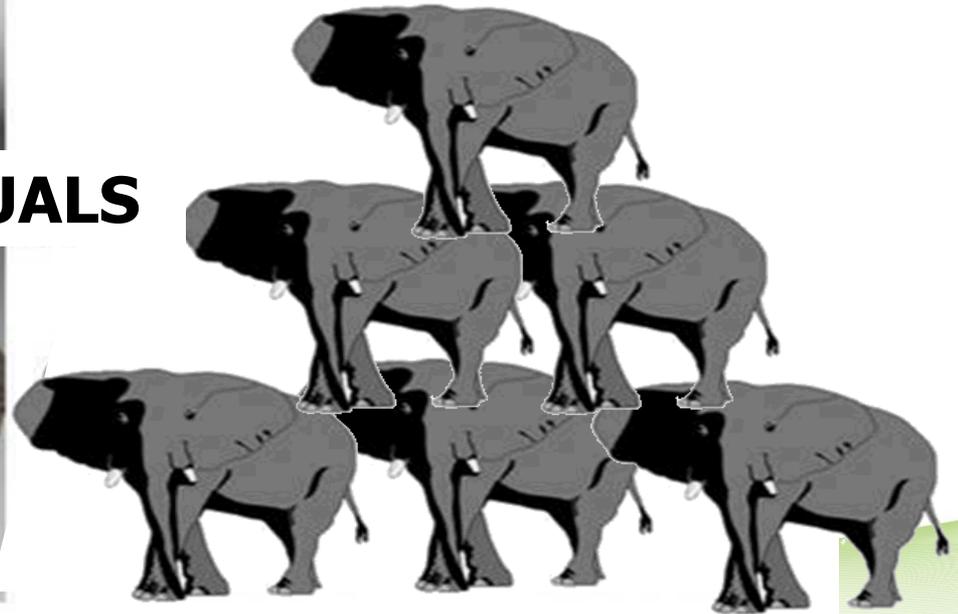
Benefits

Regenerative-Air Street Sweepers

Remove 50% More PM from City Streets



EQUALS



28 TONNES OF PM

Benefits

Benefits of the PM efficient sweepers are:

- Reduction of airborne particulate matter at street level, by at least 27%;
- Improvement in air quality will be beneficial to the general health of City's residents, workers and visitors;
- Reduce the number of cases of acute and chronic exposure of fine particulates;
- Improve stormwater quality and reduce the cost of treatment;
- Permits sweeping during smog days and will help to reduce smog impacts;
- Capable of street sweeping year-around; and
- Improve the level of street sweeping service across the City with more efficient PM street sweepers

Part 5:

PM₁₀ & PM_{2.5} Street Sweeper Efficiency Test Protocol

PM₁₀ & PM_{2.5} Street Sweeper Efficiency Test

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

PM₁₀ & PM_{2.5} Street Sweeper Efficiency Test

PM Efficiency Criteria

Removal Efficiency	%
Sidewalk Efficiency	%
Air Contamination PM ₁₀ Maximum Concentration	[mg/m ³]/kg
Air Contamination PM ₁₀ Total Concentration	[mg/m ³]/kg
Air Contamination PM _{2.5} Maximum Concentration	[mg/m ³]/kg
Air Contamination PM _{2.5} Total Concentration	[mg/m ³]/kg

PM₁₀ & PM_{2.5} Street Sweeper Efficiency Test



Transportation Services
Toronto Environment Office



Road Condition



Diesel Test



Pre-Testing Condition



PM₁₀/ PM_{2.5} Street Sweeper
Efficiency Test - 2005



PM₁₀/ PM_{2.5} Street Sweeper
Efficiency Test - 2005



Side-View



Transportation Services
Toronto Environment Office



Post Tunnel Condition



Washing Sweeper



Post Tunnel
Clean-Up

Part 6:

Operational On-Street Test Protocol

Operational On-Street Test

Key **operational requirements** were evaluated:

- Sweeping under **wet road surface** conditions;
- **Maneuverability** around parked cars;
- **Leaf** pick-up efficiency;
- **Large debris** pick-up efficiency;
- **Heavy silt** loading pick-up efficiency; and
- Operating sweeper **without gutter brooms**

Operational On-Street Test

Section A

Sweeping During Wet Conditions

Regenerative-Air
Street Sweeper



Operational On-Street Test

Section B

Maneuverability Around Parked Cars



Regenerative-Air Street Sweeper



Operational On-Street Test

Section C

Pick-Up of Leaves

Regenerative-Air
Street Sweeper



Operational On-Street Test

Section D

Pick-Up of Large Debris



Regenerative-Air
Street Sweeper



Operational On-Street Test

Section E

Pick-Up of Heavy Silt-Loading

Regenerative-Air
Street Sweeper

Operational On-Street Test

Section F

Dustless Mode

Regenerative-Air
Street Sweeper

Part 7:

ETV Certification Process

ETV Certification Process

- **Developed testing protocols and criteria** to objectively evaluate the environmental and operational effectiveness of street sweepers now and in the future;
- Established the **ETV Certificates** under the Canadian Environmental Technology Verification (ETV), under licence from Environment and Climate Change Canada, that are based on the Toronto's Testing Protocols and that verify the environmental and operational performance claims of street sweepers;
- A **standard** which Toronto recommends and will use for all our future sweeper purchases.

ETV Certification Process

The International Organization for Standardization (ISO), led by Environment and Climate Change Canada, is in the final stages of creating a new standard to address environmental performance.

ISO 14034 Environmental management -- Environmental technology verification (ETV) will outline a process for verifying environmental technologies. This means that by following the standard, an independent party can effectively assess test results so that the results can be considered reliable, here in Canada, and abroad.

ETV Certification Process

ETV relies on science, high-quality data, and recognized protocols to offer an independent assessment and verification of environmental performance claims. As a result, potential buyers and other parties can make informed decisions about purchasing and using environmental technologies

Here is a video clip that illustrates the value of the new ISO using the City of Toronto developed protocols.

<https://www.youtube.com/watch?v=NayF7tv2xrA>

Clean Roads to Clean Air Program

Thank You



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