

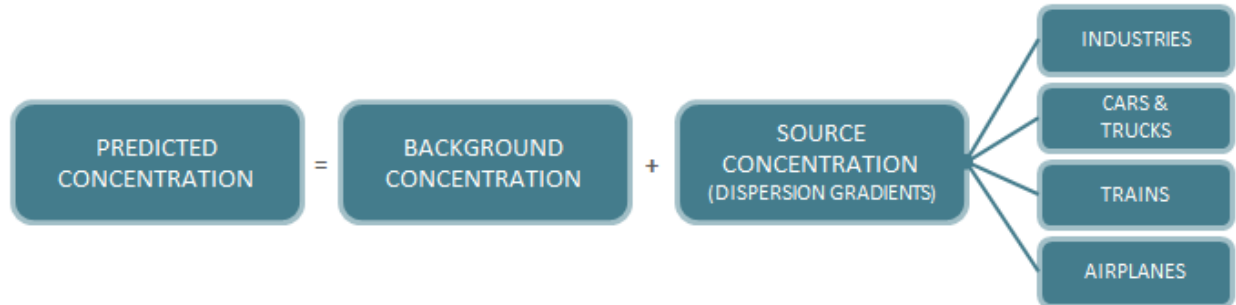


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**Environmental exposures**

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## 1,3-Butadiene

Concentrations of 1,3-butadiene in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of 1,3-butadiene emissions to outdoor air may be present, but are not included due to a lack of suitable data.

### Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
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## Identifying Dispersion Gradients for Roads, Rails, Large Industries and Airports

### INDUSTRIES

We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

### CARS & TRUCKS

We estimated the influence of motor vehicle emission on outdoor air concentrations using gradients applied to highways, major roads and minor roads in Canada. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

### AIRPLANES

We used a screening level dispersion model (SCREEN3), to estimate concentrations around medium and large airports based on estimated emissions. The model estimates worst-case ground level concentrations from emissions. Estimates were produced up to 5000m from airports. Emissions from airports were estimated using landing/take-off volumes at each airport and aircraft emission factors specific to each substance.

### Summary of Gradients Identified for Roads and Rails

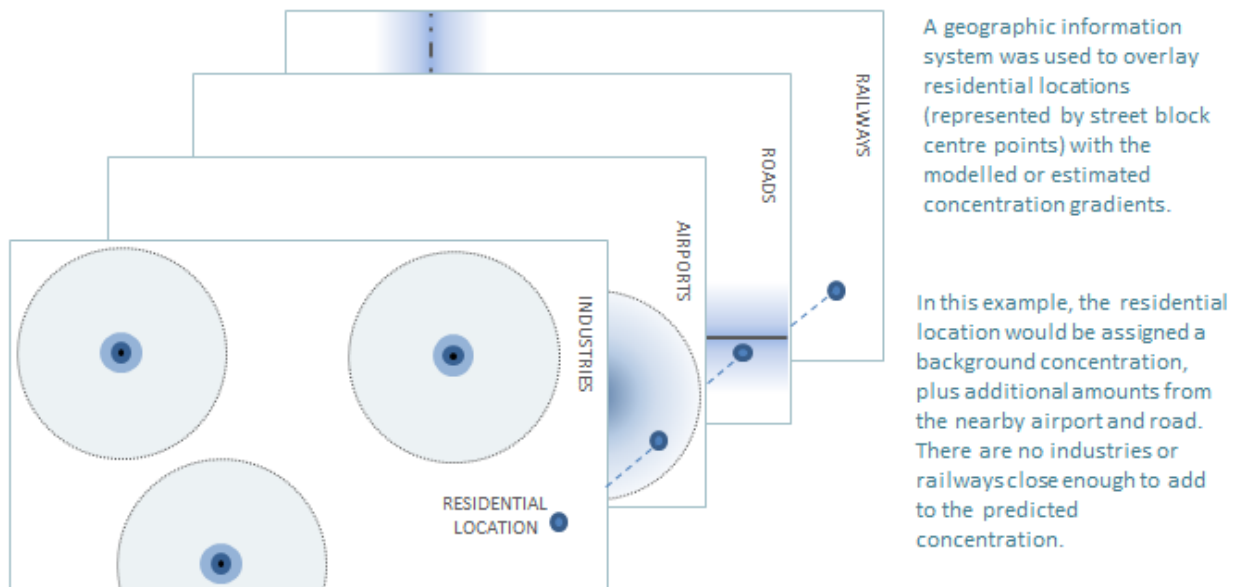
Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)
Benzene	Highways/Major roads	3.25 <sup>1,2,3,4</sup>	50 <sup>3,5,6</sup>
	Local Roads	1.5 <sup>1,2,3,4</sup>	50 <sup>3,5,6</sup>
1,3-Butadiene	Highways	4.0 <sup>6</sup>	75 <sup>6</sup>
Ethylbenzene	Highways	3.7 <sup>2,7,8</sup>	300 <sup>8</sup>
	Major Roads	2.2 <sup>2,7,8</sup>	300 <sup>8</sup>
	Local Roads	1.4 <sup>2,7,8</sup>	300 <sup>8</sup>

#### References:

- Hellen H, Hakola H, Pirjola L, Laurila T, Pystynen KH. (2006). Ambient air concentrations, source profiles, and source apportionment of 71 different C<sub>2</sub> to C<sub>10</sub> volatile organic compounds in urban and residential areas of Finland. Environ Sci Technol 40(1):103-108.
- Parra M, Elustondo D, Bermejo R, Santamaria J. (2009). Ambient air levels of volatile organic compounds (VOC) and nitrogen dioxide (NO<sub>2</sub>) in a medium size city in northern Spain. Sci Total Environ 407(3):999-1009.

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4. Vardoulakis S, Gonzalez-Flesca N, Fisher B. (2002). Assessment of traffic-related air pollution in two street canyons in Paris: Implications for exposure studies. *Atmos Environ* 36(6):1025-1039.
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8. Wang P, Zhao W. (2008). Assessment of ambient volatile organic compounds (VOCs) near major roads in urban Nanjing, China. *Atmos Res* 89(3):289-297.

### Applying Dispersion Gradients to Residential Locations



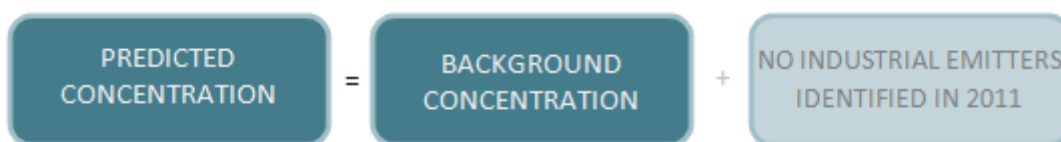
## Limitations

This high-level approach was used to estimate spatial variation in outdoor air concentrations across Canada. Only national, readily available data were used to enable future mapping using the same approach as a means of identifying trends.

- Although we estimated concentrations for all street block centre points in Canada, many local factors are not included that could influence concentrations, for example: road and rail estimates are based only on road type or presence of a railway, not actual vehicle or train volume; and prevailing wind patterns due to local topography may affect gradient shape and distances.
- No independent monitoring was available or conducted to evaluate how well the predicted concentrations match actual measured levels. The results presented are best used to make regional comparisons, and should not be used to assess regulatory compliance.
- National air pollution surveillance (NAPS) monitors were used to represent concentrations for all block points within 50km, regardless of monitor siting criteria. Different monitor siting characteristics and representativeness will therefore affect the accuracy of this assumption.
- The estimates produced represent a 'worst-case scenario', as the screening level dispersion model calculates maximum expected concentrations given emissions levels.
- Limited / no information was available on industrial facility operating parameters required to do more exact dispersion modelling. Industrial facilities were grouped into small, medium and large by emission amounts and assigned standard operating parameters by category.
- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## 2,3,7,8-Tetrachlorodibenzo-para-dioxin

Concentrations of 2,3,7,8-tetrachlorodibenzo-para-dioxin (TCDD) in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors. No industrial emitters for 2011 were identified. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.

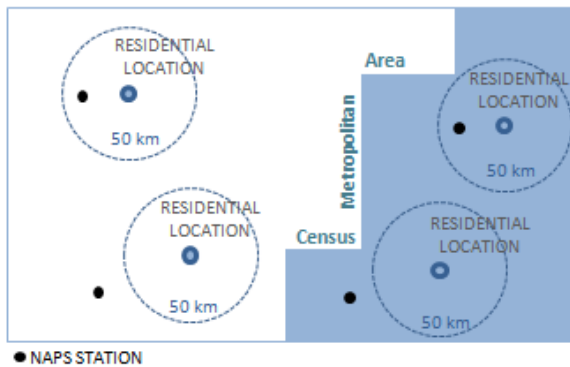


Other sources of TCDD emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Determining Concentrations at Residential Locations

No industries reporting emissions of 2,3,7,8-tetrachlorodibenzo-para-dioxin (TCDD) to air were identified in the National Pollutant Release Inventory (NPRI) for 2011.

Concentrations at residential locations are assigned using measured levels from National Air Pollution (NAPS) monitors using the following rules:



- For all locations within 50 km of a NAPS monitoring station, the annual average concentrations measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

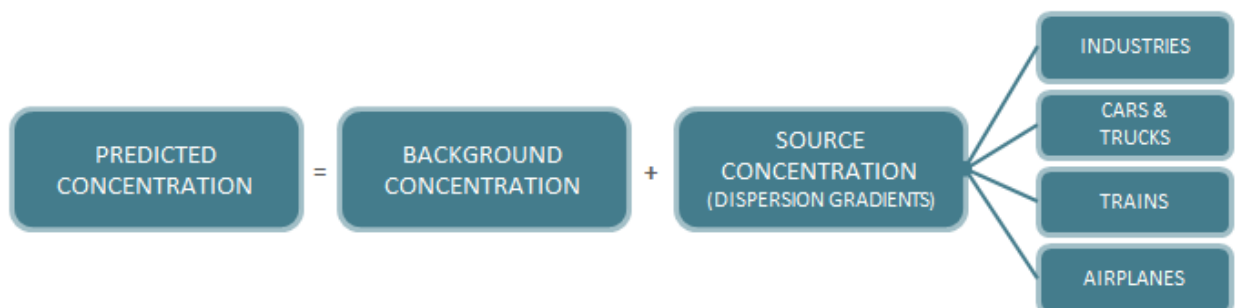
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- National air pollution surveillance (NAPS) monitors were used to represent concentrations for all block points within 50km, regardless of monitor siting criteria. Different monitor siting characteristics and representativeness will therefore affect the accuracy of this assumption.

## Acetaldehyde

Concentrations of acetaldehyde in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of acetaldehyde emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
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## Identifying Dispersion Gradients for Roads, Rails, Large Industries and Airports

### INDUSTRIES

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### CARS & TRUCKS

We estimated the influence of motor vehicle emission on outdoor air concentrations using gradients applied to highways, major roads and minor roads in Canada. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

### AIRPLANES

We used a screening level dispersion model (SCREEN3), to estimate concentrations around medium and large airports based on estimated emissions. The model estimates worst-case ground level concentrations from emissions. Estimates were produced up to 5000m from airports. Emissions from airports were estimated using landing/take-off volumes at each airport and aircraft emission factors specific to each substance.



### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)	
Acetaldehyde	Highways	3.7 <sup>1</sup>	200 <sup>1</sup>	
	Major roads	2.6 <sup>2</sup>	200	
	Rail	1.15	200 <sup>3</sup>	
Formaldehyde	Highways	2.0 <sup>1,4</sup>	200 <sup>1</sup>	
	Major roads	1.4 <sup>2</sup>	200 <sup>1</sup>	
	Rail	1.15	200 <sup>3</sup>	
Diesel Exhaust <sup>5</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>	
	Rail	1.15	200 <sup>3</sup>	
Metals	Highways	2.9 <sup>4</sup>	161 <sup>4</sup>	
	Arsenic	Major roads	2.0 <sup>2</sup>	161 <sup>4</sup>
	Cadmium, Hexavalent Chromium	Rail	1.15	200 <sup>3</sup>
	Lead Nickel			
Polycyclic Aromatic Hydrocarbons <sup>6</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Benz[a]anthracene	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>
	Benzo[b]fluoranthene	Rail	1.15	200 <sup>3</sup>
	Benzo[k]fluoranthene			
	Benzo[a]pyrene			
	Chrysene Indeno(1,2,3-cd)pyrene			

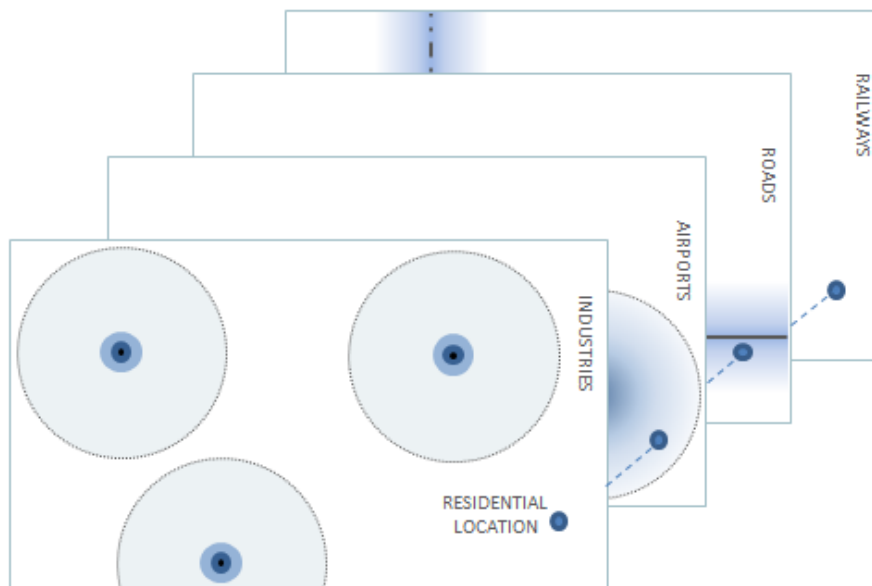
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6. We assume polycyclic aromatic hydrocarbons are mainly bound to ultra-fine particles in outdoor air, based on: Miguel et al (2004). Seasonal variation of the particle size distribution of polycyclic aromatic hydrocarbons and of major aerosol species in Claremont, California. *Atmosphere Environment* 38 (20) pp 3241-3251.) Gradients are therefore based on those identified for ultrafine particles.

### Applying Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

In this example, the residential location would be assigned a background concentration, plus additional amounts from the nearby airport and road. There are no industries or railways close enough to add to the predicted concentration.

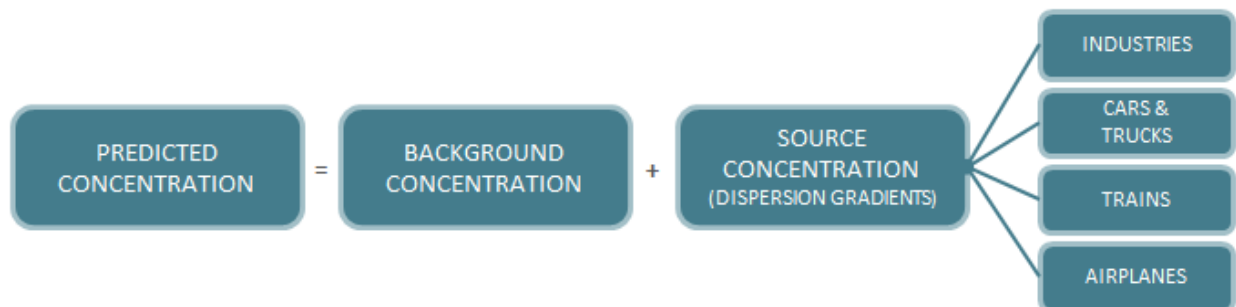
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- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Arsenic

Concentrations of arsenic in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of arsenic emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

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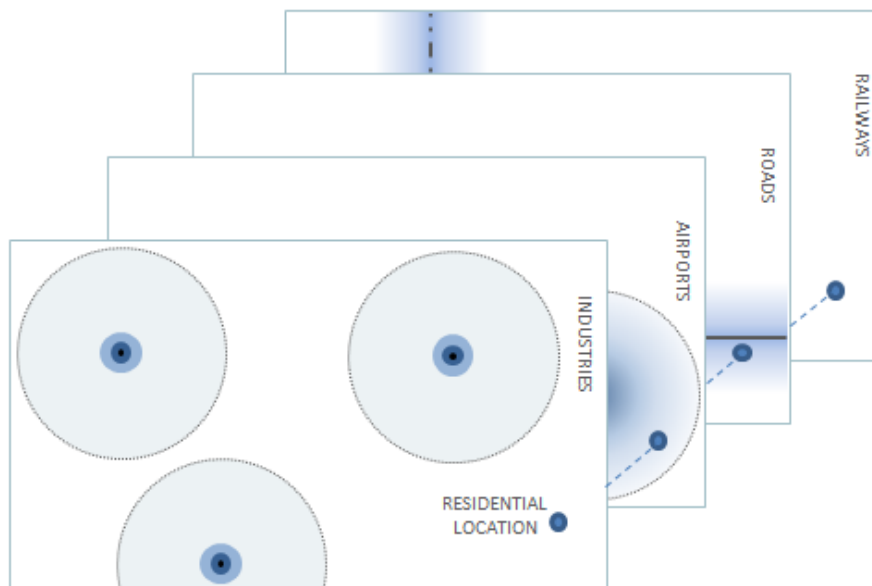
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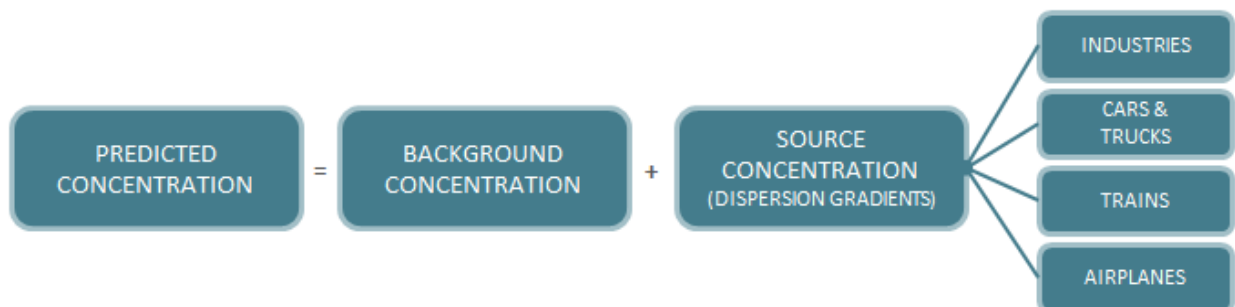
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## Benzene

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## Identifying Dispersion Gradients for Roads, Rails, Large Industries and Airports

### INDUSTRIES

We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

### CARS & TRUCKS

We estimated the influence of motor vehicle emission on outdoor air concentrations using gradients applied to highways, major roads and minor roads in Canada. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

### AIRPLANES

We used a screening level dispersion model (SCREEN3), to estimate concentrations around medium and large airports based on estimated emissions. The model estimates worst-case ground level concentrations from emissions. Estimates were produced up to 5000m from airports. Emissions from airports were estimated using landing/take-off volumes at each airport and aircraft emission factors specific to each substance.



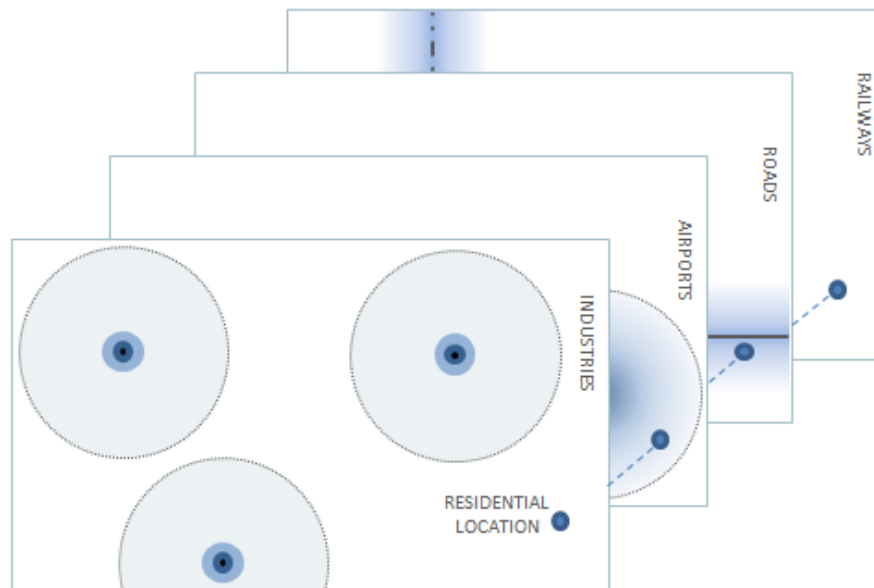
### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)
Benzene	Highways/Major roads	3.25 <sup>1,2,3,4</sup>	50 <sup>3,5,6</sup>
	Local Roads	1.5 <sup>1,2,3,4</sup>	50 <sup>3,5,6</sup>
1,3-Butadiene	Highways	4.0 <sup>6</sup>	75 <sup>6</sup>
Ethylbenzene	Highways	3.7 <sup>2,7,8</sup>	300 <sup>8</sup>
	Major Roads	2.2 <sup>2,7,8</sup>	300 <sup>8</sup>
	Local Roads	1.4 <sup>2,7,8</sup>	300 <sup>8</sup>

#### References:

1. Hellen H, Hakola H, Pirjola L, Laurila T, Pystynen KH. (2006). Ambient air concentrations, source profiles, and source apportionment of 71 different C<sub>2</sub>–C<sub>10</sub> volatile organic compounds in urban and residential areas of Finland. *Environ Sci Technol* 40(1):103-108.
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## Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

In this example, the residential location would be assigned a background concentration, plus additional amounts from the nearby airport and road. There are no industries or railways close enough to add to the predicted concentration.

## Limitations

This high-level approach was used to estimate spatial variation in outdoor air concentrations across Canada. Only national, readily available data were used to enable future mapping using the same approach as a means of identifying trends.

- Although we estimated concentrations for all street block centre points in Canada, many local factors are not included that could influence concentrations, for example: road and rail estimates are based only on road type or presence of a railway, not actual vehicle or train volume; and prevailing wind patterns due to local topography may affect gradient shape and distances.
- No independent monitoring was available or conducted to evaluate how well the predicted concentrations match actual measured levels. The results presented are best used to make regional comparisons, and should not be used to assess regulatory compliance.
- National air pollution surveillance (NAPS) monitors were used to represent concentrations for all block points within 50km, regardless of monitor siting criteria. Different monitor siting characteristics and representativeness will therefore affect the accuracy of this assumption.
- The estimates produced represent a 'worst-case scenario', as the screening level dispersion model calculates maximum expected concentrations given emissions levels.
- Limited / no information was available on industrial facility operating parameters required to do more exact dispersion modelling. Industrial facilities were grouped into small, medium and large by emission amounts and assigned standard operating parameters by category.
- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Benzo[a]pyrene

Concentrations of benzo[a]pyrene in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of benzo[a]pyrene emissions to outdoor air may be present, but are not included due to a lack of suitable data.

### Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

## Identifying Dispersion Gradients for Roads, Rails and Large Industries

### INDUSTRIES

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### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

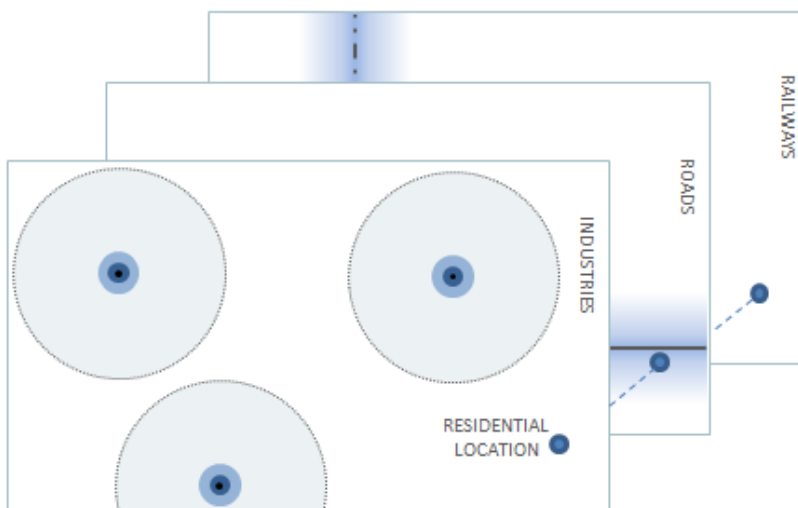
### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)	
Acetaldehyde	Highways	3.7 <sup>1</sup>	200 <sup>1</sup>	
	Major roads	2.6 <sup>2</sup>	200	
	Rail	1.15	200 <sup>3</sup>	
Formaldehyde	Highways	2.0 <sup>1,4</sup>	200 <sup>1</sup>	
	Major roads	1.4 <sup>2</sup>	200 <sup>1</sup>	
	Rail	1.15	200 <sup>3</sup>	
Diesel Exhaust <sup>5</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>	
	Rail	1.15	200 <sup>3</sup>	
Metals	Highways	2.9 <sup>4</sup>	161 <sup>4</sup>	
	Arsenic	Major roads	2.0 <sup>2</sup>	161 <sup>4</sup>
	Cadmium,	Rail	1.15	200 <sup>3</sup>
	Hexavalent Chromium			
Lead				
Nickel				
Polycyclic Aromatic Hydrocarbons <sup>6</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Benz[a]anthracene	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>
	Benzo[b]fluoranthene	Rail	1.15	200 <sup>3</sup>
	Benzo[k]fluoranthene			
	Benzo[a]pyrene			
	Chrysene			
	Indeno(1,2,3-cd)pyrene			

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### Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

In this example, the residential location would be assigned a background concentration, plus additional amounts from the nearby road. There are no industries or railways close enough to add to the predicted concentration.

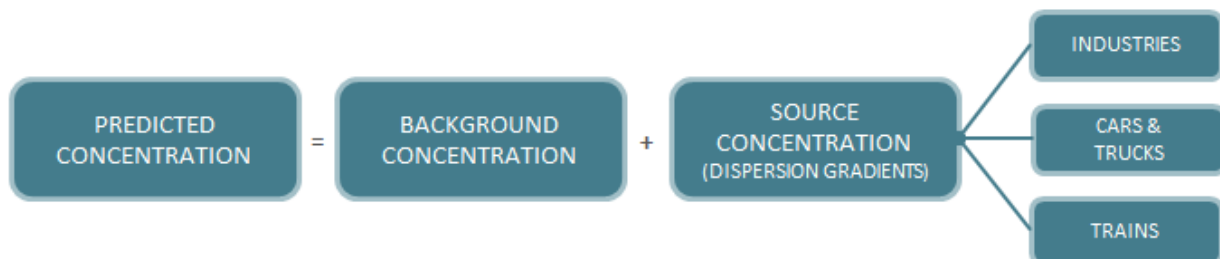
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- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Benzo[b]fluoranthene

Concentrations of benzo[b]fluoranthene in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of benzo[b]fluoranthene emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

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### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)	
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	Rail	1.15	200 <sup>3</sup>	
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	Cadmium, Hexavalent Chromium	Rail	1.15	200 <sup>3</sup>
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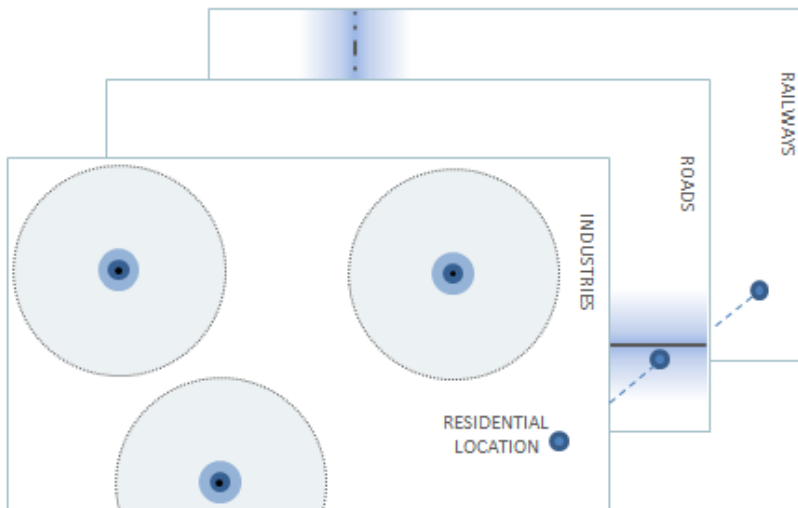
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A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

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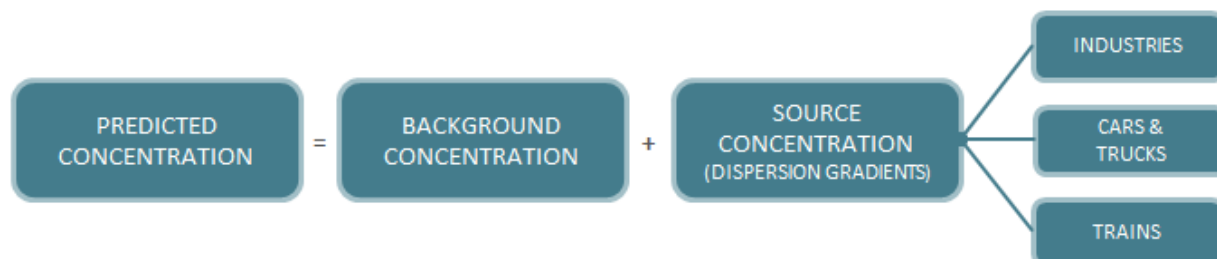
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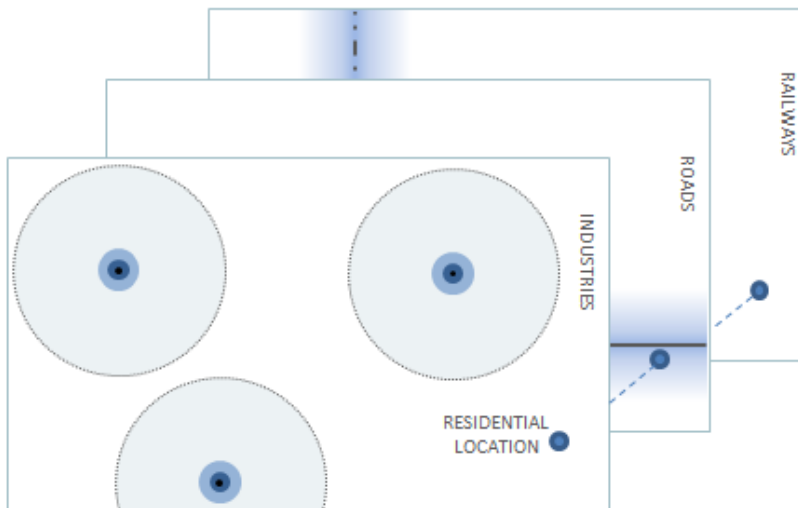
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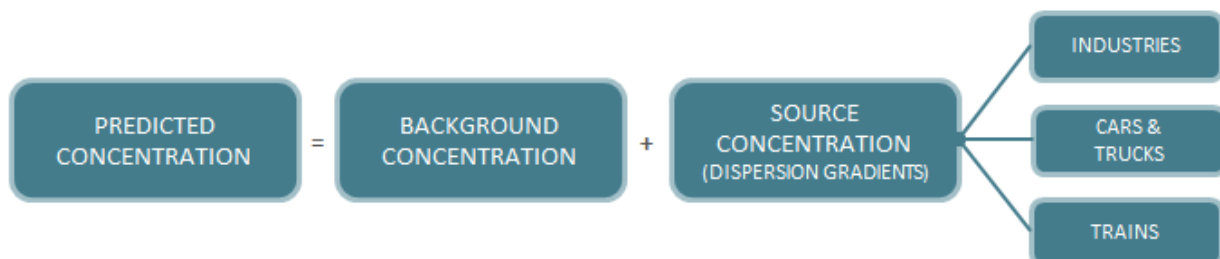
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- Although we estimated concentrations for all street block centre points in Canada, many local factors are not included that could influence concentrations, for example: road and rail estimates are based only on road type or presence of a railway, not actual vehicle or train volume; and prevailing wind patterns due to local topography may affect gradient shape and distances.
- No independent monitoring was available or conducted to evaluate how well the predicted concentrations match actual measured levels. The results presented are best used to make regional comparisons, and should not be used to assess regulatory compliance.
- National air pollution surveillance (NAPS) monitors were used to represent concentrations for all block points within 50km, regardless of monitor siting criteria. Different monitor siting characteristics and representativeness will therefore affect the accuracy of this assumption.
- The estimates produced represent a 'worst-case scenario', as the screening level dispersion model calculates maximum expected concentrations given emissions levels.
- Limited / no information was available on industrial facility operating parameters required to do more exact dispersion modelling. Industrial facilities were grouped into small, medium and large by emission amounts and assigned standard operating parameters by category.
- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Benz[a]anthracene

Concentrations of benz[a]anthracene in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of benz[a]anthracene emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

## Identifying Dispersion Gradients for Roads, Rails and Large Industries

### INDUSTRIES

We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

### CARS & TRUCKS

We estimated the influence of motor vehicle emission on outdoor air concentrations using gradients applied to highways, major roads and minor roads in Canada. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)	
Acetaldehyde	Highways	3.7 <sup>1</sup>	200 <sup>1</sup>	
	Major roads	2.6 <sup>2</sup>	200	
	Rail	1.15	200 <sup>3</sup>	
Formaldehyde	Highways	2.0 <sup>1,4</sup>	200 <sup>1</sup>	
	Major roads	1.4 <sup>2</sup>	200 <sup>1</sup>	
	Rail	1.15	200 <sup>3</sup>	
Diesel Exhaust <sup>5</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>	
	Rail	1.15	200 <sup>3</sup>	
Metals	Highways	2.9 <sup>4</sup>	161 <sup>4</sup>	
	Arsenic	Major roads	2.0 <sup>2</sup>	161 <sup>4</sup>
	Cadmium, Hexavalent Chromium	Rail	1.15	200 <sup>3</sup>
	Lead Nickel			
Polycyclic Aromatic Hydrocarbons <sup>6</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Benz[a]anthracene	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>
	Benzo[b]fluoranthene	Rail	1.15	200 <sup>3</sup>
	Benzo[k]fluoranthene			
	Benzo[a]pyrene			
	Chrysene Indeno(1,2,3-cd)pyrene			

#### References:

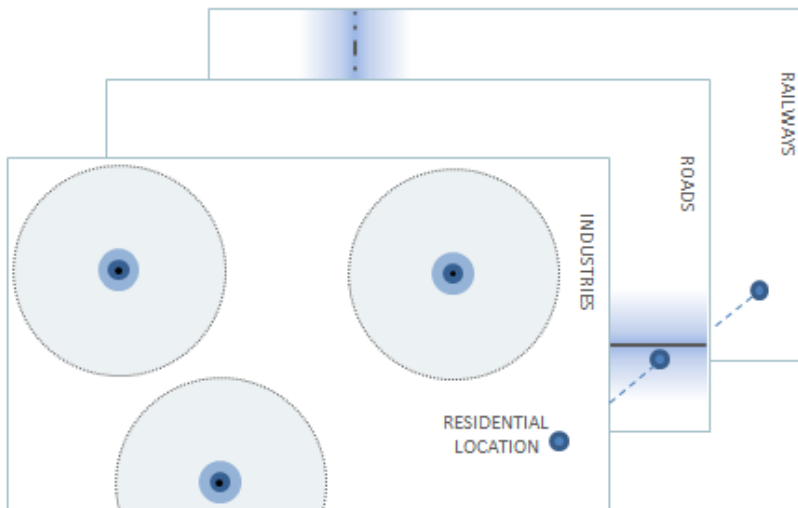
1. Viskari, E., Vartiainen, M., Pasanen, P. (2000). Seasonal and diurnal variation in formaldehyde and acetaldehyde concentrations along a highway in Eastern Finland. *Atmospheric Environment*; 24(6): 917-923.
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apportionment of fine particle air pollutants in Southeastern United States using solvent-extractable organic compounds as tracers. *Environmental Science and Technology*, 36(11):2361-2371. (d) Wu, C.F., Wu, S.Y., Wu, Y.H. et al. (2009). Cancer risk assessment of selected hazardous air pollutants in Seattle. *Environment International*, 35(3), 516-522.

6. We assume polycyclic aromatic hydrocarbons are mainly bound to ultra-fine particles in outdoor air, based on: Miguel et al (2004). Seasonal variation of the particle size distribution of polycyclic aromatic hydrocarbons and of major aerosol species in Claremont, California. *Atmosphere Environment* 38 (20) pp 3241-3251.) Gradients are therefore based on those identified for ultrafine particles

### Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

In this example, the residential location would be assigned a background concentration, plus additional amounts from the nearby road. There are no industries or railways close enough to add to the predicted concentration.

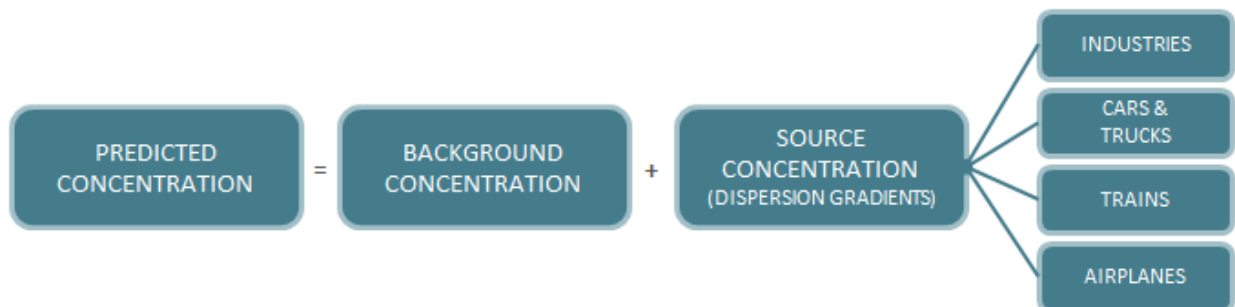
## Limitations

This high-level approach was used to estimate spatial variation in outdoor air concentrations across Canada. Only national, readily available data were used to enable future mapping using the same approach as a means of identifying trends.

- Although we estimated concentrations for all street block centre points in Canada, many local factors are not included that could influence concentrations, for example: road and rail estimates are based only on road type or presence of a railway, not actual vehicle or train volume; and prevailing wind patterns due to local topography may affect gradient shape and distances.
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- National air pollution surveillance (NAPS) monitors were used to represent concentrations for all block points within 50km, regardless of monitor siting criteria. Different monitor siting characteristics and representativeness will therefore affect the accuracy of this assumption.
- The estimates produced represent a 'worst-case scenario', as the screening level dispersion model calculates maximum expected concentrations given emissions levels.
- Limited / no information was available on industrial facility operating parameters required to do more exact dispersion modelling. Industrial facilities were grouped into small, medium and large by emission amounts and assigned standard operating parameters by category.
- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Cadmium

Concentrations of cadmium in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of cadmium emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

## Identifying Dispersion Gradients for Roads, Rails, Large Industries and Airports

### INDUSTRIES

We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

### CARS & TRUCKS

We estimated the influence of motor vehicle emission on outdoor air concentrations using gradients applied to highways, major roads and minor roads in Canada. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

### AIRPLANES

We used a screening level dispersion model (SCREEN3), to estimate concentrations around medium and large airports based on estimated emissions. The model estimates worst-case ground level concentrations from emissions. Estimates were produced up to 5000m from airports. Emissions from airports were estimated using landing/take-off volumes at each airport and aircraft emission factors specific to each substance.

### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)	
Acetaldehyde	Highways	3.7 <sup>1</sup>	200 <sup>1</sup>	
	Major roads	2.6 <sup>2</sup>	200	
	Rail	1.15	200 <sup>3</sup>	
Formaldehyde	Highways	2.0 <sup>1,4</sup>	200 <sup>1</sup>	
	Major roads	1.4 <sup>2</sup>	200 <sup>1</sup>	
	Rail	1.15	200 <sup>3</sup>	
Diesel Exhaust <sup>5</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>	
	Rail	1.15	200 <sup>3</sup>	
Metals	Highways	2.9 <sup>4</sup>	161 <sup>4</sup>	
	Arsenic	Major roads	2.0 <sup>2</sup>	161 <sup>4</sup>
	Cadmium, Hexavalent Chromium	Rail	1.15	200 <sup>3</sup>
	Lead Nickel			
Polycyclic Aromatic Hydrocarbons <sup>6</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Benz[a]anthracene	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>
	Benzo[b]fluoranthene	Rail	1.15	200 <sup>3</sup>
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	Benzo[a]pyrene			
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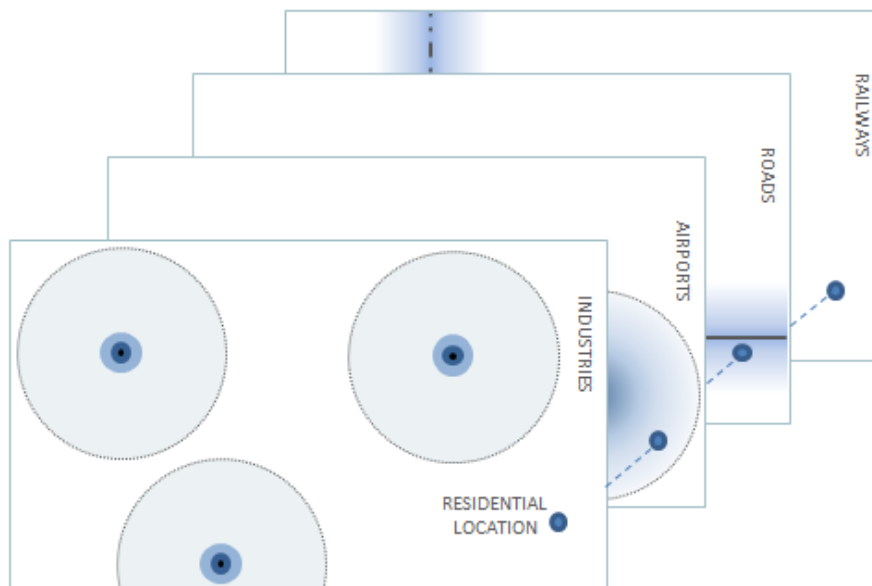
#### References:

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### Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

In this example, the residential location would be assigned a background concentration, plus additional amounts from the nearby airport and road. There are no industries or railways close enough to add to the predicted concentration.

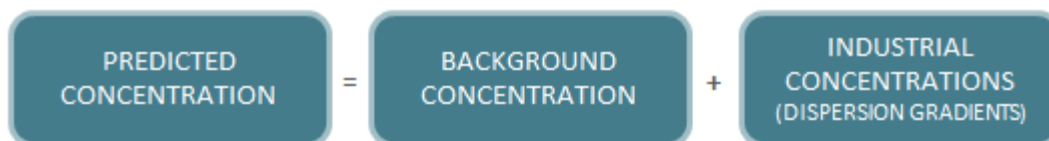
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- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Chloroform

Concentrations of chloroform in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of chloroform emissions to outdoor air may be present, but are not included due to a lack of suitable data.

### Setting the Background Level

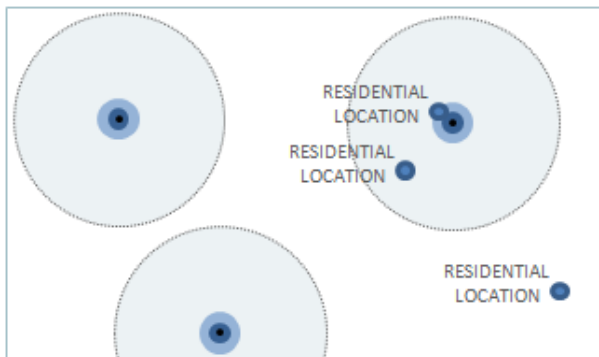
The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

## Identifying Dispersion Gradients for Industries

**INDUSTRIES** We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

## Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients of industrial emitters.

In this example, two residential locations would be assigned a background concentration plus additional amounts from the nearby industry. There are no industries close enough to the third residential location to add to the predicted concentration.

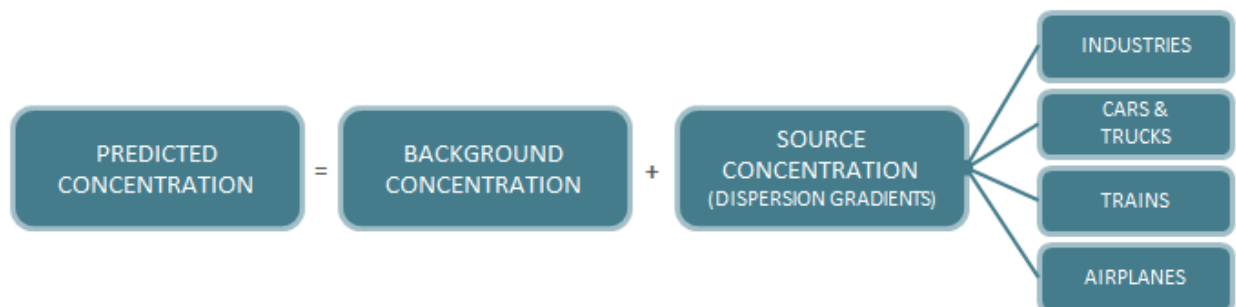
## Limitations

This high-level approach was used to estimate spatial variation in outdoor air concentrations across Canada. Only national, readily available data were used to enable future mapping using the same approach as a means of identifying trends.

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- The estimates produced represent a 'worst-case scenario', as the screening level dispersion model calculates maximum expected concentrations given emissions levels.
- Limited / no information was available on industrial facility operating parameters required to do more exact dispersion modelling. Industrial facilities were grouped into small, medium and large by emission amounts and assigned standard operating parameters by category.

## Chromium (Hexavalent)

Concentrations of hexavalent chromium in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of hexavalent chromium emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:



- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

## Identifying Dispersion Gradients for Roads, Rails, Large Industries and Airports

### INDUSTRIES

We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

### CARS & TRUCKS

We estimated the influence of motor vehicle emission on outdoor air concentrations using gradients applied to highways, major roads and minor roads in Canada. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

### AIRPLANES

We used a screening level dispersion model (SCREEN3), to estimate concentrations around medium and large airports based on estimated emissions. The model estimates worst-case ground level concentrations from emissions. Estimates were produced up to 5000m from airports. Emissions from airports were estimated using landing/take-off volumes at each airport and aircraft emission factors specific to each substance.

### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)	
Acetaldehyde	Highways	3.7 <sup>1</sup>	200 <sup>1</sup>	
	Major roads	2.6 <sup>2</sup>	200	
	Rail	1.15	200 <sup>3</sup>	
Formaldehyde	Highways	2.0 <sup>1,4</sup>	200 <sup>1</sup>	
	Major roads	1.4 <sup>2</sup>	200 <sup>1</sup>	
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Diesel Exhaust <sup>5</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>	
	Rail	1.15	200 <sup>3</sup>	
Metals	Highways	2.9 <sup>4</sup>	161 <sup>4</sup>	
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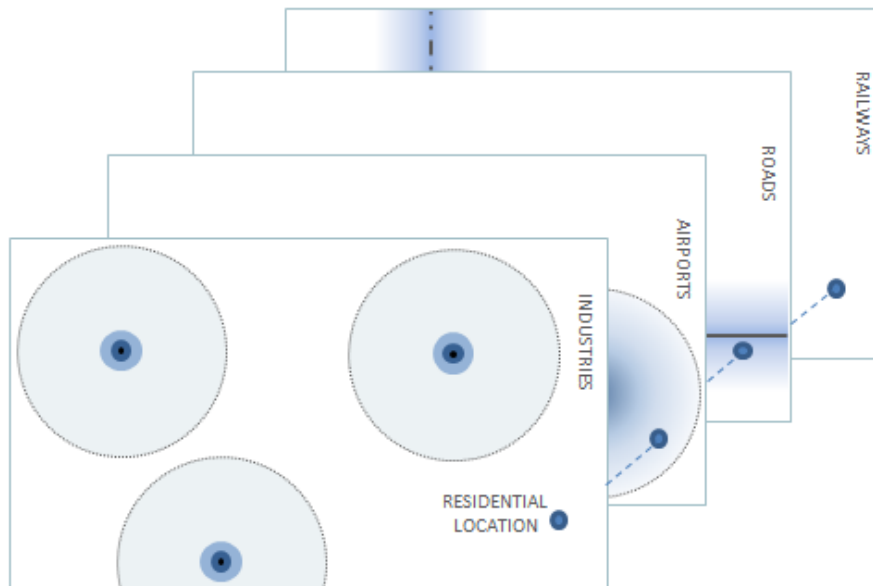
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### Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

In this example, the residential location would be assigned a background concentration, plus additional amounts from the nearby airport and road. There are no industries or railways close enough to add to the predicted concentration.

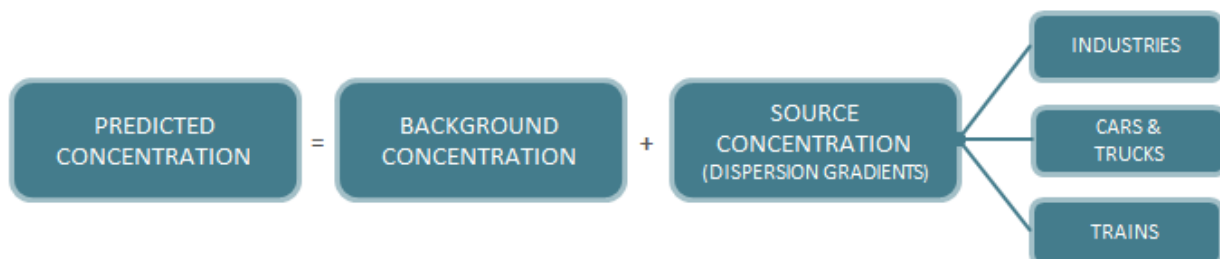
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- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Chrysene

Concentrations of chrysene in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of chrysene emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

## Identifying Dispersion Gradients for Roads, Rails and Large Industries

### INDUSTRIES

We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

### CARS & TRUCKS

We estimated the influence of motor vehicle emission on outdoor air concentrations using gradients applied to highways, major roads and minor roads in Canada. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)	
Acetaldehyde	Highways	3.7 <sup>1</sup>	200 <sup>1</sup>	
	Major roads	2.6 <sup>2</sup>	200	
	Rail	1.15	200 <sup>3</sup>	
Formaldehyde	Highways	2.0 <sup>1,4</sup>	200 <sup>1</sup>	
	Major roads	1.4 <sup>2</sup>	200 <sup>1</sup>	
	Rail	1.15	200 <sup>3</sup>	
Diesel Exhaust <sup>5</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>	
	Rail	1.15	200 <sup>3</sup>	
Metals	Highways	2.9 <sup>4</sup>	161 <sup>4</sup>	
	Arsenic	Major roads	2.0 <sup>2</sup>	161 <sup>4</sup>
	Cadmium, Hexavalent Chromium	Rail	1.15	200 <sup>3</sup>
	Lead Nickel			
Polycyclic Aromatic Hydrocarbons <sup>6</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Benz[a]anthracene	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>
	Benzo[b]fluoranthene	Rail	1.15	200 <sup>3</sup>
	Benzo[k]fluoranthene			
	Benzo[a]pyrene			
	Chrysene Indeno(1,2,3-cd)pyrene			

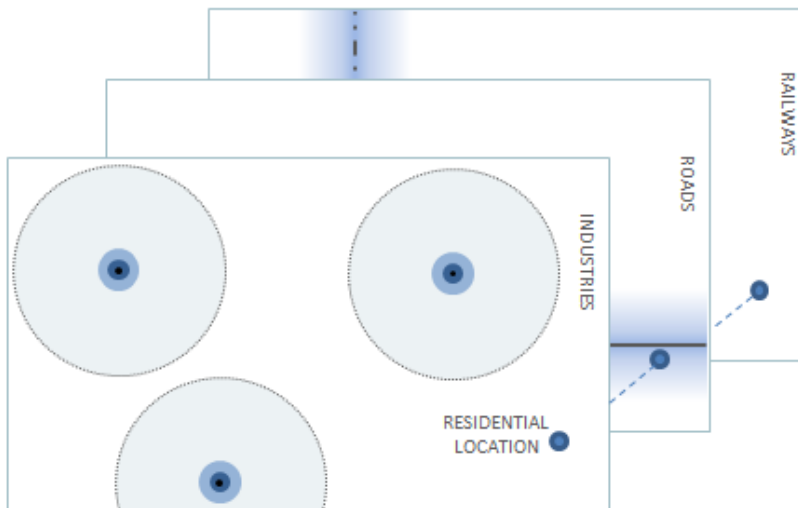
#### References:

1. Viskari, E., Vartiainen, M., Pasanen, P. (2000). Seasonal and diurnal variation in formaldehyde and acetaldehyde concentrations along a highway in Eastern Finland. *Atmospheric Environment*; 24(6): 917-923.
2. When gradients were not available for major roads, the gradient increase was set at 70% of the associated pollutant increase documented at highways. This percentage was based on the ratio of average traffic volumes for major roads and highways. (Setton et al (2005). *Road Classification Schemes – Good Indicators of Traffic Volume?* UVIC SSL Working Paper 05-014 <http://www.cher.ubc.ca/UBCBAQS/SSL05-014-TRAFFIC.pdf>)
3. Hamid, R. (2008) Development of an exposure model for diesel locomotive emissions near the Alameda Corridor. <http://www.metrotrans.org/research/final/AR%2005-03%20Final.pdf>. Accessed July 28 2011.
4. Karner, A., Eisinger, D.S., Niemeier, D.A. (2010). Near-Roadway Air Quality: Synthesizing the Findings from Real-World Data. *Environ. Sci. and Technol.*; 44(14), 5334-5344.
5. We assume 12 percent of total fine particulates measured are of diesel origin based on: (a) Brook, J.R., Poirot, R.L., Dann, T.F. et al. (2007). Assessing sources of PM<sub>2.5</sub> in cities influenced by regional transport. *Journal of Toxicology and Environmental Health Part A*, 70:3-4: 191-199. (b) Keill, L., Maykut, N. (2003). Final Report: Puget Sound Air Toxics Evaluation. In: Seattle: Puget Sound Clean Air Agency. (c) Zheng, M., Cass, G.R., Schauer, J.J. et al. (2002). Source

apportionment of fine particle air pollutants in Southeastern United States using solvent-extractable organic compounds as tracers. *Environmental Science and Technology*, 36(11):2361-2371. (d) Wu, C.F., Wu, S.Y., Wu, Y.H. et al. (2009). Cancer risk assessment of selected hazardous air pollutants in Seattle. *Environment International*, 35(3), 516-522.

6. We assume polycyclic aromatic hydrocarbons are mainly bound to ultra-fine particles in outdoor air, based on: Miguel et al (2004). Seasonal variation of the particle size distribution of polycyclic aromatic hydrocarbons and of major aerosol species in Claremont, California. *Atmosphere Environment* 38 (20) pp 3241-3251.) Gradients are therefore based on those identified for ultrafine particles.

### Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

In this example, the residential location would be assigned a background concentration, plus additional amounts from the nearby road. There are no industries or railways close enough to add to the predicted concentration.

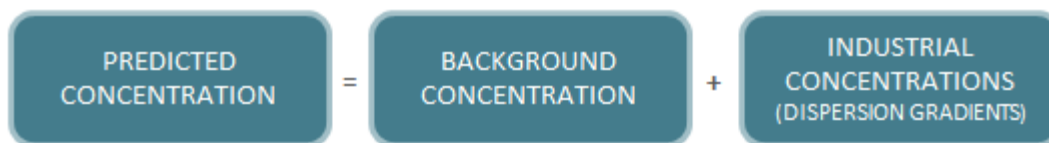
## Limitations

This high-level approach was used to estimate spatial variation in outdoor air concentrations across Canada. Only national, readily available data were used to enable future mapping using the same approach as a means of identifying trends.

- Although we estimated concentrations for all street block centre points in Canada, many local factors are not included that could influence concentrations, for example: road and rail estimates are based only on road type or presence of a railway, not actual vehicle or train volume; and prevailing wind patterns due to local topography may affect gradient shape and distances.
- No independent monitoring was available or conducted to evaluate how well the predicted concentrations match actual measured levels. The results presented are best used to make regional comparisons, and should not be used to assess regulatory compliance.
- National air pollution surveillance (NAPS) monitors were used to represent concentrations for all block points within 50km, regardless of monitor siting criteria. Different monitor siting characteristics and representativeness will therefore affect the accuracy of this assumption.
- The estimates produced represent a 'worst-case scenario', as the screening level dispersion model calculates maximum expected concentrations given emissions levels.
- Limited / no information was available on industrial facility operating parameters required to do more exact dispersion modelling. Industrial facilities were grouped into small, medium and large by emission amounts and assigned standard operating parameters by category.
- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Dichloromethane

Concentrations of dichloromethane in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of dichloromethane emissions to outdoor air may be present, but are not included due to a lack of suitable data.

### Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:



- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

## Identifying Dispersion Gradients for Industries

**INDUSTRIES** We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)	
Acetaldehyde	Highways	3.7 <sup>1</sup>	200 <sup>1</sup>	
	Major roads	2.6 <sup>2</sup>	200	
	Rail	1.15	200 <sup>3</sup>	
Formaldehyde	Highways	2.0 <sup>1,4</sup>	200 <sup>1</sup>	
	Major roads	1.4 <sup>2</sup>	200 <sup>1</sup>	
	Rail	1.15	200 <sup>3</sup>	
Diesel Exhaust <sup>5</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>	
	Rail	1.15	200 <sup>3</sup>	
Metals	Highways	2.9 <sup>4</sup>	161 <sup>4</sup>	
	Arsenic	Major roads	2.0 <sup>2</sup>	161 <sup>4</sup>
	Cadmium,	Rail	1.15	200 <sup>3</sup>
	Hexavalent Chromium			
Lead				
Nickel				
Polycyclic Aromatic Hydrocarbons <sup>6</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Benz[a]anthracene	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>
	Benzo[b]fluoranthene	Rail	1.15	200 <sup>3</sup>
	Benzo[k]fluoranthene			
	Benzo[a]pyrene			
	Chrysene			
Indeno(1,2,3-cd)pyrene				

References:

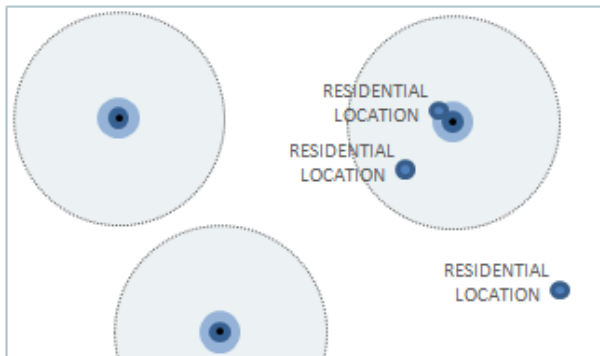
- A) Viskari, E., Vartiainen, M., Pasanen, P. (2000). Seasonal and diurnal variation in formaldehyde and acetaldehyde concentrations along a highway in Eastern Finland. *Atmospheric Environment*; 24(6): 917-923.
- B) When gradients were not available for major roads, the gradient increase was set at 70% of the associated pollutant increase documented at highways. This percentage was based on the ratio of average traffic volumes for major roads and highways. (Setton et al (2005). Road Classification Schemes – Good Indicators of Traffic Volume? UVIC SSL Working Paper 05-014 <http://www.cher.ubc.ca/UBCBAQS/SSL05-014-TRAFFIC.pdf>)
- C) Development of an exposure model for diesel locomotive emissions (2008) <http://www.metrotrans.org/research/final/AR%2005-03%20Final.pdf>
- D) Karner, A., Eisinger, D.S., Niemeier, D.A. (2010). Rear-Roadway Air Quality: Synthesizing the Findings from Real-World Data. *Environ. Sci. and Technol.*; 44(14), 5334-5344.
- E) We assume 18 percent of total fine particulates measured is of diesel origin based on: Keill L, Maykut N. 2003. Final Report: Puget Sound Air Toxics Evaluation. In: Seattle:Puget Sound Clean Air Agency.
- F) Polycyclic aromatic hydrocarbons are mainly bound to ultra-fine particles in outdoor air (Miguel et al (2004). Seasonal variation of the particle size distribution of polycyclic aromatic hydrocarbons and of major aerosol species in Claremont, California. *Atmosphere Environment* 38 (20) pp 3241-3251.) ) Gradients are therefore based on those identified for ultrafine particles.

#### **Additional References:**

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### Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients of industrial emitters.

In this example, two residential locations would be assigned a background concentration plus additional amounts from the nearby industry. There are no industries close enough to the third residential location to add to the predicted concentration.

## Limitations

This high-level approach was used to estimate spatial variation in outdoor air concentrations across Canada. Only national, readily available data were used to enable future mapping using the same approach as a means of identifying trends.

- Although we estimated concentrations for all street block centre points in Canada, many local factors are not included that could influence concentrations, for example: road and rail estimates are based only on road type or presence of a railway, not actual vehicle or train volume; and prevailing wind patterns due to local topography may affect gradient shape and distances.
- No independent monitoring was available or conducted to evaluate how well the predicted concentrations match actual measured levels. The results presented are best used to make regional comparisons, and should not be used to assess regulatory compliance.
- National air pollution surveillance (NAPS) monitors were used to represent concentrations for all block points within 50km, regardless of monitor siting criteria. Different monitor siting characteristics and representativeness will therefore affect the accuracy of this assumption.
- The estimates produced represent a 'worst-case scenario', as the screening level dispersion model calculates maximum expected concentrations given emissions levels.
- Limited / no information was available on industrial facility operating parameters required to do more exact dispersion modelling. Industrial facilities were grouped into small, medium and large by emission amounts and assigned standard operating parameters by category.
- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Diesel Engine Exhaust

Fine particulates from diesel exhaust are not measured directly in Canada. Concentrations of diesel exhaust in outdoor air were predicted for residential locations in 2011 by assuming that 12 percent of total fine particulates measured at National Air Pollution Surveillance (NAPS) monitors originate from diesel exhaust. Estimates of concentrations from cars, trucks, and trains are also included. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of diesel exhaust emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

## Identifying Dispersion Gradients for Roads and Rail

### CARS & TRUCKS

We estimated the influence of motor vehicles emissions using gradients applied to highways, major roads and minor roads. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions to substance using gradients applied to all operating railways in Canada (not including light rail transportation). There are few published studies documenting increases in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)	
Acetaldehyde	Highways	3.7 <sup>1</sup>	200 <sup>1</sup>	
	Major roads	2.6 <sup>2</sup>	200	
	Rail	1.15	200 <sup>3</sup>	
Formaldehyde	Highways	2.0 <sup>1,4</sup>	200 <sup>1</sup>	
	Major roads	1.4 <sup>2</sup>	200 <sup>1</sup>	
	Rail	1.15	200 <sup>3</sup>	
Diesel Exhaust <sup>5</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>	
	Rail	1.15	200 <sup>3</sup>	
Metals	Highways	2.9 <sup>4</sup>	161 <sup>4</sup>	
	Arsenic	Major roads	2.0 <sup>2</sup>	161 <sup>4</sup>
	Cadmium, Hexavalent Chromium	Rail	1.15	200 <sup>3</sup>
	Lead Nickel			
Polycyclic Aromatic Hydrocarbons <sup>6</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Benz[a]anthracene	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>
	Benzo[b]fluoranthene	Rail	1.15	200 <sup>3</sup>
	Benzo[k]fluoranthene			
	Benzo[a]pyrene			
	Chrysene Indeno(1,2,3-cd)pyrene			

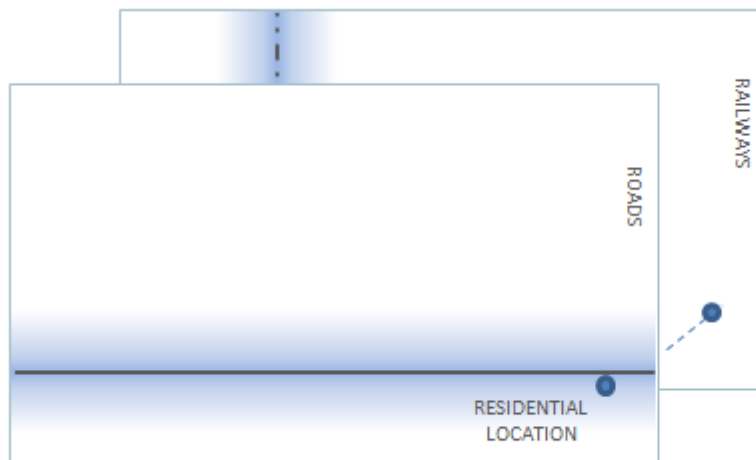
#### References:

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5. We assume 12 percent of total fine particulates measured are of diesel origin based on: (a) Brook, J.R., Poirot, R.L., Dann, T.F. et al. (2007). Assessing sources of PM<sub>2.5</sub> in cities influenced by regional transport. *Journal of Toxicology and Environmental Health Part A*, 70:3-4: 191-199. (b) Keill, L., Maykut, N. (2003). Final Report: Puget Sound Air Toxics Evaluation. In: Seattle:Puget Sound Clean Air Agency. (c) Zheng, M., Cass, G.R., Schauer, J.J. et al. (2002). Source

apportionment of fine particle air pollutants in Southeastern United States using solvent-extractable organic compounds as tracers. *Environmental Science and Technology*, 36(11):2361-2371. (d) Wu, C.F., Wu, S.Y., Wu, Y.H. et al. (2009). Cancer risk assessment of selected hazardous air pollutants in Seattle. *Environment International*, 35(3), 516-522.

6. We assume polycyclic aromatic hydrocarbons are mainly bound to ultra-fine particles in outdoor air, based on: Miguel et al (2004). Seasonal variation of the particle size distribution of polycyclic aromatic hydrocarbons and of major aerosol species in Claremont, California. *Atmosphere Environment* 38 (20) pp 3241-3251.) Gradients are therefore based on those identified for ultrafine particles.

## Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

In this example, the residential location would be assigned a background concentration, plus additional amounts from the nearby road. There are no railways close enough to add to the predicted concentration.

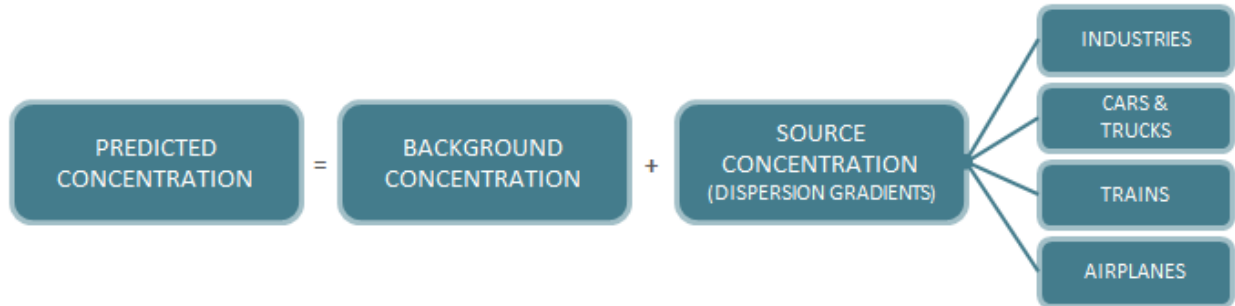
## Limitations

This high-level approach was used to estimate spatial variation in outdoor air concentrations across Canada. Only national, readily available data were used to enable future mapping using the same approach as a means of identifying trends.

- Although we estimated concentrations for all street block centre points in Canada, many local factors are not included that could influence concentrations, for example: road and rail estimates are based only on road type or presence of a railway, not actual vehicle or train volume; and prevailing wind patterns due to local topography may affect gradient shape and distances.
- No independent monitoring was available or conducted to evaluate how well the predicted concentrations match actual measured levels. The results presented are best used to make regional comparisons, and should not be used to assess regulatory compliance.
- National air pollution surveillance (NAPS) monitors were used to represent concentrations for all block points within 50km, regardless of monitor siting criteria. Different monitor siting characteristics and representativeness will therefore affect the accuracy of this assumption.
- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Ethylbenzene

Concentrations of ethylbenzene in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of ethylbenzene emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.



## Identifying Dispersion Gradients for Roads, Rails, Large Industries and Airports

### INDUSTRIES

We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

### CARS & TRUCKS

We estimated the influence of motor vehicle emission on outdoor air concentrations using gradients applied to highways, major roads and minor roads in Canada. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

### AIRPLANES

We used a screening level dispersion model (SCREEN3), to estimate concentrations around medium and large airports based on estimated emissions. The model estimates worst-case ground level concentrations from emissions. Estimates were produced up to 5000m from airports. Emissions from airports were estimated using landing/take-off volumes at each airport and aircraft emission factors specific to each substance.

### Summary of Gradients Identified for Roads and Rails

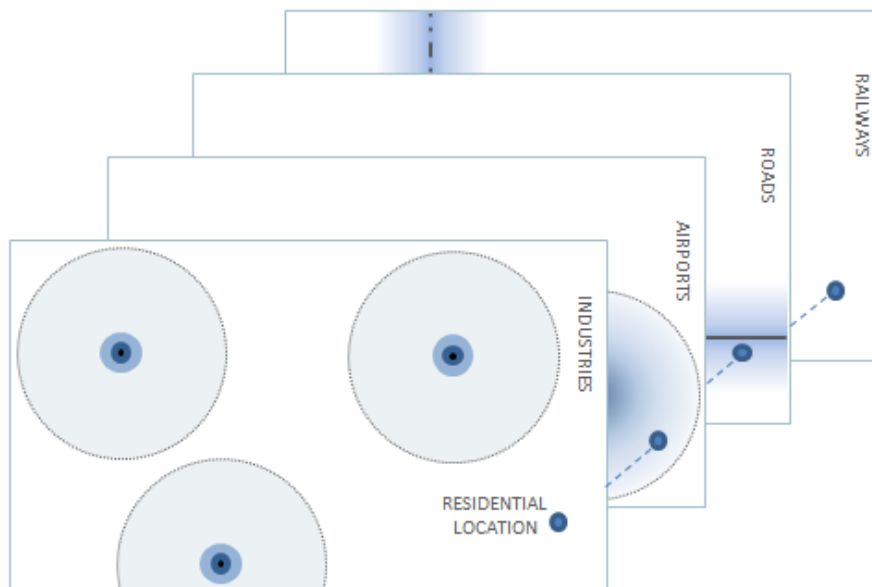
Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)
Benzene	Highways/Major roads	3.25 <sup>1,2,3,4</sup>	50 <sup>3,5,6</sup>
	Local Roads	1.5 <sup>1,2,3,4</sup>	50 <sup>3,5,6</sup>
1,3-Butadiene	Highways	4.0 <sup>6</sup>	75 <sup>6</sup>
Ethylbenzene	Highways	3.7 <sup>2,7,8</sup>	300 <sup>8</sup>
	Major Roads	2.2 <sup>2,7,8</sup>	300 <sup>8</sup>
	Local Roads	1.4 <sup>2,7,8</sup>	300 <sup>8</sup>

#### References:

- Hellen H, Hakola H, Pirjola L, Laurila T, Pystynen KH. (2006). Ambient air concentrations, source profiles, and source apportionment of 71 different C2 to C10 volatile organic compounds in urban and residential areas of Finland. Environ Sci Technol 40(1):103-108.
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### Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

In this example, the residential location would be assigned a background concentration, plus additional amounts from the nearby airport and road. There are no industries or railways close enough to add to the predicted concentration.

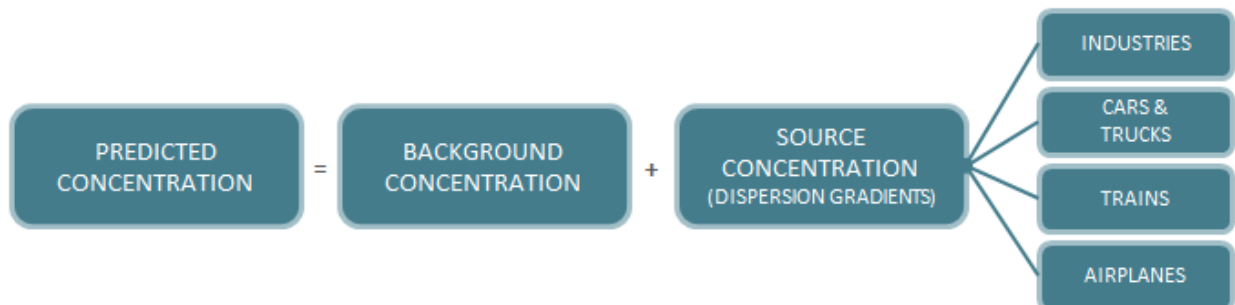
## Limitations

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- Although we estimated concentrations for all street block centre points in Canada, many local factors are not included that could influence concentrations, for example: road and rail estimates are based only on road type or presence of a railway, not actual vehicle or train volume; and prevailing wind patterns due to local topography may affect gradient shape and distances.
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- National air pollution surveillance (NAPS) monitors were used to represent concentrations for all block points within 50km, regardless of monitor siting criteria. Different monitor siting characteristics and representativeness will therefore affect the accuracy of this assumption.
- The estimates produced represent a 'worst-case scenario', as the screening level dispersion model calculates maximum expected concentrations given emissions levels.
- Limited / no information was available on industrial facility operating parameters required to do more exact dispersion modelling. Industrial facilities were grouped into small, medium and large by emission amounts and assigned standard operating parameters by category.
- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Formaldehyde

Concentrations of formaldehyde in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of formaldehyde emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
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## Identifying Dispersion Gradients for Roads and Rail, Large Industries and Airports

### INDUSTRIES

We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

### CARS & TRUCKS

We estimated the influence of motor vehicle emission on outdoor air concentrations using gradients applied to highways, major roads and minor roads in Canada. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

### AIRPLANES

We used a screening level dispersion model (SCREEN3), to estimate concentrations around medium and large airports based on estimated emissions. The model estimates worst-case ground level concentrations from emissions. Estimates were produced up to 5000m from airports. Emissions from airports were estimated using landing/take-off volumes at each airport and aircraft emission factors specific to each substance.

### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)	
Acetaldehyde	Highways	3.7 <sup>1</sup>	200 <sup>1</sup>	
	Major roads	2.6 <sup>2</sup>	200	
	Rail	1.15	200 <sup>3</sup>	
Formaldehyde	Highways	2.0 <sup>1,4</sup>	200 <sup>1</sup>	
	Major roads	1.4 <sup>2</sup>	200 <sup>1</sup>	
	Rail	1.15	200 <sup>3</sup>	
Diesel Exhaust <sup>5</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>	
	Rail	1.15	200 <sup>3</sup>	
Metals	Highways	2.9 <sup>4</sup>	161 <sup>4</sup>	
	Arsenic	Major roads	2.0 <sup>2</sup>	161 <sup>4</sup>
	Cadmium,	Rail	1.15	200 <sup>3</sup>
	Hexavalent Chromium			
	Lead			
Polycyclic Aromatic Hydrocarbons <sup>6</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Benz[a]anthracene	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>
	Benzo[b]fluoranthene	Rail	1.15	200 <sup>3</sup>
	Benzo[k]fluoranthene			
	Benzo[a]pyrene			
	Chrysene			
	Indeno(1,2,3-cd)pyrene			

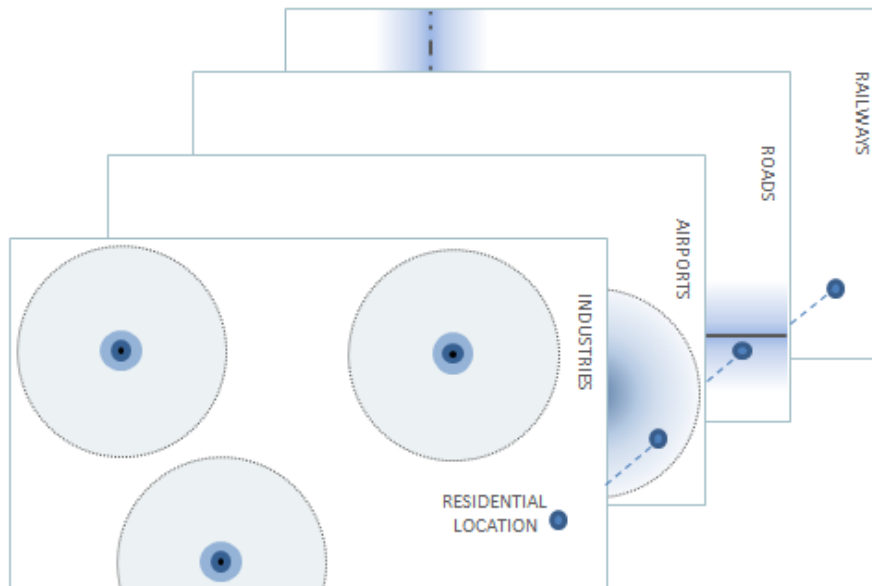
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### Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

In this example, the residential location would be assigned a background concentration, plus additional amounts from the nearby airport and road. There are no industries or railways close enough to add to the predicted concentration.

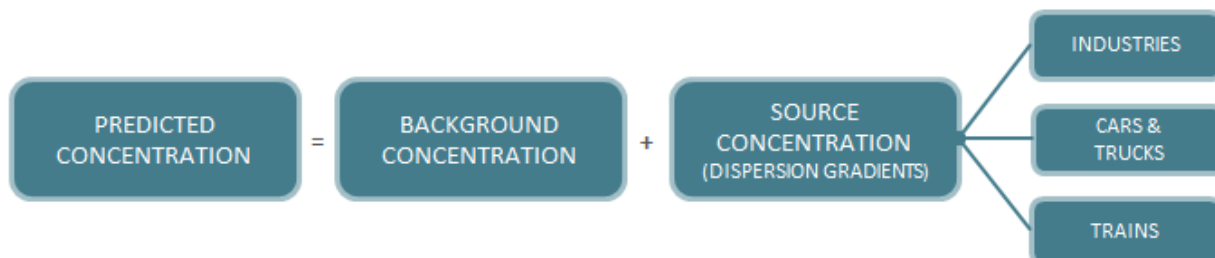
## Limitations

This high-level approach was used to estimate spatial variation in outdoor air concentrations across Canada. Only national, readily available data were used to enable future mapping using the same approach as a means of identifying trends.

- Although we estimated concentrations for all street block centre points in Canada, many local factors are not included that could influence concentrations, for example: road and rail estimates are based only on road type or presence of a railway, not actual vehicle or train volume; and prevailing wind patterns due to local topography may affect gradient shape and distances.
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- The estimates produced represent a 'worst-case scenario', as the screening level dispersion model calculates maximum expected concentrations given emissions levels.
- Limited / no information was available on industrial facility operating parameters required to do more exact dispersion modelling. Industrial facilities were grouped into small, medium and large by emission amounts and assigned standard operating parameters by category.
- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Indeno[1,2,3-cd]pyrene

Concentrations of indeno(1,2,3-cd)pyrene in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of indeno(1,2,3-cd)pyrene emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

## Identifying Dispersion Gradients for Roads and Rails and Large Industries

### INDUSTRIES

We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

### CARS & TRUCKS

We estimated the influence of motor vehicle emission on outdoor air concentrations using gradients applied to highways, major roads and minor roads in Canada. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.



### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)	
Acetaldehyde	Highways	3.7 <sup>1</sup>	200 <sup>1</sup>	
	Major roads	2.6 <sup>2</sup>	200	
	Rail	1.15	200 <sup>3</sup>	
Formaldehyde	Highways	2.0 <sup>1,4</sup>	200 <sup>1</sup>	
	Major roads	1.4 <sup>2</sup>	200 <sup>1</sup>	
	Rail	1.15	200 <sup>3</sup>	
Diesel Exhaust <sup>5</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
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	Rail	1.15	200 <sup>3</sup>	
Metals	Highways	2.9 <sup>4</sup>	161 <sup>4</sup>	
	Arsenic	Major roads	2.0 <sup>2</sup>	161 <sup>4</sup>
	Cadmium,	Rail	1.15	200 <sup>3</sup>
	Hexavalent Chromium			
	Lead			
Polycyclic Aromatic Hydrocarbons <sup>6</sup>	Nickel			
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	Benz[a]anthracene	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>
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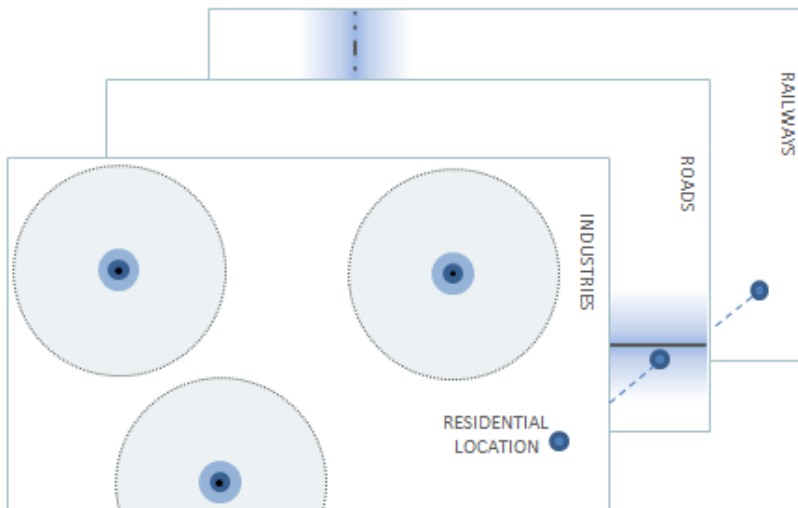
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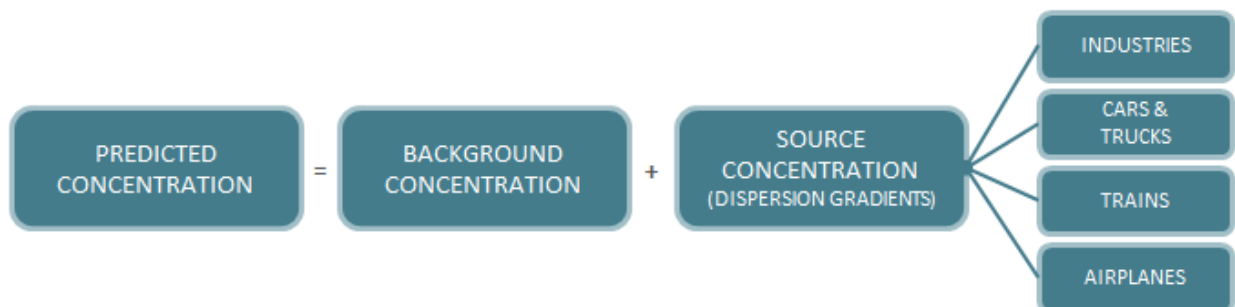
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## Lead

Concentrations of lead in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of lead emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

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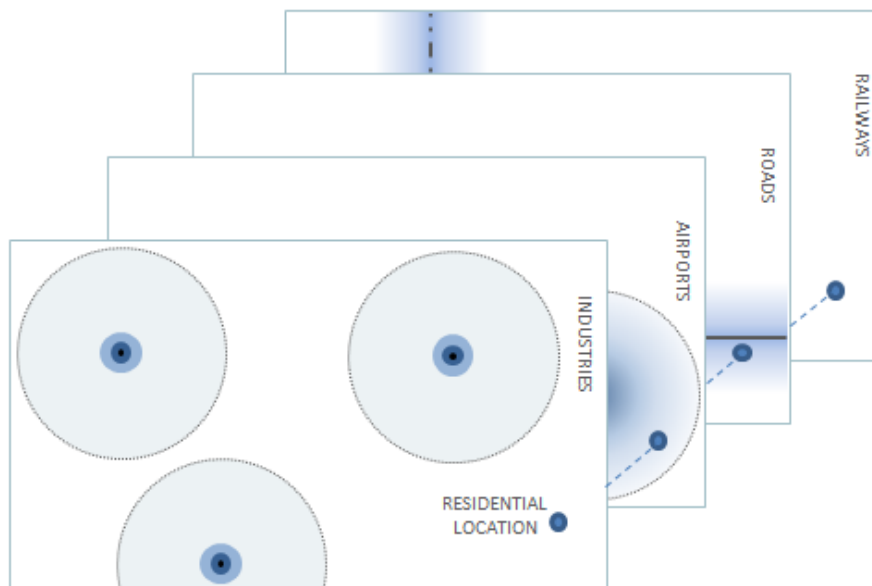
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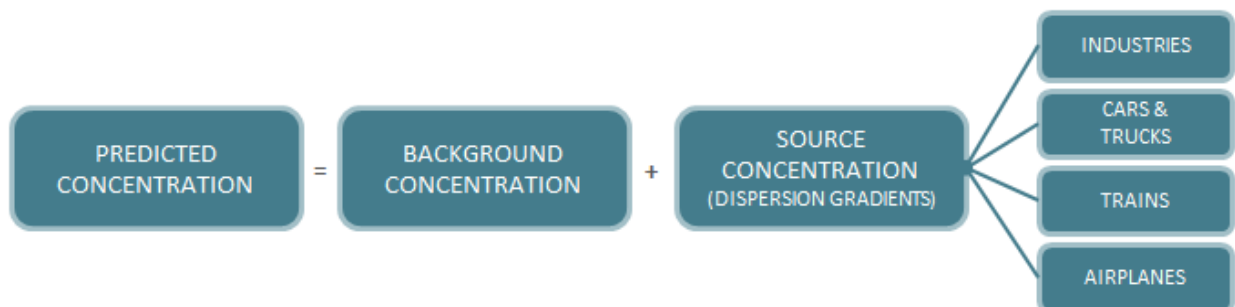
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## Nickel

Concentrations of nickel in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of nickel emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

## Identifying Dispersion Gradients for Roads and Rail, Large Industries and Airports

### INDUSTRIES

We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

### CARS & TRUCKS

We estimated the influence of motor vehicle emission on outdoor air concentrations using gradients applied to highways, major roads and minor roads in Canada. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

### AIRPLANES

We used a screening level dispersion model (SCREEN3), to estimate concentrations around medium and large airports based on estimated emissions. The model estimates worst-case ground level concentrations from emissions. Estimates were produced up to 5000m from airports. Emissions from airports were estimated using landing/take-off volumes at each airport and aircraft emission factors specific to each substance.



### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)	
Acetaldehyde	Highways	3.7 <sup>1</sup>	200 <sup>1</sup>	
	Major roads	2.6 <sup>2</sup>	200	
	Rail	1.15	200 <sup>3</sup>	
Formaldehyde	Highways	2.0 <sup>1,4</sup>	200 <sup>1</sup>	
	Major roads	1.4 <sup>2</sup>	200 <sup>1</sup>	
	Rail	1.15	200 <sup>3</sup>	
Diesel Exhaust <sup>5</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>	
	Rail	1.15	200 <sup>3</sup>	
Metals	Highways	2.9 <sup>4</sup>	161 <sup>4</sup>	
	Arsenic	Major roads	2.0 <sup>2</sup>	161 <sup>4</sup>
	Cadmium,	Rail	1.15	200 <sup>3</sup>
	Hexavalent Chromium			
	Lead			
Nickel				
Polycyclic Aromatic Hydrocarbons <sup>6</sup>	Highways	4.0 <sup>4</sup>	189 <sup>4</sup>	
	Benz[a]anthracene	Major roads	2.8 <sup>2</sup>	189 <sup>4</sup>
	Benzo[b]fluoranthene	Rail	1.15	200 <sup>3</sup>
	Benzo[k]fluoranthene			
	Benzo[a]pyrene			
	Chrysene			
	Indeno(1,2,3-cd)pyrene			

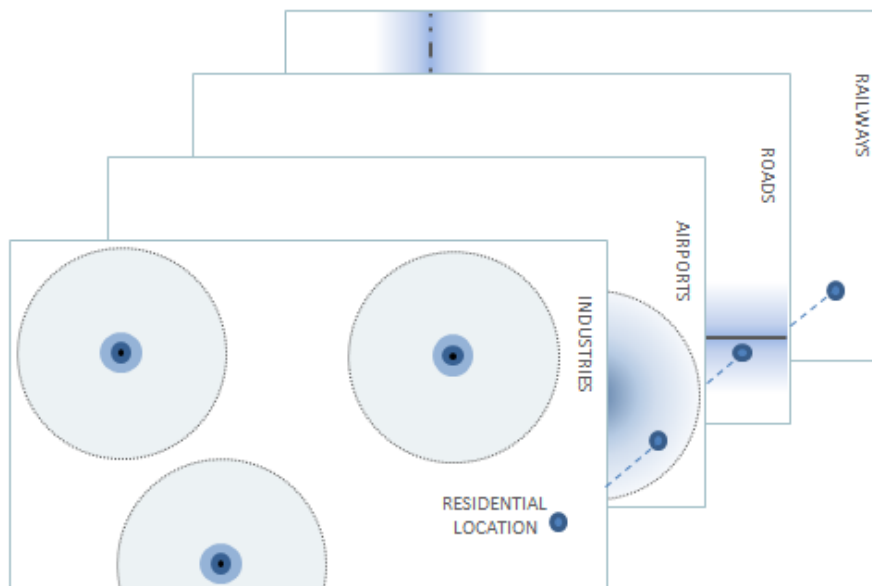
#### References:

1. Viskari, E., Vartiainen, M., Pasanen, P. (2000). Seasonal and diurnal variation in formaldehyde and acetaldehyde concentrations along a highway in Eastern Finland. *Atmospheric Environment*; 24(6): 917-923.
2. When gradients were not available for major roads, the gradient increase was set at 70% of the associated pollutant increase documented at highways. This percentage was based on the ratio of average traffic volumes for major roads and highways. (Setton et al (2005). *Road Classification Schemes – Good Indicators of Traffic Volume?* UVIC SSL Working Paper 05-014 <http://www.cher.ubc.ca/UBCBAQS/SSL05-014-TRAFFIC.pdf>)
3. Hamid, R. (2008) Development of an exposure model for diesel locomotive emissions near the Alameda Corridor. <http://www.metrotrans.org/research/final/AR%2005-03%20Final.pdf>. Accessed July 28 2011.
4. Karner, A., Eisinger, D.S., Niemeier, D.A. (2010). Near-Roadway Air Quality: Synthesizing the Findings from Real-World Data. *Environ. Sci. and Technol.*; 44(14), 5334-5344.
5. We assume 12 percent of total fine particulates measured are of diesel origin based on: (a) Brook, J.R., Poirot, R.L., Dann, T.F. et al. (2007). Assessing sources of PM<sub>2.5</sub> in cities influenced by regional transport. *Journal of Toxicology and Environmental Health Part A*, 70:3-4: 191-199. (b) Keill, L., Maykut, N. (2003). Final Report: Puget Sound Air Toxics Evaluation. In: Seattle:Puget Sound Clean Air Agency. (c) Zheng, M., Cass, G.R., Schauer, J.J. et al. (2002). Source

apportionment of fine particle air pollutants in Southeastern United States using solvent-extractable organic compounds as tracers. *Environmental Science and Technology*, 36(11):2361-2371. (d) Wu, C.F., Wu, S.Y., Wu, Y.H. et al. (2009). Cancer risk assessment of selected hazardous air pollutants in Seattle. *Environment International*, 35(3), 516-522.

6. We assume polycyclic aromatic hydrocarbons are mainly bound to ultra-fine particles in outdoor air, based on: Miguel et al (2004). Seasonal variation of the particle size distribution of polycyclic aromatic hydrocarbons and of major aerosol species in Claremont, California. *Atmosphere Environment* 38 (20) pp 3241-3251.) ) Gradients are therefore based on those identified for ultrafine particles.

### Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

In this example, the residential location would be assigned a background concentration, plus additional amounts from the nearby airport and road. There are no industries or railways close enough to add to the predicted concentration.

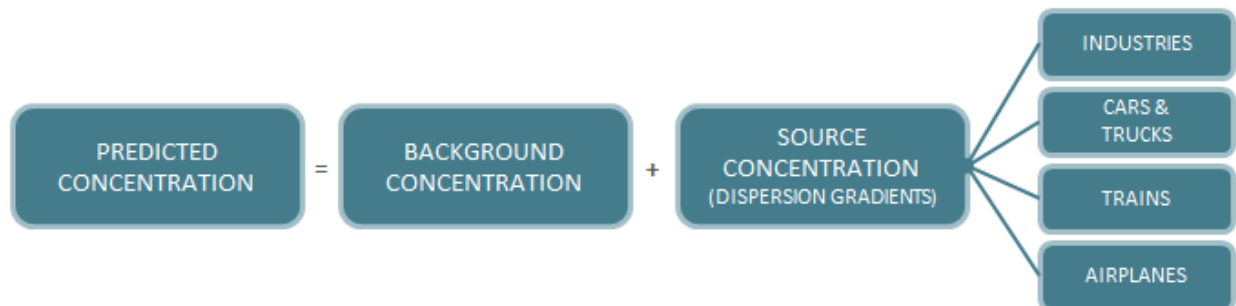
## Limitations

This high-level approach was used to estimate spatial variation in outdoor air concentrations across Canada. Only national, readily available data were used to enable future mapping using the same approach as a means of identifying trends.

- Although we estimated concentrations for all street block centre points in Canada, many local factors are not included that could influence concentrations, for example: road and rail estimates are based only on road type or presence of a railway, not actual vehicle or train volume; and prevailing wind patterns due to local topography may affect gradient shape and distances.
- No independent monitoring was available or conducted to evaluate how well the predicted concentrations match actual measured levels. The results presented are best used to make regional comparisons, and should not be used to assess regulatory compliance.
- National air pollution surveillance (NAPS) monitors were used to represent concentrations for all block points within 50km, regardless of monitor siting criteria. Different monitor siting characteristics and representativeness will therefore affect the accuracy of this assumption.
- The estimates produced represent a 'worst-case scenario', as the screening level dispersion model calculates maximum expected concentrations given emissions levels.
- Limited / no information was available on industrial facility operating parameters required to do more exact dispersion modelling. Industrial facilities were grouped into small, medium and large by emission amounts and assigned standard operating parameters by category.
- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Outdoor Air Pollution

Concentrations of fine particulates (PM<sub>2.5</sub>) in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of PM<sub>2.5</sub> emissions to outdoor air may be present, but are not included due to a lack of suitable data.

## Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

## Identifying Dispersion Gradients for Roads and Rail, Large Industries and Airports

### INDUSTRIES

We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

### CARS & TRUCKS

We estimated the influence of motor vehicle emission on outdoor air concentrations using gradients applied to highways, major roads and minor roads in Canada. Dispersion gradients were determined from a comprehensive search of the published literature. Gradients are created from two key components: 1) the typical increase in substance concentrations at a road compared to background pollutant levels, and 2) the distance from a road at which concentrations return to background levels.

### TRAINS

We estimated the influence of diesel locomotive emissions on outdoor air concentrations using gradients applied to all operating railways in Canada (not including light rail) transportation. There are few published studies documenting increase in pollutant concentrations near railways; therefore, we applied a 15% increase at railways to all pollutants and a linear decrease reaching background levels at 200m.

### AIRPLANES

We used a screening level dispersion model (SCREEN3), to estimate concentrations around medium and large airports based on estimated emissions. The model estimates worst-case ground level concentrations from emissions. Estimates were produced up to 5000m from airports. Emissions from airports were estimated using landing/take-off volumes at each airport and aircraft emission factors specific to each substance.

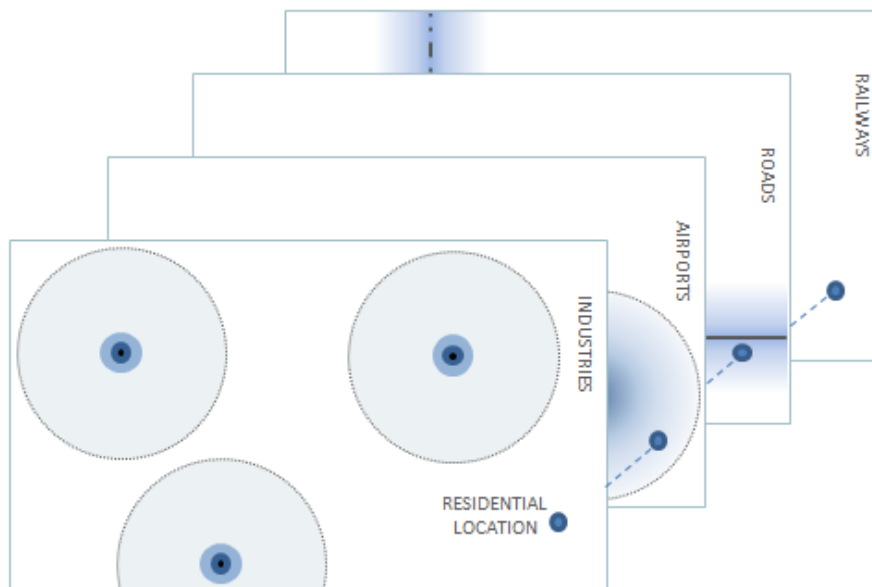
### Summary of Gradients Identified for Roads and Rails

Pollutant	Source	Elevated at Source by a Factor of:	Gradient Distance (meters)
Fine particulates (PM <sub>2.5</sub> )	Highways	1.25 <sup>1</sup>	75 <sup>2,3,4,5</sup>
	Major roads	1.10 <sup>1</sup>	75 <sup>2,3,4,5</sup>

#### References:

1. Smargiassi A, Baldwin M, Pilger C, Dugandzic R, Brauer M. 2005. Small-scale spatial variability of particle concentrations and traffic levels in Montreal: a pilot study. *Sci Total Environ* 338(3):243-251.
2. Beckerman B, Jerrett M, Brook JR, Verma DK, Arain MA, Finkelstein MM. (2008). Correlation of nitrogen dioxide with other traffic pollutants near a major expressway. *Atmos Environ* 42(2):275-290.
3. Hitchins J, Morawska L, Wolff R, Gilbert D. 2000. Concentrations of submicrometre particles from vehicle emissions near a major road. *Atmos Environ* 34(1):51-59.
4. Roorda-Knape MC, Janssen NAH, De Hartog JJ, Van Vliet PHN, Harssema H, Brunekreef B. 1998. Air pollution from traffic in city districts near major motorways. *Atmos Environ* 32(11):1921-1930.
5. Tiitta P, RRaunemma T, Tissari J, Yli-Tuomi T, Leskinen A, Kikkonen J, et al. 2002. Measurements and modeling of PM<sub>2.5</sub> concentrations near a major road in Kuopio, Finland. *Atmos Environ* 36(25):4057-4068.

### Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients.

In this example, the residential location would be assigned a background concentration, plus additional amounts from the nearby airport and road. There are no industries or railways close enough to add to the predicted concentration.

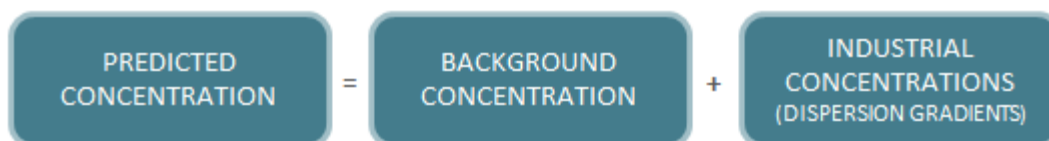
## Limitations

This high-level approach was used to estimate spatial variation in outdoor air concentrations across Canada. Only national, readily available data were used to enable future mapping using the same approach as a means of identifying trends.

- Although we estimated concentrations for all street block centre points in Canada, many local factors are not included that could influence concentrations, for example: road and rail estimates are based only on road type or presence of a railway, not actual vehicle or train volume; and prevailing wind patterns due to local topography may affect gradient shape and distances.
- No independent monitoring was available or conducted to evaluate how well the predicted concentrations match actual measured levels. The results presented are best used to make regional comparisons, and should not be used to assess regulatory compliance.
- National air pollution surveillance (NAPS) monitors were used to represent concentrations for all block points within 50km, regardless of monitor siting criteria. Different monitor siting characteristics and representativeness will therefore affect the accuracy of this assumption.
- The estimates produced represent a 'worst-case scenario', as the screening level dispersion model calculates maximum expected concentrations given emissions levels.
- Limited / no information was available on industrial facility operating parameters required to do more exact dispersion modelling. Industrial facilities were grouped into small, medium and large by emission amounts and assigned standard operating parameters by category.
- Specific gradients developed from the literature for roads and railways were often based on limited amounts of studies, especially for railways where one gradient was applied to all diesel combustion related substances.

## Tetrachloroethylene

Concentrations of tetrachloroethylene in outdoor air were predicted for residential locations in 2011 using levels measured at National Air Pollution Surveillance (NAPS) monitors and estimates of concentrations from known emitters. Residential locations are represented by the geographic coordinates for all street blocks in Canada in 2011, as provided by Statistics Canada.



Other sources of tetrachloroethylene emissions to outdoor air may be present, but are not included due to a lack of suitable data.

### Setting the Background Level

The background concentration is assigned using measured levels from National Air Pollution Surveillance (NAPS) monitors using the following rules:

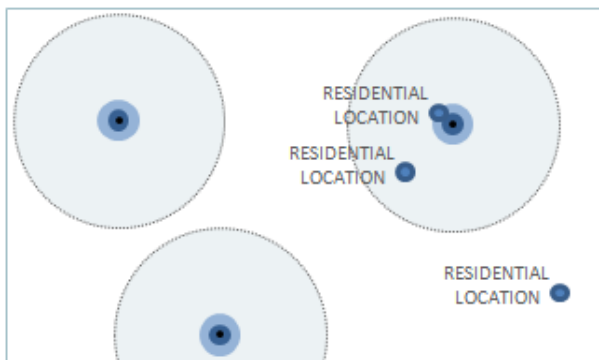
- For all locations within 50 km of a NAPS monitoring station, the annual average concentration measured at that station is assigned as background.
- For all locations within Census Metropolitan Areas (defined by Statistics Canada) and more than 50 km from a NAPS monitoring station, the overall annual average from all urban NAPS stations in Canada is assigned as background.
- For all locations in Non-Census Metropolitan Areas and more than 50 km from a NAPS monitoring station, the overall annual average from all rural NAPS stations in Canada is assigned as background.

## Identifying Dispersion Gradients for Industries

### INDUSTRIES

We used a screening level dispersion model (SCREEN 3) to estimate concentrations around industries reporting emissions to air to the National Pollutant Release Inventory (NPRI). The model estimates worst-case ground level concentrations from total emissions. Estimates were produced from 500m, 1000m, and 5000m from each industrial facility categorized into small, medium and large, based on emissions amounts.

## Applying the Dispersion Gradients to Residential Locations



A geographic information system was used to overlay residential locations (represented by street block centre points) with the modelled or estimated concentration gradients of industrial emitters.

In this example, two residential locations would be assigned a background concentration plus additional amounts from the nearby industry. There are no industries close enough to the third residential location to add to the predicted concentration.

## Limitations

This high-level approach was used to estimate spatial variation in outdoor air concentrations across Canada. Only national, readily available data were used to enable future mapping using the same approach as a means of identifying trends.

- Although we estimated concentrations for all street block centre points in Canada, many local factors are not included that could influence concentrations, for example: prevailing wind patterns due to local topography may affect gradient shape and distances.
- No independent monitoring was available or conducted to evaluate how well the predicted concentrations match actual measured levels. The results presented are best used to make regional comparisons, and should not be used to assess regulatory compliance.
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