Air Quality in Truck Cabins and Its Effect on Occupational Performance and Road Safety

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Introduction

- Trucking is the dominant mode of transport for goods and services in Canada, accounting for 53% of exports and 78% of imports and employing 260,000 truck drivers (Transport Canada, 2004).

- With the high exposure on the roads, crashes involving trucks are a major concern, with commercial vehicles accounting for about 20% of all traffic fatalities and 10% of all serious injuries each year in Canada (Transport Canada, 2004).

- Although the factors contributing to these crashes are complicated, driving while fatigued is widely accepted as one of the main contributing factors and the main focus has been targeted at controlling the workload of truckers.

- Little effort has been directed at investigating the influence of environmental factors like the air quality in the truck on driver alertness and health.
Since many drivers spend most of their time working and sleeping in the truck cabins, the in-cabin air quality could have a significant impact on their health, well being and productivity.

**Temperature & Relative Humidity:** The temperature and the relative humidity level affect the comfort, health and welfare of the truck occupants. They also affect the dryness of their skin, eyes and noses as well as lung functions and in some cases resulting in coughing, wheezing and asthma. Low humidity is also associated with fatigue, headaches and nosebleeds.

**Particles:** Coarse and fine particles are mainly responsible for respiratory diseases (asthma, bronchitis, lungs inflammation, allergies, etc), while ultra-fine particles (<250 nm) and nano-particles could penetrate through the lungs and enter the circulation system causing brain and heart diseases.
- **Carbon Dioxide**: Exposure to carbon dioxide (CO2) of 5000 ppm or higher can cause drivers to feel dizzy and become less vigilant.

- **Carbon Monoxide**: CO poisoning has its most acute toxic effects on organs with high oxygen requirements such as the heart and brain.

- **Nitrogen Dioxide**: As for nitrogen dioxide (NO2), it may damage the lungs at concentrations of 0.3 ppm or above. NO2 also impairs vision and reduces the brain function.

- Despite its importance, data for the air quality in truck cabins are still very limited. No relevant data have been found in the literature that are accessible to the public.

- Moreover, unlike the normal offices and factories, there is no regulation on the air quality in trucks, which is a work place for many drivers as well as a sleeping place.
Objectives of Research

- Develop a portable indoor quality (IAQ) monitoring system for real-time in-truck air quality monitoring.

- Carried out field measurement of IAQ in the cabin of a truck traveling within the City of Calgary.

- Compared data obtained with existing standards or recommendations.

- Compared data obtained with data for other types of transportation cabins that are reported in literature.

- Survey truck drivers about their perceptions of air quality and their self-reported general health and alertness while driving.
Air Quality Measurement Method

- Developed a LabView software to automatically run the system:
  - Gases: 30 seconds
  - Particle numbers: 10 minutes
  - PM$_{2.5}$: integrated sampling

- Error probing and problem solving in lab and office to make sure the system can be running steadily and reliably, the calibration was conducted in lab and office.

- T, RH, CO, CO$_2$, NO$_2$, Particle number and PM$_{2.5}$ were monitored
Deployed in two trucks

In summer: August 16 to September 20, 2005
In winter: January 15 to February 21, 2006

Sampling location

Summer truck: in front of the passenger seat
Winter truck: on bunker bed at the left rear side of the truck cabins
# Measurement Results

<table>
<thead>
<tr>
<th></th>
<th>Temp (°C)</th>
<th>RH (%)</th>
<th>CO (ppm)</th>
<th>CO₂ (ppm)</th>
<th>NO₂ (ppm)</th>
<th>PM₂.₅ (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standards</td>
<td>19.5-23(w)</td>
<td>30-60%</td>
<td>9</td>
<td>1000</td>
<td>0.053</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>22.5-26(s)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Peak value</td>
<td>37.1</td>
<td>56.4</td>
<td>12</td>
<td>1929</td>
<td>0.5</td>
<td>835</td>
</tr>
<tr>
<td>Average</td>
<td>19.2</td>
<td>12.8</td>
<td>1.9</td>
<td>677</td>
<td>0.0026</td>
<td>310</td>
</tr>
<tr>
<td>Out of comfort (%)</td>
<td>75.4%</td>
<td>95.3%</td>
<td>0.11%</td>
<td>1.6%</td>
<td>2.4%</td>
<td>100%</td>
</tr>
</tbody>
</table>

- **Recommended Standards:** ASHRAE, EPA, OSHA
- **All concentrations of gaseous pollutants are well below the threshold values.**
- **The mass concentrations of fine particles are extremely high.**
- **The thermal conditions are out of comfortable ranges. Most of time, it is too dry in truck cabins.**

9/26/2013

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Temperature and Relative Humidity

Shaded areas: Recommended Values by Standards
Gases (CO, CO$_2$, NO$_2$)

- CO
- NO$_2$
- CO$_2$
Particle number and PM$_{2.5}$
Almost all peak values occurred when the truck was idling.
Survey of Truck Drivers

- Data collected in questionnaire:
  - Background (age, gender, experience, etc)
  - Work pattern (hrs, days, partner, etc)
  - Perception of air quality
  - Steps taken to improve air quality
  - Stanford Sleepiness Scale (current/last trip)
  - Epworth Sleepiness Scale (general fatigue)
  - General health problems
  - Respiratory & sleep related health issues

- 253 participants conveniently selected from two truck shops in Calgary.

- Respondents are assured of the confidentiality of data as outlined in the University of Calgary Ethics on Human Research.
Ventilation Modes

- Combined all the above: 42.4%
- Natural ventilation: 40.6%
- Fresh-air intake: 6.8%
- Recirculation: 1.2%

the air in the cabin is fresh

After how many hours, air is not fresh

1. 7.82% 0 hrs or more
2. 42.11% 1-5 hrs
3. 17.49% 6.6 hrs
4. 30.81% less than 4 hrs

the irritation to eyes, nose, throat, skin

- 22.31% none
- 4.42% very often
- 7.63% often
- 29.32% sometimes
- 31.33% rarely

9/26/2013

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Suffering from sleep related problems – time to see a doctor or sleep specialist.

Epworth Sleepiness Scale

to measure fatigue

- Poor: 48.83%
- Average: 16.90%
- Enough: 34.27%
Stanford Sleepiness Scale

to measure sleepiness of the subjects while at work

- feeling active, vital, awake: 71.8%
- functioning at high levels, but able to concentrate: 14.1%
- awake, but relaxed; responsive but not fully alert: 29.6%
- somewhat foggy, lay down: 5.1%
- fuzzy, losing interest in remaining awake, slowed down: 28.2%
- sleepy, woozy, fighting sleep, prefer to lie down: 17.9%
- Asleep: 0.0%

have a serious sleep debt and you need more sleep
Sleep and Health Issues

- Sleep disorder: 85.1% in Drivers, 14.71% in Population
- High Blood: 16.2% in Drivers, 18.38% in Population
- Heart: 4.5% in Drivers, 8.09% in Population
- Depression: 6.9% in Drivers, 5.3% in Population
- Chronic pain: 2.8% in Drivers, 11.2% in Population
- Asthma or Bronchitis: 6.1% in Drivers, 5.5% in Population

Percentage prevalence in Drivers vs Population.
The concentrations of gaseous contaminants are acceptable within most time.

The concentrations of PM$_{2.5}$ are up to 2-13 times higher than recommended threshold from EPA (4.8-113 times the background concentration).

The air quality in winter is worse than that in summer except NO$_2$.

There are strong adverse effects on occupants due to high levels of particles.

Many have sleep problems & almost have scored poorly on Epworth Sleepiness Scale.

Only a third reported no long term medical problems,

Almost one in five had a collision over the last three years.

27% had a ticket (moving violation) during the last 12 months.