



# Ontario School Safety

Carbon Dioxide (CO<sub>2</sub>) Monitoring





# Including School Transportation

Why you should care about CO<sub>2</sub> on the bus.





# A school bus is...

- The only option for some students to get to school
- A place where students may spend a considerable amount of their day
- A safe method of transportation
- “An extension of the classroom”





Classrooms aim for:

**>6 air changes per hour  
&  
<1000 ppm CO<sub>2</sub>**





Buses can experience:

**0.13-1.9 air changes per hour  
&  
> 3000 ppm CO<sub>2</sub>**





# What is happening on buses?





# Ventilation on a School Bus

- Poor ventilation and high CO<sub>2</sub>
  1. Low ceilings
  2. Closed windows
  3. No ventilation system
  4. Crowded





# High Carbon Dioxide = Health Risks

- Tiredness
- Headaches
- Dizziness
- Concentration difficulties







**High Carbon  
Dioxide  
=  
Inhaling  
Others' Breath**

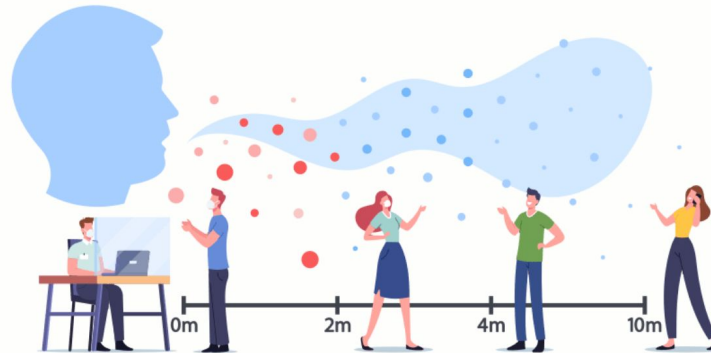
When a kid drinks  
from your cup...





# Inhalable Illnesses & Health Impacts

- Inhalable (airborne) illnesses:
  - Measles, Streptococcus A, SARS-CoV-2 (COVID), Influenza, Respiratory Syncytial Virus (RSV), Norovirus, and more...

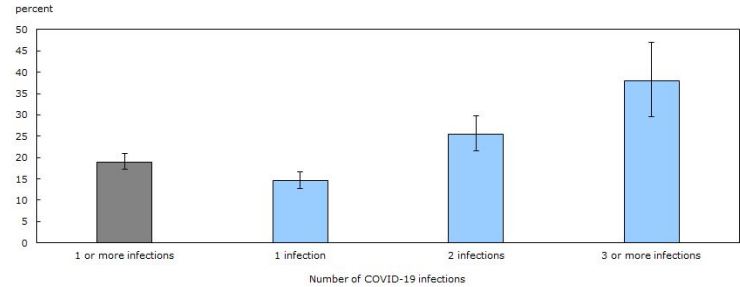




# Inhalable Illnesses & Health Impacts

- Measles:
  - Blindness, deafness, and permanent neurological damage
- Streptococcus A:
  - Kidney and heart damage
  - Sepsis → Septic shock
    - Post-Sepsis Syndrome:  
Persistent immune, cognitive, neurological and cardiovascular dysfunction
- SARS-CoV-2 (COVID):
  - Blood vessel and neurological damage
  - [Long Covid](#)

Chart 2  
Percentage of Canadian adults with long-term symptoms, by number of self-reported COVID-19 infections, June 2023



Source: Statistics Canada, Canadian COVID-19 Antibody and Health Survey - Follow-up Questionnaire, 2023.

*“Even mild cases of SARS-CoV-2 infection are at risk of becoming long covid, and these results suggest the threat increases with multiple infections.”*

- Dr. Mona Nemer, Chief Science Advisor of Canada





**Measles**  
remains infectious for  
**2 hours in the air**





**SARS-CoV-2**  
can infect within  
**6-37 minutes**





# **Frequency, Intensity, and Time on the Bus Increases Exposure Risk...**

- **Frequency:**
  - Loading and unloading the bus every Monday to Friday
- **Intensity:**
  - Loading mixed classes of students in crowded aisles
  - Singing, shouting, laughing, talking – generating virus particles and CO<sub>2</sub>
- **Time:**
  - Sitting shoulder-to-shoulder for 20-30 minutes in compartmentalized seats with minimal fresh air





# Improving Air Quality on Buses

Stopping the virus on the bus from going  
'round and 'round...





# What can we do tomorrow?







# Open Windows & Roof Hatches

- Student Transportation Services of Waterloo Region, September 2021 Memo: “[Public health has identified the need for good ventilation inside school bus to reduce the spread of COVID-19](#)”
- **Limitations:**
  - a. Exposure to vehicle emissions:
    - Pulmonary and cardiovascular health risks for children/drivers
    - Associated with poor academic performance
  - b. Wildfire smoke days
  - c. Extreme weather conditions





# Maximize Fresh Air Defroster Fan Speed

- Increase fresh air intake near the bus driver
  - Supplies fresh air to the driver
- **Limitations:**
  - Can't filter outdoor air
  - Not sufficient for all students





# **What can we do after tomorrow?**





# Provide Better Masks

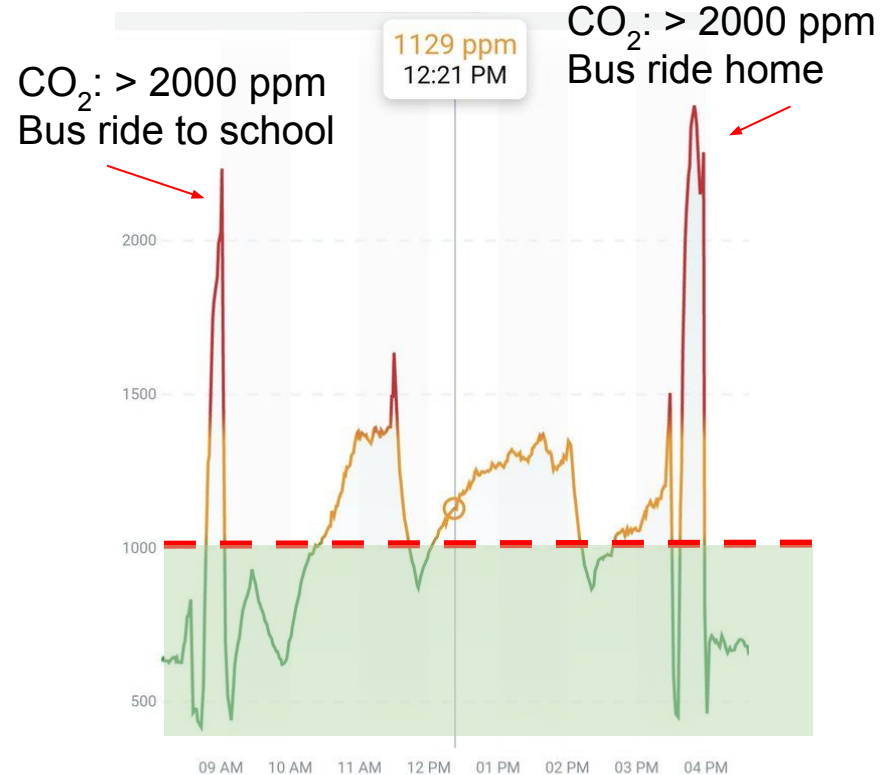
- High-quality, tight-fitting, high-filtration masks like N95s, CA-N95s, and KN95s can:
  - Filter inhaled air
  - Filter exhaled air
- Canadian Standards Association (CSA) Certified respirators meet a new engineering standard (Z94.4.1:21) for safety, filtration, fit, and breathability
  - XS (young children), S, M, and L sizes





# Advocate for: Monitoring Carbon Dioxide

- Real-time monitoring (not averages)
  - Collect time-series data
  - Start: 20 min. before first person boards
  - End: 20 min. after last person leaves



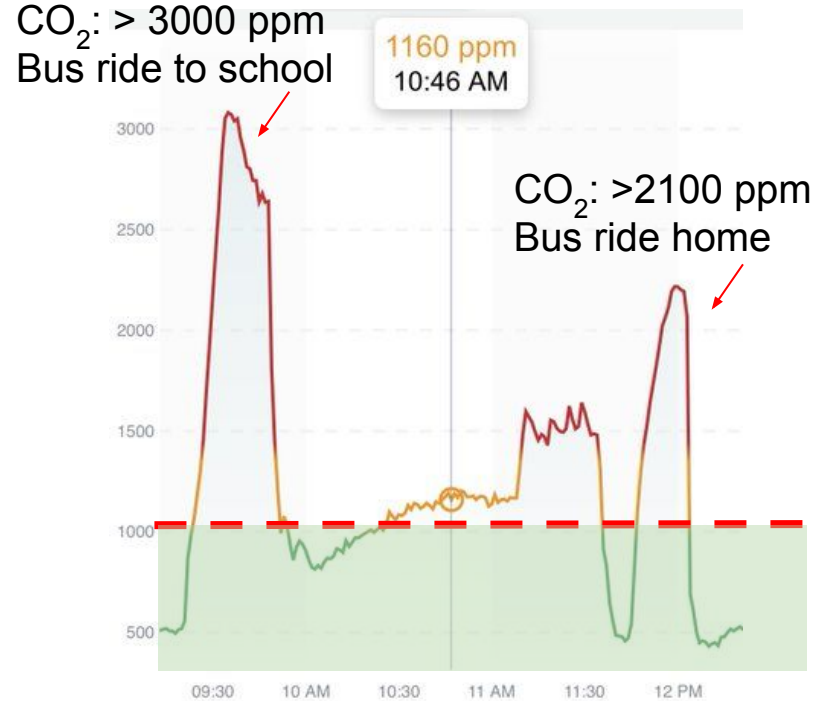
Example 1





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# Advocate for: Investments in Air Quality

1. Installation of portable air filtering units on the bus
  - HEPA air purifiers
  - MERV-13 air purifiers
  - UVC filtration/disinfection devices
2. Installation of ventilation/filtration systems on the bus
  - Bring in fresh and filtered outdoor air
  - Filter and/or disinfect recirculated air
3. Electrification of school bus fleets to reduce emissions





## **Dr. William Bahnfleth, ASHRAE Epidemic Task Force Chair:**

“The density of people [on a bus] is ordinarily much higher than in buildings. This density inherently increases the risk of short-range transmission [of pathogens], and it is difficult, if not impossible, to isolate passengers.”

“Code minimum ventilation and MERV-13 filter efficiency should be viewed as baseline requirements that may not be sufficient.... Air cleaners may be used as a supplement... The best-established technology (to supplement ventilation and filtration) currently is disinfection with germicidal ultraviolet light.”







Last Modified: 21-Dec-2023



# Ontario School Safety School Buses

[www.ontarioschoolsafety.com](http://www.ontarioschoolsafety.com)

## Ventilation on a School Bus

Due to their design, many school buses have poor ventilation, causing high levels of carbon dioxide (CO<sub>2</sub>) on the bus. They have low ceilings and not enough fans or filters to move the air. Classrooms aim for 6+ air exchanges per hour (ACH) using ventilation and filtration but school buses may only get 0.13-1.9 ACH with fresh air [1, 2]. Opening the windows on a bus can help improve the air quality [2], but this may be challenging when outdoor air quality is poor, like on wildfire smoke days.



## Airborne Viruses & Health Impacts



High CO<sub>2</sub> levels mean you are breathing other people's exhaled air—including whatever illnesses they have. Influenza, RSV, SARS-CoV-2 (the virus that causes COVID-19), the common cold, strep and even norovirus can float and spread in the air like smoke [3-8]. SARS-CoV-2 can infect someone within 6-37 minutes in air that is not moving [9]. With each COVID-19 infection, the risk of experiencing long-term symptoms like fatigue, shortness of breath, and "brain fog" increases [10]. Approximately 1 in 9 Canadians have long-term COVID-19 symptoms, and some have yet to fully recover [10]. **Kids can suffer with long-COVID, too [11].**



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## Crowding & Time on a School Bus

The design of school buses, combined with how we load and unload them, increases the risk of exposure to high levels of CO<sub>2</sub> and inhaling rebreathed air. Students often sit at shoulder-to-shoulder for 20-30 minutes to and from school in a space with low ceilings and little to no fresh air supplied. Each seat acts like a small compartment where kids talk, shout, laugh and sing while shaving air. Crowding also occurs in the aisles when boarding or leaving the bus [12].



## Monitoring CO<sub>2</sub> & Ventilation Quality



Humans are the main source of the CO<sub>2</sub> that contributes to poor indoor air quality. Exhaling especially increases the CO<sub>2</sub> concentration in poorly-ventilated spaces. Measuring CO<sub>2</sub> levels can indicate how well our exhaled air is replaced with fresh air. Outdoor air ranges from 300-500 parts per million (ppm) of CO<sub>2</sub>. **Community members have measured 3000 ppm on fully occupied school buses.** These levels are 3x higher than Canada's long-term exposure limit of 1000 ppm, which aims to limit health risks. For example, as CO<sub>2</sub> increases, humans are at a higher risk of tiredness, headaches, dizziness, and concentration difficulties. No one wants to be behind the wheel when feeling tired, dizzy, or having difficulty concentrating—especially when transporting students. [13]

## Improving Air Quality on School Buses

Reducing CO<sub>2</sub> and the risk of spreading preventable diseases on school buses is important for keeping drivers healthy and working and students safe on their way to and from school. We have tools—let's use them!

- Opening windows and any available roof hatches on their way to and from school.
- Maximizing the fresh air defroster fan speed to improve ventilation when the bus moves
- Investing in portable air filtering units with high clean air delivery rates for the driver and the entire bus
- Wearing high-quality, tight-fitting, high-filtration masks like KN95 respirators to filter rebreathed air
- ...and more! [12]



1. Ontario School Safety, "Ventilation on a School Bus," 2023. <https://www.ontarioschoolsafety.com/ventilation-on-a-school-bus/>





# References

1. WRDSB, "Administrative Procedure 4260: Student Transportation," 2019. [\[Online\]](#).
2. Lancet COVID-19 Commission, "Proposed Non-infectious Air Delivery Rates (NADR) for Reducing Exposure to Airborne Respiratory Infectious Diseases," 2022. [\[Online\]](#).
3. M. Van Dyke et al., "Investigating dilution ventilation control strategies in a modern U.S. school bus in the context of the COVID-19 pandemic," *Journal of Occupational and Environmental Hygiene*, May 2022. [\[Online\]](#).
4. Canada, "Flu (influenza): For health professionals," Government of Canada, 2023. [\[Online\]](#).
5. Canada, "Respiratory syncytial virus: Infectious substances pathogen safety data sheet," Government of Canada, 2023. [\[Online\]](#).
6. Canada, "Rapid review on SARS-CoV-2 aerosol transmission: update 2," Government of Canada, 2021. [\[Online\]](#).
7. Canada, "Pathogen Safety Data Sheets: Infectious Substances – Rhinovirus," Government of Canada, 2011. [\[Online\]](#).
8. Canada, "Measles: For health professionals," Government of Canada, 2024, [\[Online\]](#).
9. D. D. Barth et al., "Modes of transmission and attack rates of group A Streptococcal infection: a protocol for a systematic review..." *BMC Sys Reviews*, Dec. 2021. [\[Online\]](#).
10. G. Tung-Thompson et al., "Aerosolization of a Human Norovirus Surrogate, Bacteriophage MS2, during Simulated Vomiting," *PLoS ONE*, Aug. 2015. [\[Online\]](#).
11. M. Alsved et al., "Infectivity of exhaled SARS-CoV-2 aerosols is sufficient to transmit covid-19 within minutes," *Nature Scientific Reports*, Dec. 2023. [\[Online\]](#).
12. S. Kuang et al., "Experiences of Canadians with long-term symptoms following COVID-19," *Statistics Canada*, 2023. [\[Online\]](#).
13. Canada, "Post COVID-19 condition in Canada: What we know, what we don't know, and a framework for action," Government of Canada, 2023. [\[Online\]](#).
14. E. C. Van Der Slikke, A. Y. An, R. E. W. Hancock, and H. R. Bouma, "Exploring the pathophysiology of post-sepsis syndrome to identify therapeutic opportunities," *EBioMedicine*, vol. 61, p. 103044, Nov. 2020, [\[Online\]](#).
15. Y. Abulhassan and G. A. Davis, "Considerations for the transportation of school aged children amid the Coronavirus pandemic," *Transportation Research Interdisciplinary Perspectives*, Mar. 2021. [\[Online\]](#).
16. Canada, "Carbon dioxide in your home," Government of Canada, 2021. [\[Online\]](#).
17. D. Fillenwarth, "Students Need School Bus Air As Clean As in Their Classroom," 2021. [\[Online\]](#).
18. Student Transportation Services of Waterloo Region, "Policies, Procedures & Forms Section: Windows for Ventilation," 2021. [\[Online\]](#).





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