

Health Impact Review of HB 2387
Limiting the exposure of public school students and school personnel to diesel emissions
from school bus engines (2020 Legislative Session)

January 13, 2020

Staff contact:

Cait Lang-Perez

Phone: (360) 628-7342

Email: caitlin.lang@sboh.wa.gov



Full review

The full Health Impact Review report is available at:

<https://sboh.wa.gov/Portals/7/Doc/HealthImpactReviews/HIR-2020-03-HB2387.pdf>

Acknowledgements

We would like to thank the key informants who provided consultation and technical support during this Health Impact Review.

Contents

Executive Summary 1

Introduction and Methods 2

Analysis of HB 2387 and the Scientific Evidence 2

Logic Model 8

Summaries of Findings 9

Annotated References 14

Executive Summary
HB 2387, Limiting the exposure of public school students and school personnel to diesel emissions from school bus engines
(2020 Legislative Session)

Evidence indicates that HB 2387 would likely result in some number of public school districts implementing school bus idling restrictions, which could reduce environmental exposure to diesel exhaust on public school property, improve health outcomes, and reduce health inequities for sensitive populations.

BILL INFORMATION

Sponsors: Kilduff, Ybarra, Leavitt, Fitzgibbon

Summary of Bill:

- Directs Office of Superintendent of Public Instruction (OSPI) to adopt rules to limit the exposure of students and school personnel to diesel emission from school bus engines.
- OSPI rules must:
 - Establish limits on idling of school bus engines while buses are on school property or are otherwise engaged in providing student transportation;
 - Include potential exemptions, including exemptions necessary for weather conditions, health and safety issues, and vehicle maintenance;
 - Be included in the School Bus Drivers Handbook; and
- Require district compliance by September 1, 2022.

HEALTH IMPACT REVIEW

Summary of Findings:

This Health Impact Review found the following evidence for relevant provisions in HB 2387:

- This review makes the **informed assumption** that directing OSPI to adopt rules to limit school bus idling while on public school property will likely result in some number of public school districts in Washington implementing school bus idling restrictions. This informed assumption is based on information from key informant interviews.
- This review makes the **informed assumption** that school districts' implementation of school bus idling restrictions will likely reduce environmental exposure to diesel emissions by some level at some number of public schools. This informed assumption is based on evidence from the U.S. Environmental Protection Agency (EPA), data for Washington's school bus fleet, and information from key informants.
- **Strong** evidence that decreasing environmental exposure to diesel exhaust will likely improve health outcomes.
- **Strong** evidence that improving health outcomes for public school students and personnel would decrease inequities particularly for sensitive populations.

Introduction and Methods

A Health Impact Review is an analysis of how a proposed legislative or budgetary change will likely impact health and health disparities in Washington State ([RCW 43.20.285](#)). For the purpose of this review ‘health disparities’ have been defined as the differences in disease, death, and other adverse health conditions that exist between populations ([RCW 43.20.270](#)). This document provides summaries of the evidence analyzed by State Board of Health staff during the Health Impact Review of House Bill 2387 ([HB 2387](#)).

Staff analyzed the content of HB 2387 and created a logic model depicting possible pathways leading from the provisions of the bill to health outcomes. We consulted with experts and contacted key informants about the provisions and potential impacts of the bill. We conducted an objective review of published literature for each pathway using databases including PubMed, Google Scholar, and University of Washington Libraries. More information about key informants and detailed methods are available upon request.

The following pages provide a detailed analysis of the bill including the logic model, summaries of evidence, and annotated references. The logic model is presented both in text and through a flowchart (Figure 1). The logic model includes information on the strength-of-evidence for each relationship. The strength-of-evidence has been defined using the following criteria:

- **Very strong evidence:** the review of literature yielded a very large body of robust evidence supporting the association with few if any contradictory findings. The evidence indicates that the scientific community largely accepts the existence of the association.
- **Strong evidence:** the review of literature yielded a large body of evidence on the relationship (a vast majority of which supported the association) but the body of evidence did contain some contradictory findings or studies that did not incorporate the most robust study designs or execution or had a higher than average risk of bias; or there were too few studies to reach the rigor of “very strong evidence;” or some combination of these.
- **A fair amount of evidence:** the review of literature yielded several studies supporting the association, but a large body of evidence was not established; or the review yielded a large body of evidence but findings were inconsistent with only a slightly larger percentage of the studies supporting the association; or the research did not incorporate the most robust study designs or execution or had a higher than average risk of bias.
- **Not well researched:** the review of literature yielded few if any studies or only yielded studies that were poorly designed or executed or had high risk of bias.

This review was subject to time constraints, which influenced the scope of work for this review. The annotated references are only a representation of the evidence and provide examples of current research. In some cases only a few review articles or meta-analyses are referenced. One article may cite or provide analysis of dozens of other articles. Therefore, the number of references included in the bibliography does not necessarily reflect the strength-of-evidence. In addition, some articles provide evidence for more than one research question, so are referenced multiple times.

Analysis of HB 2387 and the Scientific Evidence

Summary of relevant background information

- EPA states, “Unnecessary school bus idling affects human health, pollutes the air, wastes fuel, and causes excess engine wear.”¹ EPA recommends that school officials voluntarily establish an idle reduction policy.¹
- The EPA recommends:
 - At a minimum, buses should be moving whenever the engine is on; engines should be turned off quickly after arriving at loading or unloading areas; buses should not be restarted until they are ready to depart; morning warm-up idling time should be limited to manufacturers’ recommendations; and whenever possible, shorten commute times for children.¹
 - To maximize the effects of idling reduction policies, districts should effectively train bus drivers on idle reduction policies; spot-check (depots, loading, unloading, and delivery areas) for idling compliance; use idle reduction technologies; recognize and celebrate drivers who successfully reduce idling; post no-idling signs on school grounds; develop air pollution educational programs for students; involve community leaders; and share successes publicly.¹
- Particulate matter (PM) are “inhalable and respirable particles composed of [sulfate], nitrates, ammonia, sodium chloride, black carbon, mineral dust and water.”² Sources of PM include combustible diesel engines.²
- Nitrogen oxides (NO_x) comprise a group of highly reactive gases.³ EPA uses Nitrogen Dioxide (NO₂), which forms from emissions of cars, trucks and buses, power plants, and off-road equipment, as the indicator for NO_x.³
- In 2000, the EPA signed new emission standards for model year 2007 and later heavy-duty highway engines (“Clean Diesel Emissions Standards”).⁴ The rule addressed emission standards and diesel fuel regulations.
 - The EPA Clean Diesel Emissions Standards for heavy-duty highway engines and vehicles include “very stringent limits for PM (0.01 [grams per brake horsepower hour] g/bhp·hr) and NO_x (0.20 g/bhp·hr).”⁴ The PM emission standard took full effect in 2007. The NO_x standard was phased-in for diesel engines: 50% of sales from 2007 to 2009 and 100% in 2010.⁴ However, “very few engines meeting the 0.20 g/bhp·hr NO_x limit actually appeared before 2010.”⁴ Therefore, engine model years 2007 and later are required to meet the 2007 PM standards. Engines produced in 2010 and later are required to meet both the 2007 PM standards and the 2010 NO_x standards.
- As of June 2016, Washington, D.C. and 24 states, not including Washington State, had implemented laws or regulations to limit engine idling.⁵ These laws range from restricting all motor vehicles from idling at a loading zone, parking or servicing area, or other off-street area to limiting commercial diesel buses from idling for more than 15-minutes per hour for the purposes of operating heaters or air conditioners.⁵
- As of June 2016, 14 states and Washington, D.C. specifically referenced school buses in laws or regulations limiting engine idling.⁵

- Washington State idling reduction efforts:
 - The state’s School Bus Driver Handbook (2019) contains a section on Diesel Emissions and Anti-Idling Policies.⁶ It recommends that “bus drivers should turn off engines upon reaching the school or as soon as engine specifications permit.”⁶ Furthermore, it notes that most of the pre-trip inspection can be completed without the engine running. Pre-trip idling “should take no more than five minutes.”⁶
 - The Washington State Department of Ecology (Ecology) has provided nearly \$4,000,000 to 62 schools to install idle reduction technologies on more than 1,100 diesel buses (Ecology, personal communication, December 2019). The majority of recipients are located in colder weather regions of Central and Eastern Washington (Ecology, personal communication, December 2019).
 - In 2018-2019, Ecology awarded \$12,000,000 in grant funds to help applicants (including many school districts) buy new diesel buses, many of which included idle reduction technologies (Ecology, personal communication, December 2019).

Summary of HB 2387

- Directs Office of Superintendent of Public Instruction (OSPI) to adopt rules to limit the exposure of students and school personnel to diesel emission from school bus engines.
- OSPI rules must:
 - Establish limits on idling of school bus engines while buses are on school property or are otherwise engaged in providing student transportation;
 - Include potential exemptions, including exemptions necessary for weather conditions, health and safety issues, and vehicle maintenance;
 - Be included in the School Bus Drivers Handbook; and
 - Require district compliance by September 1, 2022.

Health impact of HB 2387

Evidence indicates that HB 2387 would likely result in some number of public school districts implementing school bus idling restrictions, which could reduce environmental exposure to diesel exhaust on public school property, improve health outcomes, and reduce health inequities for sensitive populations.

Pathway to health impacts

The potential pathway leading from the provisions of HB 2387 to decreased health inequities are depicted in Figure 1. This review makes the informed assumptions that directing OSPI to adopt rules to limit school bus idling while on public school property will likely result in some number of public school districts in Washington implementing school bus idling restrictions; and that school districts’ implementation of school bus idling restrictions will likely reduce environmental exposure to diesel emissions by some level at some number of public schools. These informed assumptions are based on information from key informant interviews, evidence from the EPA, and data for Washington’s school bus fleet. There is strong evidence that decreasing environmental exposure to diesel exhaust will likely improve health outcomes.^{2,3,7-15} There is also strong evidence that improving health outcomes for public school students and personnel would decrease inequities particularly for sensitive populations.^{12-14,16-20}

Scope

Due to time limitations, we only researched the most direct connections between the provisions of the bill and decreased health inequities and did not explore the evidence for all possible pathways. Therefore, this Health Impact Review focused on the impact that establishing idling limits would have on environmental diesel exposure on public school property. We did not evaluate potential impacts related to:

- Health impacts for people living or working adjacent to public school properties;
- Cost savings from reducing use of diesel fuel as a result of idling limitations;
- Greenhouse gas emissions from diesel buses and their contribution to climate change; or
- Other requirements to lessen diesel exposure that OSPI may consider (e.g., idle reduction technologies). For example, Fuel-Operated Heaters, also known as Direct Fired Heaters or block heaters, use only half a cup of diesel per hour to warm up engines and passenger compartments compared to half a gallon or more per hour while idling.¹ Other versions operate using electrical outlets. EPA states, “benefits of these heaters are fuel savings, lower emissions, longer oil life, less wear-and-tear on the engine, and relatively easy installation and maintenance.”¹ A key informant shared that if not included standard on newer buses, these heaters can generally be added to an order for a minimal cost (personal communication, January 2020).

Magnitude of impact

Washington State has 295 public school districts,²¹ which served 1,105,391 students (K-12) during the 2018-2019 school year.²² This includes approximately 507,000 students enrolled in elementary school (grades K-5); 256,000 students in middle school (grades 6-8); and 343,000 in high school (grades 9-12).²²

The EPA’s Clean Diesel Emissions Standards (signed in 2000) were phased in from 2007 to 2010. Beginning in 2007, all new school bus diesel engines are required to include filtration systems to eliminate the majority of PM produced (0.01 g/bhp·hr) (Ecology, personal communication, December 2019). However, some buses released in 2007 still included 2006 diesel engines that were not compliant with the stricter PM emission standards. In 2010, diesel engine manufacturers became compliant with the EPA’s updated NO_x standards (0.20 g/bhp·hr).⁴ Therefore, engines produced in 2007 or later are compliant with 2007 PM standards and those produced in 2010 or later meet both the 2007 PM and 2010 NO_x requirements.

As of December 2019, OSPI reports that of the 10,846 school buses in Washington’s fleet 8,947 are diesel buses. Of those diesel buses, an estimated 2,567 buses (24.5% of Washington’s total fleet) contain diesel engines that predate the EPA’s 2007 PM standards,^a and 4,158 diesel buses (38.3% of the fleet) have engines that predate the EPA’s 2010 NO_x standards (unpublished data, OSPI, personal communication, January 2020). These counts include buses provided by

^a OSPI data likely overestimate the number and percentage of diesel buses with pre-2007 engines. While the majority of buses manufactured in 2007 have 2006 model year engines, some number of buses may have been produced with a 2007 engine. Additionally, some number of pre-2007 diesel buses may have had the engine replaced with a newer model. Therefore, estimates based on this data represent an upper bound.

contractor services (unpublished data, OSPI, personal communication, January 2020). For example, the largest school districts in Washington (e.g., Seattle Public Schools and Tacoma Public Schools) contract their driving services, and these buses are not allowed to be more than 12 years old (Ecology, personal communication, December 2019). OSPI estimated how many diesel school buses have engines that do not meet EPA’s 2007 PM emissions standards, and data are presented by region and corresponding Educational Service Districts (ESD) (unpublished data, OSPI, personal communication, January 2020) (Table 1).

Table 1. Estimated school buses with engines manufactured prior to EPA’s Clean Diesel Emissions Standards for particulate matter in use in Washington State school districts, by region (unpublished data, OSPI, personal communication, January 2020)

Region	ESD	Location	All school buses	Diesel buses with pre-2007 engines*	
			Count	Count	% of all buses
1	112 & 113	Southwest WA	2,199	620	28.2%
2	114 & 121	King, Pierce, Jefferson, Clallam, & Kitsap Counties	3,951	879	22.3%
3	189	Northwest WA	1,652	352	21.3%
4	105, 123, & 171	Central WA	1,748	552	31.6%
5	101	Eastern WA	1,296	254	19.6%
Total	All ESDs	Washington State	10,846	2,567	24.5%
* OSPI tracks bus purchase dates and does not have data on engine year model. Therefore, data presented are estimates of the number of buses with pre-2007 model engines. The majority of 2007 model buses have 2006 engines which were produced before the EPA’s PM standards went into effect in 2007. Data presented are inclusive of all 2007 model buses.					

Ecology has provided grant funding to install idle reduction technologies on more than 1,100 diesel buses in Washington State to reduce harmful emissions (Ecology, personal communication, December 2019). For example, grants can be used to install technology that allows drivers to preheat buses more quickly without turning on and idling the engine (Ecology, personal communication, December 2019). Key informants noted that climate variations across the state and the model of the vehicle (e.g., some newer models include preheating technologies) may affect school bus drivers’ decision to idle engines to maintain a comfortable cabin climate (personal communications, December 2019-January 2020). Staff at Ecology shared that idle reduction grants and technologies have been very popular among Central and Eastern Washington districts, where cold weather is more extreme (Ecology, personal communication, December 2019). In Western Washington where climates are generally milder school districts have been less likely to apply for idle reduction technologies (Ecology, personal communication, December 2019).

It is unclear how many school buses with pre-2007 engines have been retrofitted with technologies (e.g., preheaters, newer engines, filtration systems) to reduce emissions (e.g., PM) when idling. While Table 1 shows in which regions diesel buses with likely pre-2007 engines are in use, it is unknown where in the state those older diesel buses that have not been retrofitted are

located. Therefore, it is unclear which districts may benefit most from successfully implementing an idle reduction policy.

Furthermore, key informants shared that some number Washington public school districts have already adopted policies to limit school bus idling on school property per EPA recommendations (personal communication, December 2019-January 2020). However, it is unknown which public school districts have voluntarily implemented policies as data are not collected by OSPI, Ecology, or the Washington State School Directors' Association (WSSDA) (personal communications, December 2019-January 2020).

Logic Model

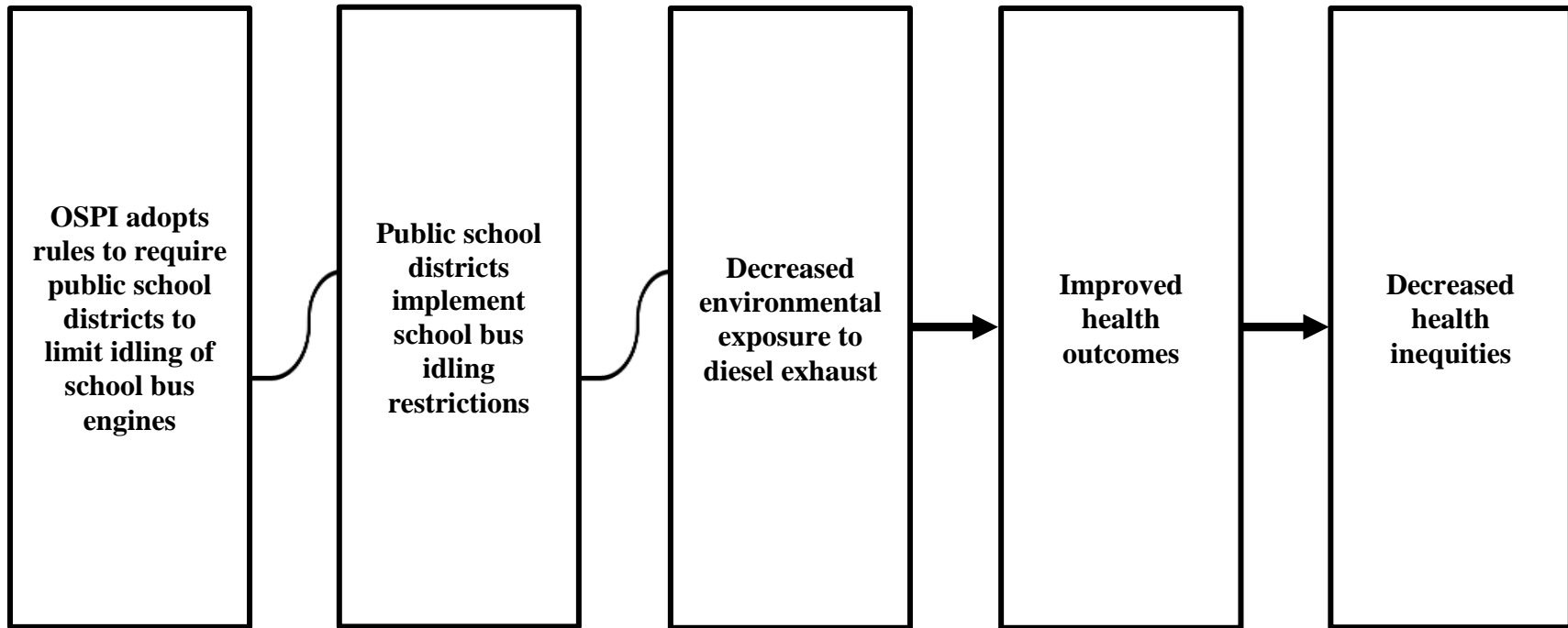
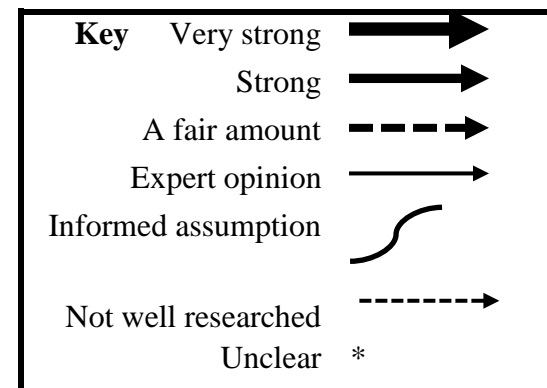


Figure 1:
Limiting the exposure of public school students and school personnel to diesel emissions from school bus engines
HB 2387



Summaries of Findings

Will OSPI rules requiring school districts to limit idling of school bus engines result in districts implementing school bus engine idling restrictions?

We have made the informed assumption that directing OSPI to adopt rules to limit school bus idling while on public school property will likely result in some number of public school districts in Washington implementing such restrictions. This assumption is based on discussions with relevant staff at OSPI, WSSDA, and Ecology and one school district transportation director.

The bill directs OSPI to adopt rules, in consultation with the Washington State Departments of Health (DOH) and Ecology, to limit the exposure of students and school personnel to diesel emissions from school bus engines. If passed, staff at OSPI confirmed the agency would be initiating rulemaking (OSPI, personal communication, December 2019). Specifically, the bill requires OSPI to adopt rules that limit school bus engine idling while on school property or otherwise providing student transportation. Therefore, we assume that final rules would address this requirement (OSPI, personal communication, December 2019). The bill would also allow the agency to include other requirements to reduce environmental exposure to diesel emissions (e.g., idling reduction technologies). This analysis does not address other potential requirements as they would be determined during rulemaking.

As Washington is a local control state, it is the responsibility of local school committees to determine how they implement state requirements. One key informant shared, “School districts are expected to implement mandates enacted by the State Legislature and OSPI and are more likely to do so with appropriate funding” (WSSDA, personal communication, December 2019). The bill requires district compliance by September 1, 2022. However, there is no inherent accountability process to confirm that districts have adopted a policy and/or are implementing as intended (WSSDA, personal communication, January 2020).

The EPA recommends school districts and schools voluntarily establish an idle reduction policy to reduce diesel emissions from school buses.¹ Key informants shared that some public school districts in Washington have implemented idle reduction policies (personal communication, December 2019-January 2020). One school transportation director shared that most districts in their area already voluntarily limit idling with the exception of severe weather (e.g., when temperatures drop to single digits) (personal communication, January 2020). Similarly, staff at Ecology shared that many of the schools the agency works with through its grant funding programs state that they have an idle reduction policy (personal communication, December 2019). However, it is unclear exactly how many school districts or schools in the state have such policies (personal communication, December 2019-January 2020).

While key informants generally support the intent of the proposal, they noted challenges to successfully implementing a policy to effectively reduce idling and associated emissions. Specifically, they identified issues related to oversight (personal communications, December 2019-January 2020). For example, the bill does not stipulate what authority would be responsible for monitoring compliance and enforcement (personal communications, December 2019-January 2020). Key informants also noted that enforcement requires a commitment of resources. However, the impression from other states and jurisdictions that have implemented idling

restrictions is that: state- and local-level regulatory agencies do not have the necessary resources to enforce, cities and counties may not wish to enforce, and law enforcement agencies may not prioritize enforcement of policies (Ecology, personal communication, December 2019). This also presents a challenge to successful implementation as one key informant noted that without an enforcement strategy there is likely very little benefit to the law (Ecology, personal communication, December 2019).

Currently, an unknown number of public school districts in Washington already restrict school bus engine idling on school property (see Magnitude of Impact on page 5), and we expect these districts and schools to take steps, if necessary, to come into compliance with future rules. Moreover, based on discussions with key informants, we would expect that requiring public school districts to limit school bus idling would result in some number of districts and schools not currently implementing voluntary idle reduction policies to take steps to comply with the new rules (personal communications, December 2019-January 2020).

Therefore, this HIR makes the informed assumption that directing OSPI to adopt rules to limit school bus idling while on public school property will likely result in some number of public school districts in Washington implementing such restrictions.

Will school districts implementing school bus engine idling restrictions decrease environmental exposure to diesel exhaust?

We made the informed assumption that Washington school districts' implementation of school bus idling restrictions will reduce environmental exposure to diesel emissions by some level at some number of public schools. This assumption is based on evidence from the EPA regarding idle reduction policies, available data for the Washington State school bus fleet, and the assumption that some number of school bus drivers implement the policy as intended.

In 2005, the EPA partnered with Katonah-Lewisboro School District in Cross River, New York to evaluate whether restarting school bus engines or periods of continuous engine idle results in higher emissions of diesel pollutants (e.g., PM_{2.5}, NO_x, carbon monoxide [CO], and particle-surface polycyclic aromatic hydrocarbons [PAHs]).^{16,23} Researchers tested three scenarios using six district buses with model years ranging from 1997 (odometer = 156,669 km) to 2004 (odometer 1,191 km).^{16,23} The first scenario involved a 20-minute idle to keep the bus warm before departure. In the second simulation, the engine was not started until children were seated and ready for immediate departure (restart and go). The third test involved turning the bus off for 10-minutes, restarting it, and idling for 10-minutes to warm the bus as children boarded. Results showed a short burst of emissions when the engine is restarted lasted less than 5 seconds for PM_{2.5}, CO, and NO_x.²³ Overall, researchers measured fewer emissions during the restart and go scenario than those in which engines were idled.²³

Researchers used the experimental data collected to develop a predictive equation, "which allows a comparison between continuous idle and hot restart for NO_x, CO, PM_{2.5}, and PAHs and which considers factors such as the restart emissions pulse and periods when the engine is not running."¹⁶ The results using the predictive equation indicated that "restart is the preferred operating scenario as long as there is no extended idling after the engine is restarted."¹⁶ Extended idling (2-minutes, 4-minutes, etc.) after the bus is restarted "erodes the emissions benefits of

shutting it off.”²³ Authors note that the resulting equation is “applicable to the specific engines, emission controls, diesel fuel, ambient conditions, and operating procedures in the study.”¹⁶

The 2005 study results described above are likely generalizable to some number of the school buses in use in Washington (see Magnitude of Impact on page 5). As the study was conducted before implementation of the EPA’s 2007 PM and 2010 NO_x standards, these results are generalizable to buses with engines manufactured before 2007. Results are less generalizable to buses with pre-2007 engines that have been retrofitted to reduce PM emissions. It is unclear how many buses with engines manufactured before 2007 have not been retrofitted with idle reduction technology and may most benefit from idling restrictions.

Evidence indicates that in order to reduce environmental exposure to diesel exhaust, all of the following would have to occur: OSPI would have to adopt rules; school districts would have to adopt and implement policies and train bus drivers on the new protocol; and bus drivers would have to implement as intended. Key informants noted that, in general, adopting a policy does not necessarily mean that the policy will be clearly communicated to those responsible for successfully implementing the policy (i.e., school bus drivers). Therefore, key informants stated training is necessary so that drivers are prepared to implement the protocol as intended. In districts that currently have an idle reduction policy, it is unknown how strictly bus drivers comply with requirements (personal communication, December 2019-January 2020).

Therefore, this HIR makes the informed assumption that Washington school districts’ implementation of school bus idling restrictions will reduce environmental exposure to diesel emissions by some level at some number of public schools.

Will decreased environmental exposure to diesel exhaust improve health outcomes for public school students and personnel?

There is strong evidence that decreasing environmental exposure to diesel exhaust will likely improve health outcomes.^{2,3,7-15} Fossil-fuel-powered engines produce emissions (e.g., PM, NO_x, carbon monoxide, hydrocarbons) which are each associated with negative health effects.^{7,8} Diesel vehicles emit more PM and NO_x than gasoline or hybrid counterparts.⁷ In 2013, the International Agency for Research on Cancer classified diesel exhaust as a carcinogen in humans based on evidence from occupational epidemiological studies.⁸ An analysis of National Air Toxics Assessment 2014 data⁹ indicates that diesel exhaust is the most harmful air pollutant affecting people’s health in Washington State.^{10,24}

Particulate matter

A 2012 systematic review of the association between PM and human health found the preponderance of data show that “PM exposure causes a small but significant increase in human morbidity and mortality.”¹¹ While PM with a diameter greater than 10 microns (µm) are largely filtered out by the nose and upper airway, smaller particles are capable of penetrating peoples’ lungs and entering their bloodstream.² The World Health Organization (WHO) notes that particles with a diameter of less than 10 µm (PM₁₀), pose the greatest risks to health.² PM with a diameter between 2.5 and 10 µm (PM_{2.5-10}) are defined as “coarse,” less than 2.5 µm as “fine,” and less than 0.1 µm as “ultrafine” particles.¹¹ The associations between PM_{2.5} and cardiovascular and respiratory mortality and morbidity are well documented.^{12,13} For example,

PM_{2.5} or less “contributes to approximately 2 million premature deaths per year, ranking it as the 13th leading cause of worldwide mortality.”¹³ Diesel vehicles disproportionately contribute to PM_{2.5} present in the atmosphere.¹⁴

Evidence shows “populations subjected to long-term exposure to PM have a significantly higher cardiovascular incidence and mortality rate.”¹¹ Evidence also indicates PM exposure exacerbates respiratory diseases (e.g., worsening respiratory symptoms, more frequent medication use, decreased lung function, recurrent health care utilizations, and increased mortality).¹¹ Data demonstrate “a dose-dependent relationship between PM and human disease.”¹¹ Further evidence suggests that decreased PM exposure results in decreases in overall mortality.¹¹

Nitrogen oxides

Globally, diesel vehicles contribute about 20% of NO_x,⁷ of which NO₂ is the most prevalent form. Evidence shows breathing air with a high concentration of NO₂—over short or longer exposures—can irritate airways in the human respiratory system and contribute to respiratory health concerns (e.g., asthma).³

Overall, there is strong evidence that decreasing environmental exposure to diesel exhaust will likely improve health outcomes, particularly cardiovascular and respiratory conditions and symptoms.

Will improved health outcomes for students and school personnel impact health inequities?

There is strong evidence that improving health outcomes for public school students and personnel would decrease inequities particularly for sensitive populations.^{12-14,16-20} It is well documented that children, people with heart or lung diseases, and older adults (65 years and older) are the most likely to be affected by particle pollution exposure.^{17,18}

Inequities by age

It is well documented that children are generally more susceptible to air pollutants, including PM and NO_x, as their respiratory systems are still developing and they have a faster breathing rate.^{14,16,18} For example, a prospective cohort study of 1,759 children (average age, 10 years) found associations between air pollution and three measures of lung function—forced vital capacity (FVC), forced expiratory volume in the first second (FEV₁), and maximum midexpiratory flow rate.¹⁴ Results of the study showed the effects of ambient air “pollutants on FEV₁ were similar in boys and girls and remained significant among children with no history of asthma and among those with no history of smoking, suggesting that most children are susceptible to the chronic respiratory effects of breathing polluted air.”¹⁴ Specifically, “cumulative deficits in the growth of lung function during the eight-year study period resulted in a strong association between exposure to air pollution and a clinically low FEV₁ at the age of 18 years.”¹⁴ Authors noted such lung function deficits may increase the risk of respiratory conditions in young adulthood.¹⁴ Furthermore, “reduced lung function is a strong risk factor for complications and death during adulthood.”¹⁴

Inequities by existing health conditions

It is well documented that people with existing health conditions (i.e., respiratory infections, respiratory diseases, heart or circulatory disease, diabetes, history of stroke) are especially

sensitive to air pollution.¹⁷⁻¹⁹ For example, “diesel exhaust can adversely affect children with underlying respiratory illnesses such as asthma, bronchitis, and infections.”^{18,19} People with heart or lung diseases are at increased risk, because PM can aggravate these diseases.¹⁸

Potential inequities for other groups

Key informants noted that idling may be more common at school bus yards, particularly in colder climates, and may disproportionately expose transportation personnel to exhaust (personal communications, January 2020). Buses that do not have preheating technology require warming up at the beginning of the day (i.e., to defrost windows, preheat the engine, warm the cabin) (personal communications, January 2020). Therefore, personnel working at these locations may experience health inequities related to such exposure.

Key informants also noted that students who ride the bus may be disproportionately exposed to diesel exhaust which may compound with environmental exposures related to other intersectional marginalized identities (e.g., low socioeconomic status).

Annotated References

1. **U.S. Environmental Protection Agency Clean School Bus Idle Reduction. Clean Diesel [Agency Webpage]. Available at: <https://www.epa.gov/cleandiesel/clean-school-bus-idle-reduction>. Accessed December, 2019.**

This US Environmental Protection Agency (EPA) webpage provides an overview of the *Clean School Bus* National Idle Reduction Campaign. It provides resources, details policy recommendations, and counters myths about the benefits of idling with scientific facts.

2. **World Health Organization. Ambient air pollution: Pollutants. Air Pollution Available at: <https://www.who.int/airpollution/ambient/pollutants/en/>. Accessed 31 December 2019, 2019.**

This World Health Organization (WHO) webpage provides an overview of ambient air pollution and discussion of various pollutants and the sources from which they are emitted. Authors note, "Adverse health consequences to air pollution can occur as a result of short- or long-term exposure. The pollutants with the strongest evidence of health effects are particulate matter (PM), ozone (O₃), nitrogen dioxide (NO₂) and sulphur dioxide (SO₂)." Fine particulate matter (PM₁₀ and PM_{2.5}) are particularly harmful to human health because they are small enough to penetrate human lungs and enter the bloodstream. Furthermore, evidence indicates that NO₂ can "increase symptoms of bronchitis and asthma, as well as lead to respiratory infections and reduced lung function and growth." Additionally, "NO₂ may be responsible for a large disease burden, with exposure linked to premature mortality and morbidity from cardiovascular and respiratory diseases."

3. **U.S. Environmental Protection Agency. Nitrogen Dioxide (NO₂) Pollution | Basic Information about NO₂. Available at: <https://www.epa.gov/no2-pollution/basic-information-about-no2#What%20is%20NO2>. Accessed 31 December 2019, 2019.**

This U.S. Environmental Protection Agency (EPA) webpage provides an overview of Nitrogen Dioxide (NO₂) and its role as an indicator for the larger group of nitrogen oxides (NO_x). The agency identifies breathing air with a "high concentration of NO₂ can irritate airways in the human respiratory system." Specifically, "exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO₂ may contribute to the development of asthma and potentially increase susceptibility to respiratory infections." Those at greater risk for the health effects of NO₂ include people with asthma, as well as children and the elderly.

4. **United States: Heavy-Duty Onroad Engines. Emissions Standards Available at: <https://www.dieselnet.com/standards/us/hd.php#stds>. Accessed December, 2019.**

This DieselNet page provides an overview of the EPA's emission standards for heavy-duty onroad diesel engines from Model Year 1974 through present.

5. **State School Bus Idling Rules & Regulations. *School Transportation News*. 9 June 2016, 2016.**

This School Transportation News article compiles regulations, laws, and recommendations on school bus idling limits in effect in 2016 in the U.S.

6. Instruction Washington State Office of Superintendent of Public Instruction WSOoSoP.School Bus Driver Handbook.Olympia, Washington: Washington State Office of Superintendent of Public Instruction;2019.

The 2019 revision of the School Bus Driver Handbook was based on previous versions. IT is intended to be both a training and reference resource for authorized school bus drivers in Washington State. Page 21 of the Handbook addresses Diesel Emissions and Anti-Idling Policies. The document references guidance provided by the US Environmental Protection Agency to restrict school bus idling to reduce exposures harmful to health.

7. Liu Norrice M , Grigg Jonathan Diesel, children and respiratory disease. *BMJ Paediatrics Open.* 2018;2018(2).

Liu and Grigg conducted a review of evidence of adverse health effects of diesel emissions on UK children and policies to reduce exposure of children to fossil-fuel-derived air pollution in the UK. Transport (i.e., exhaust, tyre, brake wear), combustion, industrial processes, and construction comprise the main sources of PM10 and PM2.5, and transport and combustion are the main sources of nitrogen dioxide (NO2). Authors note "For emissions from diesel, there is a strong correlation between locally emitted PM10 and NOx and it is reasonable to assume that, where diesel vehicles predominate, either metric is a good marker of exposure to the locally generated pollutant mix in urban areas." Globally, diesel vehicles contribute about 20% of NOx, and diesel engines emit more PM and NOx than petrol [gasoline] or hybrid counterparts. The review discusses antenatal exposure and childhood exposures. Authors note, "it is reasonable to extrapolate from studies that have assessed exposure to either PM or NOX since (1) diesel PM is not less toxic than other types of PM, and (2) the adverse effects of gases such as NOX are independent of source." Specific to childhood exposure, evidence indicates "air pollutants, particularly NOX (reflecting exposure to both NOx and PM), are associated with reduced lung function in children—for both FVC and FEV." Results of a meta-analysis reviewed showed "exposure to NO2 is linked to new-onset asthma, while exposure to PM is linked to new-onset wheeze." Authors provide national level and individual level approaches to limit exposure to diesel emissions to protect children's health.

8. IARC. Humans IMotEotCRt.Diesel and gasoline engine exhausts and some nitroarenes.Lyon, France: International Agency for Research in Cancer;2013.

This 2012 report, the International Agency for Research on Cancer (IARC) classified diesel exhaust as a carcinogen in humans. The determination was largely based on results from two epidemiological studies of occupational diesel exhaust exposures among nonmetal miners (Diesel Exhaust in Miners Study) and truck drivers in confined spaces. Because the key epidemiologic studies are based on occupational exposure and were conducted with adults, staff rated this article as moderately generalizable as opposed to highly.

9. U.S. Environmental Protection Agency NATA Overview. National Air Toxics Assessment Available at: <https://www.epa.gov/national-air-toxics-assessment/nata-overview#what-nata-is-not>. Accessed 2020, January.

This U.S. Environmental Protection Agency webpage provides an overview of the National Air Toxics Assessment (NATA), an ongoing review of air toxics in the U.S. Results help state, local, and tribal air agencies identify which pollutants, emission sources, and places might be

considered for further study and/or intervention. It uses a snapshot of outdoor air quality to "suggest long-term risks to human health if air toxics emissions are steady over time." Specifically, it estimates the cancer risks from breathing air toxics over many years and noncancer health effects for some pollutants, including diesel particulate matter. Based on necessary assumptions, "NATA can't give precise exposures and risks for a specific person. Instead, NATA results are best applied to larger areas – counties, states and the nation." NATA uses a single year's emission data to calculate concentration and risk estimates. Note, "The risk estimates assume a person breathes these emissions each year over a lifetime (or approximately 70 years)."

10. **Palcisko Gary. Overview of National Air Toxics Assessment (NATA) 2014. In: Ecology WSDo, ed. Olympia, Washington: Washington State Department of Ecology; 2018.** This Washington State Department of Ecology presentation provides an overview of 2014 National Air Toxics Assessment (NATA) data specific to Washington State. It presents results of cancer risk. Diesel particulate matter comprises 72% of the cancer risk associated with breathing toxics present in the air. NATA risk per million varies by location and has reduced over time statewide.

11. **Anderson J. O., Thundiyil J. G., Stolbach A. Clearing the air: a review of the effects of particulate matter air pollution on human health. *J Med Toxicol.* 2012;8(2):166-175.** Anderson et al. conducted a scientific review of all available published literature to determine the association or lack of association between particulate matter (PM) and human health. Authors also summarized the proposed mechanisms for associations based on existing human, animal, and in vitro studies. PM is made up of "extremely small particles and liquid droplets containing acids, organic chemicals, metals, and soil or dust particles. PM is categorized by size and continues to be the fraction of air pollution that is most reliably associated with human disease." It is thought to contribute to cardiovascular and cerebrovascular disease "by the mechanisms of systemic inflammation, direct and indirect coagulation activation, and direct translocation into systemic circulation." The data demonstrating PM's effect on the cardiovascular system show "[p]opulations subjected to long-term exposure to PM have a significantly higher cardiovascular incident and mortality rate." Moreover, "[s]hort-term acute exposures subtly increase the rate of cardiovascular events within days of a pollution spike." The data for PM's effects on cerebrovascular disease is less strong, "though some data and similar mechanisms suggest a lesser result with smaller amplitude." Evidence also indicates that respiratory diseases are similarly exacerbated by exposure to PM. "PM causes respiratory morbidity and mortality by creating oxidative stress and inflammation that leads to pulmonary anatomic and physiologic remodeling. The literature shows PM causes worsening respiratory symptoms, more frequent medication use, decreased lung function, recurrent health care utilization, and increased mortality." Overall, authors found PM exposure "to have a small but significant adverse effect on cardiovascular, respiratory, and to a lesser extent, cerebrovascular disease. These consistent results are shown by multiple studies with varying populations, protocols, and regions." Furthermore, "[t]he data demonstrate a dose-dependent relationship between PM and human disease, and that removal from a PM-rich environment decreases the prevalence of these diseases." Authors conclude "the preponderance of data shows that PM exposure causes a small but significant increase in human morbidity and mortality" and recommend "further study [...] to elucidate the effects of composition, chemistry, and the PM effect on susceptible populations"

Authors provide examples of "common sense" recommendations to reduce exposure. For example, "[s]usceptible populations, such as the elderly or asthmatics, may benefit from limiting their outdoor activity like limiting outdoor activity during peak traffic periods or poor air quality days." Such changes "may benefit individual patients in both short-term symptomatic control and long-term cardiovascular and respiratory complications."

12. **Achilleos S., Kioumourtzoglou M. A., Wu C. D., et al. Acute effects of fine particulate matter constituents on mortality: A systematic review and meta-regression analysis. *Environ Int.* 2017;109:89-100.**

Achilleos et al. note that "the link between PM_{2.5} exposure and adverse health outcomes is well documented from studies across the world." Authors conducted a meta-analysis on associations between short-term exposure to PM_{2.5} constituents and mortality using city-specific estimates. Authors systematically reviewed epidemiological studies on particle constituents and mortality up to July 2015. Forty-one studies (142 cities) met all inclusion criteria and were included in the meta-analysis (37 all-ages analysis; 9 subgroup analysis of those aged 65 or older). Ten studies were conducted in the U.S., and the number of U.S. cities included in the analysis surpassed those of any other region. Studies examined the association between short-term exposure to PM_{2.5} constituents and all-cause, cardiovascular, and respiratory mortality, in the general adult population. "Each study was summarized based on pre-specified study key parameters (e.g., location, time period, population, diagnostic classification standard), and [reviewers] evaluated the risk of bias using the Office of Health Assessment and Translation (OHAT) Method for each included study." Authors used city-specific mortality risk estimates for each constituent and cause of mortality. Studies that included multiple cities required reviewers to request city-specific risk estimates from the authors if not included in the article. Researchers performed "random effects meta-analyses using city-specific estimates, and examined whether the effects vary across regions and city characteristics (PM_{2.5} concentration levels, air temperature, elevation, vegetation, size of elderly population, population density, and baseline mortality)." Results revealed a "0.89% (95% CI: 0.68, 1.10%) increase in all-cause, a 0.80% (95% CI: 0.41, 1.20%) increase in cardiovascular, and a 1.10% (95% CI: 0.59, 1.62%) increase in respiratory mortality per 10µg/m³ increase in PM_{2.5}." Once authors accounted for "the downward bias induced by studies of single days, the all-cause mortality estimate increased to 1.01% (95% CI: 0.81, 1.20%)." The meta-analysis for elemental carbon (EC), black smoke, and SO₄²⁻ mortality effect estimates among the elderly population (65 years of age and older) revealed EC and BS were statistically significantly associated with all-cause mortality. Meanwhile, "The observed pooled associations between PM constituents and cardiovascular mortality were not as consistent as all-cause mortality." Overall, authors identified significant associations between mortality and several PM_{2.5} constituents. "The most consistent and stronger associations were observed for [EC] and potassium (K)." For most of the constituents, there was high variability of effect estimates across cities. Authors conclude the meta-analysis suggests that "(a) combustion elements such as EC and K have a stronger association with mortality, (b) single lag studies underestimate effects, and (c) estimates of PM_{2.5} and constituents differ across regions." They recommend future studies account for PM mass in constituent's health models to determine if they lead to more stable and comparable effect estimates across different studies.

13. **Requia W. J., Adams M. D., Arain A., et al. Global Association of Air Pollution and Cardiorespiratory Diseases: A Systematic Review, Meta-Analysis, and Investigation of Modifier Variables. *Am J Public Health*. 2018;108(S2):S123-S130.**

Requia et al. "systematically reviewed the evidence on the association between air pollution and cardiorespiratory diseases (hospital admissions and mortality), including variability by energy, transportation, socioeconomic status, and air quality." Authors conducted a literature search (PubMed and Web of Science) for studies published between 2006 and May 11, 2016, that met the following criteria: "(1) considered at least 1 of these air pollutants: carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, or particulate matter (PM2.5 or PM10); (2) reported risk for hospital admissions, mortality, or both; (3) presented individual results for respiratory diseases, cardiovascular diseases, or both; (4) considered the age groups younger than 5 years, older than 65 years, or all ages; and (5) did not segregate the analysis by gender." They then extracted data from included studies and performed a meta-analysis to "estimate the overall effect and to account for both within- and between-study heterogeneity." Authors initially assessed 2,183 studies, of which 529 were selected for in-depth review, and 70 articles fulfilled the study inclusion criteria. "Most of the studies reported results for more than category of pollutant, health outcome, disease, or age." Eleven of 28 studies reporting results for PM2.5 were conducted in the US, as were 2 of the 36 studies reporting results for PM10. "The 70 studies selected for meta-analysis encompass more than 30 million events across 28 countries. [Authors] found positive associations between cardiorespiratory diseases and different air pollutants." For example, the association between PM2.5 and respiratory diseases showed a risk equal to 2.7% (95% confidence interval = 0.9%, 7.7%). "With regard to hospital admissions, the youngest age group (aged <5 years) demonstrated the highest risk across all pollutants, except NO2 and CO." Specifically, "[r]espiratory diseases showed the strongest association, especially for O3 and PM10, for which [authors] found a risk equal to 2.4% (95% CI = 1.6%, 3.7%) and 2.3% (95% CI = 1.6%, 3.2%), respectively." Overall, "results showed statistical significance in the test of moderators for all pollutants, suggesting that the modifier variables influence the average cardiorespiratory disease risk and may explain the varying effects of air pollution." For example, clean electricity, consumption of motor gasoline, consumption of cooking fuel, population density, and education accounted for 64% of the heterogeneity in mortality attributable to PM2.5 exposure among regional populations studied.

14. **Gauderman W. James , Avol Edward , Gilliland Frank , et al. The Effect of Air Pollution on Lung Development from 10 to 18 Years of Age. *The New England Journal of Medicine*. 2004;351(11):1057-1067.**

Gauderman et al. conducted a prospective cohort study to assess whether exposure to air pollution adversely affects the growth of lung function during the period of rapid lung development that occurs between the ages of 10 and 18 years. The Children's Health Study recruited 1,759 children "(average age, 10 years) from schools in 12 southern California communities and measured lung function annually for eight years [1993 to 2001]. The rate of attrition was approximately 10 percent per year." The study included communities representing "a wide range of ambient exposures to ozone, acid vapor, nitrogen dioxide, and particulate matter." The relationship of air pollution to the forced expiratory volume in one second (FEV1) and other spirometric measures was assessed using linear regression. Results showed that "over the eight-year period, deficits in the growth of FEV1 were associated with exposure to nitrogen dioxide (P=0.005), acid vapor (P=0.004), particulate matter with an aerodynamic diameter of

less than 2.5 μm (PM2.5) (P=0.04), and elemental carbon (P=0.007), even after adjustment for several potential confounders and effect modifiers.” Moreover, associations were also observed for other spirometric measures. “Exposure to pollutants was associated with clinically and statistically significant deficits in the FEV1 attained at the age of 18 years. For example, the estimated proportion of 18-year-old subjects with a low FEV1 (defined as a ratio of observed to expected FEV1 of less than 80 percent [a criterion often used in clinical settings to identify those who are at increased risk for adverse respiratory conditions]) was 4.9 times as great at the highest level of exposure to PM2.5 as at the lowest level of exposure (7.9 percent vs. 1.6 percent, P=0.002).” Furthermore, results showed similar associations between these pollutants and a low FEV1 in the subgroup of children with no history of asthma and the subgroup with no history of smoking. Authors concluded “[t]he results of this study indicate that current levels of air pollution have chronic, adverse effects on lung development in children from the age of 10 to 18 years, leading to clinically significant deficits in attained FEV1 as children reach adulthood.”

15. Krall J. R., Anderson G. B., Dominici F., et al. Short-term exposure to particulate matter constituents and mortality in a national study of U.S. urban communities. *Environ Health Perspect.* 2013;121(10):1148-1153.

This study by Krall et al. provides "the first national, season-specific, and region-specific associations between mortality and PM2.5 constituents." Using data from the National Center for Health Statistics, authors "estimated short-term associations between nonaccidental mortality and PM2.5 constituents across 72 urban U.S. communities from 2000 to 2005." They used U.S. Environmental Protection Agency (EPA) Chemical Speciation Network data to "analyze seven constituents that together compose 79-85% of PM2.5 mass: organic carbon matter (OCM), elemental carbon (EC), silicon, sodium ion, nitrate, ammonium, and sulfate." Authors then "applied Poisson time-series regression models, controlling for time and weather, to estimate mortality effects." The analysis found that interquartile range increases in OCM, EC, silicon, and sodium ion were associated with estimated increases in mortality of 0.39% [95% posterior interval (PI): 0.08, 0.70%], 0.22% (95% PI: 0.00, 0.44), 0.17% (95% PI: 0.03, 0.30), and 0.16% (95% PI: 0.00, 0.32), respectively, based on single-pollutant models." EC and OCM are often generated by motor vehicles. Authors did not find evidence that associations between mortality and PM2.5 or PM2.5 constituents differed by season or region. Limitations include: the study focused on chemical composition and did not evaluate potential effects of PM2.5 mass; analyses did not account for exposure misclassification; authors estimated community-level ambient average pollutant concentrations using the arithmetic mean of monitoring concentrations, however spatial models may be less biased. Overall, "findings indicate that some constituents of PM2.5 may be more toxic than others and, therefore, regulating PM total mass alone may not be sufficient to protect human health."

16. Kinsey JS, Williams DC, Dong Y, et al. Characterization of Fine Particle and Gaseous Emissions during School Bus Idling. *Environmental Science Technology.* 2007;2007(41):4972-4979.

Kinsey et al. examine whether restarting school buses will result in higher emissions of diesel pollutants than those attributable to periods of continuous idle. In 2005 (before the implementation of the EPA's 2010 Clean Diesel Standards) researchers measured the idle emissions from 6 diesel school buses (model years ranging from 1997 to 2004) under wintertime conditions to test the hypothesis that "the benefit of anti-idling, including restart, results in less

net emissions than continuous idling." Specifically, particulate matter (PM) and gaseous emissions were determined over a simulated waiting period typical of schools in the northeastern U.S. "Testing was conducted for both continuous idle and hot restart conditions using a suite of on-line particle and gas analyzers installed in the [EPA's] Diesel Emissions Aerosol Laboratory." Researchers measured PM_{2.5} as well as carbon monoxide (CO), carbon dioxide, nitrogen oxides (NO_x), total hydrocarbons (THC), oxygen, formaldehyde, and the tracer gas in the raw exhaust. Overall, results showed "little difference in the measured emissions between a 10 min post-restart idle and a 10 min continuous idle with the exception of THC and formaldehyde." Meanwhile, engine restart resulted in an emissions pulse. Researchers developed a predictive equation from the experimental data, allowing a comparison between "continuous idle and hot restart for NO_x, CO, PM_{2.5}, and PAHs and which considers factors such as the restart emissions pulse and periods when the engine is not running." This equation indicates that restart is the preferred operating scenario as long as there is no extended idling after the engine is restarted. Authors note that the emissions data provided are limited and only applicable to the specific engines, emission controls, diesel fuel, ambient conditions and operating procedures evaluated in the study.

17. U.S. Environmental Protection Agency. Health and Environmental Effects of Particulate Matter (PM) Available at: <https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm>. Accessed January 2020, 2020.

This U.S. Environmental Protection Agency webpage provides an overview of the health and environmental effects of particulate matter. It states, "Numerous scientific studies have linked particle pollution exposure to a variety of problems, including: premature death in people with heart or lung disease nonfatal heart attacks irregular heartbeat aggravated asthma decreased lung function increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing." Particularly sensitive populations to particle air pollution include people with heart or lung diseases, children, and older adults.

18. Radiation U.S. EPA Office of Air and. Particle Pollution and Your Health. In: Agency USEP, ed. Vol EPA-452/F-03-001. Washington, DC: U.S. Environmental Protection Agency; 2003.

This pamphlet from the U.S. Environmental Protection Agency discusses particle pollution, associated risks, and ways to protect health. Risk appears to vary throughout an individual's lifetime: higher in early childhood, lower in healthy adolescents and younger adults, and increasing in middle age through old age (as the incidence of heart and lung disease and diabetes increases). Authors note, children's "lungs are still developing; they spend more time at high activity levels; and they are more likely to have asthma or acute respiratory diseases, which can be aggravated when particle levels are high."

19. Wargo John, Brown David, University of Connecticut Environmental Research Institute. Environment and Human Health I.Children's Exposure to Diesel Exhaust on School Buses.North Haven, Connecticut: Environment & Human Health, Inc.; February 2002 2002.

This study was designed and results were analyzed by J. Wargo, D. Brown, and the University of Connecticut's Environmental Research Institute. The study consisted of: experimental monitoring, experimental controls, and school day personal monitoring. Experimental

monitoring measured black carbon and PM_{2.5} on buses while idling and en route to test the effects of a) windows being opened and b) the location of monitoring equipment on the bus. Experimental control tests were run to determine how experimental buses (i.e., diesel engine next to driver; diesel engine at rear of bus; and natural gas powered) contributed to carbon and particle levels. Finally, school day personal monitoring of children's (n=15) indoor and outdoor exposure to PM₁₀ and PM_{2.5} averaged 7 hours. Each child was "accompanied by a research assistant and monitored [i.e., logging behavior, movement, and environmental conditions] from the time each left their home in the morning to the time they each returned home in the afternoon." Each study participant carried a particulate meter, personal sampling pump, and VOC canister throughout the day. Researchers noted that "children's exposure to diesel exhaust from school buses constitutes an additional exposure beyond background levels of particulates reported from current monitoring efforts." Authors found, "Fine particulate concentrations (PM_{2.5}) measured on buses in this study were often 5-10 times higher than average levels measured at the 13 fixed-site PM_{2.5} monitoring stations in Connecticut." Results showed, "Levels of fine particles were often higher under certain circumstances: when buses were idling with windows opened, when buses ran through their routes with windows closed, when buses moved through intense traffic, and especially when buses were queued to load or unload students while idling." Researchers found queued idling buses had the highest levels of particles and black carbon measured. Moreover, "idling buses tend to accumulate diesel exhaust which may be retained during the ride, depending upon bus ventilation rates," and "particulate and carbon concentrations rise rapidly once idling begins." Such increased exposure is of concern due to associated health outcomes (e.g., exacerbated of respiratory symptoms, decreased lung function, delayed lung development, increased mortality among those with cardiopulmonary diseases) and correlated healthcare needs (i.e., hospital admissions and emergency department visits for respiratory illnesses). Children are more susceptible due to their developing lungs and higher rates of respiration. Based on results, authors made multiple suggestions of how to reduce children's exposure to diesel emissions including, prohibiting bus idling, especially while loading and unloading students. While, the Connecticut Department of Environmental Protection (DEP) did have a regulation (DEP 22a-174-18 [a][5]) to limit idling time to 3 minutes, authors noted "it is neither monitored nor enforced." This finding indicates that compliance monitoring and enforcement is an important component of successful implementation to reduce exposure. Finally, authors report that "bus drivers' exposure to motor vehicle and diesel exhaust is significantly higher than children's, due to longer periods of time spent on buses."

20. Zheng Xue-yan , Ding Hong , Jiang Li-na , et al. Association between Air Pollutants and Asthma Emergency Room Visits and Hospital Admissions in Time Series Studies: A Systematic Review and Meta-Analysis. *PLoS One*. 2015(18 September 2015).

Zheng et al. conducted a systematic review of literature "to quantify the associations between short-term exposure to air pollutants [ozone (O₃), carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and particulate matter 10µm (PM₁₀) and PM_{2.5}] and the asthma-related emergency room visits (ERV) and hospitalizations." They conducted their initial search without language limitation, and screened 246 studies of which 87 were included in the final analyses (86 in English and 1 in Spanish; 62 time-series and 25 case cross-over studies). Of those included, 50 studies focused on children, 21 on adults, 13 on elderly population, and 44 on general population. Pooled relative risks (RRs) and 95% confidence intervals (95% CIs) were estimated using the random effect models, and sensitivity analyses and subgroup analyses were

also performed. Results showed that air pollutants were associated with "significantly increased risks of asthma ERVs and hospitalizations [O₃: RR(95% CI), 1.009 (1.006, 1.011); I² = 87.8%, population-attributable fraction (PAF) (95%CI): 0.8 (0.6, 1.1); CO: RR(95%CI), 1.045 (1.029, 1.061); I² = 85.7%, PAF (95%CI): 4.3 (2.8, 5.7); NO₂: RR(95%CI), 1.018 (1.014, 1.022); I² = 87.6%, PAF (95%CI): 1.8 (1.4, 2.2); SO₂: RR (95%CI), 1.011 (1.007, 1.015); I² = 77.1%, PAF (95%CI): 1.1 (0.7, 1.5); PM₁₀: RR(95%CI), 1.010 (1.008, 1.013); I² = 69.1%, PAF (95%CI): 1.1 (0.8, 1.3); PM_{2.5}: RR(95%CI), 1.023 (1.015, 1.031); I² = 82.8%, PAF (95%CI): 2.3 (1.5, 3.1)]." Fifty one studies included PM₁₀ and 37 included PM_{2.5}. Sensitivity analyses resulted in compatible findings as compared with the overall analyses without publication bias. Overall, "stronger associations were found in hospitalized males, children and elderly patients in warm seasons with lag of 2 days or greater." Authors concluded that "short-term exposures to air pollutants account for increased risks of asthma-related ERVs and hospitalizations that constitute a considerable healthcare utilization and socioeconomic burden."

21. **Washington State Office of Superintendent of Public Instruction. About OSPI | Key Facts About Washington Public Schools. 2016; Available at: <http://www.k12.wa.us/AboutUs/KeyFacts.aspx>. Accessed June, 2019.**

This Washington State Office of Public Instruction webpage provides key facts about public schools in Washington State. There are 295 public school districts in the state.

22. **Washington State Office of Superintendent of Public Instruction. Data and Reports | Enrollment. 2019; Available at: <http://www.k12.wa.us/dataadmin/enrollment.aspx>. Accessed June, 2019.**

This webpage lists the annual October Enrollment Reports for public schools in Washington. Data include student enrollment on the first business day of October. Data are available at the state, district, or school level. Data include enrollment by grade and both Federal & State Ethnicity/Race Enrollment reports. On October 1, 2018 (2018-19 school year), 1,105,391 students were enrolled in Washington public schools: Kindergarten (80,320 full day; 1,662 half day), 1st grade (82,732); 2nd (83,751); 3rd (83,978); 4th (86,487); 5th (88,217); 6th (87,544); 7th (84,877); 8th (83,110); 9th (84,396); 10th (83,700); 11th (82,401); and 12th (92,216). The racial/ethnic composition of the K-12 student population is 1.63% American Indian/Alaskan Native (AI/AN)-Hispanic/Latino; 1.19% AI/AN-Not Hispanic; 0.23% Asian-Hispanic/Latino; 7.16% Asian-Not Hispanic; 0.61% Black/African American-Hispanic/Latino; 4.30% Black/African American-Not Hispanic; 0.10% Native Hawaiian/Other Pacific Islander (NHOPI)-Hispanic/Latino; 0.99% NHOPI-Not Hispanic; 0.01% Not Provided-Hispanic/Latino; 0.01% Not Provided-Not Hispanic; 3.17% Two or More Races-Hispanic/Latino; 9.50% Two or More Races-Not Hispanic; 17.70% White-Hispanic/Latino; and 53.52% White-Not Hispanic.

23. **Agency U.S. Environmental Protection. Characterization of the Fine Particle and Gaseous Emissions from School Bus Idling. New York 2007.**

The U.S. Environmental Protection Agency (EPA) Office of Research & Development and EPA Region 2 conducted a study with Katonah-Lewisboro School District in Cross River, New York to determine whether: a) there is a net benefit of anti-idling to emissions reduction or b) school buses should be allowed to idle while waiting for kids. Researchers aimed to quantify and compare the PM and gaseous exhaust pollutants (i.e., particulate polycyclic aromatic hydrocarbons, carbon monoxide, total hydrocarbons, nitrogen oxides, and formaldehyde) emitted

from selected diesel school buses which were shut down and ultimately restarted and those which idled continuously. This presentation provides an overview of the study design, results, and conclusions.

24. **Washington State Department of Ecology. Clean diesel grants. Available at: <https://ecology.wa.gov/About-us/How-we-operate/Grants-loans/Find-a-grant-or-loan/Clean-diesel-grants>. Accessed January 2020, 2020.**

This Washington State Department of Ecology website provides an overview of its clean diesel grants program. Funding is available for eligible projects (e.g., idle reduction) for cities, counties, school districts, public utility districts/co-ops, ports, state government, transit, tribes, non-profit organizations, local clean air agencies, privately-owned diesel fleets operating mainly in Washington.