K-12 School Environmental Health & Safety in Washington

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Abstract

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The school environment is one of the primary locations where children spend time and is known to present numerous health hazards. Poor air quality is a known public health risk, especially for children, impacting health, attendance, and learning outcomes, but schools face many challenges in improving the school environment. This thesis aimed to review existing literature on indoor air quality (IAQ) hazards in U.S. schools and describe local health jurisdiction (LHJ) perspectives of school environmental health and safety (EH&S) in Washington. The narrative literature review describes school EH&S hazards related to IAQ, along with potential health effects, exposure routes, and control measures. Findings reveal that school IAQ hazards are diverse and associated with varied health effects including respiratory disease, neurological effects, and cancer. This study also investigated the state of school EH&S in Washington through a survey and interviews with key informants at LHJs. Critical needs of LHJs include updated regulations and funding for school EH&S programs. Our findings reveal the critical need for school EH&S programs, especially focused on IAQ. Essential components for such programs include improved ventilation and filtration, regular inspection and maintenance, and safer choices for materials, furnishings, equipment, and chemicals. Trained EH&S personnel on campus and established surveillance systems are also critical to identify and proactively manage health hazards. School EH&S programs offer

a unique opportunity for public health intervention on a vulnerable population. Prioritizing and investing in school EH&S creates safer and healthier learning environments, benefiting students, staff, and the community.

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Lastly, thank you to my friends and family who supported me through these long two years. To my parents, who offered love and support from afar. To my DEOHS cohort and friends, especially Anna, for the emotional support and motivation. And most of all to my spouse Jaiden, who is my rock, for pushing me to pursue this dream in the first place, and our dog Cooper, who sat patiently through every practice presentation.

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Aim 1: Literature review of air quality hazards in U.S. schools

Objective

The first aim of this thesis is to characterize indoor air quality hazards in U.S. schools and their respective health risks and control measures.

Background

Schools play a crucial role in providing a conducive learning environment for students. Besides the home environment, school is the location where children spend the majority of their time living and breathing. Nearly 50 million students are enrolled in almost 100,000 schools nationwide.[1,2] Including staff, over one-sixth of the U.S. population uses a K-12 public school building every school day. When schools are healthy and well-maintained, students have a place to learn, grow, and thrive. However, the school environment also hosts a wide variety of potential hazards. These include chemical hazards in the science laboratory, trip or fall hazards on the playground, food safety hazards in the cafeteria, traffic hazards while riding the school bus, poor air quality in the classroom, and others.

While all school environmental health and safety (EH&S) hazards are a concern, poor indoor air quality (IAQ) is a school hazard that has received recent media attention and has led to legal action.[3,4] There is a large body of research on the health effects of air quality, and in school environments it is known to have adverse effects on student health, academic performance, and attendance.[5–9] Children are especially vulnerable to air pollution due to their developing physiology and immune systems, small size and closeness to the ground, and limited capacity to recognize hazards and advocate for their own health.[10,11] IAQ hazards can contribute to long-term detrimental health effects including the development of asthma, a serious health concern affecting approximately 1 in 12 children, cancer, and neurological effects.[8,10,12] Creating a healthy indoor learning environment in schools not only improves the health and wellbeing of students, but also benefits teachers and other staff members in the school by improving the environment for everyone.

The condition of school facilities in the U.S. presents several challenges to student health and wellbeing. The U.S. Department of Education found that the average age of school buildings in 2012 was 44 years old.[13] Older schools may need frequent repairs to maintain, since building materials and systems deteriorate as they age. The 1950s and 1960s were a time of rapid school development, but also corresponded with high usage of several hazardous building materials, including PCBs, lead, and asbestos, and remain a problem, especially in schools built prior to 1980.[14–17] Just over half of all public school districts in the U.S. have building systems or features that need replacement, repairs, or updates, including heating, ventilation, and air conditioning (HVAC) systems, roofing, and environmental conditions.[18] Fewer than half of the schools surveyed by the Centers for Disease Control and Prevention (CDC) in 2016 had an IAQ management program.[19] Outdated or improperly used HVAC systems can lead to a buildup of indoor pollutants, especially in schools where students may be crowded into a small classroom.

Limited funding restricts a school district’s ability to maintain school buildings and grounds. Maintenance and operation costs are funded largely by state and local sources, but major repairs or renovations require capital funding.[18] Capital funding differs widely and often inequitably between school districts, since it is linked to the wealth of the community and state prioritization of school funding.[20] Federal funding for school repairs is also limited. Because funding is so tight for schools, many districts must rely on more affordable, temporary fixes until they can raise funds for full repairs.[18] However, when maintenance is continuously deferred, schools may fall into disrepair, emergency repairs become necessary, and costs rise.[20]

Schools are significant social infrastructures where children spend a considerable amount of their time, and they require focused attention to ensure a safe and healthy atmosphere. The conditions within schools, especially IAQ, can have profound impacts on student health, comfort, and performance. By recognizing the unique hazards in the school environment and taking proactive measures to protect the health of students, schools can create a safe and healthy environment for the hundreds of people that use school buildings. There is significant need for further research into these hazards, their health effects, and methods to prevent and control them in the school environment.

Methods

A narrative literature review was performed on school EH&S hazards related to air quality in the U.S. Available scientific literature from 1980 to 2023 was searched on PubMed and the University of Washington libraries online database. The Boolean search method was used for combinations of the following topics, seen in Figure 1: **school environment**, **school-aged children**, **exposure terms**, and various **focus areas** within the school environment. This review first explored school EH&S broadly, but further narrowed the focus to IAQ when reviewing the existing body of evidence, so not all search terms used retrieved articles relevant to IAQ. The full list of search terms can be found in Supplementary Table 1 (Appendix A: Literature review). The initial search retrieved 1,552 results.

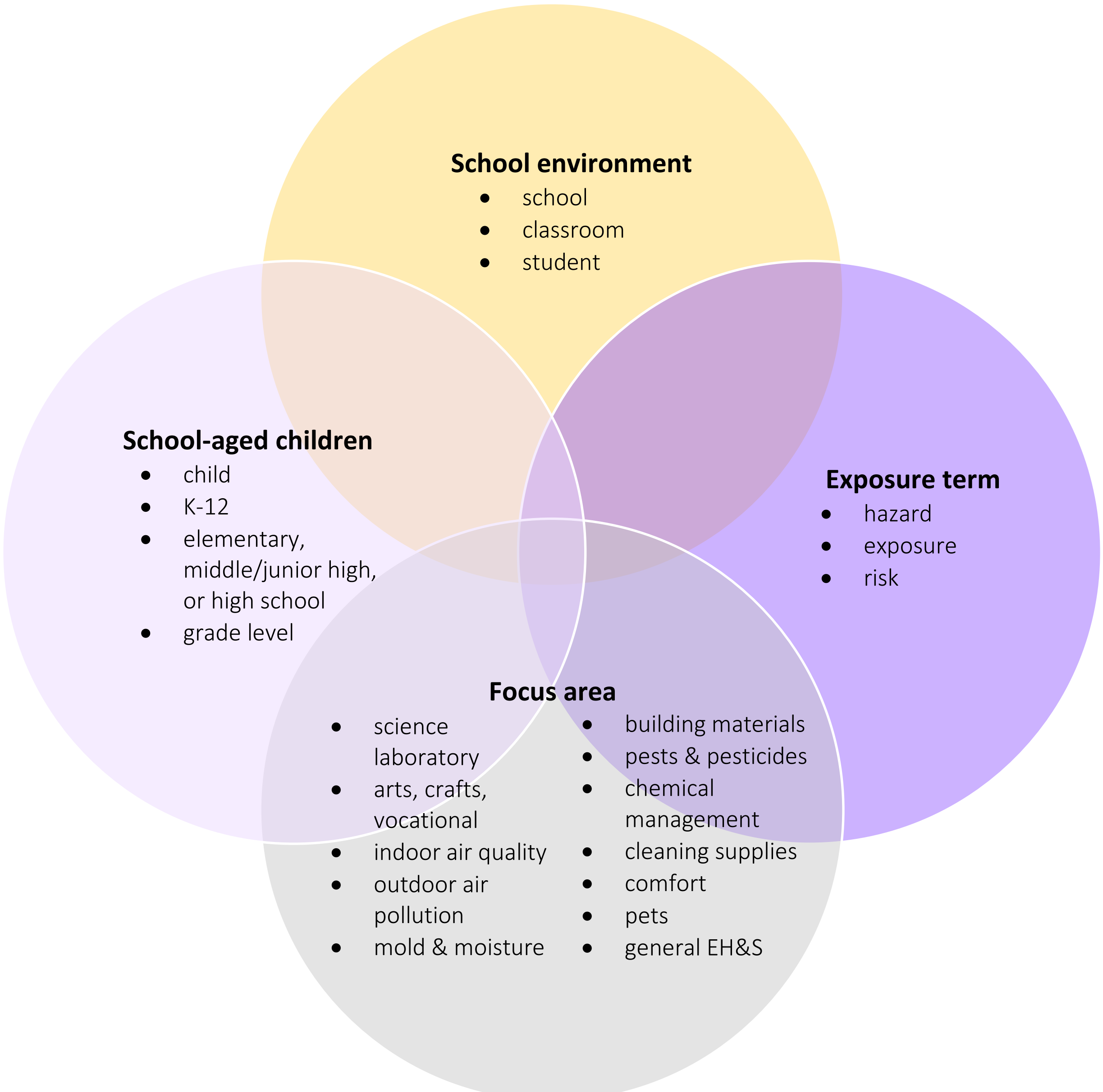

Figure 1. Summary of search terms

The four primary criteria for inclusion in this review were: 1) the focus was school environmental exposures or interventions, 2) the target population was K-12 students, 3) the target population was in the United States, and 4) the exposure or control measure was related to air quality. Only research articles, review articles, and guidance documents published by government agencies, non-profit organizations, or scientific journals were eligible; magazine articles, abstracts, opinion or viewpoint pieces, editorials, letters to the editor, news articles, historical documents, books and book chapters, legal documents, and advertisements were all ruled out. Duplicates were also removed. Articles that only covered preschool children or college students were ruled out, though articles that included these groups *along* with K-12 students were included. Articles were ruled out if they did not include the United States as a country of interest or were not written in English. Safety hazards unrelated to air quality (e.g., fall hazards on the playground) were not included. In-school exposures that were non-environmental (e.g., physical violence, bullying, firearm safety, etc.) were not addressed. We also did not include articles on natural disasters, unless the article focused on air quality hazards within the school after the disaster (e.g., mold after flooding). Additionally, food safety and communicable diseases were not included, with an exception for respiratory viruses that may be controlled via environmental control measures.

Snowball sampling methods were used to retrieve other relevant titles referenced within the original search list. Snowballed articles were used to expand upon exposures, health effects, and control measures of hazards in schools.

To fill in remaining gaps, a combination of purposive and snowball sampling methods was used on governmental resources. Using Google advanced search, the websites for the U.S. Environmental Protection Agency (EPA) and U.S. Centers for Disease Control and Prevention (CDC) were searched using the search phrase: "school environment* health safety." Initial results were used to locate relevant resources to provide additional background information on school hazards.

After reviewing the literature, articles were grouped by hazard to discern health effects, exposures, and control measures of each. Additionally, hazards were clustered by source – outdoor air pollutants, biological contaminants, building materials and furnishings, or chemical usage.

Zotero and Excel were used to track resources used throughout the review process.

Results

Summary of findings

The search and review process is visualized in Figure 2. Of the initial 1,552 results, after removing duplicates, 278 were focused on or included research relevant to the U.S. A review of titles and abstracts returned 61 school K-12 EH&S articles. These were read in full to determine relevance to IAQ, which retrieved 39 articles. From this selection, 35 more IAQ articles were snowballed, for a total of 74 relevant literature pieces.

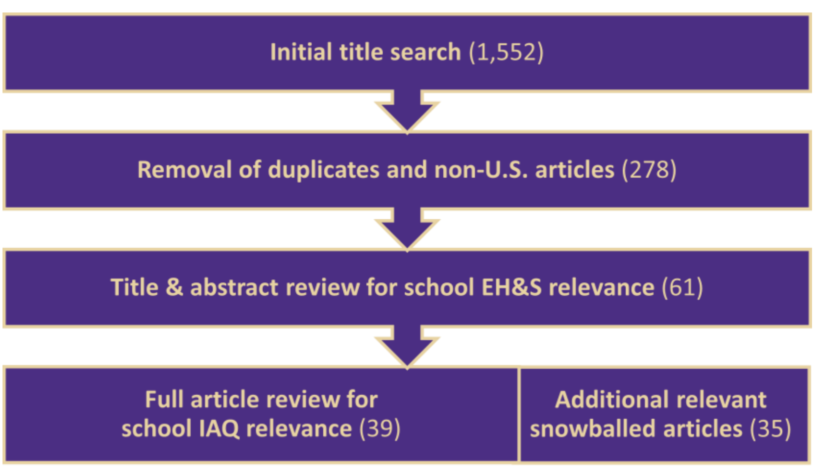

Figure 2. Search and review process flow chart

Table 1 lists the 39 articles that met final eligibility criteria, along with the primary hazards discussed and control measures used to prevent or reduce exposure. Thirty-five snowballed articles were also retrieved, which are described in Table 2. Additional government resources are listed in Table 3.

Table 1. K-12 air quality literature retrieved from review process

Author	Title	Year	Hazard/Topic	Control measures
Banda et al.	Exposure to home and school environmental triggers and asthma morbidity in Chicago inner-city children	2013	Asthma triggers (allergens, irritants)	Trigger removal/reduction
Baxi et al.	Exposures to molds in school classrooms of children with asthma	2013	Mold	*N/A*
Brown et al.	Why Green Clean Our Schools?	2012	Cleaning chemicals	Green cleaning practices
Chalupka et al.	Climate Change and Schools: Implications for Children's Health and Safety	2019	Natural disasters, emergency preparedness	
Antony Chen et al.	Schoolchildren's exposure to $PM_{2.5}$: a student club–based air quality monitoring campaign using low-cost sensors	2020	$PM_{2.5}$	Reduce $PM_{2.5}$ sources, improve air filtration, surface cleaning
Cooper et al.	School children's exposure to indoor fine particulate matter	2020	$PM_{2.5}$	Improved ventilation, high quality filters, air quality monitors, decrease classroom activity levels
Davis et al.	Associations Between School Characteristics and Classroom Radon Concentrations in Utah's Public Schools: A Project Completed by University Environmental Health Students	2020	Radon	Active or passive radon mitigation systems
Dungy et al.	Aeroallergen exposure in the elementary school setting	1986	Allergens (molds, pollens, dust, dust mites)	Air filtration, source control
Dyson & Krause-Parello	Impact of lead exposure on school age children in the U.S.	2012	Lead	Lead prevention programs, eliminate lead sources, community education and collaboration, school nurses

Author	Title	Year	Hazard/Topic	Control measures
Gaffin et al.	Nitrogen dioxide exposure in school classrooms of inner-city children with asthma	2018	NO_2	Improved ventilation and filtration
Gouge & Lame	Environmental health professionals work the bugs out--school integrated pest management	2015	Pests, pesticides	IPM strategies
Grineski et al.	Hazardous air pollutants are associated with worse performance in reading, math, and science among U.S. primary schoolchildren	2020	Hazardous air pollutants (HAPs)	*N/A*
Hochstetler et al.	Aerosol particles generated by diesel-powered school buses at urban schools as a source of children's exposure	2011	PM, DEP	Air quality control
Jhun et al.	School Environmental Intervention to Reduce Particulate Pollutant Exposures for Children with Asthma	2016	Particulate pollutants ($PM_{2.5}$, black carbon)	HEPA air cleaners, integrated pest management (IPM)
Korenstein & Piazza	An Exposure Assessment of PM_{10} from a Major Highway Interchange: Are Children in Nearby Schools at Risk?	2002	PM_{10}	Source reduction, school siting, improved ventilation, high-efficiency filters
Lin et al.	Identifying and evaluating school environmental health indicators	2020	Ventilation, mold/moisture, ambient air pollutants (ozone, $PM_{2.5}$)	Policy interventions, prevention programs, public health surveillance systems
Logue et al.	Pennsylvania's Asthma School Project and descriptive pilot investigation: a focus on environmental health tracking	2007	Asthma triggers	School nurse reporting, Asthma Action Plan, education, trigger removal
Ma et al.	Assessing schoolchildren's exposure to air pollution during the daily commute - A systematic review	2020	Outdoor air pollutants	Alternate transit options

Author	Title	Year	Hazard/Topic	Control measures
Marshall & Behrentz	Vehicle Self-Pollution Intake Fraction: Children's Exposure to School Bus Emissions	2005	Diesel PM, UFPs, NO_2, CO, benzene, butadiene	Source reduction, update school buses with emission control technologies
Martenies & Batterman	Effectiveness of Using Enhanced Filters in Schools and Homes to Reduce Indoor Exposures to $PM_{2.5}$ from Outdoor Sources and Subsequent Health Benefits for Children with Asthma	2018	$PM_{2.5}$	High efficiency filters
Mazer et al.	Reducing Children's Exposure to School Bus Diesel Exhaust in One School District in North Carolina	2013	Diesel exhaust	Strict air quality standards and policies, anti-idling policies, asthma education programs, school health teams, school health surveillance systems, alternative school bus technologies
Mendoza et al.	Absentee and Economic Impact of Low-Level Fine Particulate Matter and Ozone Exposure in K-12 Students	2020	$PM_{2.5}$, ozone	Indoor recess during pollution events, improved air quality regulations
Mirabelli et al.	Race, Poverty, and Potential Exposure of Middle-School Students to Air Emissions from Confined Swine Feeding Operations	2006	Airborne effluent, odor	School siting for vulnerable populations
Mullen et al.	Ultrafine particle concentrations and exposures in six elementary school classrooms in northern California	2020	UFPs	*N/A*
Oliveira et al.	Children environmental exposure to particulate matter and polycyclic aromatic hydrocarbons and biomonitoring in school environments: A review on indoor and outdoor exposure levels, major sources and health impacts	2019	PM, PAHs	Community education, public transport for school commute, low-emitting cleaning products, appropriate ventilation, replace of sandy playgrounds
Paulson & Barnett	Who's in charge of children's environmental health at school?	2010	Indoor air pollutants (PM, mold, allergens, etc.)	EH&S services dedicated to children, data collection systems, improved enforcement, collaboration with Pediatric Environmental Health Specialty Units, utilize HealthySEAT guidelines[21]

Author	Title	Year	Hazard/Topic	Control measures
Permaul et al.	Obesity may enhance the adverse effects of NO_2 exposure in urban schools on asthma symptoms in children	2020	NO_2	School siting, outdoor source reduction, stricter air pollution standards, improved ventilation, high efficiency filters, anti-idling policies, replace gas stoves with electric stoves
Prusiewicz et al.	Art and craft material use patterns by pre-school and elementary school children at home and school: a year long survey for refining exposure assessments	2023	Hazardous chemicals in art materials	*N/A*
Rowe	Healthful school living: environmental health in the school	1987	Ambient air pollution, mold, asbestos, hazardous chemicals, art materials	School siting, safe chemical practices, preventative maintenance, minimize disturbance of old building materials, regular inspections, safer playground equipment, data collection systems, environmental health and safety team, employee training
Sabin et al.	Characterizing the range of children's air pollutant exposure during school bus commutes	2005	Outdoor air pollutants	Minimize commute times, use "clean" buses for longer routes, reduce bus caravanning, anti-idling policies
Sabin et al.	Analysis of real-time variables affecting children's exposure to diesel-related pollutants during school bus commutes in Los Angeles	1994	Outdoor air pollutants	Minimize commute times, use "clean" buses for longer routes, regular maintenance of diesel buses, use cleaner fuels and particulate control technologies
Sanguinetti et al.	Understanding teachers' experiences of ventilation in California K-12 classrooms and implications for supporting safe operation of schools in the wake of the COVID-19 pandemic	2022	Indoor air quality perception, ventilation, CO_2	Increased ventilation, improved filtration
Santilli & Rockwell	Fungal contamination of elementary schools: a new environmental hazard	2003	Mold	Raze and rebuild the school, mold remediation, remove contaminated materials, air purifier use, regular testing
Sheehan et al.	Endotoxin exposure in inner-city schools and homes of children with asthma	2012	Endotoxins	*N/A*

Author	Title	Year	Hazard/Topic	Control measures
Shendell et al.	The Outdoor Air Quality Flag Program in Central California: A School–Based Educational Intervention to Potentially Help Reduce Children's Exposure to Environmental Asthma Triggers	2007	Outdoor air pollutants (ozone, PM)	Air Quality Flag Program
Spira-Cohen et al.	Personal exposures to traffic-related air pollution and acute respiratory health among Bronx schoolchildren with asthma	2011	Air pollutants (ozone, PM, NO_x, SO_2, BC)	*N/A*
Tinney et al.	School Siting Near Industrial Chemical Facilities: Findings from the U.S. Chemical Safety Board's Investigation of the West Fertilizer Explosion	2016	Nearby industrial hazards	School siting, community education, policy change
Wigmore	"We can't give up. It's too important." Health and safety stories from Canadian and U.S. schools	2010	Varied	Policy change, chemical management policies, low-emission building materials, IPM policies, health-based school design, improved ventilation systems, data collection systems, joint health and safety committees, staff and student training and involvement, federal comprehensive standards on school EH&S
Wolfe et al.	Impact of School Location on Children's Air Pollution Exposure	2020	Outdoor air pollutants	Clean school bus fleet, improved ventilation and filtration systems, retrofit existing diesel buses, alternative fuel buses, health-based school siting

Table 2. K-12 air quality literature snowballed from initial search process

Author	Title	Year	Hazard/Topic	Control measures
Adgate et al.	Outdoor, Indoor, and Personal Exposure to VOCs in Children	2004	VOCs	Source reduction, improved ventilation
Appatova et al.	Proximal exposure of public schools and students to major roadways: a nationwide U.S. survey	2008	Outdoor air pollutants	School siting, school design, anti-idling policies
Bannavti et al.	Room-to-Room Variability of Airborne PCBs in Schools and the Application of Air Sampling for Targeted Source Evaluation	2021	PCBs	Measurement, remediation, removal, demolition
Bateson & Schwartz	Children's response to air pollutants	2008	Air pollutants	Source reduction
Belanger et al.	Asthma Hospitalization Rates Among Children, and School Building Conditions, by New York State School Districts, 1991-2001	2006	Mold, ventilation	Building systems inspections, targeted asthma interventions, environmental interventions
Bennett & Zeman	Deposition of Fine Particles in Children Spontaneously Breathing at Rest	1998	PM	*N/A*
Chen et al.	Elementary school absenteeism and air pollution	2000	PM, ozone	*N/A*
Daisey et al.	Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information	2003	Varied air pollutants	Adequate ventilation
Eubig et al.	Lead and PCBs as Risk Factors for Attention Deficit/Hyperactivity Disorder	2010	Lead, PCBs	*N/A*
Fisk	Health and Productivity Gains from Better Indoor Environments and their Relationship with Building Energy Efficiency	2000	Indoor air pollutants, ventilation	Improved ventilation systems, ventilation systems maintenance, air quality sensors

Author	Title	Year	Hazard/Topic	Control measures
Fisk	The ventilation problem in schools: literature review	2017	Ventilation, CO_2	Improved building design, improved ventilation systems, maintenance and repairs, ban indoor smoking, ban pets indoors, air cleaners/filters, improved cleaning
Gilliland et al.	The effects of ambient air pollution on school absenteeism due to respiratory illness	2001	Ambient air pollutants (PM, ozone, NO_x)	*N/A*
Haverinen-Shaughnessy et al.	Association between substandard classroom ventilation rates and students' academic achievement	2011	Ventilation, CO_2	Improved ventilation and temperature
Haverinen-Shaughnessy et al.	Effects of Classroom Ventilation Rate and Temperature on Students' Test Scores	2015	Ventilation, CO_2	Improved ventilation
Herrick et al.	Review of PCBs in U.S. Schools: A Brief History, Estimate of the Number of Impacted Schools, and an Approach for Evaluating Indoor Air Samples	2016	PCBs	PCB surveillance system
Johnson et al.	Indoor air quality in classrooms: Environmental measures and effective ventilation rate modeling in urban elementary schools	2018	Ventilation, VOCs	Improved ventilation
Kabirikopaei et al.	Identifying the K-12 classrooms' indoor air quality factors that affect student academic performance	2021	PM, ozone, CO_2, NO_2, ventilation	Improved mechanical systems, improved ventilation rates, high efficiency filters
Lauby-Secretan et al.	Carcinogenicity of polychlorinated biphenyls and polybrominated biphenyls	2013	PCBs	*N/A*
Levin et al.	Lead Exposures in U.S. Children, 2008: Implications for Prevention	2008	Lead	Primary prevention, source identification and control, government collaboration and data sharing, surveillance systems, education
Marek et al.	Airborne PCBs and OH-PCBs inside and outside urban and rural U.S. schools	2017	PCBs	Improved ventilation

Author	Title	Year	Hazard/Topic	Control measures
Mendell et al.	Do classroom ventilation rates in California elementary schools influence standardized test scores? Results from a prospective study	2016	Ventilation, CO_2	Improved ventilation rates
Mendell et al.	Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature	2005	Indoor air pollutants	Indoor pollutant source reduction, adequate outdoor ventilation, moisture control
Morawska et al.	Airborne particles in indoor environment of homes, schools, offices and aged care facilities: The main routes of exposure	2017	PM	Regular cleaning, prevent dust ingress (shoe removal), school siting, anti-idling regulations
Morawska et al.	Indoor aerosols: from personal exposure to risk assessment	2013	PM	*N/A*
Prill et al.	School Indoor Air Quality Assessment and Program Implementation	2012	IAQ	3-Step IAQ Program (assign responsibility for IAQ, assess IAQ in buildings, adopt good practice IAQ policies and procedures)
Raysoni et al.	Binational school-based monitoring of traffic-related air pollutants in El Paso, Texas (USA) and Ciudad Juárez, Chihuahua (México)	2011	Outdoor air pollutants	*N/A*
Sadrizadeh et al.	Indoor air quality and health in schools: A critical review for developing the roadmap for the future school environment	2022	Varied air pollutants	Education, indoor and outdoor source control, improved ventilation, integrated control via improved building design and ventilation strategies
Santilli	Health effects of mold exposure in public schools	2002	Mold	Mold inspection and sampling, remediation, repairs, demolition, IAQ standards for schools
Shaughnessy et al.	A preliminary study on the association between ventilation rates in classrooms and student performance	2006	Ventilation, CO_2	Improved ventilation
Shendell et al.	Associations between classroom CO_2 concentrations and student attendance in Washington and Idaho	2004	CO_2	Improved ventilation

Author	Title	Year	Hazard/Topic	Control measures
Shorten et al.	Methods of Exposure Assessment: Lead-Contaminated Dust in Philadelphia Schools	2000	Lead	Regular surface cleaning, handwashing
Simons et al.	The Impact of School Building Conditions on Student Absenteeism in Upstate New York	2010	Mold, moisture	Improved school conditions, surveillance of building condition and issues
Thomas et al.	Polychlorinated Biphenyls (PCBs) in School Buildings: Sources, Environmental Levels, and Exposures	2012	PCBs	Improved ventilation, mitigation of primary/secondary sources, dust cleaning
Wargocki et al.	The relationships between classroom air quality and children's performance in school	2020	Ventilation, CO_2	Improved ventilation rates
Weschler et al.	Indoor ozone and nitrogen dioxide: a potential pathway to the generation of nitrate radicals, dinitrogen pentoxide, and nitric acid indoors	1992	Ozone, NO_2	Reduce ozone levels in ventilated air
Zivelonghi et al.	Mitigating aerosol infection risk in school buildings: the role of natural ventilation, volume, occupancy and CO_2 monitoring	2021	Viruses, CO_2, ventilation	Reduce size of student groups, equip teachers with microphones, CO_2 sensors in classrooms

Table 3. Air quality resources retrieved from government sources

Agency/Organization	Tool/Website	Topic
Agency for Toxic Substances and Disease Registry (ATSDR)	Toxicological Profile for Lead	Lead
Agency for Toxic Substances and Disease Registry (ATSDR)	Toxicological Profile for Mercury	Mercury
Agency for Toxic Substances and Disease Registry (ATSDR)	Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs)	PAHs
AirNow	Air Quality Flag Program	Outdoor air pollution
American Lung Association	Healthy Air Campaign	Outdoor air pollution
American Lung Association et al.	Indoor Air Pollution: An Introduction for Health Professionals	IAQ
ANSI/AARST	Radon Mitigation Standards for Schools and Large Buildings	Radon
ASHRAE	ANSI/ASHRAE Standard 62.1-2022: Ventilation and Acceptable Indoor Air Quality	IAQ, ventilation
Asthma and Allergy Foundation of America	Asthma Disparities in America	Asthma interventions, disparities
Centers for Disease Control and Prevention (CDC)	Childhood Lead Poisoning Prevention	Lead
Centers for Disease Control and Prevention (CDC)	Radon	Radon
National Pesticide Information Center	Active Ingredient Information	Pesticides
Pratt Institute et al.	Environmental Health & Safety in the Arts: A Guide for K-12 Schools, Colleges and Artisans	Arts & crafts, chemical use
U.S. Department of Transportation Federal Highway Administration	National Household Travel Survey	Outdoor air pollutants
U.S. Environmental Protection Agency (EPA)	Asbestos	Asbestos
U.S. Environmental Protection Agency (EPA)	Safer Choice	Green cleaning

Agency/Organization	Tool/Website	Topic
U.S. Environmental Protection Agency (EPA)	Reference Guide for Indoor Air Quality in Schools	IAQ
U.S. Environmental Protection Agency (EPA)	Indoor Air Quality (IAQ) Tools for Schools	IAQ
U.S. Environmental Protection Agency (EPA)	Indoor Air Quality (IAQ)	IAQ
U.S. Environmental Protection Agency (EPA)	Creating Healthy Indoor Air Quality in Schools	IAQ
U.S. Environmental Protection Agency (EPA)	Reference Guide for Indoor Air Quality in Schools	IAQ
U.S. Environmental Protection Agency (EPA)	Lead	Lead
U.S. Environmental Protection Agency (EPA)	Mold	Mold
U.S. Environmental Protection Agency (EPA)	Particulate Matter (PM) Pollution	Outdoor air pollutants
U.S. Environmental Protection Agency (EPA)	Ground-level Ozone Pollution	Outdoor air pollutants
U.S. Environmental Protection Agency (EPA)	Air Quality Guide for Ozone	Outdoor air pollutants
U.S. Environmental Protection Agency (EPA)	Diesel Emissions Reduction Act (DERA)	Outdoor air pollutants
U.S. Environmental Protection Agency (EPA)	America's Children and the Environment	Outdoor air pollutants, IAQ, lead, mercury, PCBs, other environmental health issues
U.S. Environmental Protection Agency (EPA)	Report on the Environment	Outdoor air pollutants, IAQ, other environmental health issues
U.S. Environmental Protection Agency (EPA)	Polychlorinated Biphenyls (PCBs)	PCBs
U.S. Environmental Protection Agency (EPA)	Model Pesticide Safety and IPM Guidance Policy for School Districts	Pesticide use
U.S. Environmental Protection Agency (EPA)	Model Program for the State School Environmental Health Guidelines	School EH&S

School air quality health hazards, health effects, exposures, and control measures

Outdoor air pollutants

Health effects

Outdoor air pollution can be a serious health concern, especially for children. The EPA regulates six criteria air pollutants, all of which pose a danger at ambient levels – sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter, ozone, and lead – along with hazardous air pollutants (HAPs), which are known or reasonably anticipated to cause severe health effects, including affecting academic performance in children.[22–24]

Exposures

Indoor concentrations of air pollutants are positively correlated with outdoor concentrations, due to frequent opening of windows and doors, malfunctional ventilation systems, poor-fitting windows, and general infiltration.[25]

School siting plays a key role in children's exposure to ambient air pollution.[26,27] One study found that over 30% of surveyed schools in large metropolitan areas in the U.S. were sited within 400 m of a major roadway, and over 10% were located within 100 m.[28] In rural areas, exposures can come from nearby farms spraying pesticides or feeding animals. One study evaluating the impact of swine confined animal feeding operations (CAFOs) on nearby schools found a correlation between closeness to a CAFO and low proportions of white students and low socioeconomic status of students, indicating that race and economic status is associated with the potential for school exposures to CAFO pollution.[29] Nearby industry can be hazardous not only for released pollutants, but also for other hazards such as explosions.[30]

Constructing a school in a cleaner location, however, does not always reduce children's exposure to hazardous air pollutants. As discussed in the "School bus exhaust" section, bus rides can lead to diesel and other roadway pollutant exposures for children. The health benefits of siting schools in low-traffic areas could be diminished if children must ride a bus to travel there, as one study found that children bussing from a high-traffic neighborhood to a low-traffic school were exposed to 2-3 times higher levels of air pollutants than children who walked to their local school.[31] The length of a student's commute is associated with their daily air pollution exposure.[31]

Control measures

Building design can significantly contribute to improved IAQ by reducing penetration of outdoor pollutants indoors. Airtight buildings can reduce influx and better conserve energy, though this can lead to an accumulation of indoor pollutants without appropriate ventilation.[32] New schools should be built and designed with student health in mind.

Careful choice of school location can also prevent exposures from occurring. School developers should aim to site new schools away from heavy sources of pollution, such as heavy-traffic areas or industry. However, as noted above, there is a significant challenge of balancing the benefits of siting in low-pollution areas with financial costs and potential health concerns of commuting.[31] Additionally, it is important to consider potential industrial growth and roadways that may be constructed in the future close to the school grounds. Protective zoning regulations for schools and ensuring schools are aware of current and future hazards in the area can also protect school occupants. [30]

For high air quality pollution levels beyond the school's control, schools can use the Air Quality Flag program. Schools display a brightly colored flag based on the U.S. EPA's Air Quality Index to notify school and community members of air quality conditions, which serves as a tool for education, communication, and policy change to reduce exposure to outdoor air pollutants.[33] This program can effectively reduce exposure to certain pollutants and triggers in the outdoor environment and protect not only school occupants but also the community as a whole.[34] School nurses can help establish and facilitate air quality flag programs to improve student and community health.[35]

Key findings relevant to outdoor air pollutant examples, health effects, exposures, and control measures are summarized in Table 4. This section on outdoor air pollutants utilizes findings from 44 articles retrieved from the literature review.

Table 4. Outdoor air pollutants summary

Hazard examples	Health effects	Exposures	Control measures
• Criteria air pollutants (e.g., particulate matter, ozone, NO_2, CO) • Hazardous air pollutants (e.g., PAHs, radon) • CO_2[*]	• Asthma • Cardiorespiratory disease • Cancer • Cognitive disorders • Worsened academic performance • Absenteeism	• Penetration from outdoors • School siting (roadways, industry, agriculture) • Indoor sources (e.g., gas heaters/stoves, cleaning agents) • Resuspension of PM • School bus	• School siting • Ventilation & filtration • Routine maintenance • Surface cleaning • Air quality monitors • Outdoor Air Quality Flag Program • Anti-idling policies • School bus retrofits/ replacement

Particulate matter (PM_{10}, $PM_{2.5}$, PM_1, UFPs)

Particulate matter (PM) is a type of air pollutant made up of a mixture of microscopic components of solids and liquids, including metallic compounds, black carbon, organic and inorganic compounds, dust, and soot.[36] The EPA standards for 24-hour PM concentrations in ambient air are 150 $\mu g/m^3$ and 65 $\mu g/m^3$ for coarse particulate matter (PM_{10}) and fine particulate matter ($PM_{2.5}$), respectively.[37,38]

Health effects

PM can penetrate deep within the human body, and different sizes of particles deposit in different locations within the respiratory system, so health effects vary by particle size and chemical makeup. Some of the health effects found to be associated with PM of different sizes include: increased hospital admissions, aggravated asthma symptoms, increased risk for cardiorespiratory diseases, reduced lung function, allergies and asthma, high blood pressure, increased risk of ADHD, negative impacts on cognitive development, and increased risk of skin disease.[39,40] Inhalation of black carbon, a component of PM, has been linked with respiratory disease, cardiovascular disease, and cancer.[41] Children are more

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[*] CO_2 is not a typical outdoor air pollutant, but it is reviewed in this section due to its use as an indicator of ventilation rates and general IAQ.

susceptible to the health effects of PM as their small lungs and higher ventilation rate increases the dose received per lung tissue surface area.[24,42]

Exposure to $PM_{2.5}$, even at levels compliant with National Ambient Air Quality Standards (NAAQS), is associated with school absences for children of all ages, especially for elementary schools.[43] Similar findings exist for PM_{10}, though to a lesser extent.[44] This may have long-term ramifications as absences can reduce students' abilities to achieve learning outcomes. Pollution levels can be higher at schools with a higher proportion of socioeconomically vulnerable students.[43] Note that another study found a negative correlation between PM_{10} and absenteeism in elementary schools in Nevada, but the researchers noted that this is in contrast to expected findings given the evidence of health impacts due to PM.[45] Additionally, PM is associated with academic performance. A review article found that fine particle counts were associated with mathematics scores during certain seasons in schools in the midwestern U.S.[46]

Exposures

PM is a very common pollutant in schools globally, and it is an important indicator of environmental health issues within a school.[8,47] Review articles discussing particulate matter in schools found limited studies on this topic that occurred in the U.S. compared to other countries.[39,48] One of these reviews found that all reviewed U.S. schools met EPA standards of indoor levels of PM_{10} and $PM_{2.5}$, but nearly half reported concentrations that surpassed World Health Organization (WHO) guidelines.[39]

School siting plays a key role in children's exposure to PM, since outdoor air is the primary source of PM infiltration into the school building.[26,27] Ambient air pollution can infiltrate into school buildings depending on the school's ventilation system, building materials, and the opening of windows and doors, especially if near traffic sources.[39] The primary outdoor exposure in metropolitan areas is traffic exhaust, which, among other pollutants, penetrates into school buildings. An exposure assessment study found that students attending school in close proximity to major roadways were exposed to high enough levels of PM_{10} to cause negative health effects.[49] Other ambient sources include industry, wildfire smoke, agriculture, and dust storms.[8,41,48] Indoor levels of $PM_{2.5}$ generally mirror outdoor levels, with the exception of certain acute indoor sources.[50–52]

Sources of PM within a school include school occupants, furnishings and materials in the classroom, and HVAC system usage, along with play and teaching activities, combustion sources from heating or cooking, cleaning, and printer and photocopy machine use.[8,39,46,53] Resuspension of large particles from indoor sources or tracked in on clothing or shoes also contribute to particulate matter concentration, which can lead to higher concentrations of PM indoors than outdoors.[8,46,51,52]

Extremely fine particulates, such as PM_1 and ultrafine particles (UFPs), are also growing concerns. UFP concentration, commonly measured as particle number (PN) concentration, is predominantly driven by outdoor sources such as traffic density and urbanization.[51,54] Particles from outdoors penetrate the school building envelope when windows and doors are open or if the ventilation system is frequently used with a low-efficiency or poor-fitting filter.[54] Within a school, indoor sources such as natural gas heaters, certain cleaning agents, and the use of candles can also contribute to PN concentration, though to a lesser extent than outdoor sources.[54] PN concentrations are higher in occupied classrooms compared to unoccupied, which can be attributed to indoor sources, ventilation rates, and outdoor levels.[54] Note that residential exposure is a greater source of exposure than the school environment;

one study suggested children were exposed to up to an order of magnitude greater PN concentration for homes than schools.[54]

Control measures

Monitoring pollution levels can help schools identify PM problems. Low-cost sensors can monitor classroom or personal exposures to air pollutants.[39,48,50] Sensors applied outdoors can be used to develop guidance for outdoor activities, like recess or gym class, based on air quality measurements.[43]

Exposure to PM can be reduced via improved filtration in schools.[48,50,55,56] The addition of filters or replacement of low-quality filters with higher rated filters can heavily reduce black carbon by over half and $PM_{2.5}$ levels by just over 80%, depending on the rating of the filter and length of run-time, which is associated with improvement in lung function of children with asthma.[55,56] Ventilation is frequently discussed throughout this report as a method for improving IAQ, but for pollutants with outdoor sources, ventilation is not effective without proper filtration. Ventilating outdoor air to the indoor environment allows outdoor PM to penetrate the building in the absence of appropriate filtration.[54] Increasing the run-time of HVAC systems that have poor or no filtration may increase indoor levels of PM.[56] This enforces the need for a combination of ventilation and effective filtration, with a high-quality and properly fitted filter.

Use of efficient filters yields a number of health benefits, especially for children with asthma. Asthma symptom-days can be reduced with the use of efficient filters in classrooms.[56] Replacing low-efficiency filters, such as MERV 5 filters, with high-efficiency filters in schools reduces asthma burden costs by 17-30% per school year, with higher cost reduction for higher rated filters.[56] The greatest benefits are seen in schools near roadways or other polluters.[39] Additionally, asthma-related outcomes were decreased by up to 30% during the school year with high-efficiency filters.[56] While high-efficiency filters come with higher energy usage, the cost of using high-efficiency MERV 14 filters for the entire school day is far less than the benefits of avoided asthma exacerbations.[56]

Other practical solutions to reduce exposure to PM in schools include increased surface cleaning indoors using damp dusting methods, vacuuming, and reducing dust ingress with walk-off mats.[50,52,53] One way to reduce resuspension is by decreasing active behaviors in the classroom, though this should be balanced against the benefits of exercise and play.[48]

Raising community awareness of air pollution sources and health impacts is also an important step in reducing the impacts of air pollutants. While schools generally only have control over their own internal environment, reducing pollution at the source is an effective way to reduce exposure, and can be used by school advocates to push for pollution control.[43] A study found that a 50% reduction in air pollution could save one city’s school district nearly half a million dollars due to student absences, in addition to the cost savings for families in hospitalization and medication costs for children with asthma.[43] Pollution reduction efforts are especially critical for schools in socioeconomically disadvantaged areas and elementary schools.

Ozone (O_3)

Ground-level ozone is a criteria pollutant regulated by the EPA because it is harmful to public health and the environment at ambient levels. It is formed by the reaction between nitrogen oxides (NO_x) and volatile organic compounds (VOCs), especially on warm, sunny days near urban environments.[57]

Health effects

Ozone can cause a variety of health problems, especially in children and people with asthma, including coughing, shortness of breath, airway inflammation and irritation, and increased asthma symptoms.[58,59] It is also associated with student absences and school performance. Even relatively small acute changes in ambient levels of ozone were substantially associated with increased absences from school due to respiratory illness.[44,45]

Exposures

NO_x and VOC emissions from vehicles and industrial sources are the most common cause of outdoor ozone formation.[57] Like other outdoor air pollutants, ozone can penetrate the building envelope and enter the school indoor environment.

Indoors, ozone may be produced by office equipment and ozone-generating air cleaners.[60] Ozone produced by air cleaners can react with other chemicals in the air to produce more harmful byproducts.[61]

Control measures

Like other outdoor air pollutants, a school has very little control over the source. Because ambient ozone levels are associated with student absences, tighter pollution regulation could significantly reduce student absenteeism, also reducing school costs.[43] Keeping children indoors or reducing outdoor exercise and play during periods of high ozone can also reduce exposures.[62]

To reduce exposures in the school environment, ozone-generating air cleaners should not be used. Unlike air filters, ozone-generating air cleaners do not effectively remove particulate matter from the air, and they are not effective at reducing odors or controlling microbial contaminants to acceptable indoor levels.[63]

Carbon monoxide (CO)

CO is a poisonous gas produced from combustion processes. The NAAQS standard for this criteria pollutant is 9 ppm for 8 hours.[58]

Health effects

CO can be a lethal hazard, causing death via asphyxiation, along with flu-like symptoms and cognitive impairment.[58]

CO has also been associated with student attendance and performance. One study found ambient CO levels to be a significant predictor of student absenteeism in elementary schools.[45] A review found that CO levels in the classroom are negatively associated with student performance.[46]

Exposures

The primary source of ambient CO is motor vehicle emissions, which can penetrate inside of school buildings. Indoor combustion sources that may produce CO in schools include malfunctional or improperly vented gas stoves or furnaces.[8,58] CO does not appear to be a frequent hazard in school buildings.

Control measures

Proper maintenance and ventilation of combustion equipment is the most effective way to reduce CO exposures.[64] Idling reduction policies can also reduce emissions near the school building.

Nitrogen oxides (NO_x)

Oxides of nitrogen, including nitric oxide (NO) and nitrogen dioxide (NO_2), are toxic gases, with NAAQS standards of ambient NO_2 at 0.053 ppm over 24 hours.[58]

Exposures

Sources of indoor NO_2 exposure include cooking, smoking, and gas appliances and heaters, which are all infrequent sources in schools.[8] Like many air pollutants, in the absence of a significant indoor source, indoor NO_2 concentrations tend to reflect outdoor levels, mostly attributed to vehicle traffic.[65]

Health effects

NO_2 is an irritant that can aggravate allergy and asthma symptoms.[58] A study on the effects of NO_2 on lung function of children with asthma in inner-city schools found that even low levels of NO_2 in the classroom are associated with airflow obstruction.[65] Another study found that obese schoolchildren were more susceptible to classroom NO_2 effects and were more likely to experience asthma symptoms.[66] Short-term changes in NO_2 were not found to be associated with school absenteeism in a study of elementary students in southern California, though NO_2 is known to be associated with respiratory symptoms.[44] NO_2 has also been found to be negatively associated with student performance.[46] These effects can have an impact on student success, student attendance, missed workdays for caregivers, and financial costs to the family.

Control measures

While source control is often outside a school's reach, modifying the indoor environment can reduce student exposures. Appropriate ventilation and filtration can reduce indoor levels of NO_2. Ensuring that combustion appliances are properly maintained and vented can reduce exposures.[58]

Outdoors, anti-idling measures for school buses and other vehicles can limit one significant nearby source. New schools should be carefully planned to avoid closeness to high-traffic areas.[66]

Polycyclic aromatic hydrocarbons (PAHs)

PAHs are a class of chemicals formed by burning of coal, oil, gasoline, and some organic matter.[67] They are considered semi-volatile organic compounds (SVOCs). Guidelines for exposure limits vary between individual PAHs.

Health effects

Some PAHs have been found to be toxic, mutagenic, or carcinogenic.[5,67] Other health effects associated with exposure to PAHs include aggravation of cardiorespiratory diseases, asthma and allergies, lung infections, and skin disease.[39] When bound to particulate matter, PAHs may enhance the health effects caused by PM.[39]

Exposure

PAHs are present in the air in two forms – particle-bound or gaseous. Because PAHs are released during industrial and energy production processes, urban schools may be at greater risk to outdoor exposures, especially since PM-bound PAHs can penetrate the school environment.[39]

Indoor sources due to school activities include cooking, cleaning, children's crafts, heating system usage, treated wood, and some electronic equipment.[39,67] Even if sources are removed, PAHs bound to PM can be resuspended in the air, and gaseous PAHs may be absorbed and re-emitted from indoor surfaces.[39]

Control measures

It is important to identify high PAH levels in the school environment to determine if intervention is necessary. Monitoring for PM and carcinogenic compounds can be used to evaluate pollutant levels in schools.[39]

Appropriate usage of HVAC systems and air filtration devices, especially at schools in high-traffic areas or near industry, is a necessary control measure within the school building.[39]

Source control remains a challenge for schools, since the greatest exposures are from outdoor sources not controlled by a school. Siting of new school locations and city planning for industry should be carefully considered to reduce potential exposures. Choosing low-emission building materials and furnishings within the school can also reduce exposure.[39]

Radon

Radon is a radioactive gas released from rocks and soil that may enter buildings through cracks in the foundation, and without appropriate ventilation can become trapped there. The EPA's recommended action level for radon mitigation is 4 picocuries per liter (pCi/L).[68]

Health effects

Radon is the leading cause of lung cancer in non-smokers, and the second leading cause overall.[69] It is one of the most hazardous indoor air pollutants affecting schools.

Exposures

In the U.S., average indoor residential radon levels are about 1.3 pCi/L, but can differ widely based on geology.[68] The EPA found that nearly one in five schools had at least one room with radon levels that exceeded the recommended action level.[70] One study of Utah's public schools found similar results; twenty percent of surveyed schools had radon concentrations at or above the recommended action level.[71] This study also found that concentration varied across a school's building, which can be significant for students who spend the majority of their day in one classroom, especially if that classroom is on a lower level.

Control measures

Testing for radon is the only way to determine if there is a problem, and the EPA recommends testing all schools for radon.[72] Radon testing is inexpensive and simple to conduct. Because radon concentrations can vary throughout a school building, it is important to test all regularly occupied ground-level and basement rooms.

Strategies for radon mitigation in large buildings such as schools are complex and varied and require careful examination of current standards.[73] Regular HVAC operation, especially when the building is occupied, may keep radon at a safe enough level to not warrant further mitigation. The usage of newer HVAC systems were associated with lower levels of classroom radon, indicating that installation, updating, and frequent use of HVAC systems may reduce radon exposure in students and staff in schools.[71]

Regular testing of all classrooms, education on radon aimed at school administrators, and state radon plans for schools can prepare schools for this serious health hazard.[71,74]

Carbon dioxide (CO_2)

CO_2 is not a typical outdoor air pollutant. In the school environment, high levels are produced by human activity rather than outdoor penetration. While CO_2 unaccompanied by other pollutants is associated with health effects, CO_2 concentrations are often used as a surrogate measure of overall IAQ, especially for pollutants from indoor sources, since high levels indicate ineffective ventilation.[5,8]

Health effects

A review article found an association between increased ventilation rates, measured via CO_2 concentrations, and improvement in student respiratory symptoms.[6] Reducing CO_2 by improving ventilation rates in the classroom has also been found to be associated with improvements in student performance, including math and reading scores, and decreased student abseteeism.[6,9,75–77] Student attendance is extremely important for both student success and school district funding.

This review found limited studies on the health effects of CO_2 independent of other air pollutants; one review article found an association between cognitive performance and reduced CO_2 levels.[6] The Occupational Safety and Health Administration (OSHA) has set a permissible exposure limit of 5000 ppm and lists symptoms of exposure including headaches, dizziness, difficulty breathing, and increased blood pressure.[78] Note that this exposure limit is for occupational exposure, not student exposures in schools.

Exposures

Contributors to CO_2 levels in the classroom include occupancy levels, physical activity, and natural and mechanical ventilation.

Concentrations of CO_2 over 1000 ppm are generally considered unacceptable for comfort and odor, yet many classrooms are above this threshold, nearly 50% according to one IAQ program.[5,6,79] Some classrooms may even exceed 2000 ppm up to 6000 ppm, a level exceeding the OSHA permissible exposure limit.[6,77]

Control measures

Increased ventilation rates can reduce CO_2 levels and improve overall IAQ.[75] ASHRAE specifies minimum indoor ventilation rates in schools, but improving beyond required minimums has been shown to improve student performance and attendance.[9,32,77] Natural ventilation, such as opening windows, can also effectively reduce high indoor CO_2 levels, but it can allow entry of outdoor pollutants such as NO_x.

Teachers' perceptions of classroom air quality can affect the actions they take to change their environment. One study found, however, that teachers did not accurately perceive air quality or whether ventilation was sufficient.[80] Two important tools to ensure that teachers are informed, feel safe, and are empowered to protect their class's health are training on the proper use of HVAC systems and installation of CO_2 monitors to provide a visual indicator that corrective action is needed.[80]

School bus exhaust

Schoolchildren are uniquely exposed to emissions from school buses, especially diesel-powered buses. School buses are an extension of the school environment that can represent a significant source of pollution exposure for schoolchildren, including students who do not ride the bus. Despite the short period of time spent commuting, this microenvironment plays an important role in children's exposures to air pollution.[81] About one-third of U.S. schoolchildren take the school bus, and about 10% walk or bike.[82] Over 90% of school buses are diesel-powered.[83,84]

Health effects

The EPA lists asthma, respiratory illness, the worsening of heart and lung disease as health conditions that can be caused by exposure to diesel exhaust.[85] Additionally, it is classified as likely to be carcinogenic to humans by the EPA.[86] Other studies have confirmed these health effects in children

One study found an association between personal exposures to elemental carbon and wheeze, shortness of breath, and total symptoms among children with asthma, but they did not find an association between $PM_{2.5}$ exposure and these symptoms.[87] This implies that asthma burden due to air pollution is mostly due to diesel pollution, which is a greater issue for children with asthma living or attending schools near roadways.

Exposures

School usage of diesel-powered buses significantly affects outdoor particle size distribution, especially UFPs.[25] PM concentration was highest during student drop-off and pickup hours, especially in the morning hours, and concentrations of PM and other outdoor air pollutants such as elemental carbon and organic carbon were higher at schools with greater numbers of school buses in operation.

Children can also be exposed while riding the bus to commute to and from school. According to one study modeling air pollution exposures, children attending a distant school received over half of their daily exposure to air pollutants while on the bus.[31]

Exposure can occur via self-pollution, which is when the vehicle's emissions penetrate the interior passenger compartment. One study found that students on a school bus inhale, on average, $10^5 – 10^6$ times greater emissions from a school bus than an average resident of their region.[88]

In the absence of outside sources of pollution such as other buses, concentrations of BC, PB-PAH, NO_2 are lower in a compressed natural gas (CNG) school bus than a diesel-powered bus, though formaldehyde is higher in the CNG bus.[89,90] Higher concentrations of all four pollutants occurred from self-pollution when windows were closed, due to self-pollution, roadway sources, and limited ventilation on the bus.[89]

A significant source of pollutant exposure for students riding the bus is exhaust from other buses, especially for BC and PB-PAH.[89,90] Traveling behind a diesel school bus emitting visible exhaust led to the highest concentrations of black carbon (BC), particle-bound polycyclic aromatic hydrocarbons (PB-PAH), and nitrogen dioxide (NO_2). This is concerning because school buses often end up caravanning together as they leave and return to schools around the same time.

Additionally, students who do not ride the bus may be exposed on their commute if they walk to school. One study found that students who walked to school were exposed to 19% of their total daily exposure to air pollution during their walk.[31]

Control measures

Policy changes are one of the best solutions to reducing student exposures to outdoor air pollution, both at a government level and at schools, though they require sufficient support from school administrators and staff.[91] Implementing a no-idling policy for school buses and other vehicles on school property can reduce air pollution exposures for schoolchildren both indoors and on their commute.[31,91] Alternative technologies, such as heaters or lighting that operates while the bus is off, can also reduce idling.[91]

The EPA's Clean School Bus Program provides funding for schools to replace diesel school buses with lower or zero-emission bus models, and some states provide similar funding programs.[92]

School nurses are responsible for protecting children's health and wellbeing in schools, and given appropriate training of environmental health hazards, can help reduce children's exposure to such hazards within the school environment. One article demonstrated the influence that school nurses can have on school environmental health policy.[91]

Reducing school bus emissions is key to controlling student exposures. It is more cost-effective to reduce school bus emissions than other vehicles because buses expose so many students at a time.[88] For students with a long commute, using a "clean" bus can cut exposures to air pollutants in half.[31] To reduce exposures of students to bus exhaust, school districts should minimize commute times with the most efficient routes, use the cleanest buses for the longest commutes, stagger bus arrival and leave times to reduce caravanning, and reduce unnecessary bus idling to reduce concentrations of black carbon, particle-bound PAH, and NO_2 inside the school bus.[31,90]

While students are commuting on a school bus, exposure from other diesel buses can be reduced by closing the windows,[90] but opening the windows may be more effective at reducing self-pollution exposures when there are fewer outside sources of pollution.[89] This study also found that variability was high between buses, so changing the windows may not be effective in all situations.

Biological contaminants

Biological contaminants also play a role in indoor air quality exposures. Mold, dust mites, pollen, and other microbiological hazards in the classroom can affect the health of school occupants, especially those with asthma.[58,93] Most of these types of pollutants are controlled by reducing indoor moisture levels and improving ventilation.

A summary of biological contaminant examples, health effects, exposures, and control measures retrieved from the literature review is depicted in Table 5. Seventeen articles from the literature review are used in this section on biological contaminants.

Table 5. Biological contaminants summary

Hazard examples	Health effects	Exposures	Control measures
• Mold • Dust mites • Endotoxins • Pollen • Respiratory viruses* • Animal dander & allergens	• Allergies & asthma • Respiratory symptoms • Illness • Absenteeism	• Poor maintenance (e.g., leaks, water damage, HVAC issues) • Pest infestations • Classroom pets • Flooding, natural disasters	• Frequent inspections & maintenance • Regular cleaning • Low humidity • Non-permeable flooring • Ventilation & filtration • Integrated pest management (IPM)

* Respiratory viruses are not a typical environmental health hazard, but they can be controlled with environmental interventions, particularly improved ventilation, so are reviewed in this section.

Mold & moisture

Health effects

Molds are an important allergen in sensitized individuals, especially if they have asthma, and can contribute to allergy and asthma symptoms, including asthma attacks, wheezing, watery or itchy eyes, headaches, sore throat, and weariness.[5,58,94,95] Serious mold exposure can lead to long-lasting health concerns, even after exposure has ended.[95] Mold, high humidity, and poor building conditions have been associated with student absences from schools and increased asthma hospitalizations rates of schoolchildren.[96,97] Mold and moisture problems were one of the highest rated priorities for school environmental issues, according to one study in New York.[47]

Exposures

Many types of mold spores are ubiquitous in outdoor air, but they become an issue indoors when they encounter appropriate conditions for proliferation, usually due to water damage or high humidity levels.[5] Mold species and spore counts differ based on region, climate, and season. Common molds found in school environments include *Cladosporium*, *Penicillium*, *Aspergillus*, and *Alternaria*.[5,8,98]

Moist conditions in a school are usually due to maintenance issues. Buildings with poor-fitting or damaged windows, leaks in the roofing or floors, leaky pipes, HVAC issues, flooding, or groundwater seepage can experience water damage and have issues with dampness, which may lead to mold growth.[11] One study of inner city schools found mold present in 100% of surveyed classrooms, but with great variance between classrooms.[98] A wide range of factors can play a role in the development of mold, including location within the school, the amount of sunlight received, water incursion, humidity levels, ventilation, and temperature.[6,98]

Schools can also become contaminated during natural disasters, such as flooding and hurricanes, especially if the building is water damaged. Nearby polluters, such as industry, agriculture, Superfund sites, and sewage systems may contribute to contamination of school buildings during such events.[35]

Control measures

Prevention is key to mold control. Because mold requires moisture to grow, adequate ventilation, proper maintenance of the school building and grounds, such as repairing leaks in roofing or plumbing, ensuring proper drainage, and immediately drying wet carpets can keep humidity levels low and remove damp environments that could encourage mold growth.[58,98]

A key indicator of increased mold spore levels was the visual detection of mildew or mold spots, usually on walls, ceilings, or carpeting.[5,98] Immediate reporting of mold spots to school administrators can help detect mold growth early.

Mold testing can be a low-cost way to detect very high levels of mold or to track changes over time, especially in schools with a history of water damage, with some caveats.[94] If mold testing is performed, samples from various locations within the school should be taken since levels can vary greatly across the school, including air samples in different rooms, wall cavity testing, and carpet and rug testing.[95,98] One study recommended an acceptable level of mold in the indoor environment as 1000 spores/m^3.[95] It should be noted, however, that there is no gold standard for measuring exposure to mold, there are no health-based standards for acceptable levels of mold in the air, and air measurements are generally not an effective indicator of an issue.[5,99] Visual or odor detection is generally more reliable for detecting a mold problem. More research is needed on appropriate levels of mold exposure and measuring this exposure.

Serious mold contamination can require expensive remediation or even destruction of a school building.[95] Ensuring school buildings are built to be resistant to natural disasters can prevent extreme contamination events from occurring, and current buildings should be evaluated for their resiliency and upgraded if needed.[35]

Dust and dust mites

Dust mites are tiny arthropods that live in homes, schools, and other buildings, and feed on dead skin flakes. Dust is made up of dust mite droppings and body fragments, along with dead skin cells, soil, pollen, and various other microscopic particles.

Health effects

For children sensitized to dust mite allergens, dust can exacerbate allergy and asthma symptoms and trigger asthma attacks.[58]

Exposures

Dust mites prefer high-humidity environments with an abundant food supply, which can be found in carpeting and fabric-covered furniture in schools. The presence of carpeting in classrooms has been found to be associated with allergy symptoms.[5]

However, schools better control dust mites than homes do. One study in Southern California found that mite counts were much lower in schools than the home environment, likely due to more frequent and thorough carpet cleaning, limited locations for mites to nest, and a reduced food supply.[100] This study may not apply to other climates.

Control measures

Reducing indoor humidity can decrease habitat suitability for dust mites. The EPA recommends maintaining indoor humidity levels at 30-60%.[58] Frequent vacuuming and damp dusting, along with the use of medium or high-efficiency filters in HVAC systems can remove dust mites and their food sources.[58] Because carpet is a popular habitat for dust mites in schools, replacing carpet with a smooth, non-permeable, easy-to-clean option, such as tile, can reduce allergen load and allow for easier cleaning.[5]

Bacterial endotoxins

Endotoxin is component of Gram-negative bacteria that can be released after the death of the cell and inhaled with other indoor air pollutants.

Health effects

Airborne bacterial endotoxins may be associated with flu-like symptoms.[101]

Exposures

Endotoxin levels have been associated with pets, cockroaches, carpeting, moisture, dust, and number of inhabitants.[102] One study of endotoxin exposures among inner-city children with asthma found that concentrations of endotoxin were significantly higher in children’s classrooms than in their bedrooms indicating higher exposures at school than home.[102]

Control measures

Ensuring that humidifiers and HVAC components are regularly cleaned can reduce bacterial and fungal growth.[101]

Pollen

Health effects

Pollen is an allergy and asthma trigger for sensitized individuals.[58]

Exposures

One study of allergens in the school environment found that being in school is actually protective against allergens for mold, pollens, and dust mites, and that these concentrations are much higher in homes than schools.[100]

Control measures

Like all particulates, pollen can be reduced by the use of appropriate air filtration.[58] Keep windows closed on high pollen days to prevent ingress.[53]

Carpeting can trap pollen indoors. Frequent vacuuming of carpets or removing carpeting can reduce pollen levels indoors.[60] Additionally, damp dusting to reduce dust levels can also reduce pollen.[53]

Outdoors, schools can plant flora of low allergenicity on school grounds and use grass collection bags while mowing grass to reduce allergen load.[100]

Respiratory viruses

While this report considers communicable diseases outside the scope of environmental health, there are environmental controls that may influence the spread of illness, especially respiratory viruses.

Control measures

Appropriate mechanical and natural ventilation and increased air exchange in classrooms can reduce the risk of respiratory illness.[5,8,103] Additionally, the use of CO_2 sensors can serve as an effective indicator of ventilation rates and air exchange.[104]

Animal allergens

Health effects

Animal allergens all have the potential to cause an allergic reaction or asthma attack in a sensitized individual.[58]

Exposures

Animal allergens include proteins in the dander, urine, and saliva of warm-blooded animals or in the waste products and saliva of cockroaches.[58] Exposure sources for these allergens can include classroom pets, pest problems in the school building, or even allergens clinging to the clothes of schoolchildren with pets at home.[11] Animal allergens also attach to carpeting in the school building. Carpeted floors contain higher levels of pet allergens and are challenging to clean.[5]

Pests such as cockroaches and rodents can become a problem in any school, but especially if the school is poorly maintained. Leaks, moisture problems, buildup of trash or debris, and improper food storage practices can all provide an environment for pests to thrive.[58]

Control measures

Replacing carpeting with hard-surfacing flooring may be easier to clean and remove allergens and has been associated with a reduction in respiratory symptoms.[5] Frequent vacuuming, especially of carpeted rooms, can reduce the allergen load.[58]

To reduce the presence of pests that produce allergens, integrated pest management (IPM) interventions can be effective in schools.[55] IPM uses targeted prevention and control measures to manage pests while minimizing health impacts. This can included improved food storage and handling practices, fixing moisture problems in the building, and use of traps for pests.[58] If pesticides must be used, schools should notify occupants, only use pesticides where needed and when empty of people, and ventilate well.[58] See the "Pesticides" section for more information.

Building materials & furnishings

Many school buildings throughout the U.S. were built with hazardous materials, including lead, asbestos, and PCBs. Removal or remediation of such hazards can be expensive and dangerous, so many schools opt to minimize disturbance by sealing or covering these hazards. These compounds can still be a serious issue for a number of reasons, including deterioration of materials, continued off-gassing, disturbance, or if hazardous materials are undetected by school staff. Additionally, the furnishings used within schools, such as furniture and carpeting, can contain potentially hazardous materials that also release gaseous or particulate pollutants into the school air.

Table 6 summarizes building examples, health effects, exposures, and control measures of building materials and furnishings hazards. This section utilizes 15 articles on building material and furnishing hazards from the literature review.

Table 6. Building materials & furnishings summary

Hazard examples	Health effects	Exposures	Control measures
• Asbestos • Lead • Polychlorinated biphenyls (PCBs) • Volatile organic compounds (VOCs)	• Cancer • Cognitive impairments • Neurodevelopmental disorders • Lowered IQ • Behavioral issues • Respiratory irritation • Asthma	• Aging infrastructure • Lead-based paint • Adhesives, sealants, caulking, etc. • Light ballasts • Pressed-wood furniture	• Inspections & maintenance • Remediation • Surface cleaning • Ventilation & filtration • Low-emitting materials

Asbestos

Asbestos is a mineral that forms small fibers when processed that is used in building materials for fire safety and insulation. Asbestos was partially banned in the 1970s, but it is *not* fully banned in the U.S.; importation and use continues, with some limitations.[105] Asbestos is regulated federally under the Asbestos Hazard Emergency Response Act (AHERA). Schools are required to inspect buildings for asbestos in building materials and develop asbestos management plans.[106]

Health effects

Asbestos becomes a problem when it deteriorates or is disturbed and releases fibers into the air. Exposure can cause lung disease, including lung cancer, mesothelioma, and asbestosis, usually many years after exposure.[105]

Exposures

Asbestos can be found in the school building in insulation, soundproofing materials, fireproofing materials, and in other materials such as flooring, roofing materials, ceiling tiles, and more.[17]

Control measures

Control measures required by AHERA include regular inspections of asbestos-containing materials, a management plan, notification to staff and parents of the management plan, and training of maintenance personnel.[106] It is also important to minimize disturbance to older building materials that might contain asbestos.[27] Encapsulation of asbestos-containing materials can prevent further release of fibers. Removal and demolition of asbestos is carefully controlled and must comply with Asbestos National Emissions Standards for Hazardous Air Pollutants.[107]

Lead

Health effects

Lead is a well-recognized as a health hazard, especially for children who are more vulnerable to its toxic effects. According to both the CDC and EPA, there is no safe blood lead level.[108,109] Increased blood lead levels are associated with a variety of health problems, especially in children, including cognitive impairments, developmental delays, lowered IQ, behavioral issues, and other long-term health implications.[110]

Exposures

The primary sources of elevated blood lead levels of children in the U.S. are lead paint, dust, and soil.[111]

The use of lead in paint was banned in 1978, but as discussed in the PCBs section, the U.S. was in a time of active school building from the 1950s through the 1980s, and lead paint was widely used. Lead remains ubiquitous in urban environments due to aging infrastructure and industry.

Lead-based paint peels and flakes, forming tiny particulates that can become airborne as it deteriorates. Inhalation of suspended lead particles and ingestion of settled lead dust are the primary routes of lead exposure for children.[112] In schools, this comes from both aging interior lead paint and tracked-in soil and dust containing lead.[113] Decades of using leaded gasoline in vehicles, industrial processes, and peeling outdoor lead paint have all contaminated the soil, especially in urban areas.[111] Because lead can concentrate in the schoolyard, children spending time outdoors and interacting with soil, especially near the building or playground structures, may be a potential source.

Control measures

Because lead dust is a common exposure for children, controlling dust is key to reducing lead exposure indoors.[113] Lead dust can be transported by HVAC systems, so filtration and air purifiers may help limit exposure.

Prevention is also an important part of reducing lead exposure in the school building. Testing the paint, dust, and soil in and around a school can demonstrate whether or not lead is an issue in the school.[111]

School planners should carefully consider the risks of lead exposure to students and staff before renovations and hire a lead-certified professional.[114]

School nurses play a key role in primary prevention of lead exposure in students. They can monitor students for signs of lead poisoning, provide education to community members on lead prevention, partner with local health departments to help schools develop lead prevention programs.[110]

Polychlorinated biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) are a large and diverse group of human-created organic chemicals used in industry and manufacturing. Physical and chemical properties of PCBs vary widely based on chemical makeup.[115]

Health effects

PCBs are known human carcinogens and are linked to neurodevelopmental disorders.[116,117]

Exposures

PCBs are a persistent organic pollutant widely used in a variety of building materials, with peak use from the 1950s through the 1970s, until production was banned.[15] This parallels a period of active school construction nationwide, and PCBs contaminate many school buildings that were built during this time.[15,118] The total number of schools containing PCBs in the U.S. is currently not known, but one study estimated that 12,960 to 25,920 schools in the U.S. contain PCBs in building caulk.[15]

School occupants are at risk of exposure from PCBs via inhalation and dermal contact.[15] While diet is the typical source of PCBs, inhalation exposures in school children may exceed dietary exposures, and PCB air concentrations in schools have been found to exceed measured levels near Superfund sites.[119,120]

PCB-containing caulk and sealants, both interior and exterior, are a primary source of PCBs for many schools and have led to indoor air levels of PCBs exceeding public health guidelines.[15,118] This caulk is typically present around windows or air intakes. Other sources of PCBs in schools include fluorescent light ballasts, adhesives in flooring and masonry, window glazing, and paint.[15,118,120] Light ballasts are likely to fail and leak as they exceed their expected lifetimes.[118] Additionally, PCB-containing materials can contaminate other materials after prolonged absorption, so removal of primary sources may still leave some contamination behind in paint, dust, boards and tiles, and masonry that can continue to be a source of PCB emissions.[118] Exterior window caulking and building joints can contribute to higher PCB levels in the soil, an important exposure for children.[118] Concentrations of airborne PCBs can vary across the school building depending on age and type of building materials, specifically caulking, sealants, paint pigments, and fluorescent light fixtures.[119] While older schools built when PCBs were in use are at higher risk, modern paints and sealants used in schools have also been found to be significant sources of PCB exposure.[119]

Control measures

Schools are not required to test for PCBs in building materials or air,[15] though there are health protective levels for evaluating PCB levels in air, which vary between 300 to 600 ng/m^3 for school-age children.[121]

Because PCB sources can vary across a school, it is important to tailor remediation plans based on source materials.[119] Congener-specific analysis, which detects the specific PCB compounds present, can help schools target on the primary emitters within their buildings.[118] Different congeners have different properties, exposures, and toxicity, so it is important to know which types of PCBs are present.

Ventilation can air out rooms with PCB emissions and decrease air concentrations.[118] Some materials, such as light ballasts, can be fairly straightforward to remove, but most PCB-containing materials are challenging to remove or have off-gassed into other materials, making remediation a signification challenge. Mitigation of primary sources may still require mitigation of secondary sources.[118]

Volatile organic compounds (VOCs)

Health effects

Some VOCs, such as formaldehyde and benzene, are known carcinogens and can cause severe health effects.[5] Many VOCs are toxins and irritants. Exposure to formaldehyde irritates eyes, skin, and the airways, and can lead to asthma development.[5,58] Even low exposures may increase risk of sensitization and should be carefully controlled.[5]

Exposures

Building materials, classroom furnishings, wood resin products, glues and adhesives, paints, cleaning chemicals, arts and crafts materials, and carpeting are all sources of VOCs in schools.[8,11,122] Pressed-wood products are especially problematic in schools, since pressed wood may emit formaldehyde and is often used in affordable furniture.[58]

Schools do not have as many strong sources as residential environments, such as tobacco smoke, and tend to have better ventilation and air turnover than homes.[123] However, poor ventilation in schools can led to an increase in air contaminants such as VOCs indoors.[124]

As noted in the "School bus exhaust" and "Chemical usage" sections, a schoolchild's commute and the use of chemicals in the school building can be significant sources of VOCs as well.

Control measures

To reduce student exposure to VOCs, schools can choose to use low-emitting materials and furnishings or seal and store products that release VOCs, such as paint, glue and adhesives, and cleaning products.[125]

Chemical usage

Chemical usage occurs throughout the school environment, including in science laboratories, in art and vocational studios, schoolwide for cleaning purposes, and on the school grounds to manage pests.

Table 7 summarizes examples of chemical usage hazards, along with health effects, exposures, and control measures. Five articles on chemical usage hazards in schools retrieved from the literature review are used in this section.

Table 7. Chemical usage summary

Hazard examples	Health effects	Exposures	Control measures
• Science lab chemicals • Art/vocational studio (e.g., metal oxides, VOCs, sawdust) • Cleaning chemicals (e.g., bleach, spot remover, finishing agents) • Pesticides	• Respiratory disease or irritation • Asthma • Neurological damage • Liver damage • Kidney damage • Cancer • Endocrine or hormonal effects	• Improper chemical use or storage • Art/vocational activities (e.g., painting, ceramics, woodworking, welding) • Cleaning • Routine pesticide/ herbicide application	• Chemical management policy • Safer product choices • Safety equipment • Staff training • Local ventilation • Integrated pest management (IPM)

Science laboratory chemicals

Health effects

Science laboratories and chemical storage areas can be a source of chemical releases that affect IAQ.[27,126,127] Many chemicals, such as mercury, can cause neurological damage or other toxic effects.[128]

Exposures

Exposures in the science lab occur via improper use or storage of hazardous laboratory chemicals, such as strong acids or bases, solvents, or metals.[127] Mercury remains an issue in schools, along with old chemicals that have not been removed and chemicals brought from home.[128]

Control measures

Ensure chemicals are safely stored and inaccessible to children to reduce the possibility of spills. If potentially hazardous chemicals are used, all students and staff should have appropriate safety equipment. Staff must be appropriately trained in chemical management. Schools should have a chemical management policy for storage, cleanup, and disposal, and should not accept chemical gifts.[27,126,128]

Art studio and vocational shop materials

In elementary school, students may use arts and crafts materials on a daily basis in their classrooms. As students reach middle and high school, there is a wider range of arts, crafting, and vocational options.

Health effects

The health effects are as varied as the art materials being used. Using paints, solvents, varnishes, glazes, or glues may exposure children to hazardous chemicals and heavy metals including lead, arsenic, cadmium, and mercury, all of which can cause severe neurological effects.[129] Volatile solvents can evaporate and release VOCs if improperly sealed and cause respiratory damage, nervous system damage, or harm to the liver or kidneys.[129] Welding and metalworking can exposure students to metal oxides, NO_x, and ozone.[129] Woodworking students may inhale sawdust, which can cause respiratory disease or be carcinogenic.[129]

Exposures

Children of all ages use art and craft materials at school, such as markers, crayons, pencils, and glue, which may expose them to unsafe solvents, pigments, or heavy metals.[27,130]

Older students may be exposed to dust, sprays, solvent vapors, and other hazards via ceramics, woodworking, welding, photography darkroom, printing, and more, depending on the school.[129]

Control measures

Art materials should be carefully vetted before use, and expired and unlabeled donated materials should be appropriately discarded following hazardous waste disposal regulations.[27] Proper storage of art materials is also important to prevent student access and ensure that VOCs are not being released into the air.[129] While students are creating art, adequate local ventilation should be used, along with protective equipment for the eyes, lungs, and skin if appropriate.[129] Wet cleaning methods, such as damp dusting and mopping, are preferred over dry dusting or sweeping to prevent particulates from becoming airborne.

Cleaning chemicals

A clean and safe learning environment is important for student health, academic performance, and attendance. Schools must be kept clean to prevent and reduce communicable disease, pests, allergens, and dust. However, sometimes the compounds used to clean can be more problematic than the mess.

Health effects

Some cleaning products can contain chemicals that cause irritation, and some can trigger asthma attacks and other respiratory symptoms in school occupants, or be a potent toxicant.[131,132] Children are especially sensitive to the effects of chemical exposures since their lungs and immune systems are still developing.[10]

Exposures

Conventional cleaners such as bleach, glass cleaners, spot removers for carpeting, floor finish, and polishing agents can all contain ingredients that are hazardous to health if inhaled, touched, or ingested.[131]

Control measures

Choosing safer cleaners can prevent exposure to toxic substances contained in harsh conventional cleaning products. Safer cleaners are those that use ingredients which are safer for human and environmental health and use more sustainable packaging, such as EPA's Safer Choice or others recognized by third-party sources.[133] Besides their benefits to health, safer cleaners are still effective and can save costs for schools.[131] The health of school occupants should be a top priority when choosing cleaning chemicals for use.

Developing a chemical management program can also effectively protect schoolchildren's health. Besides using safer and low-emitting cleaners, other aspects of this program could include using fragrance-free products, using microfiber cloths, prohibiting the use of outside chemicals, and ensuring all staff are trained on appropriate chemical usage in the school building.[132] There are also many options for safe removal of expired or toxic cleaning compounds.

Pesticides

Pests can be a problem in any school building, especially those that are poorly maintained. Some building managers attempt to prevent this problem with regular pesticide application, but overuse of pesticides and herbicides on school grounds can be an exposure route for school occupants.[134] Routine pesticide application is not necessary and more likely to be harmful to human and environmental health. Instead, taking preventative measures and choosing the least toxic options only when needed can be an effective way to control pests and reduce exposure.

Health effects

The wide range of chemicals used in pesticides means there are varied health effects, and dose and route of exposure also play an important role. Many pesticides can be irritants or cause respiratory effects, some can damage the nervous system or kidneys, some cause endocrine or hormonal effects which are especially concerning for children, and others may cause cancer or death.[135] Risk is higher for certain populations, such as children, who have developing nervous and immune systems and may spend more time in environments where pesticides are sprayed.[136]

Exposures

There are multiple types of pesticides that are used in school settings, including disinfectants, fumigants, fungicides, herbicides, insecticides, repellents, and rodenticides. School maintenance staff may apply these outside on school grounds, where children play, or indoors in classrooms, cafeterias, or any other area with a pest problem.

Control measures

Integrated pest management (IPM) is a more sustainable approach to pest management that aims to control pests while minimizing health and financial impacts. IPM is focused on taking preventative action to remove attractants and shelter for pests and targeting specific pest vulnerabilities by understanding their biology. The EPA recommends that all schools implement IPM programs to reduce the use of pesticides and has developed a model policy for school usage.[137] IPM can reduce both chemical exposures and pests, along with litigation risks due to pesticide use.

Preventing pests requires proper school maintenance, including repairing leaks, ensuring windows close completely, and closing cracks in the building.[134] Regular monitoring of school grounds for pests and promptly correcting the conditions that benefit that pest can prevent a problem.[134]

Pesticides can still be used safely if used with caution, such as choosing low-toxicity pesticides, following the instructions, and the stored and sprayed pesticide locations are not accessible to children.[136] Traps can be an effective control method for some pests and are less risky.

Staff that are especially important to the implementation of IPM custodial or maintenance staff, food service managers, environmental health practitioners, and school nurses.[134] School nurses or other human or environmental health staff can press administrators on the need for IPM in the school setting. Maintenance or food service managers can manage the IPM program on school grounds by monitoring for pests, preventing and repairing maintenance problems that attract pests, and using traps or pesticides as necessary.

Discussion

The air quality hazards present in schools are widely varied, as are the measures required to prevent and control them, but there are common threads that exist throughout this review which schools can incorporate into the regular management to improve student and staff health and wellbeing.

Outdoor air pollutants, which penetrate the indoor environment from industry or vehicles, can cause health effects such as asthma, cancer, and worsened academic performance and attendance. Improved ventilation and the use of high-efficiency filters in combination with air quality monitors can ensure staff are able to provide optimal air quality indoors. Practical, low-cost control options for schools to reduce exposure to particulates are increased surface cleaning, particularly the use of damp dusting, vacuuming with a high-efficiency filter, and reducing dust ingress. Schools can provide education to the wider community with the Air Quality Flag Program. Anti-idling policies and retrofitting or replacing diesel school buses can reduce outdoor sources.

Biological contaminants, including mold, pollen, and other microbial hazards, are known to trigger allergies or asthma, which can in turn affect student attendance. Exposure to biological contaminants is typically due to poor maintenance, especially related to moisture, which is important for mold, dust mite, and pest success. The best control measures for biological hazards are frequent inspections, routine maintenance and cleaning, and improved ventilation and filtration. Additionally, pest management may be needed to reduce animal allergen levels.

The school building and materials within can be a source of various hazards including asbestos, lead, and PCBs, which can be found in flooring, adhesives, paint, and other aging materials. Pressed wood furniture and newer materials and furnishings may be a source of VOCs. Health effects from these hazards include cancer and neurodevelopmental disorders. Regular inspection and maintenance are critical, since asbestos and lead are generally only a problem if disturbed or deteriorated. Simple, effective control measures for schools include regular damp cleaning and vacuuming to control dust. As above, improved ventilation and filtration can reduce both particulate and gaseous hazards produced by building materials. Low-emitting materials and furnishings can reduce sources.

Chemical usage is a concern school-wide, but especially in the science laboratory, in the art studio or vocational shops, anywhere that hazardous cleaning chemicals are used, and on the school grounds when pesticides are used. Health effects can be severe, damaging various bodily systems or leading to cancer. Schools should have a chemical management policy to ensure chemicals and art materials are purchased, used, stored, and disposed of safely. Ventilation can reduce exposure indoors. An integrated pest management policy can also reduce risk of exposure to pesticides.

Developing a comprehensive IAQ program is critical for schools to manage air quality hazards and protect school occupants' health and safety. The following discussion draws from the common threads recognized above to propose critical components and benefits of a school IAQ program.

Key components of a school indoor air quality (IAQ) program

Ventilation and filtration

Ventilation and filtration are two key components to a healthy learning environment in schools. Minimum requirements are established by ASHRAE, but many schools still fail to meet these standards.[5,6] Insufficient ventilation is associated with higher rates of student absenteeism and increased asthma hospitalization rates, highlighting the importance of improved ventilation for student well-being and success in the classroom.[75,96,97] Improving ventilation can improve student health, academic performance, and attendance.[6,7,46,138]

Achieving proper ventilation can be a challenge in the school environment. Many schools face budget constraints and custodial staff shortages, making it difficult to prioritize and maintain optimal indoor air quality.[76,139] Additionally, variations in occupancy, student activities, and pollutant types further complicate ventilation needs. To address these challenges, implementing modern energy recovery ventilation systems can help increase ventilation rates without incurring significant energy costs.[138]

Ventilation must be accompanied by filtration for optimal air quality. Proper filtration of fresh air intake is necessary to control the infiltration of airborne pollutants, especially in areas with nearby outdoor pollution sources like roadways, industry, farms, or wildfires.[8] By effectively filtering pollutants, schools can ensure a healthier environment for students and mitigate potential health risks associated with poor indoor air quality.

The type of ventilation system used in classrooms also plays a role in student outcomes. Studies have indicated that multi-zone ventilation systems, which can deliver fresh air and filtration, have been associated with higher academic performance compared to classrooms with unit ventilators.[46] Natural ventilation can also be an effective method for improving IAQ, but it must be used with caution if there are nearby sources of pollution. These findings highlight the importance of considering the design and functionality of ventilation systems to optimize student learning environments, especially in new buildings that do not yet have ventilation systems installed.

Ventilation and filtration systems cannot be fully effective without appropriate maintenance. This includes regular system inspections, filter replacements, and cleaning as needed. User behavior also plays a role in the effectiveness of ventilation systems, since teachers may turn the HVAC system off if it is a distraction in the classroom.[6,80] Ensuring ease of use, low noise levels, and comfortable temperatures for student and teachers, along with staff training of best use practices, will help keep these systems running as intended.

While increasing ventilation rates to meet standards may incur some energy costs, these expenses are relatively low and a per-person basis.[6] Comparing these costs to the potential consequences of student absences and the benefits of improved academic performance underscores the value of investing in proper ventilation.

Ventilation is the first line of defense against poor IAQ in the school environment. Prioritizing optimal HVAC system development in new or remodeled schools is essential to protecting air quality indoors. Existing schools can focus on hiring trained custodial staff to operate HVAC systems in a way that is health conscious.

Choose safer building materials, furnishings, and equipment

While ventilation and filtration are excellent methods of controlling air quality hazards both indoors and outdoors, reducing the source is also important for improving indoor air quality. Certain building materials and furnishings can be significant sources of indoor pollution, releasing harmful substances such as VOCs, formaldehyde, lead, and PCBs. These substances can be released or off gassed from construction materials and contribute to respiratory issues and other severe health outcomes, especially for children and other sensitive groups. Other materials, such as carpeting or fabric, harbor and release dust, particulates, or allergens that can negatively affect children's health. This is especially important for children with asthma. Art supplies, copy machines, and other point sources can also be a source of chemical and particulate exposure.

School administrators should choose materials in the school building that are not harmful to human or environmental health. Low-emitting adhesives, flooring, and other materials can reduce exposure to harmful VOCs. The replacement of carpet or fabric-covered furniture with non-permeable, easy-to-clean options reduces allergen load. Regular cleaning and maintenance of all materials and furnishings can ensure durability and control health hazards. Even sources perceived as minor, such as markers, glue, or other art materials, should be carefully selected, since children spend long periods of time in close quarters with these materials.

Inspection, maintenance, and monitoring air quality hazards

The first step in addressing a problem is recognizing its existence, and regular inspections of the school environment are essential to identifying potential hazards. Assessment of school facilities is typically left to the district rather than managed by the state or county. A 2020 report by the Government Accountability Office found that only an estimated 65% of school districts had assessed facility conditions in the past 10 years.[18] By conducting routine inspections of building equipment and materials and monitoring pollutant levels, schools can proactively identify air quality hazards before they become serious problems.

Routine maintenance schedules also help schools maintain a healthy environment. This also helps with prompt identification of potential hazards, and maintenance can prevent potential problems from escalating. Important maintenance tasks relevant to air quality include cleaning ventilation systems, replacing filters, and repairing leaks. Hiring dedicated custodial and maintenance staff who are trained to perform inspections and carry out routine maintenance ensures that these responsibilities are effectively managed.

In addition to inspections and maintenance, it is important for schools to have feedback mechanisms for maintaining good IAQ. As discussed above, improper use of ventilation systems can inadvertently impact IAQ. Monitoring CO_2 levels in the classroom can serve as a useful proxy for detecting a buildup of pollutants in indoor spaces, since high CO_2 concentrations are an indicator of insufficient ventilation and the likely presence of other pollutants.[6] Particulate sensors are also useful indicators of high PM levels indoors. Either sensor provides a visual warning signal to staff to take corrective action, by opening windows, turning on the HVAC system, or contacting the building manager. Air quality monitors are most effective if teachers are trained on appropriate usage, interpretation, and actions to take when pollutant levels are high.[80] Understanding how to recognize classroom air quality issues and implement control measures empowers teachers to contribute to a healthy learning environment. Regular observation of outdoor air quality using monitors or via AirNow and the establishment of a school flag program can aid both the school and the general community by communicating outdoor conditions.

Regular inspections, maintenance, and monitoring of potential air quality hazards are crucial elements for maintaining a safe and healthy school environment. By implementing these practices, schools can promptly identify and proactively address hazards. These efforts contribute to the well-being and overall health of students, teachers, and staff, creating an optimal learning environment for all.

Data collection and surveillance

Data collection is necessary to identify, understand, and address environmental health issues in schools. However, there is currently no comprehensive data collection system for tracking school environmental health issues affecting children in the U.S. This lack of data hinders public health efforts to recognize and mitigate school hazards effectively.

The Family Educational Rights and Privacy Act (FERPA) poses challenges to collecting environmental health data from schools. FERPA considers medical and health data to be "education records," which require the express permission of parents or guardians to address such information.[140] This limits state and local health jurisdictions from collecting comprehensive environmental health data from schools.[11] However, COVID-19 case numbers at schools were publicly reported to communities without contravening FERPA, as long as no identifiable information is released.[141] The same can apply to environmental health hazards. An additional barrier is that some districts may have concerns over being held liable for environmental health hazards if made publicly available.

Despite these challenges, it is crucial to establish a comprehensive data collection system to inform all parties of potential and ongoing health hazards and concerning trends related to school environmental health. Surveillance systems are critical for informing decision-making, such as selecting environmental health repair and remediation projects to fund, identifying hazards in need of removal, and evaluating the effectiveness of public health interventions. Districts can take data collection into their own hands and utilize school nurses or other public health staff to internally collect data on environmental health trends. Some states collect data on student asthma, and states or counties set up surveillance systems for reporting required COVID-19 cases. School districts can model other environmental health data collection projects after existing systems. Larger surveillance systems would require support from the county or state. Collecting data on environmental health issues at any level can provide valuable insight into potential hazards affecting schoolchildren.

School staff training and involvement

Training and involving school staff in environmental health decision-making is a significant component of school environmental health. The behavior of school occupants, including teachers, staff, and students, significantly influences indoor environmental conditions. By empowering and educating staff members, schools can create a collaborative and informed approach to addressing environmental health concerns.

Environmental health practitioners, such as school nurses, health officers, sanitarians, and other specialists, play a vital role in managing and maintaining a healthy school environment. However, it is essential to recognize that ensuring a safe and healthy school environment is a team effort that requires the active participation of stakeholders, including faculty and staff present on campus every day. School staff need to be informed of the student health and performance benefits of protecting IAQ so they can take an active role.[6] Even students can play a part in protecting school environmental health. Involving students in solutions can contribute to their understanding of environmental health issues and provides an opportunity for students to provide input on their learning environment.[142]

Public health benefits of a school indoor air quality (IAQ) program

Most children spend nearly a third of every day for half of the year in a school building, from ages six to eighteen. The school is only outranked by the home environment for the amount of time children spend there. The school environment offers many advantages for public health interventions. Targeting interventions at schools provides a wide net of coverage, involving hundreds of children at once, along with the many teachers and staff who work at schools, making it a highly efficient intervention.

By focusing specifically on children, who are especially vulnerable to exposures in a school environment, the benefits cascade to all school occupants, including teachers and staff. This is especially true if air quality interventions prioritize children with asthma, a common and serious health condition that is proven to benefit from positive changes in the environment. Asthma burden also falls disproportionately on racial and ethnic minority groups and children of low socioeconomic status, and the school environment offers a unique opportunity to address some of these disparities.[143] Protecting children with asthma reduces negative health, learning, and monetary impacts, since asthma health effects can affect a student's attendance. Ensuring all students have a healthy environment is beneficial to both their health and their academic success, by providing an environment where students feel safe, well, and are less likely to be absent from.

A school IAQ program provides a comprehensive approach to school air quality and health, focused on prevention, maintenance, and education. Not only does it benefit the health and achievement outcomes of students and staff; a school program also offers financial benefits. Fewer absent students, improved energy efficiency, regular monitoring to catch problems early on, and reduced risk of litigation are all potential benefits of a school environmental health program.

Any person involved with a school, including teachers, staff, parents, or even students, can take action to improve environmental health, but this review largely supports the utilization of school nurses for raising concerns and providing evidence of health effects to school administrators. School nurses are equipped to understand environmental health issues and are generally trusted by school occupants.

School nurses play a crucial role in protecting school environmental health by identifying and raising health concerns, providing evidence of health effects, and promoting prevention of health hazards. They have unique access to children and their families, giving them the opportunity to educate students their families, along with the faculty and staff they work with, on the health effects of environmental exposures and prevention and control measures.[110] Nurses are also often connected to local health departments and can coordinate with them to develop and implement health programs. Additionally, they serve as a reliable source for collecting data on hazards within the school environment.[144] By ensuring access to a nurse in every school, students benefit from a healthcare professional that advocates for their well-being and delivers valuable health education.

Gaps in the research

This review article found significant gaps in the research on school IAQ hazards. Many countries have invested significant resources into school environmental health research, but there were limited recent studies on such hazards in the U.S. Studies specific to the U.S. were often over twenty years old. More research is needed on the unique challenges faced by modern schools in the U.S. to inform targeted interventions and policies.

Because one of the primary contributors to IAQ issues is outdoor air pollution, results vary widely across states, schools, and timeframes. Outdoor air pollution is affected by seasons, meteorological conditions, and regional geography. Microenvironments within a school can experience significant differences in pollutant levels. This highlights the importance of characterizing varied conditions both within and outside of the school that affect air quality exposures.

While some pollutants had a clear connection to health effects, there is still limited research on specific pollutant effects within the school environment, where dose and exposure routes may differ from other environments. There is also limited information about pollutant effects on academic performance. UFPs in particular were an air pollutant with very limited research.

Nearly all studies retrieved in this review focused on public school exposures. Private and parochial schools may be located in very different environments, including homes, churches, or other non-traditional buildings, which may have different hazards. Neglecting a school environment that millions of children use is a large gap in the research on environmental health hazards affecting schoolchildren.

Limitations

This study on school air quality and environmental health faced many limitations. For the literature search, only titles were used due to the overwhelming number of articles retrieved with title and abstract searches. By allowing the usage of snowballed articles, many of these gaps were filled, but some articles on the topic may still be missing.

As stated above, other countries have large bodies of research on school environmental health. Some of these studies may be relevant to the U.S., but they were excluded due to the unique context of the relationship between local, state, and federal oversight of school health in the U.S.

This review did not delve into the trade-off between controlling air pollutants, energy usage, and financial costs. A review of the literature on this relationship is needed to determine an optimal balance between achieving good IAQ and minimizing energy consumption in the school environment.

This study exclusively used studies on K-12 student exposures. There is a significant body of research on preschool exposures and health effects. While some of this research may also apply to children of other ages, there are significant differences in exposures, health effects, and behavior in very young children, so these studies were excluded. University students may also have some similar exposures to the K-12 age group, but these were also not included in this study due to unique hazards on university campuses. This review also did not cover staff exposures and health effects. Adult exposures in the workplace are generally well characterized, and some of this research can be applied to schoolchildren, with the understanding that children are generally more susceptible to health effects.

Lastly, this study only focused on air quality exposures. The school environment faces *many* other hazards. Accidents on the playground, bullying and mental health hazards, weapons in schools, natural disasters or fire hazards, infectious disease, and more affect school occupants on a daily basis. A full review of all school environmental health and safety hazards is necessary to characterize and understand these varied hazards.

Conclusion

Schools serve as critical environments that demand significant investment in public health due to their high density of vulnerable individuals. Their unique characteristics present an opportunity to take action and protect public health effectively.

IAQ in schools is characterized by a wide range of pollution sources, exposure routes, and potential health effects. To address the diverse factors contributing to IAQ issues, it is crucial to implement comprehensive environmental health programs in schools. Such programs should include improved ventilation and filtration systems, the use of safer building materials and equipment, and regular inspection and maintenance of systems to enhance IAQ. Furthermore, fully trained staff, particularly school nurses, play a vital role in safeguarding student health. Establishing surveillance systems for environmental health data in schools enables proactive identification and management of emerging health issues.

Optimizing IAQ not only promotes better health outcomes but also improves academic performance and attendance. The benefits of protecting children's health extend beyond their well-being. School success and funding are tied to student academic performance and attendance rates, providing financial motivation for schools to enhance the learning environment. Moreover, teachers and staff also benefit from an improved indoor environment, creating a conducive workplace.

Healthy indoor school environments are crucial to maximize student health, well-being, and academic achievement. Improperly managed school environments have the potential to cause harm, but they also present a unique opportunity for large-scale public health interventions in vulnerable populations, offering numerous co-benefits. By prioritizing and investing in the improvement of school environmental health, we can create safer and healthier learning environments that positively impact the lives of students, staff, and the broader community. Further research should expand understanding of exposures and health effects and consider the environmental health hazards beyond air quality in the school setting.

Aim 2: Washington K-12 environmental health & safety study

Objective

The second aim of this project is to investigate perspectives of school environmental health directors at local health jurisdictions (LHJs) to characterize: 1) oversight activities of LHJs regarding environmental health and safety in K-12 schools, 2) barriers, facilitating factors, and needs of LHJs related to school environmental health, and 3) priority health hazards present in school environments. This study was used to develop policy recommendations for Washington State legislators on school environmental health & safety.

Background

School environmental health and safety (EH&S) in Washington has garnered significant attention recently after a Seattle Times article shed light on the improper management of polychlorinated biphenyls (PCBs) in building fixtures in one school district.[3]

Washington has enforced school health standards since the 1950s. The current enforceable code, chapter 246-366 WAC *Primary and Secondary Schools* (WAC 246-366), was established in 1971 and last updated in 1991.[145] Oversight of K-12 school health and safety in Washington falls under the responsibility of local health jurisdictions (LHJs).

To provide guidance on interpreting codes and implementing control measures relevant to school environmental health, the Washington State Department of Health (DOH) and Washington Office of Superintendent of Public Instruction (OSPI) jointly published the *Health and Safety Guide for K–12 Schools in Washington* (*Health & Safety Guide*) in 2003. This guide assists LHJs during inspections in identification of safety violations and provides recommendations for safe facilities and best practices.[146]

In 2004, in response to complaints regarding mold, water quality, and indoor air quality in schools across the state, the Washington State Board of Health (SBOH), in coordination with stakeholders, began development on the *Environmental Health and Safety Standards for Primary and Secondary Schools* (WAC 246-366A).[145] These updated rules were adopted by SBOH in 2009. However, due to budgetary concerns surrounding K–12 funding, the implementation of these rules has been continuously prohibited by a proviso in the state's supplemental operating budget.[147] The current bill (ESSB 5693) is effective through June 2023.[148,149] An updated version of the *Health & Safety Guide* was initiated to accompany WAC 246-366A but remains unpublished until the rule is implemented. It is currently undergoing technical corrections.

Several years into this cycle of delaying WAC 266-246A implementations, the PCB mismanagement case at a Washington school district has led to substantial settlements and judgements amounting to over half a billion dollars. This incident prompted DOH to contract with the University of Washington Department of Environmental and Occupational Health Sciences (UW DEOHS) to conduct a report on the current state of school environmental health in Washington and provide recommendations for improvement. The objectives of the DEOHS report included: 1) a summary of the literature on PCBs in schools, 2) a content analysis of school EH&S regulations in other states, and 3) a characterization of LHJ oversight activities related to school EH&S. The report was submitted to the legislature in December 2022.

The purpose of this study was to fulfill the third objective by collecting and summarizing current school EH&S program activities undertaken by Washington's LHJs and to identify barriers, facilitating factors, and needs of LHJs for implementing and maintaining successful EH&S programs.

Methods

Survey

We used a purposive sample approach and invited the school EH&S lead in each of the state's 35 LHJs to complete a web-based survey tool. In cases where no school EH&S lead existed, the jurisdiction's environmental health director (EHD) was invited to complete the survey. Contact information was provided by the Washington State Department of Health (DOH) School Environmental Health & Safety Program Manager. A survey link with an explanation was emailed, along with weekly reminders for one month.

The survey tool (Appendix B: Survey tool) was created and distributed via REDCap and featured questions informed by existing state regulations and state and federal guidelines, as well as a previous baseline DOH questionnaire. The following resources provided the basis for activity-based questions:

1. Washington State codes: Chapter 246-366 WAC *Primary and Secondary Schools*[150] and chapter 246-366A WAC *Environmental Health and Safety Standards for Primary and Secondary Schools*[151] (not implemented due to budget proviso),
2. State guidelines: *Health and Safety Guide for K–12 Schools in Washington* (2003) (*Health & Safety Guide*), DOH and OSPI, developed specifically to guide school health programs per WAC 246-366-140,[152]
3. *Local Health Jurisdiction School Environmental Health Program Survey*, DOH (2004),[153] and
4. Federal guidelines: EPA *Model K–12 School Environmental Health Program*, a comprehensive strategy for preventing and addressing environmental health issues in schools.[132]

Survey questions covered current school inspection activities, resources used by LHJs for developing programs and health recommendations, frequent violations and corrective action taken by LHJs, capacity for LHJs to offer support to schools, needs and barriers of school programs, and specific chemical hazard activities. The survey varied in length based on whether the LHJ self-selected as having a school program. LHJs that selected no school program did not answer questions specific to those having implemented a school program.

Key informant interviews

Key informant interviews were utilized to provide additional depth and clarification regarding barriers and facilitators in school EH&S program implementation.

A semi-structured interview guide (Appendix C: Interview guide) was developed in preparation for each interview and was used to guide the discussion. To identify key informants, we used purposive and snowball selection methods, where interviewees recommended additional key informants with expertise. LHJ key informants were asked about their school EH&S program, historical and present strengths of their program, barriers and facilitators to program implementation, recent emerging hazard management, and key recommendations necessary to ensure success.

Interviews were attended by at least two research team members, and notes were hand-recorded by each member. One team member combined all notes into a master interview document for each interview. Themes were co-identified by two to three team members. A single team member developed a summary of the key themes and summarized by relevant content area.

Results

We administered a survey to LHJ school EH&S leads to summarize current LHJ school activities and identify program implementation and maintenance barriers, facilitating factors, and needs. *Routine programs* are defined as established EH&S inspection-based programs, while *Developing programs* include programs actively being built, as of December 2022.

Current school inspection program activities

> *"Schools are a community resource and include health centers, libraries, play fields, community art rooms and gardens, etc. They are not just for instruction. A past survey of one of our partner districts showed their schools were used more hours per year by community members than by students. School health and safety protects our entire community." – Routine program*

A total of 22 LHJs completed an online REDCap survey. The 63% response rate represents approximately 90% of public-school children across the state. Figure 3 illustrates the geographical distribution of LHJ survey responses. It is important to note that several of the non-responding LHJs have routine and developing programs, and that the survey's timing likely competed for very limited staff time in these rural counties. Additionally, five key informant interviews were conducted with routine and developing programs to further elucidate barriers and facilitators to successful program implementation.

Our first survey question split our survey findings into LHJs with some semblance of a school EH&S program and those without:

> *Does your LHJ currently have a K–12 school EH&S inspection program that focuses on health and safety issues in schools (besides food safety)?*

Thirteen of the 22 LHJs answered "Yes" or "Other" and were given the full survey, which included questions about program activities, administration, and implementation barriers and facilitators. Nine LHJs that selected "No" were not asked questions about activities about administering a school program but were asked questions about perceived barriers and facilitators to program implementation, as well as resources used.

Figure 3. LHJ survey responses

This question allowed an open-ended comment box connected to "Other" for LHJs to further describe the degree to which a program delivered EH&S activities. Seven (32%) of the 22 LHJs have a routine school program; seven (32%) have a program in development; and eight (36%) have no program or only complete building plan reviews for new construction or remodels. Unfortunately, two respondents misclassified their response to this question, selecting "No program" even though they are actively developing a program and were not given the full survey to complete. An additional program that only provides plan review services answered "Other" but didn't complete the program activity-related questions. Therefore, many of the findings throughout this section are based on the 12 developing or routine programs that answered "Yes" or "Other" to having a program (percentages from these 12 are henceforth labeled with ‡).

Inspection frequency

LHJs were asked how frequently they visit schools for EH&S inspections. Only two (17%)‡ of the 12 conducted annual routine school inspections (Figure 4). Half‡ performed inspections every two to three years, including one LHJ that allows schools to self-inspect in between LHJ inspector visits. The remaining one-third‡ only inspected for complaints or as requested, or they marked "Other." As required by chapter 246-215 WAC all LHJs inspect school food service facilities twice per year. We found no reported difference between school type (public, private, etc.) or school age group (elementary, middle, and high school) frequency. The seven LHJs with full inspection programs all complete school inspections every one to three years. All LHJs surveyed conducted routine food service inspections in schools, typically twice per year. These were usually conducted separately from full EH&S inspections.

> *"[Our] program includes an innovative self-inspection model, developed with the advisory committee in 1999. It consists of risk-based inspections conducted by the health*

district, followed by re-inspections and comprehensive self-inspections conducted by school representatives. [We] assists schools in identifying and prioritizing inspection items. Accountability is ensured through written agreements, annual training and spot checks. This collaborative approach incorporates the expertise of all school partners and has resulted in strong partnerships, earlier identification/correction of health and safety concerns (more cost-effective for schools), and safer learning environments for students and the community." – Routine program

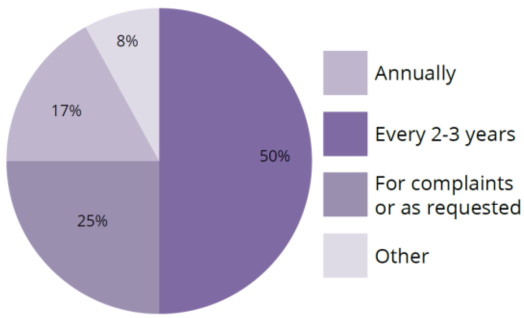

Figure 4. School inspection frequency

Hazard identification

The survey asked about the most frequently cited hazards identified by LHJ inspectors. Chemical hazards in science labs and lighting issues were the two most frequently cited, followed by playground hazards, unsafe conditions, and heating, ventilation, and air conditioning (HVAC) or poor air quality issues (Table 8). It is an important note that "playground hazards" were not included on the survey as an option but were identified in an open-ended response box connected with "Other," and were still a top hazard. Other hazards listed included chemical and physical hazards in vocational classrooms, cleanliness, chemical hazards in the classroom, and plumbing/sewage issues.

"Overall poor chemical management (for labs, arts, shop, and facilities) are perennial problems for most schools." – Routine program

"HVAC: lack of exhaust ventilation for 3D printers or CNC machines installed after initial school construction" – Routine program

The most common complaints received by LHJs include indoor air quality issues, food safety, mold and moisture issues, and general safety. The LHJ serves as a liaison between the complainant and the school district to resolve health complaints, but their response is limited by legislation and resources.

Table 8. Frequently cited hazards

Hazards cited	Total (%)‡	Routine program	Developing program
Chemical hazards in Science Labs	9 (75%)	7	2
Lighting	7 (58%)	6	1
Playground hazards*	5 (42%)	3	2
Unsafe conditions, including Maintenance conditions	5 (42%)	4	1
HVAC issues or poor air quality	5 (42%)	4	1
Chemical hazards in Vocational classrooms	4 (33%)	4	0
Physical hazards in Vocational classrooms	4 (33%)	4	0
Cleanliness	4 (33%)	4	0
Unapproved chemicals in classrooms**	3 (25%)	3	0
Plumbing/sewage issues	3 (25%)	2	1
Unsecured chemicals in classrooms**	2 (17%)	2	0
Tipping hazard*	2 (17%)	2	0
Noise	2 (17%)	2	0
Food safety	2 (17%)	0	2
Fall hazards*	1 (8%)	0	1
Electric hazards*	1 (8%)	1	0
Pests	1 (8%)	1	0
Earthquake issues***	1 (8%)	1	0
Fire hazard***	1 (8%)	1	0

**Other physical hazards written in*
***Other chemical hazards written in*
****Other hazards written in*

Corrective action

When hazards are discovered in schools, nearly three-quarters‡ of LHJs with programs follow up with schools, either immediately or at the next routine inspection, depending on severity (Figure 5). Note that one developing program did not respond and is not included in this percentage. About one-quarter do not follow up with schools at all.

Follow-up policies vary between LHJs and include requesting schools to provide their own corrective actions and time frame, documenting school responses to cited hazards, and reevaluating the hazards at the next inspection. If schools fail to address corrective actions after follow-up, over half of LHJs that follow up said there are no ramifications for schools. Only one jurisdiction described potential escalation. Note that LHJs can prevent a school from opening in the plan review phase, but in routine EH&S inspections, there are few ramifications for schools that fail to meet environmental health standards. When asked if LHJs require schools to notify the school community in the event of an imminent health hazard, one-fourth‡ selected yes, but all added caveats that notification is not required, only recommended, except for pesticide use. When asked what reasons schools give for not correcting issues after an inspection, the top two responses were lack of funding and that it was not required in regulations.

> *"Draft inspection reports are sent to schools/districts (per the K–12 Guide) via spreadsheet format. They respond with correction comments. Final reports are then issued with their comments included. We inspect with an escort, so if there are hazards*

that need immediate attention, the school/district can initiate corrective action while we are there." – Routine program

"Lack of a clear, concise code and inability to easily enforce regulations force us to dedicate a large amount of our available time coming up with solutions for school districts when they do not willingly make changes in response to inspections. While this aspect would not be removed with a new code/enforcement tool, our time commitment would be greatly reduced." – Developing program

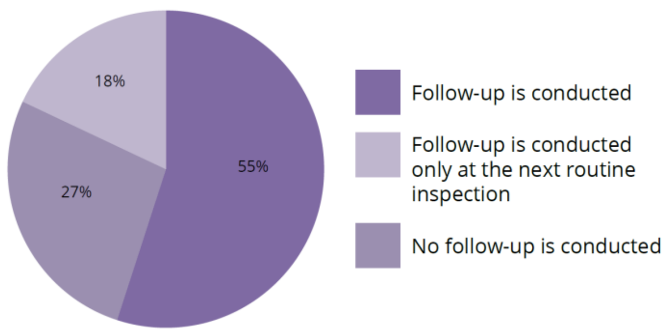

Figure 5. Corrective action follow-up

Trained workforce

All twelve LHJs with a program reported that their inspectors had received training from DOH's School Program, with three-quarters[‡] receiving training annually or more frequently, including via a weekly/biweekly Zoom meeting run by DOH. Inspectors also engaged in a variety of other trainings provided by EPA, the U.S. Centers for Disease Control and Prevention, the U.S. Food and Drug Administration, L&I, the National Association of County and City Health Officials, Washington State and National Environmental Health Associations, and the Washington Association of Maintenance and Operation Administrators. The most frequently mentioned training need described was for playgrounds—specifically, the Certified Playground Safety Inspector (CPSI) training.

Lastly, a little over one-third of LHJs surveyed publish an environmental health newsletter or keep schools regularly updated on environmental health issues. Topics covered include COVID-19 and other communicable disease prevention, food safety, and ventilation.

Chemical hazards in schools

Only one-quarter of the 22 LHJs reported surveying schools for chemical hazards, including PCBs, asbestos, lead-based paint, lead pipes, hazardous waste storage, or mercury-containing products. When asked about PCBs specifically, only one jurisdiction had any estimation of the number of PCB-containing light ballasts in current use within their jurisdiction's schools but did not maintain a list. Additionally, three LHJs reported responding to reports of leaking or smoking PCB-containing light ballasts. For the few LHJs that had surveyed schools for other chemical hazards, nearly all described the surveys as part of a larger hazardous waste program, including "Rehab the Lab,"[*] Ecology's Pollution Prevention Partnership, and their local county hazardous waste management program.

When asked about whether LHJs had knowledge of and shared current hazardous waste management funding programs, including OSPI's Lead in Water Remediation Grant and Ecology's Fluorescent Light Ballast Replacement Grant, there was a wide gap between LHJs familiar with available programs and LHJs sharing that information with schools. Over half said their inspectors were familiar with the Lead in Water grant, but only two (10%) shared information with schools. Similarly, about 40% reported familiarity with Ecology's light ballast replacement grant, but only three (14%) reported having passed along the information.

Capacity and equipment for technical support

Among the 12 LHJs with a routine or developing program, half provided technical support to schools when EH&S issues were discovered that required sampling or testing. Technical support was most frequently provided for issues related to noise control, pest control, mold and moisture management, HVAC/ventilation, and water contamination concerns. Other technical areas where support was provided included concerns around air contaminants, contaminated building supplies, electrical issues, playground safety, food safety, and building plan reviews. LHJs unable to offer technical support can usually still provide guidance and referrals to schools.

> *"Staff FTE and time limitations restrict the depth of campus safety inspection effort conducted. More importantly, the level of training and PPE provided to inspectors limits their activity. I do not expect my inspectors to be plumbers, electricians, building inspectors, and especially, hazardous waste specialists. Our best effort lies in validating a school's active managerial control of risks. For example, does a school have a chemical management plan, do they follow it, and do they have a current chemical inventory, vs looking bottle-by-bottle in each cabinet." – Routine program*

While technical support for schools is limited, many LHJs have tools locally available for sampling or testing. All 12[‡] reported having access to a light meter and sound meter, while most also reported having access to an infrared thermometer, moisture meter, and carbon dioxide monitor. Approximately half reported having access to an air flow meter, electrical tester, smoke pen for evaluating air flow, pH meter, chemical testing kit, and/or playground safety tools. Very few LHJs reported having access to chemical-protective gloves, hygrometers for humidity, carbon monoxide sensors, particle counters, light meters, total dissolved solids meters, wipe sampling supplies, voltage detectors, or respirators. No LHJs described having access to a dew point meter, wet bulb temperature monitor, radon monitor, combustible gas detector, oxidation-reduction potential meter for water, microwave tester, electrical

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[*] "Rehab the Lab" was a program funded by Ecology and implemented at the county level to assist in the removal of hazardous waste from schools. It was the most recent statewide effort to survey and remove school chemical hazards, such as lead, mercury, and otherwise outdated and unwanted chemicals. The program ran from 1998 to 2002, successfully disposing 38.2 tons of hazardous chemicals from school buildings. Ecology is in the initial stages of creating a new school lab cleanout program that will assist individual schools in identifying waste chemicals that are either expired or toxic for proper collection and disposal. While the criteria for this new grant program are not fully developed, it is projected to launch mid- to late 2023. Participating schools will be encouraged to adopt a green chemistry curriculum or switch to safer alternatives to be eligible. The application process will work similarly to Ecology's current PCB Light Replacement in Schools program, and it will initially be offered to under-resourced and tribal schools, and to Pollution Prevention Assistance partners.

gloves, or thermal infrared camera. Survey questions on sampling and testing tools for inspections were drawn from EPA's Indoor Air Quality Tools for Schools[74] and departmental exposure science expertise. Table 9 summarizes the difference between the types of reported information and technical support delivered to schools for the specified EH&S hazards and control topics. For each topic, most responses were from LHJs with routine or developing programs, but all 22 LHJs surveyed were given the opportunity to respond.

Table 9. Information and support provided by LHJs to schools

Topic	Information	Technical support
Asbestos	3 (14%)	2 (9%)
COVID-19 ventilation	12 (55%)	4 (18%)
Green cleaning	7 (32%)	2 (9%)
Lead (paint)	5 (23%)	3 (14%)
Lead (pipes)	6 (27%)	2 (9%)
Mercury	4 (18%)	3 (14%)
Mold	7 (32%)	3 (14%)
PCBs	3 (14%)	2 (9%)
Radon	2 (9%)	1 (5%)
Wildfire smoke	12 (55%)	3 (14%)

Legal authority and guidance resources

All LHJs with current or developing programs reported relying on the same three regulations, guidance documents, and state departmental resources to implement their school EH&S programs:

- Chapter 246-366 WAC[150] (last updated in 1991),
- Individual consultation with DOH School Program, and
- DOH *Health & Safety Guide*[152] (last updated in 2003).

Aside from local codes, other resources used include:

- Chapter 246-366A WAC (implementation suspended since 2009),[149,151]
- EPA *Indoor Air Quality Tools for Schools*,[74]
- EPA *Model K–12 School Environmental Health Program*,[132]
- *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards* by the National Research Council of the National Academies,[154] and
- The U.S. Consumer Product Safety Commission *Public Playground Safety Handbook*.[155]

When seeking guidance on air quality recommendations, most LHJs use:

- DOH *School Indoor Air Quality Best Management Practices Manual* (2003),[156]
- DOH School Program *Responding to Indoor Air Quality Concerns in our Schools* (2005),[157] and
- EPA *Indoor Air Quality Tools for Schools*.[74]

Other mentioned resources include the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) recommendations[158] and local guidance.

When asked what resources are most frequently used to support hazardous chemical-related recommendations, roughly half of LHJs cited:

- DOH School Program and Ecology-supported "Rehab the Lab" programs. Note that while "Rehab the Lab" occurred throughout the 1990s and early 2000s, it is still one of the most important resources for chemical hazard-related information and recommendations.

Other mentioned guidance includes:

- Ecology *Laboratory Guide for Managing Dangerous Waste* (2015)[159] and Hazardous Waste and Toxics Reduction Program,[160]
- EPA *Toolkit for Safe Chemical Management in Schools*,[127]
- Local county solid/dangerous waste program recommendations and specialists,
- Chapter 296-62 WAC: *General Occupational Health Standards*,[161]
- Ecology Pollution Prevention Assistance grant,[162] and
- Chapter 296-800 WAC: *Safety & Health Core Rules*.[163]

Finally, when asked about pest control, integrated pest management (IPM), and pesticide use, LHJs reported using:

- DOH School Program guidance (41%),
- EPA *Model Pesticide Safety & IPM Guidance Policy for School Districts*[137] (27%),
- Washington State University (WSU) *School IPM* website,[164]
- IPM Institute of North America: *IPM Standards for Schools*[165] or *IPM STAR Certification*,[166] and
- Washington State Department of Agriculture.

Unlike the previous resource questions, nearly 32% of LHJs were unsure of what guidance resources were available to consult for pest control.

Barriers, facilitators, and needs for LHJ school EH&S program implementation

All LHJs, regardless of existing program status, were asked to rank their top three program implementation-related barriers, facilitators, and support needs from a select list of factors. Programs were also given an opportunity to choose "Other" and write in a barrier, facilitator, or need not listed. Each category was then weighted using the following formula to calculate a summary score that was used to rank the factors:

*Score = (3 * Factor #1) + (2 * Factor #2) + (1 * Factor #3)*

Barriers

The top three cited barriers to program implementation—reported by at least 50% of surveyed LHJs—were lack of funding, staffing, and training, followed by the lack of a clear, concise code (Table 10Table 10). Funding and staffing were reported as greater barriers by LHJs with full inspection programs than LHJs with programs in development. Each of our key informant interviews with LHJs revealed that Foundational Public Health Services (FPHS) funds have been instrumental for LHJs developing a new program or building capacity for an existing program. The following quotes from survey comments illustrate common differences in funding and capacity constraints between LHJs with established, routine programs and those without:

"There is a constraint on FPHS funding that does not allow us to use it to replace existing fees. While we can use it to supplement existing fees, it puts us in a difficult position as LHJs with new programs can use the funding in lieu of fees, e.g., our schools pay for services, their schools don't." – Routine program

"I am contemplating a school program, but even with Foundational Health funding, it is difficult because of the historic underfunding in core programs." – Program that conducts plan review only

"We currently do not have a full school inspection program. If we were required to start one, I would need our Board of Health support and adequate funding to add FTE and inspection equipment in order to do the work. Additionally, since we don't have in-house experience, we would need training provided by DOH or coordinated regionally with LHJs that have programs currently." - Program that conducts plan review only

The top reported barriers for LHJs with programs in development were lack of training and clear codes. The following quotes from survey comments reflect sentiments from other programs in the process of developing their school EH&S programs.

"In addition, standardized and widely available training is a huge barrier—training is mostly self-led and, without a standardized program, can take up to a year to fully train a new inspector. With a high turnover rate in public health, this often leaves us with a revolving door of new/partially trained staff, which benefits neither the LHJ nor the school. A 'new inspector training' model similar to that of the DOH Food Safety Group would be extremely helpful. Standardized state forms and inspection field marking guides would significantly help training efforts as well." – Developing program

"Lack of defined codes and enforcement tools mean each interaction/inspection results in sometimes a month of follow-up and negotiation on corrections. Having defined tools for enforcement would not only minimize the need for these lengthy follow-ups but would also help significantly with standardizing our training and decision-making in the field." – Developing program

Additional barriers, in order of score, include competing priorities, time constraints, enforcement inability, resistance from school districts, COVID-19, outdated guidance, politics, and a limited understanding of requirements versus recommendations.

When asked what their perception was of the top barriers for schools in their jurisdiction with respect to meeting EH&S requirements and recommendations, LHJs reported budget constraints or lack of funding as the top barrier. This was followed by lack of staff and clear, concise regulations (Table 11).

"All of our school partners desire to have safe, healthy learning environments and all have budgetary concerns." – Routine program

Other perceived barriers for schools were lack of support from district officials, time constraints, lack of training, limited understanding of health impacts, and COVID-19.

Table 10. Top barriers for EH&S program implementation

LHJ barriers	Total (%)	Routine program	Developing program	No program	Score
Budget constraints or lack of funding	11 (50%)	3	3	5	**26**
Staffing constraints or lack of personnel	14 (64%)	4	2	8	**24**
Lack of training	11 (50%)	2	3	6	**20**
Lack of a clear, concise code	9 (41%)	2	4	3	**14**

Table 11. Top perceived barriers for school compliance

Perceived barriers	Total (%)	Routine program	Developing program	No program	Score
Budget constraints or lack of funding	18 (82%)	5	6	7	**45**
Staffing constraints or lack of personnel	15 (68%)	6	5	4	**27**
Lack of clear, concise regulations	9 (41%)	2	4	3	**13**

Facilitators

As shown in Table 12, the top factor LHJs reported as important to facilitate school EH&S program implementation was adequate funding, reported by 68% of surveyed LHJs, followed by clear, concise codes, frequent DOH training, and dedicated school EH&S personnel, aligning with the barriers reported by LHJs. LHJs with full inspection programs considered funding and clear codes to be more important facilitating factors than LHJs with programs in development.

> *"Long-term funding support through FPHS or other mechanism would be most helpful." – Routine program*

> *"We had two staff trained 5+ years ago, but our program never materialized due to funding, and these two staff have left our agency. We have new staff with no training." – No program*

Other facilitators include enforcement support, political support, county administrative support, low-cost or free training from the DOH School Program, community support, and program evaluation. Additional "Other" write-in facilitators included updated guidance, statewide consistency, ESD support, State Board of Health support, and a clear understanding of requirements versus recommendations.

> *"[Our ESD] has an industrial hygienist; that expertise and partnership allows [our] school program to focus on areas such as playground safety and student-related complaints. The industrial hygienist provides services such as sound level surveys, Asbestos Hazard Emergency Response Act inspections, employee complaint response, etc. The expertise and partnership are beneficial to schools and public health." – Routine program*

> *"Successful school programs are based on trusting, collaborative relationships with school partners, including maintenance/facilities, administrators, nurses, principals,*

teachers, ESDs, designers, etc., not on enforcement. LHJs are one piece of a very complex puzzle, which includes many agencies, funding streams, etc." – Routine program

Table 12. Top facilitating factors for EH&S program implementation

Facilitating factors	Total (%)	Routine program	Developing program	No program	Score
Adequate funding	15 (68%)	5	4	6	**40**
Clear, concise codes	13 (59%)	6	3	4	**24**
Frequent training from DOH School Program	12 (55%)	4	6	2	**20**
Personnel specifically dedicated to school EH&S	11 (50%)	3	5	3	**20**

An important facilitator identified through an additional key informant is the need to develop a risk-based model for school EH&S inspections, based on evidence from previous inspection encounters and/or a cross-sectional study of hazards identified in schools across the state. Many LHJs with routine programs have a thorough understanding of common hazards within schools in their jurisdiction, but new programs do not have the historical inspection experience to know what hazards to expect. A risk-based approach could provide the foundation for a baseline inspection form highlighting the most prevalent hazards, efficacious control measures, and technical assistance resources. Additionally, utilizing illness reporting systems established during COVID-19 response to identify situations where the school building and grounds could be contributing to student illnesses could further focus LHJs and school districts on priority areas. One LHJ used the COVID-19 reporting infrastructure to also collect data on other respiratory systems, gastrointestinal symptoms, playground-related injuries, athletics and physical education-related injuries, and other injuries. The epidemiology team at this LHJ created a dashboard to visualize the data and identify problematic trends.

Needs

Sixty-eight percent of surveyed LHJs reported clear, concise codes as a top support need from state agencies, followed by funding, technical support, low-cost training and certification, and more frequent training opportunities (Table 13). Support needs were ranked similarly by routine programs and programs in development.

Additional support needs include plan review technical assistance and training, educational materials for schools, funding for training and equipment, liaison with OSPI and school districts, enforcement support, public relations support, EH&S newsletters, and access to tools and equipment. Under "Other," LHJs wrote in long-term funding support, updated guidance, ESD industrial hygienist staff, and new program set-up guidance.

"In addition, there is a large gap with plan review training—more resources and opportunities in this area would yield a good return, as many of the issues we find on complaints/in the field could have been easily prevented during the plan review process if caught." – Developing program

Table 13. EH&S program support needs from state agencies

Needs	Total (%)	Routine program	Developing program	No program	Score
Clear, concise codes	15 (68%)	5	5	5	**26**
Funding for school EH&S program	10 (45%)	3	3	4	**16**
Technical support	12 (55%)	3	3	6	**14**
Low-cost or free training & certification	16 (73%)	5	5	6	**13**
More frequent training opportunities	10 (45%)	5	3	2	**13**

The top two reported support needs from Washington State legislators were funding and updated, enforceable regulations, both cited by over three-quarters of surveyed LHJs, followed by a clear legislative mandate (Table 14). The need for a clear mandate was ranked higher by LHJs developing their programs than by those with routine programs.

Table 14. EH&S program support needs from legislators

Needs	Total (%)	Routine program	Developing program	No program	Score
Funding for school EH&S program resources & staff	17 (77%)	5	5	7	**36**
Updated & enforceable regulations	17 (77%)	6	5	6	**36**
Clear legislative mandate	15 (68%)	3	6	6	**25**

Limitations

Our survey faced some limitations. Of 35 LHJs, we received submissions from 22, for a response rate of 63%. We recognize the time it took to complete our survey and the seasonal time in which it was delivered may have been a significant burden to LHJs. The opinions and perspectives of 13 LHJs are not included in this report, including a few LHJs with long-standing, routine programs. These LHJs represent just over 10% of public school children in the state, and all thirteen are classified as rural counties by the Washington State Office of Financial Management.[167]

Twenty-four surveys were submitted, but one LHJ submitted two surveys from different school EH&S personnel, and one LHJ submitted both an incomplete and complete survey. We used the survey from the higher-ranking personnel and the survey that was complete. As described above, there was some inconsistency in response to the question: *Does your LHJ currently have a K–12 school EH&S inspection program that focuses on health and safety issues in schools (besides food safety)?* We attempted to correct for it by making most calculations about survey programs out of the 12 LHJs with a routine or developing program that answered "Yes" to the above question. This omitted the one LHJ that responded "Yes" but only reviews construction plans and the two LHJs with developing programs that responded "No" and were, therefore, not given the opportunity to answer the full survey tool.

While we sent the survey to environmental health directors at each LHJ, some surveys were completed by someone in a different position. There are likely differences in perspective between environmental health staff in an administrative role compared to those in a technical role.

Lastly, our survey was largely based on EPA's Model K–12 School Environmental Health Program, which does not incorporate all areas of EH&S that our Washington state LHJs prioritize, such as playground safety.

> *"This survey [based on the EPA Model Program] has been challenging as it is limited in focus and does not include important priority areas such as playground safety, operational issues (e.g., testing eye washes, providing equipment user instructions) or innovative curriculum issues (e.g., necessary ventilation for adding 3D printers). Many of the areas not included in the survey are as (or more) frequently addressed than those in the EPA model program." – Routine program*

Discussion

School programs ensure that children, teachers, school staff, and other community members are kept healthy and safe within school buildings. Of the 22 LHJs surveyed, only seven currently provide routine school program services, and nearly all felt their capacity and influence was limited by outdated codes and inadequate funding. A similar number of LHJs have programs in various stages of development, and nearly all voiced the same concerns for their programs moving forward. Many without programs worry that they would not have the staff or funding to create a program if the Legislature requires regular inspections.

Outdated codes and guidance documents

> *"Since there is a proviso on WAC 246-366A, [our department] only uses it to facilitate or provide context to discussions, e.g., what was intended to be in the next iteration of the regulations, how certain terms were defined, etc." – Routine program*

> *"We are working with a 50+-year-old rule, and the Legislature refuses to fund and implement the new rule that is already over 10 years old." – Developing program*

Overwhelmingly, in both the survey results and key informant interviews, participants enumerated the many ways in which outdated codes and guidance documents affect their ability to ensure a safe school environment. When comparing Washington's currently enforceable code to the *EPA Model Program*, WAC 246-366 is outdated, limited in scope, and only provides for basic EH&S standards in school facilities. The adopted but not yet implemented WAC 246-366A contains more thorough standards than its predecessor, but it is now over a decade old and has fallen behind current federal standards and guidance for various environmental health issues. While LHJs can use these updated codes to facilitate discussions with schools, they cannot compel schools to comply until implemented.

Allowing the current implementation suspension proviso to lapse would allow the newer WAC 246-366A to come into effect.[149] The implementation of these more comprehensive standards would expand school health and safety to include a wider range of hazards and control measures, including concerns identified by the Legislature that led to the development of this report. None of the Legislature's stated hazards of concern (including PCBs, lead, asbestos, or mold) are addressed in the existing WAC 246-366, but all are in WAC 246-366A. In every interview and throughout the survey, school EH&S leads communicated the need for implementing WAC 246-366A.

However, the "new" codes, WAC 246-366A, were adopted 13 years ago and are out of date for a number of existing and emerging hazards in schools, including lead, 3D printers, wildfire smoke, and others not yet identified. Updating these codes using an evidence-based approach to identify and prioritize common existing and emerging hazards and associated best control practices will help to focus limited resources of both school district and LHJ on what really impacts health and safety in schools.

Further study is needed to elucidate priority hazards in Washington schools and identify appropriate efficacious controls. One solution would be to conduct a retrospective study, examining past inspection data from LHJs and follow-up corrective actions taken by school districts. Another approach would be to conduct a cross-sectional study using a validated survey tool in participating schools to quantify consistently identified hazards, along with control strategies used by school districts. A final approach would be to use illness and injury data collected by schools to identify impacts from hazards found in school buildings and grounds (e.g., playgrounds). It is important to note, however, that continued flexibility for program implementation will be important to those LHJs with existing collaborative relationships with schools.

> *Updated K–12 Guide, WAC 246-366-140, references the K–12 Guide (a DOH/OSPI document), so that is a higher priority for updating than the WAC. The L&I references are in particular need of an update. - Routine program*

The primary guidance document used to interpret applicable codes and control measures for identified hazards is the *Health & Safety Guide* by DOH and OSPI. The 2003 guidance document remains the most comprehensive school EH&S resource for LHJs and schools in Washington. An updated version to meet WAC 246-366A code requirements and other updates since its publication was initiated, but it remains unpublished. Until WAC 246-366A is implemented, LHJs and schools rely on a 20-year-old guide for school health and safety based predominately on outdated regulations.

If WAC 246-366A is allowed to come into effect, this guide will require substantial revision. Additionally, this guidance document will need to be updated every four years.[168] Regardless of WAC status, the Legislature could choose to initiate and fund an update to the existing guidance document. While the guide itself would not be enforceable, it could better outline current best practices for controlling priority hazards and provide recommendations for school health and safety, setting clear and consistent expectations for school health and safety across the state. It is important to note that this guide, although 20 years old, is still the top resource used by LHJs for program implementation and for guidance related to indoor air quality, hazardous chemical guidance, and pest control. Updating the Health & Safety Guide was consistently identified as one of the top facilitators to EH&S program implementation.

Inconsistency in school EH&S program implementation

> *"Since very few LHJs have a comprehensive program, those of us who do are sometimes looked upon as putting additional requirements on our schools. In addition, we are tasked with providing consultations and training to other LHJs, which takes staff time and funding." – Routine program*

The stratified state of school program scope and capacity across Washington creates inequitable environmental public health service delivery. Students in jurisdictions without a school program presumably are not receiving the same level of health and safety oversight as those jurisdictions with a fully developed and implemented EH&S program. Schools left to manage their own EH&S may differ in effective implementation based on the school district's knowledge and resources. In jurisdictions with an LHJ oversight program, schools may feel that undue burdens are placed upon them for health and safety management when compared to jurisdictions without. Additionally, our survey found that LHJs with full inspection-based programs were more likely to rely on WAC 246-366A for additional guidance than the developing programs. The influence that updated EH&S guidance documents have on LHJ technical assistance and support to school districts is likely to further disparities in program implementation across the state.

In this report, we identified inconsistencies in the school inspection process across Washington. While school program presence or absence is the primary contributor to differences in inspection comprehensiveness, even programs that perform routine inspections differ in frequency, breadth, and depth. Both annual and alternative inspection frequency models were identified and advocated for by their respective LHJs. One example of an alternative school inspection model is a multi-year rotation, giving schools the opportunity to self-inspect between LHJ inspections. A collaborative model can result in schools building their own risk management teams that, reportedly, reduce the financial burden on schools, improve school ability to identify hazards outside of LHJ inspections, and relieve staff and time burdens on LHJs.

In both our interviews and survey results, we observed significant variation in the type of inspection checklist used across programs in the state, including the use of no checklist at all. This is due in part to the minimum standards for school EH&S set by WAC 246-366 and the lack of an explicit requirement to use a survey tool. Meanwhile, the *Health & Safety Guide* serves as a surrogate checklist for LHJs that choose to use it, though inspectors are not required to use the guide during inspections. Setting clear, comprehensive expectations for both the health agency and school is important to ensuring standards are consistent across the state. A universal checklist with options for school- or jurisdiction-specific modifications can be used to achieve this goal.

Inadequate regulatory capacity to address existing and emerging hazards

Without school EH&S program implementation statewide and updated comprehensive codes, Washington is not positioned to adequately address existing or emerging hazards. The top five cited existing hazards during school inspections, according to LHJs surveyed, were chemical hazards in the lab, lighting, playground hazards, unsafe conditions including hazardous maintenance conditions, and HVAC issues or poor air quality. Lighting is the only one of these that is thoroughly covered in WAC 246-366. The other top hazards are only briefly mentioned in the code or not covered at all, like playground safety. Additionally, hazards important to the scope of this report, such as lead, PCBs, radon, asbestos, and mercury-containing products, are not directly referenced in the currently enforceable code. However, note that asbestos and mercury-containing products are regulated elsewhere.[106,169]

When a hazard is identified during an inspection, surveyed LHJs frequently described challenges with school corrective action for issues beyond the current standards set by WAC 246-366. LHJs report attempting to persuade or encourage schools to remediate known hazards in the absence of being able to cite a specific code. Lack of clear, updated regulatory guidance results in extended back-and-forth discussion between LHJs and schools. Survey responses and interviews also revealed LHJ interest in guidance that includes a clear time frame for resolution, such as those for pool or food inspections, that are based on current best control practices.

WAC 246-366A takes steps toward addressing some of these shortcomings, including chemical hazards related to laboratories and cleaning activities, playground safety, drinking water hazards such as lead and copper, and indoor air quality concerns, including mold and moisture. However, the updated Washington code regulates existing structures differently from new construction and renovations. The code is more comprehensive for new and renovated buildings, addressing various health issues such as ventilation and playground safety in greater depth. Regulations for existing structures are more limited in scope. As such, students in existing buildings may not benefit from the updated code. Neither WAC 246-366 nor WAC 246-366A include a lack of descriptive control methods to prevent and mitigate health issues in school buildings. They do not provide structure for corrective action or enforcement options for noncompliance. Additionally, neither of these codes prepares schools for new or future hazards, such as wildfire smoke, emerging diseases, and new technologies.

The gaps in currently implemented school codes have led to a piecemeal legislative approach in addressing important health and safety concerns for the state's schools. One example of this approach has been the passage of Engrossed Second Substitute House Bill (E2SHB) 1139, an act to address testing and remediation requirements for lead in school drinking water outlets.[170] Many of the requirements in E2SHB 1139 are included in WAC 246-366A, albeit the existing lead action levels are now out of date. Developing comprehensive standards that support capacity-building for school EH&S will better position Washington to protect school health now and in the future.

Equitable funding

Budgetary constraints ranked as the top barrier for LHJs implementing a school program and for schools carrying out recommendations. Funding was also by far the number one facilitating factor for a successful school program and one of the top needs from legislators. Each of our interviews with LHJs revealed that Foundational Public Health Services (FPHS) funds have been instrumental for LHJs developing a new program or building capacity for an existing program. However, the interviewees also explained that this money is strictly earmarked for certain usages and cannot be used to replace existing fees for inspections, which creates inequities in program implementation across the state.

Funding and staffing issues also heavily affect schools. According to our interviews, LHJs report schools struggle to improve health and safety for students and staff without the appropriate resources to correct identified hazards.

While the scope of this study did not include a cost-benefit analysis of impact from various legislative solutions, it did document the overwhelming sentiment of funding needs across the system. Funding and resources for capacity topped the list of concerns for LHJs seeking to develop programs, as well as those committed to sustaining their services. Key informants at all levels spoke of the need to fund remediation and control activities in both private and public schools and to eliminate contract barriers that impede efficient interventions. Stakeholders involved with the K–12 EH&S system are already currently complementing ways to reduce barriers, streamline service delivery, and leverage existing collaborations. Convening such stakeholders could provide a venue for advising the Legislature on equitable funding needs, allocations, and solutions.

Conclusion

This report identified that Washington is not currently positioned to address existing and emerging environmental health hazards in our schools. The suspension on implementation of WAC 246-366A, funding constraints, and lack of a consistent program implemented statewide, are among the current barriers to addressing the school EH&S problem. This report provides suggested recommendations for facilitating comprehensive school EH&S programming, including updating codes and guidance to be more comprehensive and up to date, increased collaboration between schools and LHJs, and funding at all levels to meet EH&S needs for capacity-building and program maintenance. Additionally, a well-designed school EH&S program can incorporate the indoor air quality key components highlighted in Aim 1. By using a comprehensive approach, Washington can ensure equity within school EH&S implementation while positioning itself to be ready for the next emerging EH&S hazard in the school environment.

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Appendices

Appendix A: Literature review supplemental materials

Supplementary Table 1. Complete search terms

SEARCH CATEGORY	SEARCH TERMS
School environment	"school*" OR "classroom*" OR "student*"
School-aged children	(child* OR kid OR kids)
	(schoolchild* OR kindergarten* OR "elementary educat*" OR "elementary school*" OR "primary educat*" OR "primary school*" OR "K-12*" OR K12 OR "1st-grade*" OR "first-grade*" OR "grade 1" OR "grade one" OR "2nd-grade*" OR "second-grade*" OR "grade 2" OR "grade two" OR "3rd-grade*" OR "third-grade*" OR "grade 3" OR "grade three" OR "4th-grade*" OR "fourth-grade*" OR "grade 4" OR "grade four" OR "5th-grade*" OR "fifth-grade*" OR "grade 5" OR "grade five" OR "6th-grade*" OR "sixth-grade*" OR "grade 6" OR "grade six" OR "intermediate general" OR "middle school*" OR "secondary educat*" OR "secondary school*" OR "7th-grade*" OR "seventh-grade*" OR "grade 7" OR "grade seven" OR "8th-grade*" OR "eight-grade*" OR "grade 8" OR "grade eight" OR "9th-grade*" OR "ninth-grade*" OR "grade 9" OR "grade nine" OR "10th-grade*" OR "tenth-grade*" OR "grade 10" OR "grade ten" OR "11th-grade*" OR "eleventh-grade*" OR "grade 11" OR "grade eleven" OR "12th-grade*" OR "twelfth-grade*" OR "grade 12" OR "grade twelve" OR "junior high*" OR highschool* OR "high school*")
Exposure term	hazard* OR exposur* OR injur* OR safe* OR accident* OR precaution* OR risk*
Focus: Playground	(playground* OR "play ground*")
Focus: Science laboratory	("school lab" OR "school laborator*" OR "school labs" OR "chemistry laborator*" OR "chem lab" OR "chem labs" OR "biology laborator*" OR "bio lab" OR "bio labs" OR "science laborator*" OR "science lab" OR "science labs" OR "science class*")
Focus: Shop, CTE, STEM, industrial arts	(shop* OR carpent* OR weld* OR architect* OR "industrial art*" OR mason* OR woodshop* OR woodwork* OR "wood work*" OR "metal-work*" OR "automotive*" OR "technology education shop*") NOT "workshop"
	(CTE OR "career-technical educat*" OR "career and technical educat*" OR "career & technical educat*" OR "career-tech educat*" OR "vocational program*" OR "vocational educat*" OR "stem lab" OR "stem labs" OR "stem laborator*" OR "stem class*")
Focus: Arts, Crafts, Cooking, Gardening	("home economic*" OR "home ec" OR "ceramic*" OR cosmet* OR cooking OR art OR arts OR craft* OR potter* OR paint* OR garden* OR darkroom*)

SEARCH CATEGORY	SEARCH TERMS
Focus: IAQ	("indoor air" OR "air quality" OR IAQ OR VOC OR VOCs OR "volatile organic compound*" OR "volatile organic chem*" OR vacuum* OR HEPA OR HVAC OR heat* OR ventilat* OR "air-condition*" OR "AC" OR "air filter*" OR "air filtrat*" OR "filtration system*" OR "PM2.5" OR "PM10" OR "particulate matter" OR dust OR allerg* OR irrita* OR "carbon monoxide" OR "carbon dioxide" OR radon OR solvent* OR fume*)
Focus: Outdoor air pollution	("bus idle*" OR "bus idling" OR "outdoor air" OR "air pollut*" OR AQI OR "air quality index" OR "school flag program*" OR "flag program*" OR diesel OR emission* OR "idling reduc*" OR "anti-idling" OR ozone OR "particle pollut*" OR smog OR "hazardous air pollut*" OR HAPs OR wildfire* OR "wild fire")
Focus: Mold & moisture	Mold OR mould "water damag*" OR condensat* OR moisture OR humid*
Focus: Drinking water	"drinking water" OR "lead in drinking water" OR "lead in water" OR "leaded plumbing" OR "lead in plumbing"
Focus: Building materials	Asbestos OR lead OR "lead-based" OR "leaded paint" OR "lead-containing" OR mercury OR PCB OR PCBs or "polychlorinated biphenyl*" OR "fluorescent light*" OR carcinogen* OR arsenic OR "preventative maint*" OR "building material*" OR renovat* OR demol* OR "off-gas*" OR formaldehyde OR "electrical hazard*"
Focus: Pests	pesticid* OR "pest control" OR "pest manag*" OR IPM OR fertiliz*
Focus: Chemical Management	"chemical manag*" OR "chemical mismanag*" OR "chemical inventor*" OR "approved chemical*" OR "chemical spill*" OR "chemical clean*" OR "chemical hygien*" OR "hazard communicat*" OR "green clean*" OR "green chem*" OR "safer clean*" OR "safer choice*" OR "safe clean*" OR "green suppl*" OR "safe chemical*" OR "green curricul*" OR "chemical safe*" OR "chemical polic*"
Focus: Cleaners & Maintenance	solvent* OR fume* OR "maintenance suppl*" OR "cleaning product*" OR "chemical spill*" OR "clean*" OR bleach* OR volatil* OR "hazardous chem*" OR "hazardous clean*" OR disinfect* OR soap* OR laund*
Focus: Comfort	Comfort* OR light OR lighting OR lights OR acoustic* OR temperat* OR noise OR heat* OR odor*
Focus: Pets	pet OR pets OR animal*
Focus: General EH&S	"environmental health" OR "environmental safe*" OR "health and safe*" OR "health & safe*" OR "EH&S" OR EHS OR "environmental public health"

Appendix B: Survey tool

2022 Local Health Jurisdiction (LHJ) K-12 School Environmental Health & Safety (EH&S) Program Survey

This survey was designed by the University of Washington's Department of Environmental & Occupational Health Sciences (DEOHS) in response to a legislative request for the purpose of understanding K-12 school environmental health and safety at a local level, specifically to understand gaps in legislation, needs of local health jurisdictions (LHJs), and barriers and facilitators to the implementation of effective, high-quality school environmental health and safety programs. The results from this survey will be summarized for a larger report on K-12 EH&S and will inform (in part) recommendations delivered to the 2023 Washington State legislative body.

This survey is to be completed by your school K-12 EH&S program lead or whoever best represents the school program within your LHJ. Please answer all questions to your best ability. This survey is expected to take 30-60 minutes. There is an "Additional Information" section at the end to place any miscellaneous information that you believe is relevant for us to understand your school EH&S program.

School K-12 EH&S Program Representative Information:

Which Local Health Jurisdiction (LHJ) do you represent?* ______
Name:* ______
Title*: ______
Years worked in the school EH&S program: ______
Phone:* ______
Email:* ______
Program website (if applicable): ______

Inspection Activity in Schools

Does your LHJ currently have a K-12 school EH&S inspection program that focuses on health and safety issues in schools (besides food safety)?	◯ No ◯ Yes ◯ Only for Public Schools ◯ Other (please specify)
If other, please specify:	__________________________
Does your LHJ conduct routine food safety inspections for K-12 schools within your jurisdiction?	◯ Yes, all schools ◯ Only for public schools ◯ Other (please specify)
If other, please specify:	__________________________
Is the inspection of school food service facilities combined with school EH&S inspections?	◯ No, conducted separately ◯ Yes, conducted at the same time ◯ Other (please specify)
If other, please specify:	__________________________
How frequently are food service inspections conducted for schools in your jurisdiction?	☐ Routinely ☐ As requested or when complaints arise ☐ Other (please specify)
Routine food service inspections occur every ____ years.	__________________________
If other, please specify:	__________________________

Who is the lead food services inspector for schools in your jurisdiction?	◯ I am the lead food services inspector ◯ Someone else (please specify):

Name: ______
Title: ______
Workplace: ______
Phone: ______
Email: ______

Please attach your fee schedule(s) for school food service inspections here:

Unless otherwise explicitly stated, the following questions refer to non-food safety related inspectional activity.

How frequently do you conduct routine EH&S inspections in schools?

	Annually	Every 2-3 years	For complaints or if requested	Other
Elementary schools	☐	☐	☐	☐
Middle or junior high schools	☐	☐	☐	☐
Senior high schools	☐	☐	☐	☐

If other, please specify (elementary school): ______________________________

If other, please specify (middle school): ______________________________

If other, please specify (high school): ______________________________

Does the inspection frequency vary based on school type (Public, Private, or other)?	◯ No, inspection frequency is the same for all schools ◯ Yes, frequency varies between school types

If yes, please explain: ______________________________

Do you maintain a digitized database of K-12 school EH&S inspections?	◯ No ◯ Yes ◯ Unsure

Please attach the fee schedule(s) associated with your K-12 EH&S program here:

Inspection Checklists

Do inspectors utilize a checklist for routine EH&S inspections?	◯ No, inspectors do not utilize a checklist ◯ Yes, inspectors utilize a checklist
If no, please explain how your inspectors track inspection activity:	______________________________
Please attach the checklist(s) used here.	

We use the following resources to implement our K-12 school EH&S program (select all that apply):

- Legal requirements & recommendations:

______ Chapter 246-366 WAC: Primary & Secondary Schools
______ Chapter 246-366A WAC: Environmental Health & Safety Standards for Primary & Secondary Schools

- EH&S guidance documents:

______ ______
______ EPA Model K-12 School Environmental Health Program
______ EPA Indoor Air Quality Tools for Schools
______ Other EH&S guidance document (please specify or attach): ___________
______ Consultation with WA DOH School Program
______ Unsure
______ Other (please specify or attach): ___________

Do schools complete a self-inspection between EH&S inspector visits?	◯ No, schools do not self-inspect ◯ Yes, schools self-inspect (please explain)
If yes, please explain self-inspection policies and procedures for schools (e.g., frequency, requirements, checklists, typical process):	______________________________
Please attach self-inspection checklist(s) if different from EH&S inspector checklist here (optional): Self-inspection policies & procedures may also be attached here:	
Do you require your schools to establish a process to notify their school community in the event of an imminent health hazard? Please explain or attach notification policies.	◯ No ◯ Yes ◯ Unsure
If yes, please explain a typical notification process:	______________________________
If yes, optionally attach a typical notification process here:	

Corrective Actions & Enforcement

What hazards, control violations, or other issues are most commonly cited by inspectors in your jurisdiction? Please check all that apply and describe.	☐ Chemical hazards in Science Labs ☐ Microbial hazards in Science Labs ☐ Chemical hazards in Vocational classrooms ☐ Physical hazards in Vocational classrooms ☐ Chemical hazards in Darkrooms ☐ Chemical hazards in Other (please specify) ☐ Physical hazards in Other (please specify) ☐ Microbial hazards in Other (please specify) ☐ Noise ☐ Lighting ☐ Unsafe conditions ☐ Plumbing/sewage issues ☐ HVAC issues or poor air quality ☐ Food safety ☐ Cleanliness ☐ Pests ☐ Waste management ☐ Other (please specify)
If "Chemical hazards in Other," please specify:	______________________
If "Physical hazards in Other," please specify:	______________________
If "Microbial hazards in Other," please specify:	______________________
If other, please specify:	______________________
Please generally describe the hazards checked above.	____________________________
Does your LHJ have procedures in place for following up on corrective actions?	◯ No follow-up is conducted ◯ Yes, follow-up is conducted (please explain procedures) ◯ Yes, follow-up is only conducted only at the next routine inspection (please explain procedures)
Please describe and/or attach follow-up policies and a typical timeline for a non-imminent health hazard.	____________________________
If follow-up is only conducted at next routine inspection, please describe and/or attach additional information about follow-up policies and a typical timeline for a non-imminent health hazard.	____________________________
Optionally, attach follow-up policies and/or a typical timeline here:	
Optionally, attach follow-up policies and/or a typical timeline here:	

Based on your experience, what reasons do schools give for not correcting items noted during an inspection? Please check all that apply.	☐ Not required in regulations ☐ Lack of funding ☐ Lack of staff ☐ Lack of specifically trained staff ☐ Disagreement with risk/control strategies ☐ Other:
If other, please specify:	__________________________
Are there ramifications if a school continues to fail to address corrective actions after follow-up?	◯ No ramifications ◯ Yes, there are ramifications for schools that fail to address corrective actions (please describe and/or attach)
Please describe ramifications for schools:	________________________________
Optionally, attach ramifications for schools:	

Sampling & Testing

When EH&S issues are discovered that require sampling or testing, does your LHJ offer technical support to schools?	◯ No, our LHJ cannot or does not offer support ◯ Yes, our LHJ offers support (please explain)
Please select all issues that your LHJ has the capacity and equipment to provide technical support for:	☐ Noise control ☐ Mold & moisture ☐ HVAC issues ☐ Air contaminants ☐ Water contamination ☐ Contaminated building supplies ☐ Electrical issues ☐ Pest control ☐ Other (please specify)
If other, please specify:	__________________________

What equipment is locally available to your EH&S inspectors for sampling or testing? Select all that apply.

For all equipment locally available, please include the brand, model, and/or year along with any other relevant details for each equipment piece if known.

Equipment	Equipment details (e.g., brand, model, year, availability)
Noise:	
______	______
Light:	
______	______
Moisture:	
______	______
______	______
______	______
______	______
Air quality:	
______	______
______	______
______	______
______	______
______	______
______	______

Water quality:
______ ______
______ ______
______ ______
______ ______
______ ______
Deposition:
______ ______
Electrical:
______ ______
______ ______
______ ______
PPE:
______ ______
______ ______
______ ______
Thermal:
______ ______
______ ______
Other:
______ ______ ______

Barriers & Facilitators to EH&S Programs

What are the top barriers for your LHJ to implementing or maintaining a K-12 EH&S program? Select all that apply.

- ☐ Budget constraints or lack of funding
- ☐ Staffing constraints or lack of personnel
- ☐ Time constraints
- ☐ Lack of training
- ☐ Competing priorities within your LHJ
- ☐ Resistance from local health boards
- ☐ Resistance from school districts
- ☐ Lack of a clear, concise code
- ☐ Inability to enforce regulations
- ☐ Other (please specify)

If other, please specify:
____

Please rank the top three barriers from #1 to #3 barrier for your LHJ:

	#1 barrier	#2 barrier	#3 barrier
Budget constraints or lack of funding	○	○	○
Staffing constraints or lack of personnel	○	○	○
Time constraints	○	○	○
Lack of training	○	○	○
Competing priorities within your LHJ	○	○	○
Resistance from local health boards	○	○	○
Resistance from school districts	○	○	○
Lack of a clear, concise code	○	○	○

Inability to enforce regulations	○	○	○
Other	○	○	○

Please include additional notes about the barriers you selected (optional): ______________________

What are the top barriers you perceive schools in your jurisdiction face in meeting EH&S requirements and/or recommendations? Select all that apply.

- ☐ Budget constraints or lack of funding
- ☐ Staffing constraints or lack of personnel
- ☐ Time constraints
- ☐ Lack of training
- ☐ Lack of support from district officials
- ☐ Lack of clear, concise regulations
- ☐ Limited understanding of health impacts
- ☐ Other (please specify)

If other, please specify: ______________________

Please rank the top three barriers from #1 to #3 barrier for schools:

	#1 barrier	#2 barrier	#3 barrier
Budget constraints or lack of funding	○	○	○
Staffing constraints or lack of personnel	○	○	○
Time constraints	○	○	○
Lack of training	○	○	○
Lack of support from district officials	○	○	○
Lack of clear, concise regulations	○	○	○
Limited understanding of health impacts	○	○	○
Other	○	○	○

Please include additional notes about the barriers you selected (optional): ______________________

What do you think are the most important factors that facilitate or could facilitate your LHJ's EH&S program? Select all that apply.

- ☐ Adequate funding
- ☐ Personnel specifically dedicated to school EH&S
- ☐ Frequent training from DOH School Program
- ☐ Low-cost or free training from DOH School Program
- ☐ Political support
- ☐ County admin support
- ☐ Community support
- ☐ Clear, concise codes
- ☐ Enforcement support
- ☐ Program evaluation
- ☐ Other (please specify)

If other, please specify: ______________________

Please rank the top three factors from #1 to #3 facilitator:

	#1 facilitator	#2 facilitator	#3 facilitator
Adequate funding	◯	◯	◯
Personnel specifically dedicated to school EH&S	◯	◯	◯
Frequent training from DOH School Program	◯	◯	◯
Low-cost or free training from DOH School Program	◯	◯	◯
Political support	◯	◯	◯
County admin support	◯	◯	◯
Community support	◯	◯	◯
Clear, concise codes	◯	◯	◯
Enforcement support	◯	◯	◯
Program evaluation	◯	◯	◯
Other	◯	◯	◯

Please include additional notes about factors that facilitate you LHJ's EH&S program (optional):

____

What additional support does your LHJ EH&S program need from state agencies? Select all that apply.

- ☐ Low-cost or free training & certification
- ☐ More frequent training opportunities
- ☐ Technical support
- ☐ Increased access to sampling tools & equipment
- ☐ Educational materials for schools
- ☐ Funding for equipment
- ☐ Funding for training
- ☐ Funding for school EH&S program
- ☐ PR support (for local Board of Health and/or school districts)
- ☐ Plan review support
- ☐ Regular newsletters on EH&S topics
- ☐ Liaison with OSPI and/or school districts
- ☐ Clear, concise codes
- ☐ Enforcement support
- ☐ Other (please specify)

If other, please specify:

____

Please rank the top three support needs from state agencies from #1 to #3 need:

	#1 need	#2 need	#3 need
Low-cost or free training & certification	◯	◯	◯
More frequent training opportunities	◯	◯	◯

Technical support	○	○	○
Increased access to sampling tools & equipment	○	○	○
Educational materials for schools	○	○	○
Funding for equipment	○	○	○
Funding for training	○	○	○
Funding for school EH&S program	○	○	○
PR support (for local BOH and/or school districts)	○	○	○
Plan review support	○	○	○
Regular newsletters on EH&S topics	○	○	○
Liaison with OSPI and/or school districts	○	○	○
Clear, concise codes	○	○	○
Enforcement support	○	○	○
Other	○	○	○

Please include additional details about your LHJ's needs from state agencies: __________________________________

What support does your LHJ need from Washington State legislators? Select all that apply.

- ☐ Funding for school EH&S program resources & staff
- ☐ Updated & enforceable regulations
- ☐ Clear legislative mandate
- ☐ Enforcement support
- ☐ Other (please specify)

If other, please specify: ____________________________

Please rank the top three support needs from legislators from #1 to #3 need:

	#1 need	#2 need	#3 need
Funding for school EH&S program resources and staff	○	○	○
Updated & enforceable regulations	○	○	○
Clear legislative mandate	○	○	○
Enforcement support	○	○	○
Other	○	○	○

Please include additional details about your LHJ's needs from legislators: __________________________________

Training

Have your school EH&S inspectors received training from WA DOH School Program?	◯ No ◯ Yes, all have received training from DOH ◯ Yes, most have received training from DOH ◯ Yes, some have received training from DOH
How frequently do EH&S inspectors receive training from WA DOH School Program?	◯ Annually or more frequently ◯ Every 2-3 years ◯ Other (please specify)
If other, please specify:	__________________________
Do your school EH&S inspectors engage in training outside of WA DOH School Program?	◯ No ◯ Yes (please explain)
If yes, please explain training received outside of DOH School Program (including other DOH training):	__________________________

Complaints

Does your LHJ respond to school-related EH&S complaints?	◯ No ◯ Yes, we always respond (please explain) ◯ Yes, we sometimes respond (please explain)
If yes, please explain (e.g., most common complaints, response process, timeline):	__________________________
If yes, please explain (e.g., why only sometimes, most common complaints, response process, timeline):	__________________________

Topic-Specific Questions:

Plan Review

Does your LHJ review plans for new construction in schools in your jurisdiction?	◯ No ◯ Yes, we review all new construction plans ◯ Yes, we review some new construction plans (please explain)
If your LHJ reviews some new construction plans, please explain:	__________________________
Does your LHJ review plans for remodels in schools in your jurisdiction?	◯ No ◯ Yes, we review all remodel plans ◯ Yes, we review some remodel plans (please explain)
If your LHJ reviews some remodel plans, please explain:	__________________________

How does your LHJ determine when repairs or remodeling are significant enough for a plan review? Please describe the threshold for a plan review. ________________________________

Indoor Air Quality (IAQ)

What guidance documents or programs are used to support indoor air quality recommendations in schools?

______ N/A, no IAQ recommendations made
______ WA DOH School Indoor Air Quality Best Management Practices Manual (2003)
______ WA DOH Responding to Indoor Air Quality Concerns in our Schools (2005)
______ WA DOH School Program
______ EPA Indoor Air Quality Tools for Schools
______ Unsure
______ Other (please specify or attach):
______
______

What guidance documents, programs, or legal requirements are used to support hazardous chemicals recommendations in schools?

______ N/A, no hazardous chemicals recommendations made
______ Chapter 296-62 WAC: General Occupational Health Standards
______ Chapter 296-800 WAC: Safety & Health Core Rules
______ WA Department of Ecology Laboratory Guide for Managing Dangerous Waste (2015)
______ WA DOH School Program
______ EPA Toolkit for Safe Chemical Management in Schools
______ "Rehab the Lab" program
______ Local hazardous waste program recommendations (please specify or attach): ______
______
______ Unsure
______ Other (please specify or attach): ______
______

Pest Control

What guidance documents or programs are used to support pest control, IPM, and pesticide use recommendations in schools?

______ N/A, no pest control recommendations made
______ WSU School IPM
______ WA DOH School Program
______ EPA Model Pesticide Safety & IPM Guidance Policy for School Districts
______ The IPM Institute of North America: IPM Standards for Schools or IPM STAR Certification
______ Unsure
______ Other (please specify or attach): ______
______

Hazardous Building Materials

Has your LHJ conducted a survey in schools for PCB building materials (e.g., lighting, caulking, waste storage)?	◯ No ◯ Yes
Please describe school survey, including what materials were surveyed and when the survey was conducted.	__________________________________
Were any samples (e.g., surface, product, or air) taken as a result of your surveys?	◯ No ◯ Yes (please explain)
What kind of samples (e.g., surface, product, air) were taken?	__________________________________
Do you have an estimated number of PCB-containing light ballasts in current use throughout schools in your jurisdiction?	◯ No, we have no information ◯ No, we do not have an estimate, but PCB ballasts are present in our schools ◯ Yes, we have an estimate (please explain) ◯ Yes, there are zero PCB ballasts in use in our schools
Do you maintain a list of PCB ballast numbers and locations in schools?	◯ No ◯ Yes
Has your LHJ ever responded to reports of leaking or smoking PCB-containing lighting ballasts?	◯ No ◯ Yes
Has your LHJ conducted a survey in schools for other hazards such as asbestos, lead-based paint, lead pipes, hazardous waste storage, or for products containing mercury?	◯ No ◯ Yes
Please describe school survey, including what hazards were surveyed and when the survey was conducted.	__________________________________

Education, Outreach, & Support

Please use the table to answer the following:

Is your LHJ familiar with the following programs?

Do inspectors share information about these programs with schools?

Have any schools in your jurisdiction utilized the following programs?

	Familiar with program	Sharing program with schools	Schools have utilized program
Lead in Water Remediation Grant - WA Office of Superintendent of Public Instruction (OSPI)	______	______	______
Fluorescent Light Ballast Replacement Grant - WA Department of Ecology	______	______	______

If available, please provide a list of schools that have utilized the Lead in Water Remediation Grant:

If a list is not available, please estimate the number of schools that have utilized the Lead in Water Remediation Grant in your jurisdiction:	______________________________
If available, please provide a list of schools that have utilized the Fluorescent Light Ballast Replacement Grant:	
If a list is not available, please estimate the number of schools that have utilized the Fluorescent Light Ballast Replacement Grant in your jurisdiction:	______________________________

Please use the table to answer the following:

Does the inspector on site or your LHJ provide information to schools on the following topics?
What specific information is provided (e.g., general information, remediation, prevention, best practices)? Does your LHJ provide support to schools for correcting issues of the following topics?

What specific support is provided (e.g., expertise, product recommendations, sampling/testing, referrals to consultants, legal assistance)?

Provides info on: Specific topics covered: Provides support for: Specific support provided:
PCBs ______ ______

______

______ ______

______

Lead (pipes) ______ ______

______

______ ______

______

Lead (paint) ______ ______

______

______ ______

______

Asbestos ______ ______

______

______ ______

______

Mercury ______ ______

______

______ ______

Radon ______ ______

______

______ ______

______

Mold ______ ______

______

______ ______

______

Wildfire smoke ______ ______

______

______ ______

______

COVID-19 ventilation ______ ______

______

______ ______

______

Green cleaning ______ ______

______

______ ______

______

Does your LHJ publish an environmental health newsletter or otherwise keep schools updated on environmental health issues?	◯ No ◯ Yes (please explain)
Please provide details on school EH&S updates, including mode of outreach, topics covered, frequency, etc.	____

Additional Information

Is there anything else you would like to share with us regarding school EH&S? We especially want to hear about your needs and ways your program can be improved. ______________________________

Appendix C: Interview guide

Key Informant Interview Template

- Introductions

- Tell me about your program.
    - [insert known info from survey about program here]

- What are the **strengths** of your school EH&S **program?**
- What are the **strengths** of your school EH&S **team**?
- What is **unique** about your program that has allowed you to thrive?

- Reflect on **recent emerging hazards** such as COVID, wildfire smoke, etc. How did your program manage these?
- What **barriers** did you face with these hazards?
- What did your program **do well**?
- Where could your program have **improved**?
- What other hazards & demands do you anticipate encountering?
    - Consider your flexibility, capacity, enforcement ability, etc.

- What are your **biggest anticipated barriers** to offering a high-quality school EH program in the next 5-10 years?

- What **recommendations** do you feel are most important to be included in our report?
- What do you want **legislators** to know about school EH&S, especially **in your community**?

- What question(s) do you think we've missed?

- Thank you!