Asthma, Particulates, and Diesel Exhaust

Leanne Chiaverini

Asthma exacerbations are caused by irritants known as "triggers." Common triggers include particulate matter and other substances in tobacco smoke and vehicular exhaust, dust mites, pet dander, cockroach feces, mold spores, pollen, and strong odors. Activity, respiratory infections, and climate (temperature and humidity) can also precipitate asthma attacks.

Particulate matter (PM), one of several major air pollutants, is considered an important asthma trigger in urban locations because of the public's heavy reliance on cars, trucks, and buses. The U.S. Environmental Protection Agency (EPA) defines PM as a mixture of solid and liquid particles in the air. The EPA and several other federal agencies have labeled it a primary air pollutant and a probable human carcinogen.[1,2] PM less than 2.5 micrometers in diameter ($PM_{2.5}$), a common component of exhaust from vehicles, power plants, and industrial facilities,[2] is of particular concern because its small size allows it to bypass the body's defenses and easily reach the deepest recesses of the lungs where it is more likely to be retained. Because PM can act as an asthma trigger, causing a decrease in lung function and inflammation of the airways, asthmatics are at a considerable risk of experiencing adverse effects from exposure to it.[2-4] Dozens of studies worldwide confirm that PM (often from diesel fuel) can aggravate or produce symptoms of asthma and other respiratory illnesses, retard lung development, and cause premature death, especially among people with cardiopulmonary diseases. A study conducted by the National Health and Environmental Effects Research Laboratory found that exposure to PM promotes airway inflammation and hyperresponsiveness.[5] High levels of PM have been linked with high levels of medication use, hospital and emergency room admissions, and work and school absences.[2-4]

The EPA estimates that diesel exhaust is the source of more than 20% of the fine PM in New England air.[6] Diesel exhaust is comprised of hundreds of constituent chemicals, many of which are harmful to both humans and the environment. Under the Clean Air Act, forty of these chemicals are classified as "hazardous pollutants;" some of them have been designated probable human carcinogens.[3] The major pollutants in diesel exhaust include:

- Diesel particulate matter (DPM)
- Polynuclear aromatic hydrocarbons (PAH)
- Nitrogen oxides (NOx)
- Volatile organic compounds (VOC), which include hydrocarbons (HC)
- Sulfur dioxide (SO2)
- Carbon monoxide (CO)[7]

PM is a significant ingredient in diesel exhaust. Composed of more than 98% $PM_{2.5}$, these particulates are very small.[4] The release of DPM into the atmosphere is caused by poor refinement of diesel fuel and incomplete fuel combustion, and

Table 1. Encapsulated History of Diesel Exhaust Policy in the United States

1970:	Congress revised the Clean Air Act, requiring 90% CO, HC and NOx reductions from light-duty diesel vehicles by 1976. Authority to regulate motor vehicle pollution was given to the United States EPA.[18]
1977:	Congress amended the Clean Air Act, requiring heavy-duty vehicles to make 90% CO and HC reductions by 1984, and a 75% NOx reduction by 1985.[18]
1982:	Air Resources Board regulates PM_{10}[4]
1985:	EPA, under the Clean Air Act, set emissions standards for new diesel-powered trucks and buses.[18]
1987:	EPA regulates PM_{10}[4]
1990:	Congress amended the Clean Air Act, including more stringent control over PM from diesel engines. EPA placed restrictions on the sulfur content of diesel fuel.[18]
1993:	EPA put forth regulations for 80% reduction of sulfur content in fuel, and 60% reduction in particulate emissions from urban buses.[18]
1993:	EPS initiated the Urban Bus Retrofit/Rebuild Program. Required that urban buses operating under certain conditions use EPA certified retrofit pollution control technology or be rebuilt using certified low emission components during engine rebuilds.[1]
1994:	EPA reduced PM standards for new diesel-powered truck and bus engines.[18]
1996:	EPA further reduced PM standards for new diesel-powered truck and bus engines.[18]
1997:	EPA adopted new National Ambient Air Quality Standards for particles under 2.5 microns in size.[4]
2000:	EPA adopted new diesel regulations requiring reduced emissions from new engines, along with the use of ultra low sulfur fuel. Expected to be fully implemented in 2010.[18]

Adapted from: Massachusetts Enhanced Emissions and Safety Test. Diesel Background. http://vehicletest.state.ma.us/dieselbg.html

is directly related to the sulfur and PAH content of the fuel.[8] NOx and VOC combine in the atmosphere to create ozone.[9] Ozone is the prime ingredient in smog, which is annually responsible for an estimated 6 million asthma attacks and 150,000 emergency room visits.[10]

Children, with airways that are small in diameter and not fully developed, are especially sensitive to diesel exhaust. "There is no known safe level of exposure to diesel exhaust for children, especially those with respiratory illness."[3] Diesel exhaust may cause difficulty in breathing, especially if airways are already inflamed or constricted by asthma. Children riding on school buses may be exposed to unusually high concentrations of DPM. In 2001, the National Resource Defense Council found this exposure to be as much as four times that of someone riding in a car in front of the bus.[11] More recently, an **Environment and Human Health, Inc.** (EHHI) research team found that concentrations of $PM_{2.5}$ in school buses were often 5-10 times higher than average levels measured at fixed-site monitoring stations.[3] Concentrations increased when buses were idling with windows open (especially when queued to load or unload students), when driving on routes with their windows closed, and when moving through heavy traffic.[3] In the United States, 24 million children make nearly 10 billion school bus rides on 600,000 school buses.[3] More than 99% of school buses in the U.S. are powered by diesel fuel.[3]

Adults are also susceptible to diesel exhaust. Occupational exposures put more than one million workers at risk for adverse health effects ranging from headaches and nausea to cancer and respiratory diseases.[12] Those occupations at increased risk include but are not limited to: workers of railroads, mines, loading docks, farms, toll booths, and bridges and tunnels; truck drivers; and auto, truck and bus mechanics/garage workers.[12]

Sources of diesel exhaust may be categorized into three groups: mobile sources (cars, trucks, tractors, lawnmowers), stationary point sources (factories, refineries, power plants), and smaller stationary area sources (dry cleaners, gas stations).[13] Heavy-duty diesel trucks and buses are a major contributor to air pollution. In the United States, heavy-duty vehicles (such as semi-trucks, buses, and waste-haulers) account for a mere 2% of all on-road vehicles, but produce one third of all nitrogen oxide emissions and almost two-thirds of all particulates from on-road vehicles.[8] Heavy-duty vehicles in Rhode Island emit 347 tons of PM per year and are responsible for 52% of the total PM emitted by all Rhode Island vehicles.[8]

The United States has been cognizant of improving air quality since the creation of the Air Pollution Control Act in 1955.[14] Major actions taken in the past three decades to reduce pollution from diesel exhaust are summarized in Table 1. The Urban Bus Retrofit Program, organized in 1993, has retrofitted or rebuilt approximately 10,000 of 42,000 eligible urban buses.[1] New diesel regulations adopted by the EPA in 2000 are expected to prevent annually an estimated 8,300 premature deaths, 360,000 asthma attacks, 386,000 cases of respiratory symptoms in asthmatic children, 1.5 million lost work days, 7100 hospital admissions, and 2400 emergency room visits for asthma.[15]

Despite these accomplishments and the development of more stringent air quality standards, the matters surrounding diesel exhaust are far from resolved. There are numerous ways to limit emissions of and exposures to diesel exhaust.

- Create and implement anti-idling programs and laws. Anti-idling campaigns, programs, and laws are an inexpensive and efficient approach to reducing diesel exhaust. Idling engines emit unnecessary toxins into the air, adding to the levels of diesel exhaust. For example, idling school buses expose children to high levels of diesel exhaust. In addition to the health impact, vehicle idling is an environmental hazard and an expensive practice. Truck drivers often leave their engines running during 6-hour sleep periods, burning approximately one gallon of diesel fuel each hour.[6] At this rate, a vehicle in operation for 300 days will idle away 1,800 gallons of fuel per year.[6] Each truck releases an annual ten pounds of particulate matter into the air, and at $1.25 per gallon, pays an idling fee of $2,250.[6] With an estimated 1.3 million large trucks and 4.2 million tractor-trailer rigs on US highways, the costs mount.[16] Companies accept this cost because it is convenient (diesels are hard to start when cold) and because running the engines keeps heaters or refrigerators running. Small generators or auxillary power units that supply heat, air conditioning and power, provide efficient alternatives to idling.[6]
- Require, promote or provide incentives to increase the use of cleaner diesel fuels and non-diesel alternatives. Pollution control devices in engines are destroyed by the sulfur in diesel fuel.[8] The use of **ultra-low sulfur diesel fuel (ULSD)**, which contains less than 15 parts of sulfur per million, can reduce PM by 20-25%.[6] To support these efforts, ULSD should be made available nationwide. Emulsified diesel fuel, which has been mixed with water and other additives, is an option for vehicles that do not remain dormant for long periods. Emulsified diesel fuel can reduce PM by 50%.[6] Other alternatives include battery electric vehicles, hybrid electric vehicles, compressed gases, and fuel cells.[8] Buses that run on natural gas emit 60-98% less carbon than diesel-powered buses.[3]
- Retrofit diesel vehicles with pollution control equipment. Heavy-duty vehicles may be retrofitted with interior air filters, oxidation catalysts, and particulate traps.[3] Use of the latter in combination with ULSD can reduce PM emissions by 90%.[6]
- Replace existing Heavy Duty Engines with newer vehicles. "Require and provide financial support for eventual replacement of existing diesel fleets with low emission vehicles, especially in areas of the country beyond compliance with current federal pollution standards."[3]
- Require routine maintenance and implement routine emissions testing. Require on-board equipment and in-use emissions testing to prevent cheating.[8]
- Federal, state and local governments, and school districts should work together to implement the following changes in school bus emissions:

  Prohibit school bus idling.

  Plan and implement a school bus retrofit program.

  Require routine maintenance and periodic tailpipe

emissions testing.

Require the design and installation of air filtration equipment capable of removing vehicle exhaust from air entering bus passenger cabins.

Limit ride duration.

Allocate buses with the lowest emissions to the longest routes, giving priority to communities with the poorest outdoor air quality and to routes that have the highest traffic intensity.

Reconsider location of bus parking lots.

Adjust contract provisions to lease retrofit buses and require clean fuels.[3]

- Account for other exposures to air pollutants. Develop air quality monitoring programs that consider indoor and within-vehicle exposure to air pollution, and establish health protective standards accordingly. Create additional stationary monitoring networks and use personal monitoring devices to collect data. Efforts to better understand the variability in exposure should begin by focusing on susceptible populations.[3]

Commentary on Public Health Briefing

Charles Sherman, MD

The increased prevalence and incidence of asthma are alarming. Although newer medications have helped in managing symptoms, only through environmental control can we expect to greatly lessen the severity of disease.

Leanne Chiaverini has written an excellent briefing on the adverse health effects of particulate matter, especially diesel exhaust particulates, for both asthmatics and non-asthmatics. She clearly summarizes the significant morbidity and mortality resulting from exposure to small particles. Of great concern is the recent association between diesel exhaust particulates and lung cancer.

Ms. Chiaverini has also outlined several interventions that can limit diesel exhaust particulates. The medical community must support these measures and become more vocal in advocating for tougher air pollution standards.

Physicians can get involved in several ways. They can testify at legislative hearings. They can write letters to local and state representatives, voicing their concerns and those of their patients. Physicians can also work directly with school administrators to devise a plan to reduce school bus emissions (before those emissions drive kids to your office). Contact Molly Clark of the American Lung Association of Rhode Island (MClark@ lungri.org or 401-421-6487) to find out how to get involved.

I often tell my patients that they would do best to live in a bubble, where all respiratory triggers could be eliminated. Given that this solution is not viable, we must control all harmful environmental exposures as a first step.

- Create safer work environments. Use safe work practices, ventilation, and personal protective equipment to protect workers who are exposed to diesel exhaust.
- Promote recycling. The burning of diesel fuel is a significant source of carbon and other greenhouse gas emissions. Recycling reduces the amount of energy used in industrial processes and transportation, thus reducing greenhouse gas emissions. Rhode Island recycling efforts in 1995 reduced greenhouse gas emissions by approximately 30,000 tons of carbon equivalent per year, an amount equal to nearly 5% of all industrial carbon dioxide emissions.[17]

As Rhode Island develops policy to manage PM in the air, the medical and public health communities must work together to assure that health concerns are given appropriate weight. In addition to formal representation at official policy forums, physicians are well-positioned as credible advocates for improved air quality.

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