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Diesel Engines: Emissions and Human Exposure


Whether you live in the city or the rural countryside, harmful diesel emissions are everywhere in our environment. Diesel engines power transit buses, construction and farm equipment, trains, and they carry our children to school. The following is a brief summary of the composition of diesel emissions and exposure to diesel emissions in our communities. Companion Clean Air Task Force diesel fact sheets include: 1) Health and Environmental Impacts, 2) Emissions Sources and Regulations, and 3) Emissions Controls and Retrofits. Also see Clean Air Task Force's 2005 Report *Diesel and Health in America: The Lingering Threat* at **www.catf.us/goto/dieselreport**/. Find out about health impacts of diesel soot in your community at **www.catf.us/goto/dieselhealth**/.

Toxic Diesel Emissions Are Released at Ground Level in Our Communities and Penetrate Our Cars, Homes, and Offices

- Unlike smokestacks, diesel emissions are released at ground level in our communities and at our places of work where they are fresh and most toxic.
- Commuters are exposed to some of the highest diesel emissions in their cars, due to pollutants released from trucks and buses on the road with them.
- Minority populations and the poor are more likely to live in cities and near diesel sources and therefore may be disproportionately impacted because their neighborhoods are exposed to some of the highest diesel exhaust levels.

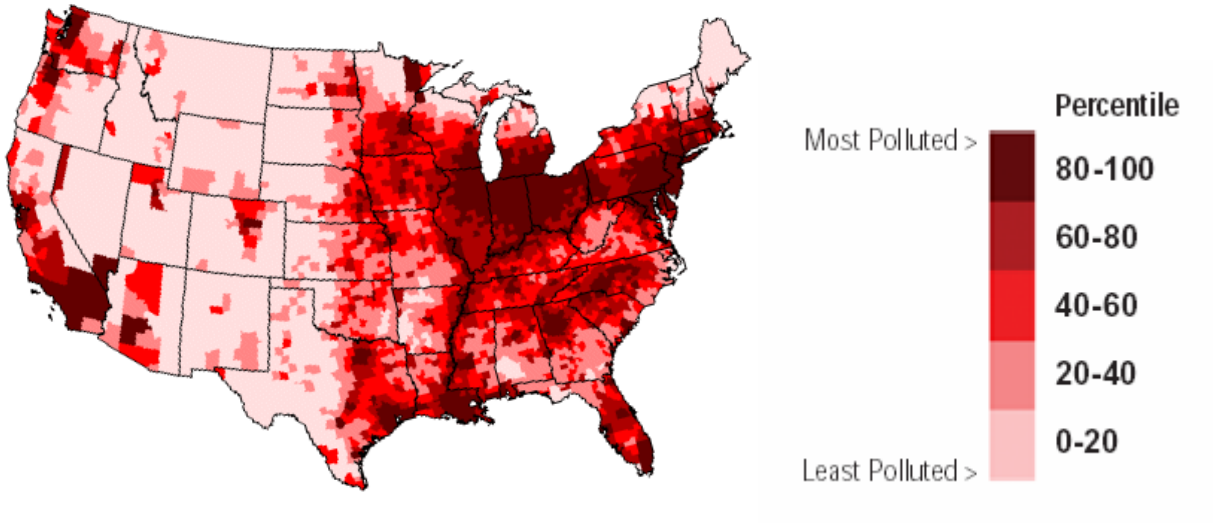
- Diesel exhaust is the largest source of particulate matter (small airborne particles) from motor vehicles. Diesel smoke from trucks and buses is trapped in 'urban canyons' and penetrates into buildings.
- Diesel exhaust from school buses idling in queues seeps into the buses through open windows and doors, exposing both the children on the buses and children waiting to board. Diesel exhaust also can get into school ventilation systems causing poor indoor air quality.
- Worse than most air toxics, long-term exposures to diesel exhaust in the general population may approach the unhealthy levels observed in some diesel-based occupations.

Diesel Emissions: A Complex Mixture of Toxic Chemicals, Some of the Most Hazardous to Human Health

- Diesel exhaust is a mixture of harmful gases and solids, including particulate matter, nitrogen oxides (NO_X), toxic metals, and toxic organic substances such as acrolein, polycyclic aromatic hydrocarbons (PAHs), and formaldehyde. See summary of some of the most harmful diesel emissions in the chart below.
- Diesel emissions contain 40 hazardous air pollutants (HAPs) listed by EPA, 15 of which are listed by the International Agency for Research on Cancer (IARC) as known, probable, or possible carcinogens.
- Diesel emissions account for one-quarter of the ozone and PM-forming nitrogen oxides emissions in the U.S.
- Diesels contribute more PM than gasoline-powered engines; two thirds of mobile source PM emitted is from diesels.[1]
- Heavy-duty diesel engines are the dominant source of diesel emissions including 95 percent of emissions from *on-road* diesels[2] and 85-90 percent of all diesel particulate matter.
- DPM typically has hundreds of chemicals ("soluble organics"), many carcinogenic, adsorbed onto their surfaces. Gaseous diesel emissions also contain toxic chemicals and irritants.[3]
- Fresh diesel particulate matter emitted by diesels includes "ultrafine" particles—less than one tenth of a micron giving them the ability to bypass the lung's natural defenses and enter the bloodstream causing cardiovascular effects. Ultrafine particulate matter is particularly concentrated within 100 meters of busy roadways according to a recent California study.[4]

Cancer-causing Pollutants in Diesel Exhaust			
Pollutant	Diesel Emissions % of all Mobile 1996	EPA Carcinogen Status	Cancer Risk (per million/microgram in 70-yr life)
Formaldehyde	52%	probable	1 in a million
Acetaldehyde	59%	probable	1 in a million
Butadiene	8%	probable	2 in a million
Acrolein	50%	possible	n/a
Benzene	5%	known	2-8 in a million
Diesel Particulate Matter	77%	probable	EPA: 12 to 1210 in a million; CARB: 300 in a million

A summary of cancer-causing pollutants from diesel engines. [5, 6, 7]



Diesel particulate matter in the U.S. (ASPEN 1999)

Diesel Particulate Matter Exposures Are High in Our Communities

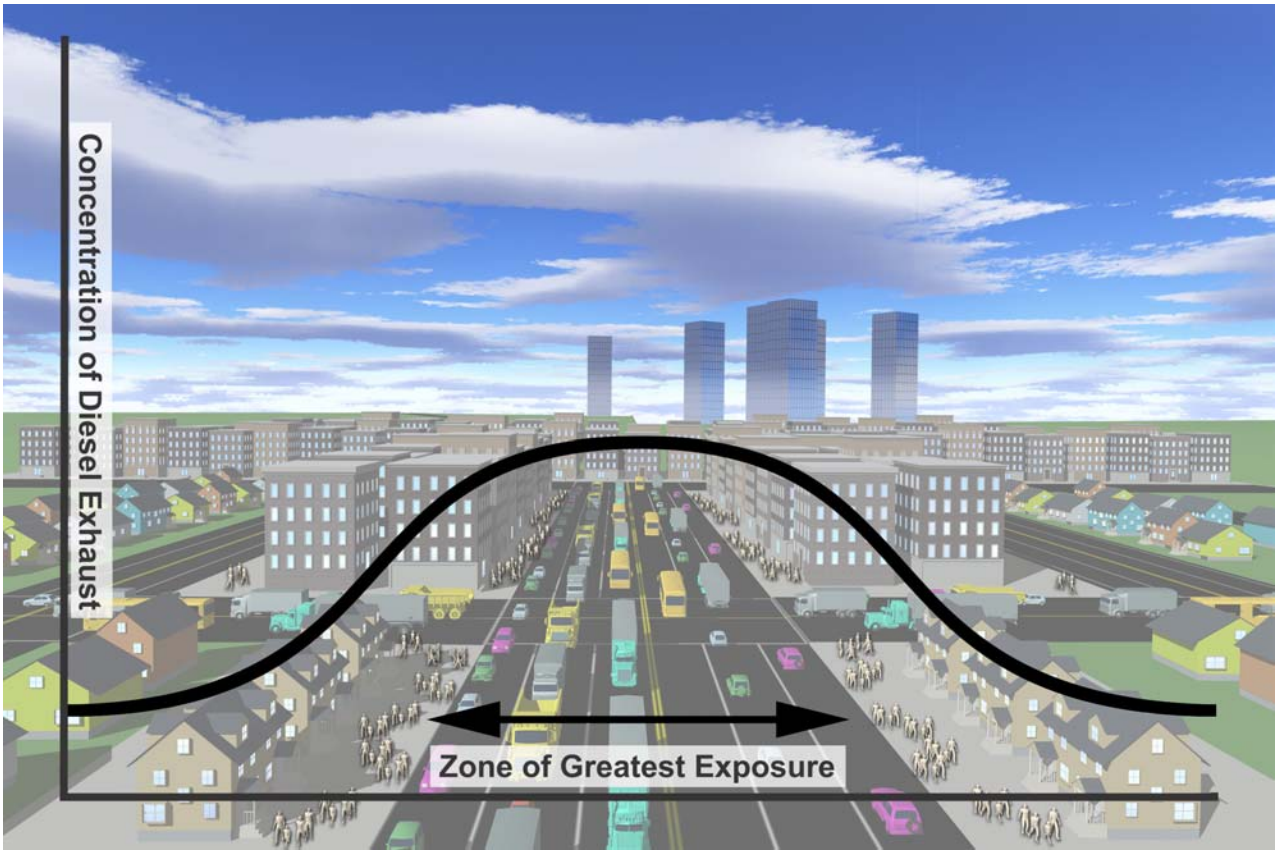
Diesels create hot spots in our urban communities in places such as downtown crossings, urban areas, bus stops, and bus depots. These areas experience chronic elevated levels of diesel PM that contribute to violations of the $PM_{2.5}$ standard.[8] These hot spots are also characterized by sharp, unhealthy short-term spikes in diesel exhaust during commuting hours. Such contributions of diesel exhaust to PM in some urban environments have been documented in studies summarized below:

- DPM is concentrated along our roadways. Diesel emissions penetrate into cars even when windows are closed.[9]

- In one roadway study at a Manhattan bus stop, DPM was estimated at 13-47 ug/m^3 (micrograms per cubic meter of air). [10]
- In California traffic, measured black carbon inside the vehicle ranged from 3-40 ug/m^3 in Los Angeles over two hours. [11]
- In another California study, Los Angeles researchers measured the following concentrations of black carbon: 5 ug/m^3 for a vehicle following no other vehicles; 15 ug/m^3 following a diesel truck with a high exhaust stack; 50 ug/m^3 following a diesel truck with a ground-level tailpipe; 130 ug/m^3 behind an urban transit bus making numerous stops. [12]

Your Individual Risk May be High if You:

- Operate or work around diesel engines – Occupational exposures to diesel are among the highest and have been associated with increased incidence of lung and bladder cancer. Furthermore, a study of diesel mechanics and train crewmen, and electricians working in a closed space near diesel generators suggests that diesel exposure may have caused both airway obstruction and serious impairment to the central nervous system. The report concludes that "impaired crews may be unable to operate trains safely."[13]
- Live or work near areas where diesel emissions are concentrated such as: highways, busy roadways, bus depots, freight warehouses or port facilities; [14] Risk levels near a California rail yard adjacent to where 14,000-26,000 people live were estimated at 100 to 500 in a million.[15] In another study, the cancer risk for persons exposed to emissions from a ferry in port and that live about 200 meters away, ranged from 50 to 280 potential cancer cases in a million.[16]
- Numerous recent medical studies have also linked roadway proximity and traffic pollution to disease, asthma hospitalizations and shortened life expectancy.[17] For example, a 2004 study in Ontario Canada found increased risk of mortality from heart and lung disease in people living within 100 meters of a roadway. New York city studies demonstrate that diesel trucks create air toxics hot spots at crossings, urban areas, bus stops, and bus depots.[18]
- Regularly ride on school or transit buses;
- Commute daily in heavy traffic or commonly drive in industrial areas; Exposures in vehicles can have serious effects: a 2004 study suggests that young male state troopers experienced cardiac inflammation and rhythm changes. [19]
- Ride on commuter trains to get to work.



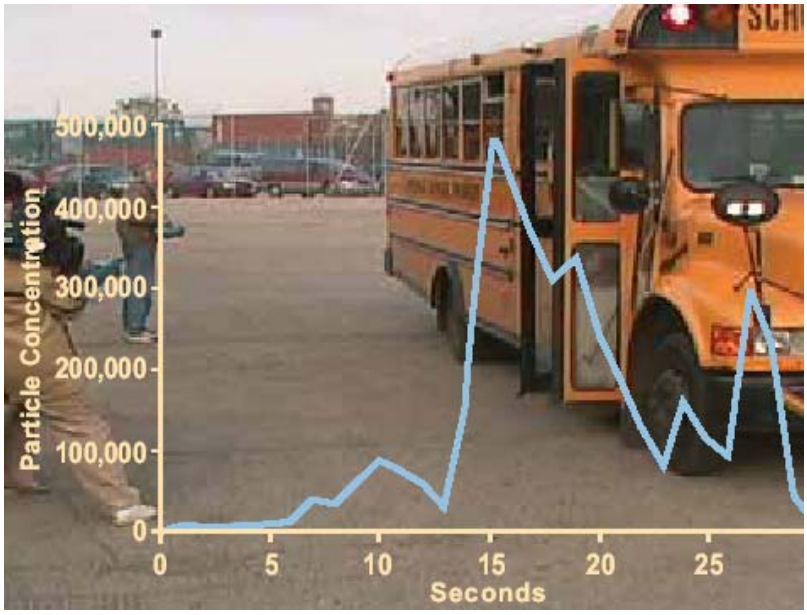
Exposure to diesel exhaust is concentrated near major roadways. (Artist: Alan Morin)

Children Breathe Hazardous Diesel Particulate Matter on School Buses.

A recent study undertaken by Clean Air Task Force in cooperation with Purdue University researchers investigated cabin air quality on yellow buses in three cities (Chicago, IL, Atlanta, GA, and Ann Arbor MI). [20] In all three U.S. cities researchers found that diesel exhaust routinely entered into the bus cabin during typical school bus routes from the tailpipe and the engine compartment through the front door.

- At many stops, levels entering the bus exceeded multiple times the level of the daily fine particle (PM2.5) standard.
- During idling and queuing—where buses are parked closely end-to-end-- rapid build up of fine particles (PM2.5), ultrafine particles and black carbon occurred.
- Most importantly and as demonstrated by CATF's research, installation of a diesel particulate filter and ultralow sulfur diesel fuel (ULSD) along with a closed crankcase filtration device eliminated all in-cabin particulate matter self-pollution including PM2.5, ultrafine particles, black carbon and particle bound PAH..
- A closed crankcase filtration system by itself has major benefits and can provide immediate and low cost reductions in particulate matter levels on school buses that have crankcase vents by rerouting the crankcase emissions back into the engine instead of into the engine compartment where it can blow into the front door of the bus.

For a comprehensive report on the study go to: http://www.catf.us/goto/schoolbusreport/.



Non-Road and On-Road NO_X Emissions Continue to Climb.

- Nitrogen oxides are the key ingredient in ground level ozone and an important source of nitrate particulate matter.
- Whereas NO_X and PM emissions from individual new on-road diesel engines have declined about 80 and 90 percent, respectively since 1970[21], the overall tons of NO_X from these sources have increased dramatically because of increases in vehicle miles traveled (VMT).
- Nationally, diesel NO_X emissions have doubled since 1970 from 2.8 million tons to the present level of 6 million tons per year in 2000 (Figure 1). Since 1980, diesel NO_X increased by 30 percent from 4.6 million tons. Since the 1990 Clean Air Act Amendments, diesel NO_X rose by 25 percent from 4.8 million tons.

Diesels Are Significant Sources of Mobile Source Air Toxics (MSATs)

- According to CATF analysis urban counties are characterized by 3 times the cancer risk of rural counties in the U.S (see: **www.catf.us/goto/dieselreport**). 83 percent of the U.S. population lives in urban areas.
- Mobile sources contribute a significant percent of the national inventory of air toxics; EPA has listed diesel particulate matter and diesel exhaust organic gases as well as formaldehyde, acrolein, and acetaldehyde as 5 of the 21 mobile source air toxics.[22]
- Of mobile sources, diesel engines contribute most significantly to acetaldehyde (47% of on-road, 73% of non-road), acrolein (29% of on-road, 57% of non road) and formaldehyde (51% of on-road, 68% of non-road).
- Diesel exhaust is a major contributor to ambient levels toxic polycyclic aromatic hydrocarbons (PAHs) that are associated with significant cancer risks.[23, 24] PAH in diesel fuels has been increasing except in California where it is limited by law.
- Particulate matter is a criteria pollutant, but diesel particulate matter, in part due to its ability to adsorb toxic gases and metals, is listed by EPA as a *motor vehicle air toxic*.
- The 1996 National Air Toxics Assessment (NATA) determined that formaldehyde (with a cancer risk of over 10 in a million) affects 100 million people in the U.S.; this is ten times

the one-in-a-million protective level for cancer established by EPA in 1989 for hazardous air pollutants.[25]

Americans are Exposed to Diesel Exhaust Levels Similar to Some Occupations.

- Most of diesel exposure and health studies have examined the health impacts in occupational exposure settings (e.g. miners, railroad workers, truckers). Few studies have assessed the health effects of diesel exhaust in our communities, however those that have suggest that there may be some overlap between exposure to workers in some occupations and long-term exposures in our communities (compare tables below.)
- Occupational exposures to diesel particulate matter are typically much higher on a short-term basis, but when adjusted for annual hours exposed (an "environmental equivalent" exposure) the dosages may be reasonably close to the range of exposures typical in urban environments.

Environment	Estimated DPM Exposure (ug/m^3)
Residences	1.9
Offices	1.6
Schools	1.9
Stores	2.1
Industrial Plants	3.0
Restaurants	2.1
Enclosed vehicles	3.0

Estimated annual average diesel particulate matter (DPM) exposures in California (Cal EPA).[26]

Occupation	Environmental Equivalent Exposure[27]
Miners	2-269
Railroad workers	8-40
Airport crew, public transit workers	2-21
Dockworkers, mechanics	1-13
Truckers	0.4-2

Table of environmental "equivalent" exposures to diesel particulate matter (EPA). This is the calculated equivalent of an occupational exposure spread over 24 hours, 7 days a week. This data suggests that the greater public is exposed to levels on the lower end of the scale of some occupational exposures (truckers for example).[28]

References.

[1] EPA, *Health Assessment Document for Diesel Exhaust:* Office of Research and Development, Sept. 2002. p.2-20.
[2] Heavy duty engines emit 95% of the pollution from all onroad diesel engines. From: the Projection of Mobile Source Air Toxics from 1996 to 2007: Emissions and Concentrations August, 2001.
[3] Health Effects Institute (1995). Diesel exhaust: a critical analysis of emissions, exposure and health effects.
[4] Zhua, Y., Hinds,W., Kimb, S., Shenc, S. and Sioutas, C. (2002). Study of ultrafine particles near a major highway with heavy-duty diesel traffic Atmospheric Environment 36 (2002) 4323–4335
[5] EPA Health Assessment for Diesel Exhaust (2002). EPA declined to assign a unit risk for DPM in the diesel HA, however EPA has indicated a probable range of 10^{-3} to 10^{-5}.
[6] EPA Health Assessment for Diesel Exhaust (2002) deemed diesel particulate matter a "likely" carcinogen, using yet to be approved terminology. "Likely" under EPA's proposed terminology is equivalent to "probable" under EPA's approved terminology.
[7] Findings of the California Air Resources Board Scientific Review Panel on *The Report on Diesel Exhaust* as adopted at the Panel's April 22, 1998, meeting. http://www.arb.ca.gov/toxics/dieseltac/de-fnds.pdf . See also, http://www.arb.ca.gov/regact/diesltac/diesltac.htm.
[8] 15 ug/m^3
[9] Lloyd, A.C., and Cackette, T.A. (2001). Diesel engines: environmental impacts and control. Journal of the Air and Waste Management Association, v. 51, p. 809-847. June 2001.
[10] Lloyd, A.C., and Cackette, T.A. (2001). Diesel engines: environmental impacts and control. Journal of the Air and Waste Management Association, v. 51, p. 809-847. June 2001.
[11] Rodes et al (1998). Measuring concentrations of selected air pollutants inside California vehicles. Report 93U-6786-000, California Air Resources Board and South Coast Air Quality Management District by Research Triangle Institute, research Triangle Park, NC.
[12] Fruin et al (2000). Fine particle and black carbon concentrations inside vehicles. 10th Annual Conference of the International Society of Exposure Analysis, Oct. , 2000.
[13] See, e.g.:

For summary of occupational studies: Cohen, A.J. and Higgins, M.W.P. (1995). Health effects of diesel exhaust: epidemiology. In Diesel Exhaust : A critical analysis of emissions, exposure and health effects. p. 251-292. Health Effects Institute, Cambridge MA. April 1995;

For most comprehensive and recent U.S. study: Railroad study: Garshick, E., Laden, F., Hart, J., Rosner, B., Smith, T., Dockery, D. and Speizer, F. (2004). Lung cancer in railroad workers exposed to diesel exhaust. Environmental Health Perspectives, v. 122, no. 15, p. 1539-1543. November 2004.

For nervous system effects: Kilburn, K.H. (2000). Effects of diesel exhaust on neurobehavioral and pulmonary functions. Archives of Environmental Health, v. 55, no. 1, p. 11-17.

[14] EPA. Analysis of the Impacts of Control Programs on Motor Vehicle Toxics Emissions and Exposure in Urban Areas and Nationwide: Volume 1, EPA420-R-99-029, November 1999, Table 10-2.
[15] California Air Resources Board (2004) Staff report: initial statement of reasons for proposed rulemaking. Proposed Regulatory Amendments Extending the California Standards for Motor Vehicle Diesel Fuel to Diesel Fuel Used in Harborcraft and Intrastate Locomotives. October 2004. Available at: http://www.arb.ca.gov/regact/carblohc/isor.pdf
[16] The number per million is the chance in a population of a million people who might be expected to get cancer over a 70-year lifetime. A potential cancer risk of 10 in a million means if one million people were exposed to a certain level of a pollutant or chemical there is a chance that 10 of them may develop cancer over their 70-year lifetime. This would be 10 new cases of cancer above the expected rate of cancer in the population. Accrording to CARB expected rate of cancer for all causes, including smoking, is about 200,000 to 250,000 chances in a million (one in four to five people).
[17] See e.g.,

Finkelstein, M. Jerrett, M., and Sears, M. (2004) Traffic air pollution and mortality rate advancement periods. American Journal of Epidemiology, v. 160, p. 173-177.

Peters, A., Von Klot, S, Heier, A., Trentinaglia, I., Hormann, A., Wichmann, E., Lowel, H. (2004). Exposure to traffic and the onset of myocardial infarction. NEJM, v. 351, no 17, October 15, 2004.

Hoek, G., Brunekreef, B., Goldbohm, S., Fischer, P. and van den Brandt, P. (2002). Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. The Lancet vol. 360, p. 1203-1209. December 19, 2002.

Brauer, M., Hoek, G., Van Vliet , P, et al (2002). Air Pollution from Traffic and the Development of Respiratory Infections and Asthmatic and Allergic Symptoms in Children. American Journal of Respiratory and Critical Care Medicine, v.166 , p. 1092-1098.

Lin, S., Munsie, J., Hwang, S., Fitzgerald, E and Cayo, M. (2002) Childhood Asthma Hospitalization and Residential Exposure to State Route Traffic. Environmental Research Section A 88, p. 73-81.

[18] See, e.g.:

Kinney, P., Aggarwal, M., Northridge, M., Janssen, N. and Shepard, P. (2000). Airborne Concentrations of PM2.5 and Diesel Exhaust Particles on Harlem Sidewalks: A Community-Based Pilot Study. Environmental Health Perspectives, vol 108, no.3.

Lena, S., Ochieng, V., Carter, M., Holguín-Veras, J., and Kinney, P.. (2002) Elemental Carbon and PM2.5 Levels in an Urban Community Heavily Impacted by Truck Traffic. Environmental Health Perspectives, vol 110, no.10.

[19]See, e.g.

Weinhold, B. (2001) Pollutants lurk inside vehicles: Don't breathe and drive? Environmental Health Perspectives, vol. 109, no. 9, September 2001

Riediker, M., Cascio,, W., Griggs, T., Herbst, M., Bromberg, P., Neas, L., Williams, R., and Devlin, R., (2004). Particulate Matter Exposure in Cars Is Associated with Cardiovascular Effects in Healthy Young Men. American Journal of Respiratory and Critical Care Medicine Vol 169. pp. 934-940, (2004)Marr, L.C., Grogan, L.A., Wohrnschimmel, H., Molina, L, Molina, M., Smith, T., Garshick, E. (2004). Vehicle traffic as a source of particulate polycyclic aromatic hydrocarbon exposure in the Mexico City metropolitan area. Environmental Science and Technology, v. 38, no. 9, p. 2584-2592.

Fruin et al (2000). Fine particle and black carbon concentrations inside vehicles. 10th Annual Conference of the International Society of Exposure Analysis, Oct. , 2000.

[20] See the full school bus report at: http://www.catf.us/publications/reports/CATF-Purdue_Multi_City_Bus_Study.php

[21] Lloyd, A. C., and Cackette, T.A. (2001). Diesel engines: Environmental Impact and Control. Journal of Air and Waste Management Association, v. 51, p. 809-847, June 2001.

[22] 40 CFR Part 80 & 86, Fed.Reg. Mar. 29, 2001 Final Rule. Control of Emissions of Hazardous Air Pollutants from Mobile Sources, p.17230-17273.

[23] www.epa.gov/ttn/atw/nata/rcharts/figure18.pdf

[24] Lloyd, A.C., and Cackette, T.A. (2001). Diesel engines: environmental impacts and control. Journal of the Air and Waste Management Association, v. 51, p. 809-847. June 2001.

[25] A 1985 court decision that said EPA had to determine that a certain level was safe or that a chosen level would provide an ample margin of safety. In 1989 EPA published its response to the court protecting the greatest number of persons possible to an individual lifetime risk level no higher than approximately one in a million. US EPA 1989k. National Emissions Standards for Hazardous Air Pollutants. 54 FR 38073. Sept. 14, 1989.

[26] California Environmental Protection Agency (1998a). Report to the California Air Resources Board on the proposed identification of diesel exhaust as a toxic air contaminant. Appendix III, part A: Exposure assessment. April 1998.

[27]EPA calculates "environmental equivalent" exposure as an occupational exposure * 0.21. The factor assumes 5 day a week daily exposure, 48 weeks per year over a 45-year career/70 year lifetime.

[28] EPA, *Health Assessment Document for Diesel Exhaust:* Office of Research and Development, September 2002.

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