APPENDIX B

IMPACTS OF DIESEL PARTICULATE MATTER

Impacts of Diesel Particulate Matter

Background

The California Legislature granted ARB the authority to identify toxic air contaminants (TACs) and establish airborne toxic control measures (ATCMs) to reduce risk. In controlling TACs, the Board is directed to address specific issues pursuant to the need for regulation (H&SC section 39665). These requirements were addressed in detail in the Diesel Risk Reduction Plan (DRRP) (ARB 2000), including the extent of present and anticipated future emissions, the estimated levels of human exposure, and the risks associated with those levels. The DRRP describes the physical and chemical characteristics of diesel particulate matter (PM) and the contribution to emissions by present sources, as well as the costs, availability, technological feasibility of control measures, and the potential adverse health or environmental impacts.

Particulate matter is the general term for tiny airborne particles. Diesel PM, emitted from engines that burn diesel fuel, is a complex mixture that consists of dry solid fragments, solid cores with liquid coatings and small droplets of liquid. These tiny particles vary greatly in shape, size and chemical composition and can be divided into several size fractions. Coarse particles are between 2.5 and ten microns in diameter, and arise primarily from natural processes, such as wind-blown dust or soil. Fine particles are less than 2.5 microns in diameter and are produced mostly from combustion or burning activities and are termed $PM_{2.5}$. Particles with an aerodynamic diameter less than or equal to a nominal ten microns (about 1/7 the diameter of a single human hair) are termed PM_{10}; PM_{10} is a criteria air pollutant for which federal and state ambient air quality standards have been set. Diesel PM is a subset of PM_{10}.

Ambient Air Quality Standards for Particulate Matter

Both the ARB and U.S. EPA have established standards for the amount of PM_{10} in the ambient air. These standards define the maximum amount of particles that can be present in outdoor air without threatening the public's health and welfare. California's current PM_{10} standard is more protective of human health than the corresponding national standard. Standards for $PM_{2.5}$ have also been established to further protect public health. These standards are shown in Table 1 below.

Table 1. State and National Particulate Matter Standards			
California Standard		**National Standard**	
PM_{10}			
Annual Arithmetic Mean	20 $\mu g/m^3$	Annual Arithmetic Mean	50 $\mu g/m^3$
24 Hour Average	50 $\mu g/m^3$	24 Hour Average	150 $\mu g/m^3$
$PM_{2.5}$			
Annual Arithmetic Mean	12 $\mu g/m^3$	Annual Arithmetic Mean	15 $\mu g/m^3$
24 Hour Average	No separate State standard	24 Hour Average	65 $\mu g/m^3$

California's ambient air quality standards are designed to protect the most sensitive sub-populations, such as children, the elderly, or people with pre-existing disease such as cardiac patients or asthmatics.

Identification of Diesel Particulate Matter as a Toxic Air Contaminant

After ten years of extensive research and public outreach, ARB identified diesel PM as a toxic air contaminant (TAC) in August 1998. As part of the identification process, Office of Environmental Health Hazard Assessment (OEHHA) evaluated the potential for diesel exhaust to affect human health.

OEHHA found that exposures to diesel PM resulted in an increased risk of cancer and an increase in chronic non-cancer health effects, including a greater incidence of cough, labored breathing, chest tightness, wheezing, and bronchitis (ARB 2000). OEHHA estimated, based on available studies, that the potential cancer risk for exposure to diesel PM in concentrations of one microgram per cubic meter ($\mu g/m^3$) ranged from 130 to 2400 excess cancers per million.

The ARB's Scientific Review Panel (SRP) approved OEHHA's determinations concerning health effects and approved the range of risk for PM from diesel-fueled engines, concluding that a value of 300 excess cancers per million people, per $\mu g/m^3$ of diesel PM, was appropriate as a point estimate of unit risk for diesel PM.

OEHHA also concluded that exposure to diesel PM in concentrations exceeding five $\mu g/m^3$ can result in a number of long-term chronic health effects. The five $\mu g/m^3$ value is referred to as the chronic reference exposure value for diesel PM. The SRP supported OEHHA's conclusion and noted that the reference exposure value may need to be lowered further as more data emerge on potential adverse chronic effects of diesel PM.

Physical and Chemical Characteristics of Diesel Particulate Matter

Diesel PM is the non-gaseous portion of the exhaust from a diesel-fueled compression ignition engine. PM emissions result primarily from incomplete combustion of fuel in the cylinder and lubrication oil that has entered the cylinder incidentally. Secondarily produced diesel PM is formed as a result of atmospheric reactions with diesel NOx emissions. Diesel PM consists of several constituents, including an elemental carbon fraction, a soluble organic fraction, and a sulfate fraction. Approximately 98 percent is smaller than 10 microns in diameter.

Diesel PM is a mixture of materials containing over 450 different components, including vapors and fine particles coated with organic substances. The State of California considers more than 40 chemicals in diesel exhaust as TACs. Table 2 below lists those chemicals.

Table 2. Substances in Diesel Exhaust Listed by California as Toxic Air Contaminants	
Acetaldehyde	Manganese compounds
Acrolein	Mercury compounds
Aniline	Methanol
Antimony compounds	Methyl Ethyl Ketone
Arsenic	Naphthalene
Benzene	Nickel
Beryllium compounds	4-Nitrobiphenyl
Biphenyl	Phenol
Bis[2-ethylhexyl]phthalate	Phosphorus
1,3-Butadiene	Polycyclic organic matter, including polycyclic aromatic hydrocarbons (PAHs) and their derivatives
Cadmium	
Chlorine	
Chlorobenzene	
Chromium compounds	
Cobalt compounds	Propionaldehyde
Creosol isomers	Selenium compounds
Cyanide compounds	Styrene
Dibutylphthalate	Toluene
Dioxins and dibenzofurans	Xylene isomers and mixtures
Ethyl benzene	o-Xylenes
Formaldehyde	m-Xylenes
Inorganic lead	p-Xylenes
Note: California Health and Safety Code section 39655 defines a TAC as "an air pollutant which may cause or contribute to an increase in mortality or in serious illness, or which may pose a present or potential hazard to human health."	

<u>Sources and Ambient Concentrations of Diesel Particulate Matter</u>

PM emissions from diesel-fueled engines come from on-road and off-road vehicles, stationary engines, portable engines. As shown in Table 3 below, in the year 2000, outdoor diesel PM concentrations were 1.8 $\mu g/m^3$ and projected to be 1.5 $\mu g/m^3$ in 2010 after accounting for current regulations. After including indoor concentrations of diesel PM, total exposure was 1.26 $\mu g/m^3$ in 2000 and projected to be 1.05 $\mu g/m^3$ in 2010.

Table 3. Estimated Exposure of Californians to Diesel Particulate Matter for 2000, 2010, and 2020 (ARB 2000)							
Exposure Location	**Estimated Average Air Exposure Concentration – 1990 ($\mu g/m^3$)**	**Estimated Average Air Exposure Concentration ($\mu g/m^3$) and Potential Risk (excess cancers/million)**					
		2000		**2010**		**2020**	
		Conc.	**Risk**	**Conc.**	**Risk**	**Conc.**	**Risk**
Outdoor Ambient	3.0	1.8	540	1.5	450	1.2	360
Indoor	2.0	1.2	360	1.0	300	0.8	240
Total	2.1	1.26	380	1.05	315	0.84	252

Health Effects of Diesel Particulate Matter

Diesel PM has been linked to a wide range of serious health problems. Particles that are deposited deep in the lungs can result in lung cancer; increased hospital admissions; increased respiratory symptoms and disease; decreased lung function, particularly in children and individuals with asthma; alterations in lung tissue and respiratory tract defense mechanisms; and premature death. Increased PM exposure causes increased cardiopulmonary mortality risk as demonstrated in a validity and causality analysis of 57 epidemiological studies. (Dab et al. 2001). Significant positive associations exist between lung cancer incidence and the number of days per year that respirable particulates (PM_{10}) exceeded several thresholds (Beeson et al.1998).

Statewide Risk Reduction Goal of Diesel Risk Reduction Plan

As noted above, diesel PM is emitted from a variety of sources, including on- and off-road diesel-fueled vehicles and stationary engines. On a statewide basis, the average potential cancer risk associated with diesel PM emissions is 540 potential cases per million statewide, with the potential risk in the South Coast Air Basin estimated to be 1,000 per million people. Compared to other air toxics the Board has identified and controlled, diesel PM emissions are estimated to be responsible for about 70 percent of the total ambient air toxics risk. In addition to these general risks, diesel PM can also present elevated localized or near-source exposures. Depending on the activity and nearness to receptors, these potential risks can range from small to 1,500 per million or more.

The goal of the Board (ARB 2000) is to reduce diesel PM emissions and the associated cancer risk by 75 percent in 2010 and 85 percent in 2020. The proposed Clean On-Road School Bus Regulation is one of a group of regulations being developed to achieve the emission reduction goals of the ARB of protecting the health of Californians by reducing the cancer risk from diesel PM and complying with legal requirements to control a TAC. Other benefits associated with reducing diesel PM emissions include increased visibility, less material damage from soiling of surfaces, and reduced incidence of non-cancer health effects, such as bronchitis, asthma, and allergy. The emission reductions obtained from this regulation will result in lower ambient PM levels and significant reductions of exposure to primary and secondary diesel PM. Lower ambient PM levels and reduced exposure, in turn, would result in a reduction of the prevalence of the diseases attributed to PM and diesel PM, including reduced incidences of hospitalizations for cardio-respiratory disease, and prevention of premature deaths.

References:

ARB 2000. Air Resources Board, "Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles," October 2000. Available at: http://www.arb.ca.gov/diesel/documents/rrpapp.htm

Beeson et al.1998. Feeson, W. Lawrence, Abbey, David D., Knutsen, Synnove F., "Long-term Concentrtaions of Ambient Air Pollutants and Incident Lung Cancer in California Adults:Results from the AHSMOG Study," Environmental Health Perspectives 106:813-822, 1998

Dab et.al. 2001. Dab, Willian, Segala, Claire, Dor, Frederic, Festy, Bernard, Lameloise, Phillipe, Le Moullec, Yvon, Le Tertre, Alain, Medina, Sylvia, Quenel, Phillipe, Wallaert, Benoit, Zmirou, Denis, "Air Pollution and health: Correlation or Causality? The Case of the Relationship between Exposure to Particles and Cardiopulmonary Mortality," Journal of the Air and Waste Management Association, 51:220-235, 2001.