AAH Tutorial #6

The Scientific Basis for Air Pollution Control Policy and Regulations

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Glossary of Terms: Scientific - I

- **Acute Health Effect** – A health effect that occurs over a relatively short period of time (e.g., minutes or hours)
- **Air Toxics** – A generic term referring to a harmful chemical (or group of chemicals) in the air that has the potential to produce adverse health effects
- **Chronic Health Effect** – A health effect that occurs over a relatively long period of time (e.g., months or years)
- **Particulate Matter (PM)** – Any material, except pure water, that exists in the solid or liquid state in the atmosphere
- **Pollutant** – foreign and/or natural substances (above their natural concentrations) occurring in the atmosphere that may result in adverse effects to humans, animals, vegetation, and/or materials
- **Primary pollutants** – that are directly emitted into the atmosphere due to various processes such as combustion
- **Secondary Pollutants** – that are generated in the atmosphere due to chemistry

Glossary of Terms: Regulatory - I

- **Ambient Air Quality Standards (AAQS) –** Health and welfare based standards for outdoor air which identify the maximum acceptable average concentrations of air pollutants during a specified period of time.
- **California Air Resources Board (ARB)** – The State's lead air quality agency consisting of an eleven-member board appointed by the Governor and several hundred employees. CARB is responsible for attainment and maintenance of the state and federal air quality standards, and is fully responsible for motor vehicle pollution control. It oversees county and regional air pollution management programs.
- **Criteria Air Pollutant –** An air pollutant for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set
- **Office of Environmental Health Hazard Assessment (OEHHA)** – A department within the California Environmental Protection Agency that is responsible for evaluating chemicals for adverse health impacts and establishing safe exposure levels.

Glossary of Terms: Regulatory - 2

- **Policy** – a plan of action to guide decisions
- **Regulation** – a legal restriction that is enforceable
- **Risk Assessment** – An evaluation of risk which estimates the relationship between exposure to a harmful substance and the likelihood that harm will result from that exposure.
- **Risk Management** – An evaluation of the need for and feasibility of reducing risk. It includes consideration of magnitude of risk, available control technologies, and economic feasibility.
- **Scientific Review Panel (SRP)** – Mandated by AB 1807, this nine-member panel advises the ARB, OEHHA, and the Department of Pesticide Regulation on the scientific adequacy of the risk assessment portion of reports issued by those three agencies in the process of identifying substances as toxic air contaminants
- **State Implementation Plan (SIP)** – A plan prepared by states and submitted to U.S. EPA describing how each area will attain and maintain national ambient air quality standards. SIPs include the technical foundation for understanding the air quality (e.g., emission inventories and air quality monitoring), control measures and strategies, and enforcement mechanisms.

Heath Effects of Air Pollution

- Short-term (Acute)
  - irritation to the eyes, nose and throat
  - headaches, nausea, and allergic reactions
  - upper respiratory infections such as bronchitis and pneumonia
  - can aggravate the medical conditions of individuals with asthma and emphysema
- Long-term (Chronic)
  - chronic respiratory disease, lung cancer, heart disease
  - damage to the brain, nerves, liver, or kidneys
  - affects the lungs of growing children
  - may aggravate or complicate medical conditions of the elderly

What is Air Pollution?

- Presence of substances in air in excess of their natural concentrations

$$Emissions \xrightarrow{Pollutants} Atmosphere \xrightarrow{Mixing\ and\ Chemistry} Receptors$$

- Emissions of these pollutants (primary) and/or their creation in the atmosphere from precursors (secondary) causes air pollution
- Air pollution can be natural (biogenic/geogenic) or man-made (anthropogenic)

Examples of Primary Pollutants

- NO_x - oxides of nitrogen
  - ~90% NO (nitric oxide), ~9% NO_2 (nitrogen dioxide), ~1% HONO (nitrous acid)
- TOG - total organic gas (can also be secondary)
  - Methane (CH_4) + US-EPA's VOC (volatile organic compounds) or California's ROG (reactive organic gas)
- CO - carbon monoxide (can also be secondary)
- SO_x - oxides of sulfur
- Particulate matter (can also be secondary)

Secondary Pollutants

- Ozone (O_3) is generated in the out-door air as a product of chemical reactions
- Formaldehyde (HCHO) is both primary and secondary (air toxic)
- NO_x is primary but lost due to chemistry as HNO_3

Criteria Pollutants

- Air quality regulations (Federal and California Clean Air Acts) specify that ambient concentrations of certain pollutants should not exceed prescribed limits - “criteria”
- These criteria or Ambient Air Quality Standards are heath based
- Examples are those for ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), PM_{10}, $PM_{2.5}$, and lead (Pb)

Criteria Pollutants (Cont.)

- California has additional criteria pollutants: sulfates, hydrogen sulfide (H_2S), visibility reducing particles (~$PM_{2.5}$)
- Stricter limits for Lake Tahoe Air Basin due to high altitude (CO) and scenic vista (visibility reducing particles)
- If a region does not meet a criterion for a given pollutant, that region is designated as "nonattainment" for that pollutant
- Nonattainment areas must prepare State Implementation Plans (which describes how the region will attain the standard)

Ambient Air Quality Standards

- National
  - **Primary:** the level of air quality necessary, with an adequate margin of safety, to protect the public health
  - **Secondary:** the level of air quality necessary to protect the public welfare from any known or anticipated adverse effect of a pollutant
- California
  - one health-based standard

Ambient Air Quality Standards

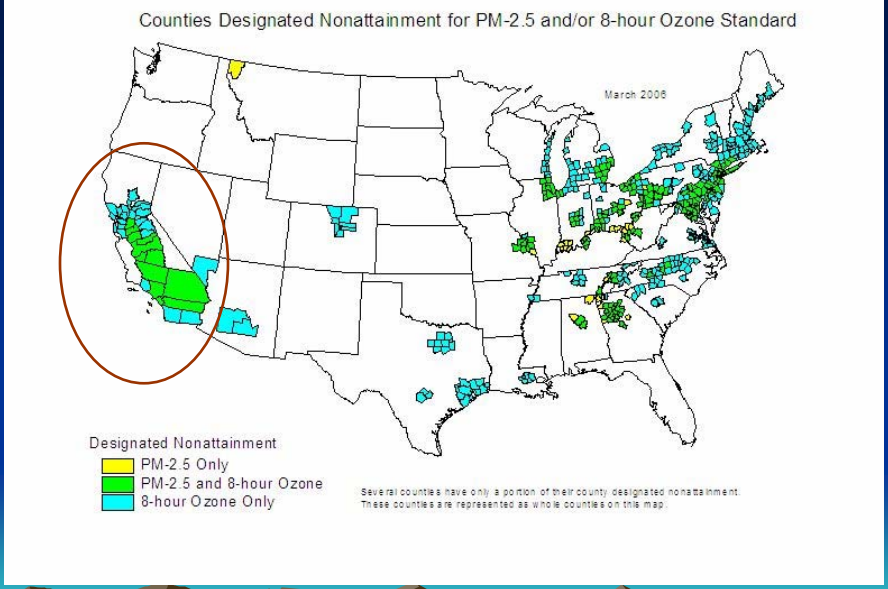
Pollutant	Averaging Time	California Standards [1]		Federal Standards [2]		
		Concentration [3]	Method [4]	Primary [3,5]	Secondary [3,6]	Method [7]
Ozone (O_3)	1 Hour	0.09 ppm (180 µg/m³)	Ultraviolet Photometry	—	Same as Primary Standard	Ultraviolet Photometry
	8 Hour	0.070 ppm (137 µg/m³)		0.08 ppm (157 µg/m³)[8]		
Respirable Particulate Matter (PM10)	24 Hour	50 µg/m³	Gravimetric or Beta Attenuation	150 µg/m³	Same as Primary Standard	Inertial Separation and Gravimetric Analysis
	Annual Arithmetic Mean	20 µg/m³		50 µg/m³		
Fine Particulate Matter (PM2.5)	24 Hour	No Separate State Standard		65 µg/m³	Same as Primary Standard	Inertial Separation and Gravimetric Analysis
	Annual Arithmetic Mean	12 µg/m³	Gravimetric or Beta Attenuation	15 µg/m³		
Carbon Monoxide (CO)	8 Hour	9.0 ppm (10mg/m³)	Non-Dispersive Infrared Photometry (NDIR)	9 ppm (10 mg/m³)	None	Non-Dispersive Infrared Photometry (NDIR)
	1 Hour	20 ppm (23 mg/m³)		35 ppm (40 mg/m³)		
	8 Hour (Lake Tahoe)	6 ppm (7 mg/m³)		—	—	—
Nitrogen Dioxide (NO_2)	Annual Arithmetic Mean	—	Gas Phase Chemiluminescence	0.053 ppm (100 µg/m³)	Same as Primary Standard	Gas Phase Chemiluminescence
	1 Hour	0.25 ppm (470 µg/m³)		—		
Sulfur Dioxide (SO_2)	Annual Arithmetic Mean	—	Ultraviolet Fluorescence	0.030 ppm (80 µg/m³)	—	Spectrophotometry (Pararosaniline Method)
	24 Hour	0.04 ppm (105 µg/m³)		0.14 ppm (365 µg/m³)	—	
	3 Hour	—		—	0.5 ppm (1300 µg/m³)	
	1 Hour	0.25 ppm (655 µg/m³)		—	—	—

Lead[9]	30 Day Average	1.5 µg/m³	Atomic Absorption	—	—	—
	Calendar Quarter	—		1.5 µg/m³	Same as Primary Standard	High Volume Sampler and Atomic Absorption
Visibility Reducing Particles	8 Hour	Extinction coefficient of 0.23 per kilometer — visibility of ten miles or more (0.07 — 30 miles or more for Lake Tahoe) due to particles when relative humidity is less than 70 percent. Method: Beta Attenuation and Transmittance through Filter Tape.		No Federal Standards		
Sulfates	24 Hour	25 µg/m³	Ion Chromatography			
Hydrogen Sulfide	1 Hour	0.03 ppm (42 µg/m³)	Ultraviolet Fluorescence			
Vinyl Chloride[9]	24 Hour	0.01 ppm (26 µg/m³)	Gas Chromatography			

See footnotes on next page ...

California Air Resources Board (5/17/06)

Found at www.arb.ca.gov/aqs/aaqs2.pdf



Air Pollution Control Policy and Regulations: The Purpose

- Needed to reduce air pollution to safeguard public health and welfare
- EPA's legal mandate is based on the Federal Clean Air Act
- ARB's legal mandate is based on the California Clean Air Act
- Policy sets the broad framework. Regulations impose legally-enforceable restrictions through rule making.

History of the Federal Clean Air Act - I

- **Air Pollution Control Act of 1955** (Public Law 84-159)
  - Provided research and technical assistance relating to air pollution control
  - First federal legislative attempt to control air pollution at its source
  - Granted $5 million annually for five years for research by the Public Health Service.
- **Amendments of 1960**
  - Extended research funding for four more years.
- **Amendments of 1962**
  - enforced the principle provisions of the original act
  - research to be done by the U.S. Surgeon General to determine the health effects of various motor vehicle exhaust substances.

History of the Federal Clean Air Act - II

- **Clean Air Act of 1963** (Public Law 88-206)
  - Improved/accelerated programs for the prevention/abatement of air pollution
  - $95 million over a three years to conduct research and create control programs.
  - Encouraged emission standards for mobile and stationary sources
- **Amendments of 1965: Motor Vehicle Air Pollution Control Act**
  - Established Standards for automobile emissions
  - Recognized the serious problem of transboundary air pollution
- **Amendments of 1966**
  - Expanded local air pollution control programs.
- **Amendments of 1967: Air Quality Act**
  - Divided parts of the nation into Air Quality Control Regions (AQCRs)
  - Established national emissions standards for stationary sources
  - Established a fixed timetable for State Implementation Plans
  - Appropriations were granted to continue research in air pollution control
- **Amendments of 1969**
  - Extended authorization for research on low emissions fuels and automobiles

History of the Federal Clean Air Act - III

- **Clean Air Act of 1970** (Public Law 91-604)
  - Amended the Clean Air Act to provide for a more effective program to improve the quality of the Nation's air by rewriting the original Clean Air Act – Turned out to be very ambitious
  - Created Environmental Protection Agency (EPA)
  - Set National Ambient Air Quality Standards (NAAQS)
  - New Source Performance Standards (NSPS)
  - New standards for hazardous and automobile emissions
  - $30 million towards research on the growing problem of noise pollution
  - Allowed citizens the right to take legal action against anyone or any organization, including the government, who is in violation of the emissions standards.
- **Amendments of 1977 – Setting realistic goals**
  - Extended deadlines for motor vehicle emissions standards and NAAQS
  - Modified the Prevention of Significant Deterioration policy
  - First attempt to prevent the destruction of stratospheric ozone

History of the Federal Clean Air Act - IV

- **Clean Air Act of 1990** (Public Law 101-549)
  - Drastically amended the Clean Air Act to provide for attainment and maintenance of health protective national ambient air quality standards
  - Designated states as being responsible for non-attainment areas
  - Raised automobile emissions standards and set a definite timetable for reductions
  - Encouraged the use of low-sulfur fuels as well as alternative fuels as a means of reducing sulfur dioxide in the atmosphere
  - Mandated the Best Available Control Technology (BACT) to reduce the amount of air toxics
  - Called for a reduction in the amount of chlorofluorocarbons (CFCs) being used as a way of preventing ozone depletion
- See www.ametsoc.org/sloan/cleanair/index.html for details.

Air Quality Management in California - I

- **1947** – **California Air Pollution Control Act**
  - Authorized the creation of an Air Pollution Control District in every county of the state
  - The Los Angeles County Air Pollution Control District (APCD) was the first of its kind in the nation
- **1950** –
  - More than 100 electric transit systems were replaced with buses in 45 cities including Los Angeles
  - California Rule 50A passed, limiting smoke based upon the Ringelmann System.
- **1955** –
  - Federal Air Pollution Control Act of 1955 enacted
  - The Bay Area APCD was established
  - Los Angeles County Motor Vehicle Pollution Control Laboratory began within the Los Angeles APCD
  - Bureau of Air Sanitation was formed within the State Department of Public Health

Air Quality Management in California - II

- 1959 –
  - Legislation requiring the state Department of Public Health to establish air quality standards and necessary controls for motor vehicle emissions
- 1960 –
  - California Motor Vehicle Pollution Control Board is established
  - Federal Motor Vehicle Act of 1960 is enacted

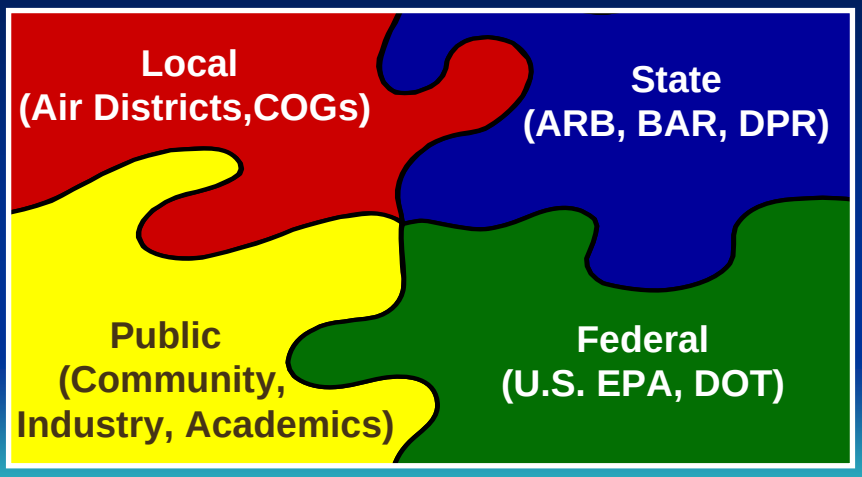
Air Quality Management in California - III

- 1967 –
  - California Air Resources Board (ARB) is created from the merging of the California Motor Vehicle Pollution Control Board and the Bureau of Air Sanitation
  - Federal Air Quality Act of 1967 is enacted
  - Allows the State of California a waiver to set and enforce its own emissions standards for new vehicles based on California's unique need for more stringent controls.
- 1969 –
  - First state Ambient Air Quality Standards are promulgated by California for total suspended particulates, photochemical oxidants, sulfur dioxide, nitrogen dioxide, and carbon monoxide
- 1971 –
  - Federal EPA promulgates National Ambient Air Quality Standards for particulates, photochemcial oxidants (including ozone), hydrocarbons, carbon monoxide, nitrogen dioxide and sulfur dioxide

Air Quality Management in California - IV

- 1988 –
  - California Clean Air Act sets forth the framework for how air quality will be managed in California for the next 20 years
- 1990 –
  - The Federal Clean Air Act Amendments of 1990. They rely largely on elements of the California Clean Air Act.
- See www.arb.ca.gov/html/brochure/history.htm for details

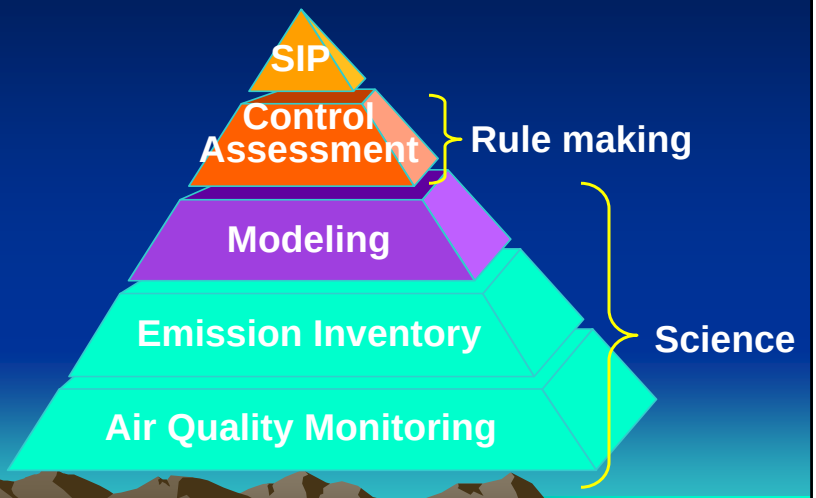
Partners for Clean Air



Who Controls What in California?

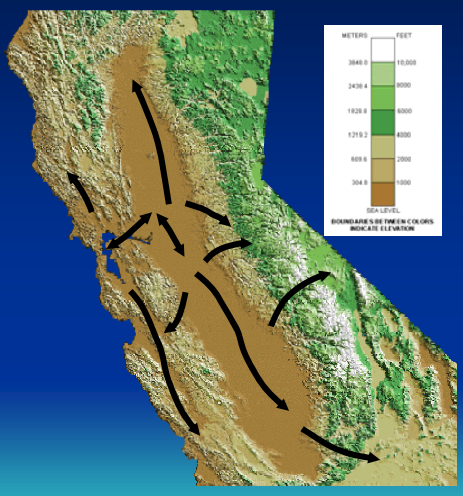
- Air Resources Board
  - Cars, trucks/buses, off-road equipment (like forklifts, lawnmowers, boats), fuels/refueling, consumer products
- Other State agencies
  - Department of Pesticide Regulation (agricultural and commercial pesticides)
  - Bureau of Automotive Repair (Smog Check)
- 35 independent local air districts
  - Stationary facilities and areawide sources
- U.S. Environmental Protection Agency
  - Interstate transportation, farm/construction equipment

Process for Developing SIPs



The San Joaquin Valley

- One of the most productive agricultural regions in the world – Cadillac Dessert
- Major goods movement corridors
- Oil production in the southern Valley
- Air Quality: Second most polluted area in the US and second most studied area in the world
- Ozone pollution in the summer and PM pollution in the winter (but the annual PM standard is controlling)



Air Quality Monitoring Stations

- Criteria and toxics monitoring
  - Compliance (routine)
  - Supplemental
  - Research
- Similar network for meteorological monitoring

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Major field studies

- 1970: Project Lo-Jet (identified summertime low-level jet and Fresno eddy)
- 1972: Aerosol Characterization Experiment (ACHEX, first TSP chemical composition and size distributions)
- 1979-1980: Inhalable Particulate Network (first long-term $PM_{2.5}$ and PM_{15} mass and elemental measurements in Bay Area, Five Points)
- 1978: Central California Aerosol and Meteorological Study (seasonal TSP elemental composition, seasonal transport patterns)
- 1979-1982: Westside Operators (first TSP sulfate and nitrate compositions in western Kern County)
- 1984: Southern SJV ozone study (first major characterization of O_3 and meteorology in Kern County)
- 1986-1988: California Source Characterization Study (quantified chemical composition of source emissions)
- 1988-89: Valley Air Quality Study (first spatially diverse, chemical characterized, annual and 24-hour $PM_{2.5}$ and PM_{10} seasonal)
- Summer 1990: San Joaquin Valley Air Quality Study/Atmospheric Utilities Signatures Predictions and Experiments (SJVAQS/AUSPEX, first central California regional study of O_3 and $PM_{2.5}$) – Also known as SARMAP (SJVAQS/AUSPEX Regional Modeling Adaptation Project)
- Winter 1995: CRPAQS Pilot Study (IMS95, first sub-regional winter study)
- December 1999 to February 2001: CRPAQS and CCOS (first year-long, regional-scale effort)
- December 1999 to present: Fresno Supersite (first multi-year experiment with advanced monitoring technology)

Key Policy Questions

- Where are the locations of greatest public exposure to air pollution?
- How much progress has been made with existing air pollution control programs?
- What additional emission reductions are needed to meet the State and National Ambient Air Quality Standards?
- What is the relative importance of the different emission sources?

Key Policy Questions (Cont.)

- What is the relative importance of emission reductions in reactive organic gases (ROG), oxides of nitrogen (NO_x), and ammonia (NH_3)?
- What is the influence of pollutant transport between and within air basins?
- Can we meet the initial 8-hour ozone (O_3), $PM_{2.5}$, and Regional Haze attainment dates? If not, what are the earliest feasible dates?

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Steps in the scientific method

1. Identify and quantify the problem
2. Formulate hypotheses about the causes of the problem
3. Design and conduct experiments to test hypotheses
4. Evaluate effectiveness of emission reduction measures
5. Implement control strategies to reduce the problem
6. Measure changes to evaluate the effectiveness of strategies
7. Go to step 1

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Limitations of the method

- Measurement and modeling technology is limited, but continually improving
- Environmental data is inherently noisy and uncertain
- Hypotheses are based on pre-conceived notions
- Atmospheric processes are nonlinear
- Control strategies have unintended consequences
- Real-world emissions differ from estimates
- Study resource requirements are high

Coordination of Air Quality Studies

- A Joint Powers Authority known as the **San Joaquin Valley-wide Air Pollution Study Agency** was formed in 1985
- It consists of:
  - **Governing Board** (elected officials)
  - **Policy Committee** (air quality planners from local/state/federal governments, industry, and environmental organizations)
  - **Technical Committee** (atmospheric scientists/engineers from local/state/federal governments and industry)
- Fosters dialog, collaboration, and consensus among participants
- Receives significant in-kind technical/coordination support from participating agencies
- Engages in significant fund raising for special studies

Central California Air Quality Studies (CCAQS) - 2000

- California Regional PM_{10}/$PM_{2.5}$ Air Quality Study (CRPAQS)
  - Builds on a pilot study in 1995-96 (IMS-95)
  - Provides the scientific basis for PM_{10}, $PM_{2.5}$, and Regional Haze State Implementation plans (SIPs)
  - 14 months
  - ~US$28 million
- Central California Ozone Study (CCOS)
  - Builds on a 1990 ozone study (SARMAP)
  - Provides the scientific basis for 1-hour and 8-hour ozone SIPs
  - 4 months in the summer
  - ~US$18 million
- Major goals of CCAQS are:
  - Further develop conceptual models of air pollution in central California
  - Obtain data for model development and validation (for the refinement of emission control strategies)
- www.arb.ca.gov/ccaqs/

Emissions Research

- Comparison of ambient measurements to emission representations for Modeling (to provide recommendations for emission inventory improvements)
- Improvements to the spatial and temporal representativeness of modeling emission estimates
- Update Integrated Transport Network
- Tunnel studies to improve mobile emissions inventory
- Validation of databases for modeling biogenic volatile organic compound emissions
- On-site dairy emission measurement using flux chambers

Meteorology Research

- Adequacy and representativeness of meteorology measurements for all seasons
- Conceptual relationship between meteorology and air quality
- Clustering of meteorology regimes (and analysis of air quality trends within those clusters)
- Application of MM5 and WRF model in complex California terrain for all seasons
- Investigation of scaling issues in prognostic meteorology models
- Alternate methods to improve MM5 model performance
  - Jackson, B., Chau., D., Gurer, K., Kaduwela, A., 2006. Comparison of ozone simulations using MM5 and CALMET/MM5 hybrid meteorological fields for the July/August 2000 CCOS episode. *Atmospheric Environment* 40(16) 2812-2822.

Chemistry Research

- The use of indicator ratios to determine limiting precursors
  - Liang, J., Jackson, B., and Kaduwela, A., 2006. Evaluation of the ability of indicator species ratios to determine the sensitivity of ozone to reductions in emissions of volatile organic compounds and oxides of nitrogen in northern California. *Atmospheric Environment, In Press.*
- Comparison of different chemical mechanisms (SAPRC99 vs. CBIV vs. CB2005)
- Improvements to chemistry solvers in air quality models
  - Lee, J., Wexler, A. Improving the efficiency of photochemical Mechanism solvers using Manifold Techniques and Artificial Neural Networks, in preparation.
- International Chemical Mechanism Conference; December 8-10, 2006; University of California at Davis
  - State-of-the-science
  - Improvements to mechanisms for aromatic compounds
  - Policy discussion on future of chemical mechanism development

Air Quality Model Improvements

- Improving mass conservation
- Investigation of aloft model performance
- Diagnostic evaluations
  - Liang, J., Kaduwela, A., Jackson, B., Gürer, K., Allen, P., 2006. Off-line Diagnostic Analysis of a three-dimensional PM model using two matrix factorization methods. *Atmospheric Environment, In Press*.
- Computer code and science improvements
  - Liang. J., Zhang, K.M., Ying, Q., Gürer, K., Allen, P., Kleeman, M., Wexler, A., Kaduwela, A., 2006. A Photochemical Model Investigation of an Extended PM Episode Captured in Central California: I. Sensitivity Simulations. *In preparation.*.

Other Significant Projects

- Development of the state-of-the-science database to house and freely distribute all special-study data
- Use of satellite products

The Rulemaking Process

- Air Toxics Control Measures (ATCM) an example and diesel exhaust as a case study
- Toxics Air Contaminants (TACs or a.k.a Air Toxics) pose a significant threat to public health in California
- Assembly Bill (AB) 1807 (California Health and Safety Code sections 39650-39674) provides ARB with legal mandate to control TACs
- AB 1807 established a two-step process: Risk assessment (or identification) and risk management (or control)
- In August 1998, ARB identified diesel PM as a TAC after a 10-year review process with OEHHA.
- The program is now in the risk management phase

Toxic Air Contaminants

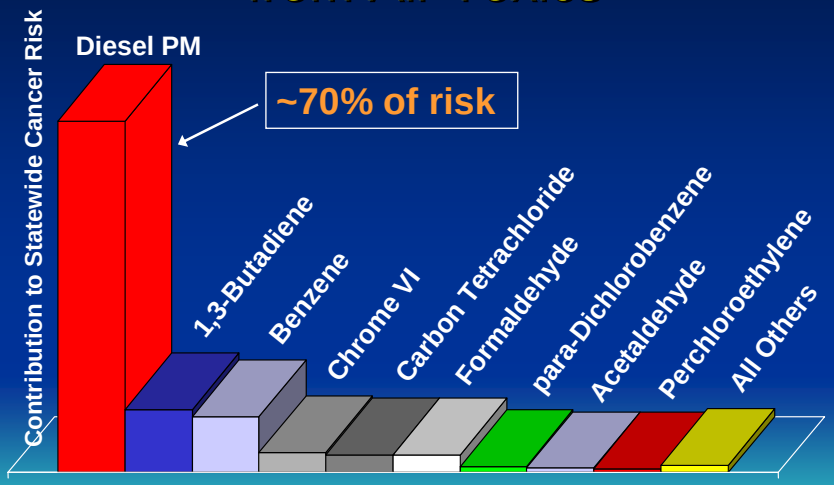
HEALTH AND SAFETY CODE SECTION 39655(a)

"Toxic air contaminant" means 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. A substance that is listed as a hazardous air pollutant pursuant to subsection (b) of Section 112 of the federal act (42 U.S.C. Sec. 7412 (b)) is a toxic air contaminant. A toxic air contaminant which is a pesticide shall be regulated in its pesticidal use by the Department of Pesticide Regulation pursuant to Article 1.5 (commencing with Section 14021) of Chapter 3 of Division 7 of the Food and Agricultural Code.

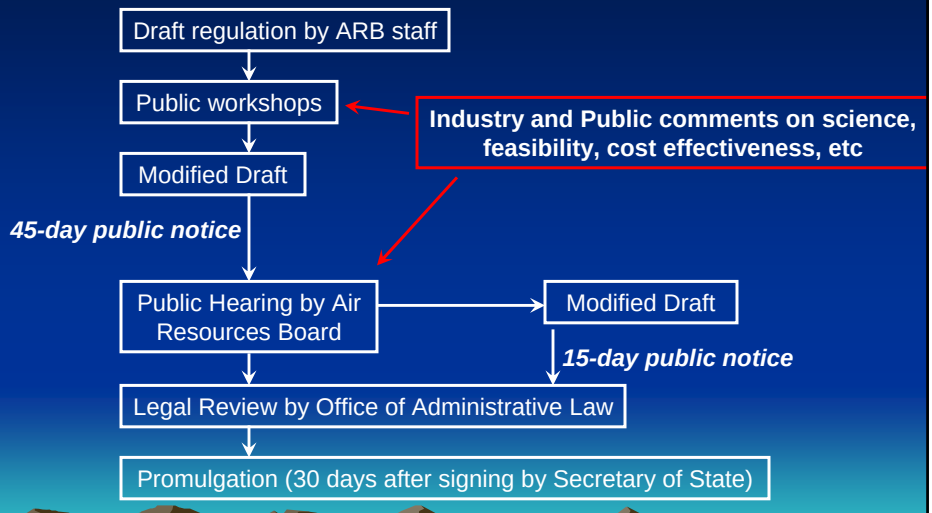
Emissions from Diesel Engines

- A complex mixture of air pollutants (gaseous and solid material or PM)
- Contains a variety of harmful gases and over 40 other cancer-causing substances
- California identified diesel PM as a toxic air contaminant based on its potential to cause cancer, premature deaths, and other health problems.
- Each year in California, diesel PM contributes to an estimated
  - 2,900 premature deaths
  - 3,600 hospital admissions
  - 240,000 asthma attacks and respiratory symptoms
  - 600,000 lost workdays
- Overall, diesel engine emissions are responsible for the majority of California's potential airborne cancer risk from combustion sources.

Diesels Dominate Cancer Risk from Air Toxics



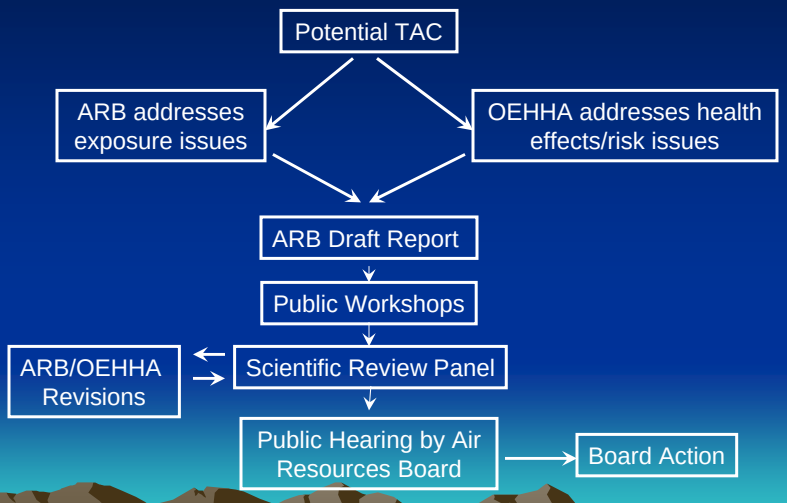
Development of a Rule



Identification of Diesel Exhaust as a TAC: Screening

- Is it used/found in California?
- How many people are exposed to it?
- How much of it is emitted?
- How long does it stay in air?
- How much of it is measured in air?
- Does it pose a potential health risk?

Identification of Diesel Exhaust as a TAC: Process



Diesel Risk Reduction Plan

- Adopted 2000
  - 75 percent risk reduction by 2010
  - 85 percent risk reduction by 2020
- Four Strategies:
  - Stringent new engine standards
  - Cleaner diesel fuel (<15 ppm sulfur)
  - Ensure in-use emissions compliance
  - Aggressive emission reductions from in-use engines

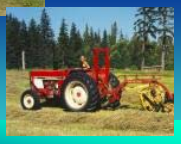
Recently Adopted Rules

- December 2005
  - Public agency/utility on-road fleets
  - Port/rail cargo handling equipment
  - Ship auxiliary engine fuel

Regulations Under Development







- 2006/07
  - On-road private fleets
  - Off-road public/private fleets
  - Harbor craft
  - Stationary agricultural engines
  - Agricultural off-road engines

Next Challenge: Ultrafine Particles

- Particles with aerodynamic diameter less than ~100 nm
- Combustion-generated ultrafine particle emissions is a research priority for ARB as some research evidence suggests that ultrafine particles may be important in the inducement of adverse health effects, but the toxicology of ultrafine particles remains poorly understood
- Until the science of ultrafine particle toxicology gives better guidance, we will continue to use particle mass as the best indicator of PM related adverse health effects

Thank you for your attention!