

CEE490 / ENVH 461

Air Pollution Control

Autumn 2009

Dr. Michael J. Pilat



What is air pollution?

- **The presence of any substances in the atmosphere in quantities which are or may be harmful or injurious to human health, welfare, animal or plant life, or property or unreasonably interfere with the enjoyment of life or property.**

Why is it important to study air pollution and air quality?

Because Human Health Effects and effects to the environment are caused by air pollution

How important is air pollution compared to other types of pollution?

Difficult to answer. Polluted water is related to human health and to the health of aquatic animals.

Water has greater *economic* significance because drinking water, irrigation water, etc. has a price (ie cities make \$ selling water) whereas Air is “free”.

There has been Air Pollution for a long time....



Chinese ink is made of soot produced by burning oil or wood in a smoke house



Indian cave painting



Cavemen used fire for energy and cooking, which also yielded air pollutants

Air Pollution serious in developing countries

Cairo (Egypt) skyline



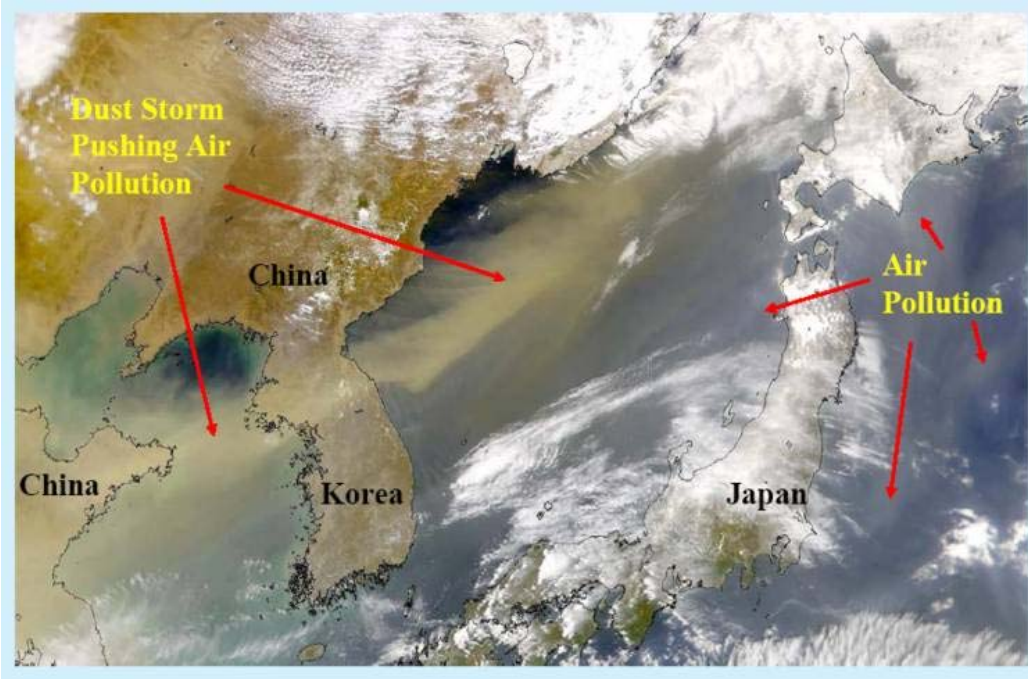
Picture courtesy Dr. Peter Raven

Indonesia Commuters wear air filter masks to clean air



Open burning of waste to recycle metals

Asian Dust Storm



A street scene in Beijing (China) during the episode



Sometimes the dust storm can reach North America in 5-7 days.

Asian Dust Cloud Over Page, Arizona



Sahara Dust

Dust off Africa Coast



Sahara dust over Austria



**Pink Sunsets in Florida
Caused by African Dust**



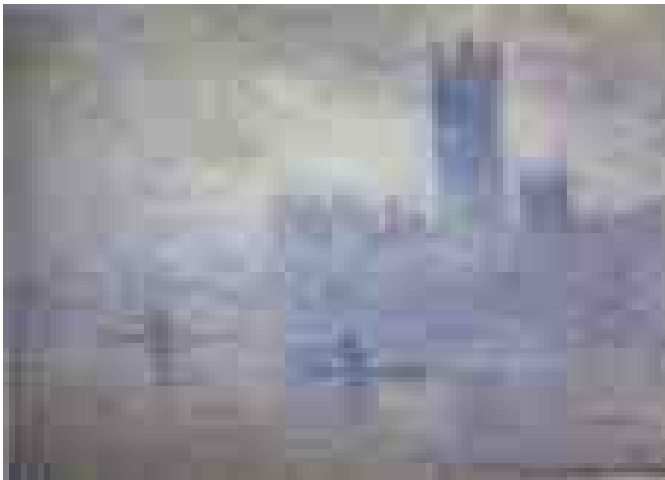
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Although air pollutants such as dust are periodically transported into the US, in general, excessive air pollutant concentrations in the US are the result of air pollutant emitted in the US; except for special cases of air pollutants transported into US from Canada (Trail BC smelter SO_2) & Mexico.

1952 London Smog



Claude Monet: House of Parliament (1904)



- In the week ending on Dec 13, 4500 people were dead due to the smog.
- From Dec 1952 through March 1953, there were over 13,500 more deaths than normal.
- Killer smog caused by excessive SO_2 & particles

Donora (Pennsylvania) Killer Smog, 1948

Noon on Oct 29, 1948



20 dead 5,190 sick



In US before 1970

St. Louis - **1939**, lanterns needed during daytime for one week;

LA - **1943**, visibility reduced to 3 blocks;

LA - **1954**, heavy photochemical smog conditions shut down industry
& schools in Oct;

New York City - **1953**, 200 dead; **1963**, 405 dead; **1965**, 65 dead;
1966, 168 dead (caused by excess SO₂ & particles)

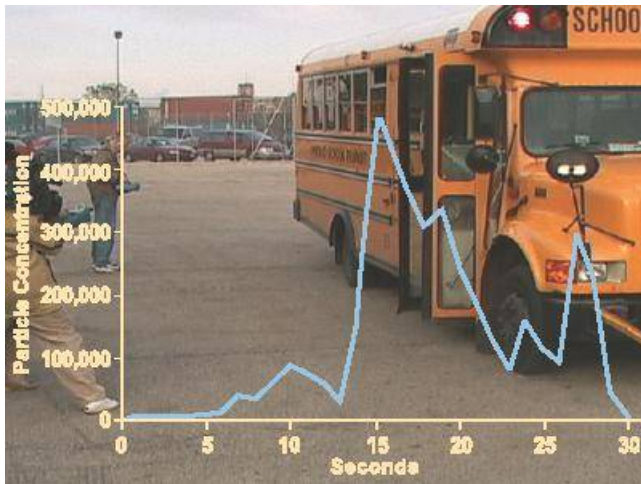
Has Seattle ever had a “Killer Smog”?

No. Need SO₂ for the classic “Killer Smog” and there are very few SO₂ emissions in this area.

However, Seattle area has been repeatedly ranked by EPA in the top 10 worst US cities with regards to hazardous and toxic air pollutants (primarily from diesel engine exhausts).

Air Pollution in developed countries nowadays ...

Soot from diesel engines



Diesel emissions cause most of air pollutant cancer in the Puget Sound region of Wash State

Allergy



Why are tire fires allowed to burn?
Difficult to extinguish
Concern for polluting nearby streams or groundwater
Desire to get rid of tires
(Tire fire near Everett WA allowed to burn for weeks with high toxic air pollutant concentrations resulting)



Reduced atmospheric visibility

Glen Canyon

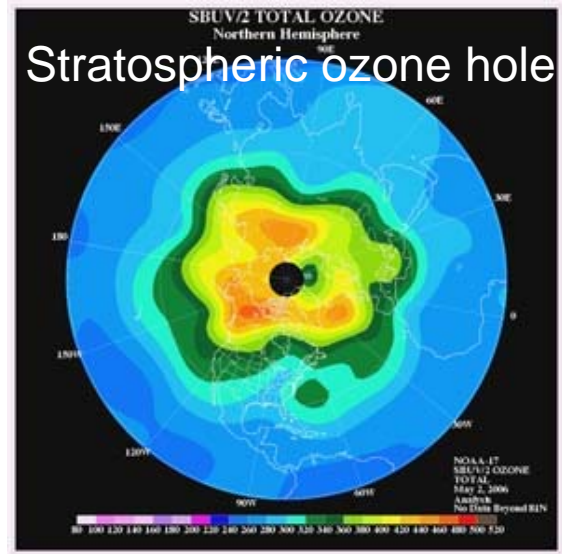


St. Louis, Missouri



On a Global Scale ...

Climate Change



Acid Deposition



How to improve the air quality we breathe?

- **First task is to know the air quality and the air we breathe.**
 - **Establish emission regulations**
autos have gms/mile limits for CO, NO_x, particles, HC;
industries, power plants have BACT (Best Available Control Technology)
 - **Set up strategies for regulation implementation**
State Implementation Plan or “SIP”
Wash State and Puget Sound Clean Air Agency are required to develop a new SIP for the South Tacoma area where measured particle concentrations (PM 2.5) exceed the National Ambient Air Quality Standards (NAAQS)

Air pollutant concentrations measured at air monitoring stations operated by government agencies (Puget Sound Clean Air Agency, Wash. Dept of Ecology)

Air quality must meet NAAQS at all *outdoor* locations where the public has access. There are no indoor air quality standards in the US (no air standards for More 220 air).

US National Ambient Air Quality Standards (NAAQS)

Pollutant	Primary Stds.	Averaging Times	Secondary Stds.
Carbon Monoxide CO	9 ppm (10 mg/m ³)	8-hour ⁽¹⁾	None
	35 ppm (40 mg/m ³)	1-hour ⁽¹⁾	None
Pb	1.5 µg/m ³	Quarterly Ave	Same as Primary
NO ₂	0.053 ppm (100 µg/m ³)	Annual (Arith. Mean)	Same as Primary
PM ₁₀	Revoked ⁽²⁾	Annual ⁽²⁾ (Arith. Mean)	
	150 µg/m ³	24-hour ⁽³⁾	
PM _{2.5}	15.0 µg/m ³	Annual ⁽⁴⁾ (Arith. Mean)	Same as Primary
	35 µg/m ³	24-hour ⁽⁵⁾	
Ozone O ₃	0.08 ppm	8-hour ⁽⁶⁾	Same as Primary
	0.12 ppm	1-hour ⁽⁷⁾ (Applies only in limited areas)	Same as Primary
Sulfur Dioxide SO ₂	0.03 ppm	Annual (Arith. Mean)	-----
	0.14 ppm	24-hour ⁽¹⁾	-----
	-----	3-hour ⁽¹⁾	0.5 ppm (1300 µg/m ³)

What are the types of air pollutants?

- **By Physical State:**
 - **Gases, Vapors (e.g. CO, CO₂, SO₂, NO_x, benzene)**
 - **Particles (e.g. sulfate, nitrate, mineral dust)**
- **By source**
 - **Natural (e.g. volcano, vegetation emission, forest fire, soil erosion, electrical storm): geogenic, biogenic**
 - **Anthropogenic (fuel combustion, industrial processes, transportation, agricultural activities, waste disposal)**
 - **Primary (emitted) vs secondary (product of atmospheric reaction such as Ozone)**
 - **Mobile (motor vehicles) vs stationary (power plant)**
 - **Combustion vs noncombustion**
 - **Area (burning grass stubble) vs point (smoke stack)**
 - **Outdoor vs indoor**

Why do emission regulations focus on anthropogenic (man-made) emissions?


- **Natural air pollution**

- Sources and human populations are often distant
- Major source emissions are episodic and transient
- Not able to control emissions (ie Mt St Helens SO₂ emissions)

- **Anthropogenic air pollution**

- Excessive concentrations downwind of emissions
- Pollutants emitted affect people
- Pollution Concentrations increase during some atmospheric conditions (low wind speeds, inversions)
- Multiple environmental impacts can result

National Emission Estimates

- Assessed periodically by US EPA
- Focuses on primary pollutant emissions
- Reported on mass/yr basis: Approximations
- **Air Pollutant emissions in 1970 (29 years ago)**
 - Transportation responsible for 50+% of emissions on mass basis (Carbon monoxide was major emission)
 - Transportation major source of CO and HCs, second major source of NO_x 
 - Stationary source fuel combustion major source of SO_x and NO_x
 - Industrial processes major source of Particles; second largest source of SO_x

- **1997 Air Pollutant Emission Estimates show**
 - **Total emission reductions on mass basis ~ 25%**
 - **Based on Air Pollutant**
 - Significant reductions in PM emissions
 - CO emission reductions ~ 25% (auto catalytic converter)
 - HC emission reductions ~ 30%
 - Small increases in NO_x
 - SO_x reductions ~ 35% (SO₂ scrubbers at power plants)
 - **Based on Source Category**
 - Transportation reductions ~ 25%
 - Stationary source fuel combustion reductions ~15%
 - Industrial process loss reductions ~50%
 - Solid waste (incinerator) reductions ~ 60%

Although 1997 motor vehicle CO emissions have been reduced 98% compared to 1970, there are more motor vehicles in 1997 compared to 1970 (including some old dirty motor vehicles)

Lead Emissions

- **Approximate 98% reduction since 1970**
- **Reflects gasoline lead phase-out in US**



Are we done with controlling air pollution?

No. For example

- 1) area south of Tacoma has particle concentrations in excess of air quality standards for PM 2.5 particles**
 - 2) Probably exceeded ozone air quality standard in King & Pierce Counties because of hot 2009 summer temperatures**
- **Mass emission vs environmental impact (e.g. CO vs Particles)**
 - **Many regions are still not in compliance with NAAQS**
 - **Population growth will require more stringent emission limits**
 - **Non-primary pollutants (air toxics, O₃) need to be regulated**
 - **Emerging air pollutants (e.g. nanoparticles)**



P U G E T S O U N D

Clean Air Agency

Puget Sound Air Quality Issues

Dennis J. McLerran

Executive Director

Puget Sound Clean Air Agency

DennisM@pscleanair.org



Overview

- **Five focus areas:**
 - **Ozone**
 - **Fine particles**
 - **Toxics**
 - **Visibility**
 - **Climate change**



Air Quality Standards



- **Federal Clean Air Act**
 - **Uniform ambient air quality standards for the nation**
 - **Established to protect public health**
 - **Ozone, PM 2.5 most significant everywhere**
 - **No ambient levels for toxics**
 - **Just benchmarks established**
 - **Few regulatory requirements for global warming gases**
 - **But goals, voluntary reporting are becoming common**

Ozone or Photochemical Smog

- A summer problem in Washington
- Unhealthy levels on hottest summer days
 - When temperatures are in upper 80F and higher
 - When air conditions are stagnant and warm air moves in from south
- EPA set new standards in 1997
 - Must track two standards
 - 8-hour O₃ standard
 - 1-hour O₃ standard

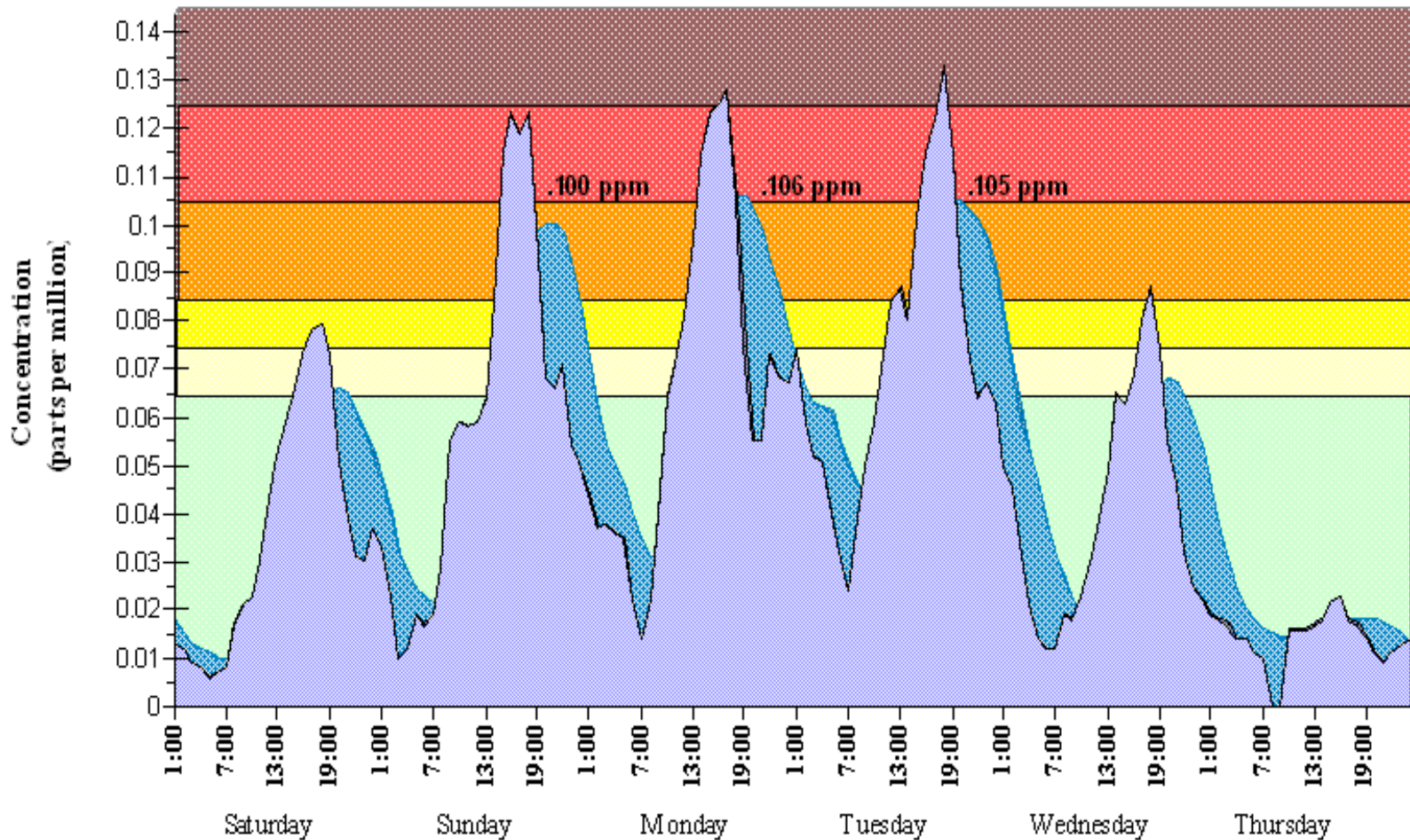


Ozone Monitoring Data: We're Close to Violating Standards

- Puget Sound currently a “Maintenance Plan” area
- 3 of last 4 summers were coolest in 45 years, good for ozone air quality
- However, 3 monitors still had recent exceedances In summer of 2008.
- Probably high ozone concentrations in summer of 2009 will put region in violation of O₃ air quality standard.



Enumclaw Ozone 1-hour and 8-hour averages

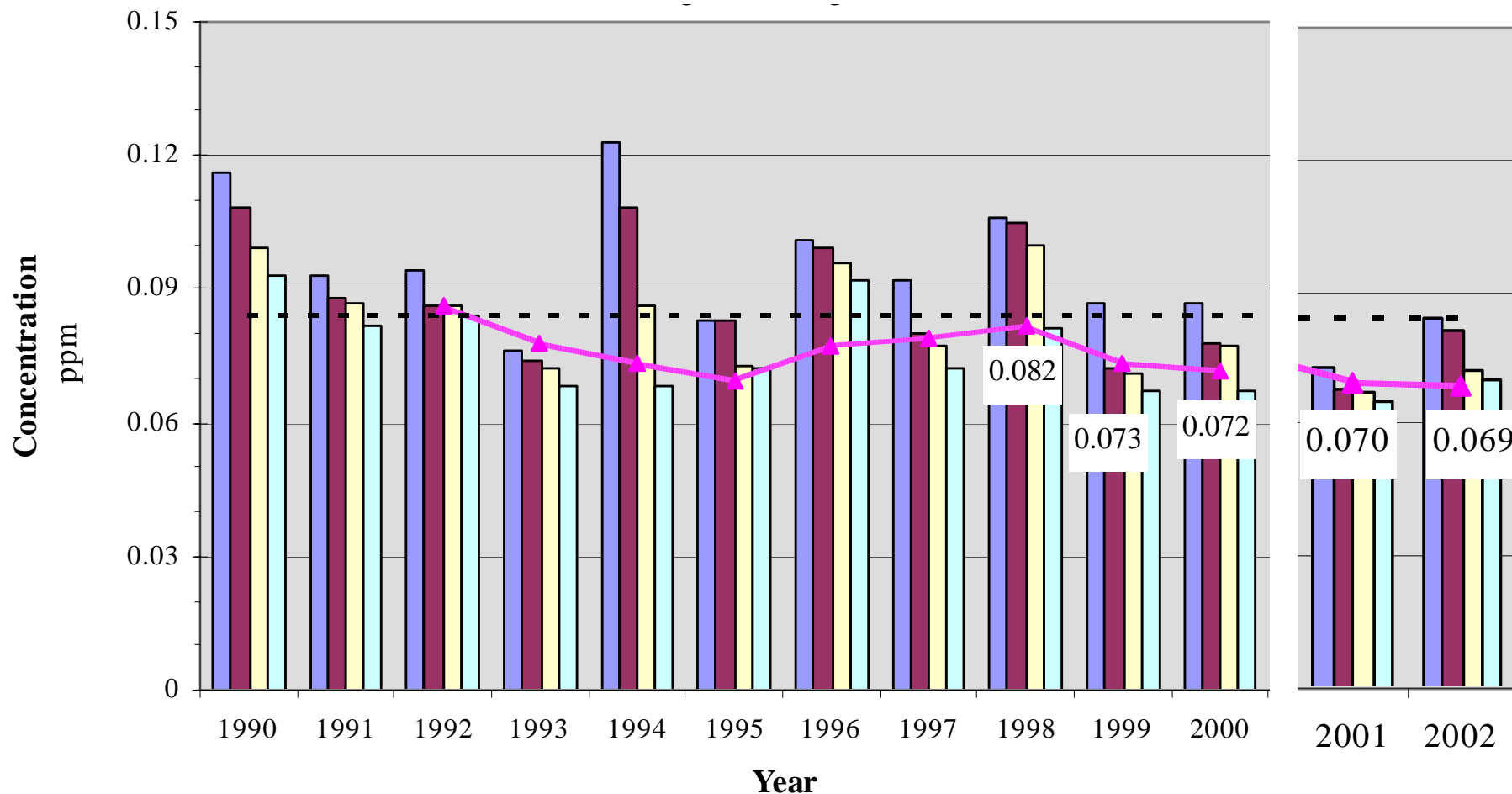


Ozone measured at Enumclaw

4 highest 8-hr averages & 3-year average of 4th highest

Highway 410 Site (shut down Oct 2000)

Mud Mt. Site



Consequences of Ozone Non-Attainment



- **Public health impacts**
 - Reduced lung function and irritation, even in healthy people
 - Impacts on asthmatics, especially children
 - Generated in urban areas, but impacts strongest from east of Federal Way to Enumclaw area
- **Negative regulatory consequences**
 - Tougher permitting, planning requirements

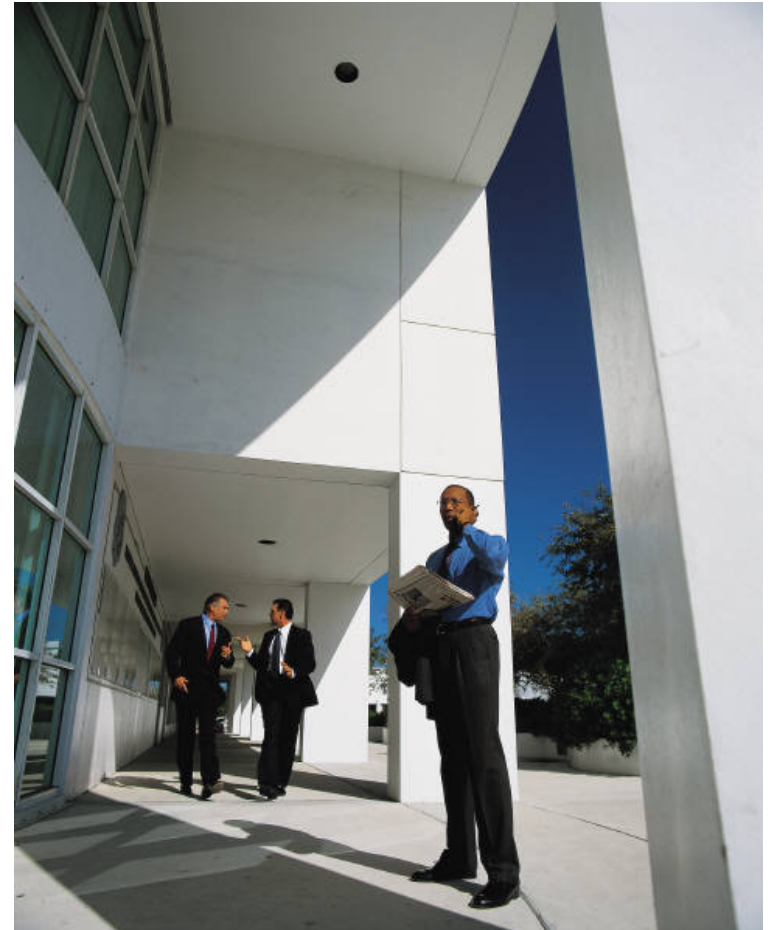
Consequences (Cont.)



- **Federal Transportation funding at risk**
 - **EPA sanctions can be imposed if inadequate progress**
 - **Projects put on hold often are capacity projects -- they add to regional emissions**
 - **Transportation conformity test also toughened**
 - **Atlanta is an example of consequences of having exceeded Ozone air quality standards**

Consequences (Cont.)

- **Economic development consequences**
 - **Loss of “most livable region” status**
 - **Companies locate where there is high quality of life**
 - **Tougher requirements would discourage locating here or expanding**



What Causes Ozone in Our Region?

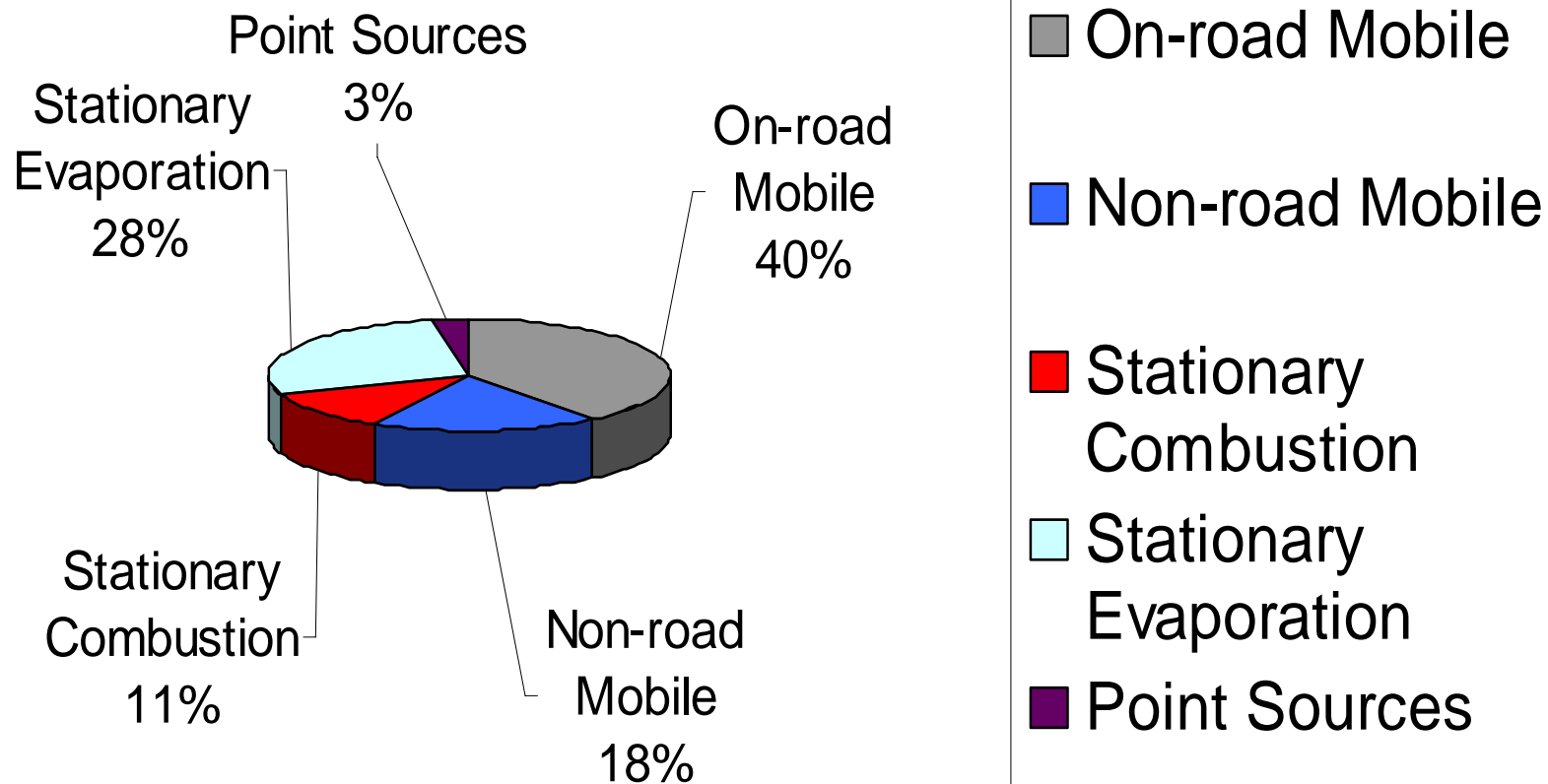


- VOC + NOx = Ozone
- Emissions from Growth
 - Population
 - Vehicle miles traveled
 - Recreational, yard care & construction equipment
 - Paints & solvents use
 - Urban activities

Puget Sound is a Major Metropolitan Area

- **More than 1 in every 100 Americans live here!**
- **We drive more than 70 million miles every day!**
- **We burn over 3 million gallons of gasoline every day!**
- **On-road & non-road mobile sources emit 74% of our summer time Volatile Organic Compounds (VOC's)**

Puget Sound 1996 annual Non-biogenic VOC emissions



What Are We Doing About It?

- **Summer “Smog Watch” to deal with episodes**
- **Low Reid Vapor Pressure gasoline program**
- **Updating Maintenance Plan to adopt new strategies**
 - **Enhance Wash State Ecology’s Motor Vehicle Inspection Program**
 - **Tougher gas station inspections**
 - **Voluntary California paints and gas cans**
 - **Other strategies to address concerns at least until 2007, possibly 2015**

Fine Particle (PM_{2.5}) Issues

- **PM_{2.5} & air toxics are largest health risk**
 - Lung irritation, asthma attacks
 - Correlation with heart arrhythmia
 - Premature deaths
- **Indoor and outdoor burning, diesel fuel combustion are primary sources**
- **Federal PM_{2.5} standard adopted in 1997, likely to be revised to more stringent level**

PM_{2.5} Stakeholder Process

- **Our goal: Never violate the federal standard and protect public health more completely than the federal air quality standard**
- **Stakeholders determined there are cost-effective strategies for early reductions in PM_{2.5} concentrations**



PM_{2.5} Emission Reduction Strategies

- **Further reduce outdoor burning consistent with state law**
- **Replace wood stoves and fireplaces with certified devices and cleaner fuels**
 - **Natural gas**
 - **Propane**
 - **Sawdust logs**
- **Ultra Low Sulfur Diesel fuel & retrofit older diesel vehicles with particle traps and catalysts**
- **Lobby EPA for cleaner diesel fuels and vehicles**

Air Toxics Issues



- **Urban air toxics a significant public health concern**
- **Recent EPA National Air Toxics Assessment (NATA)**
 - **King County among highest modeled levels of fuel-related air toxics**
 - **Current air monitoring project verifies the modeled concentrations**

Air Toxics Data and Risk Analysis

- **Existing information**
 - **NATA modeling data**
 - **Ecology pilot ambient air monitoring project**
- **Puget Sound Air Toxics Report**
 - **700 in a million cancer risk from air toxics**
 - **Diesel exhaust causes 75 - 80% of that cancer risk**

Air Pollutant Chemicals of Concern (based on risk assessment)

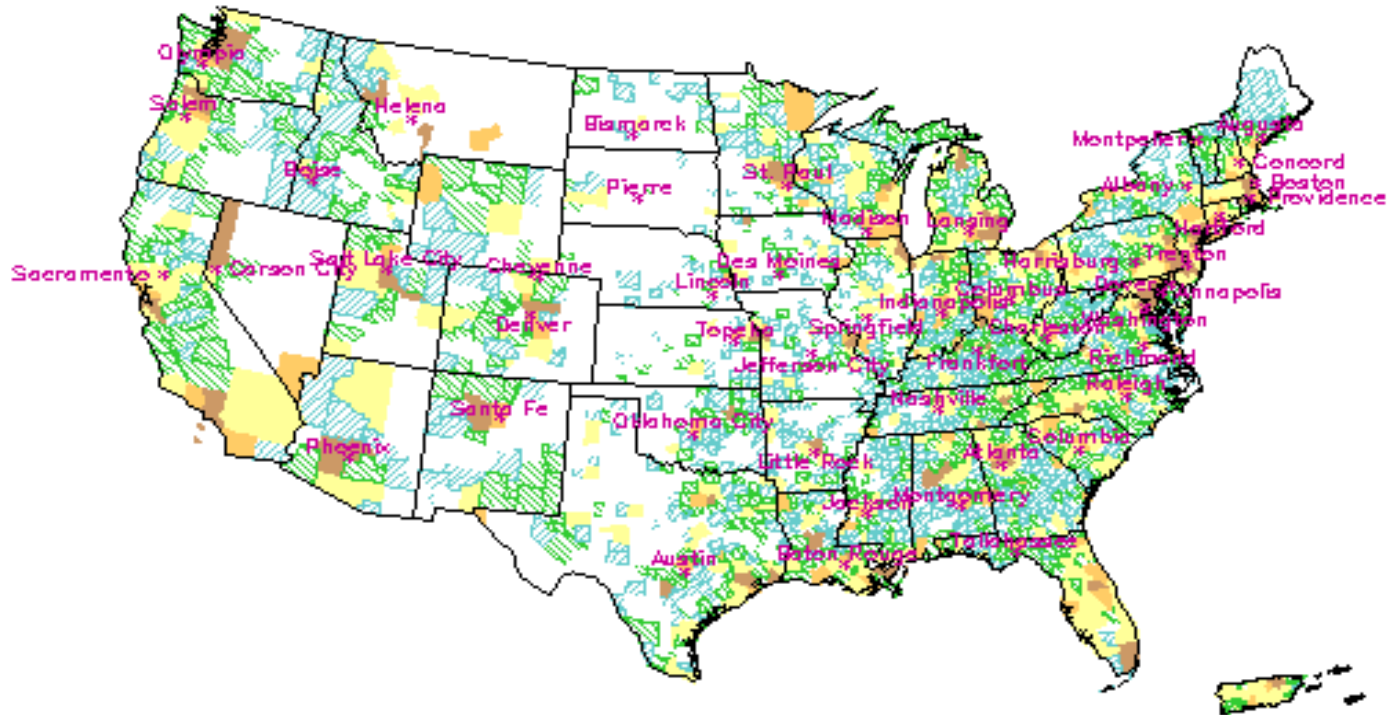
- **Benzene**
- **Chromium**
- **Acetaldehyde**
- **Formaldehyde**
- **Diesel particulate**



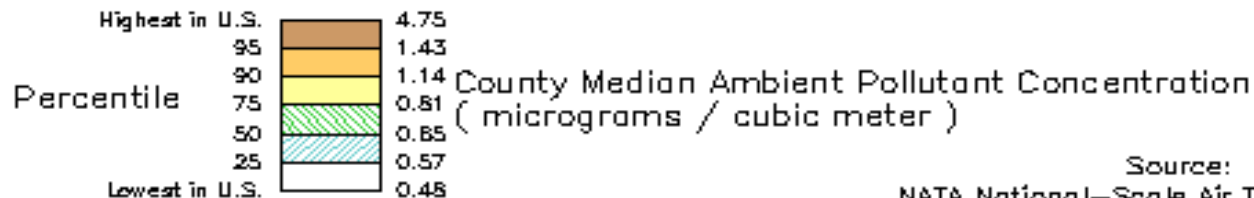
Benzene Concentrations

US Counties

1996 estimated county median ambient concentrations



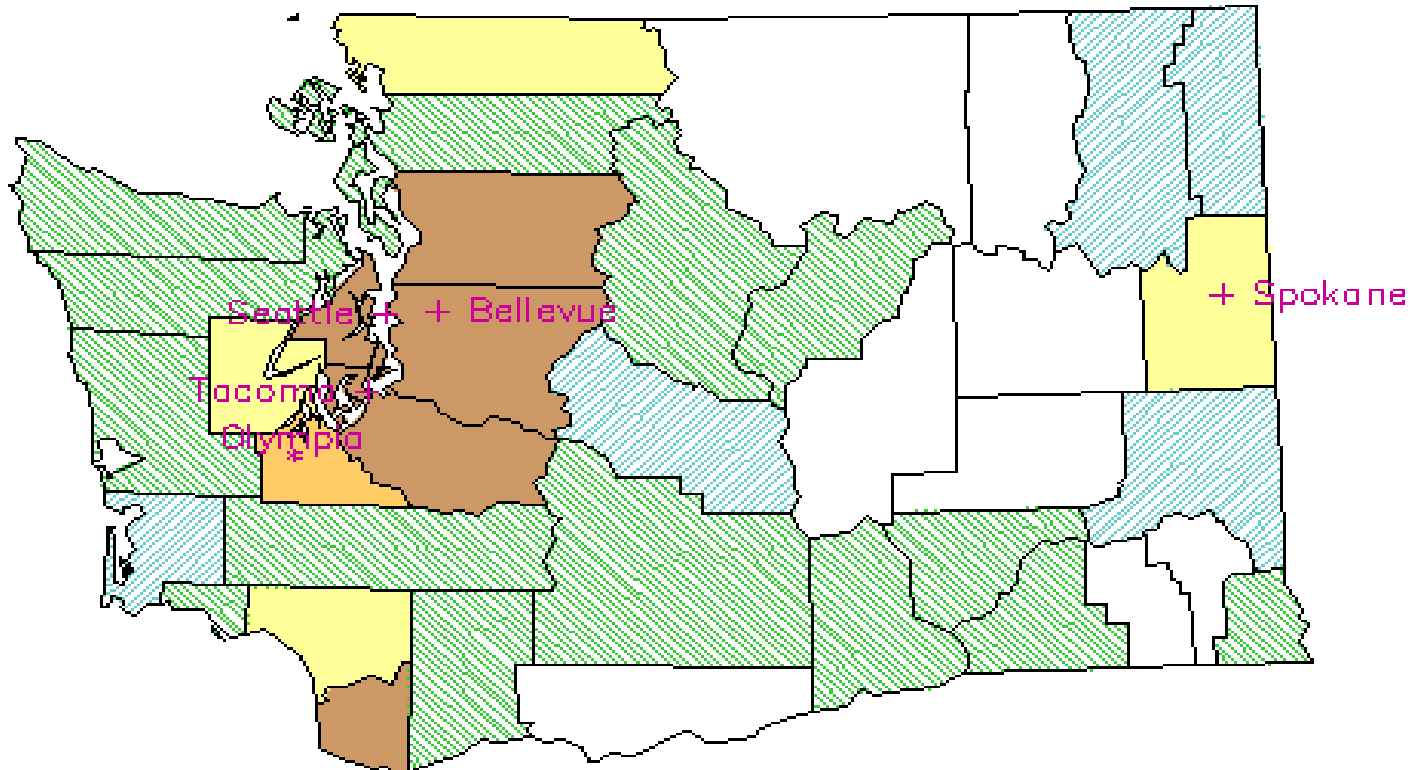
Distribution of U.S. Ambient Concentrations



Source: U.S. EPA / OAQPS
NATA National-Scale Air Toxics Assessment

Benzene Concentrations Washington Counties

1996 estimated county median ambient concentrations



Distribution of U.S. Ambient Concentrations

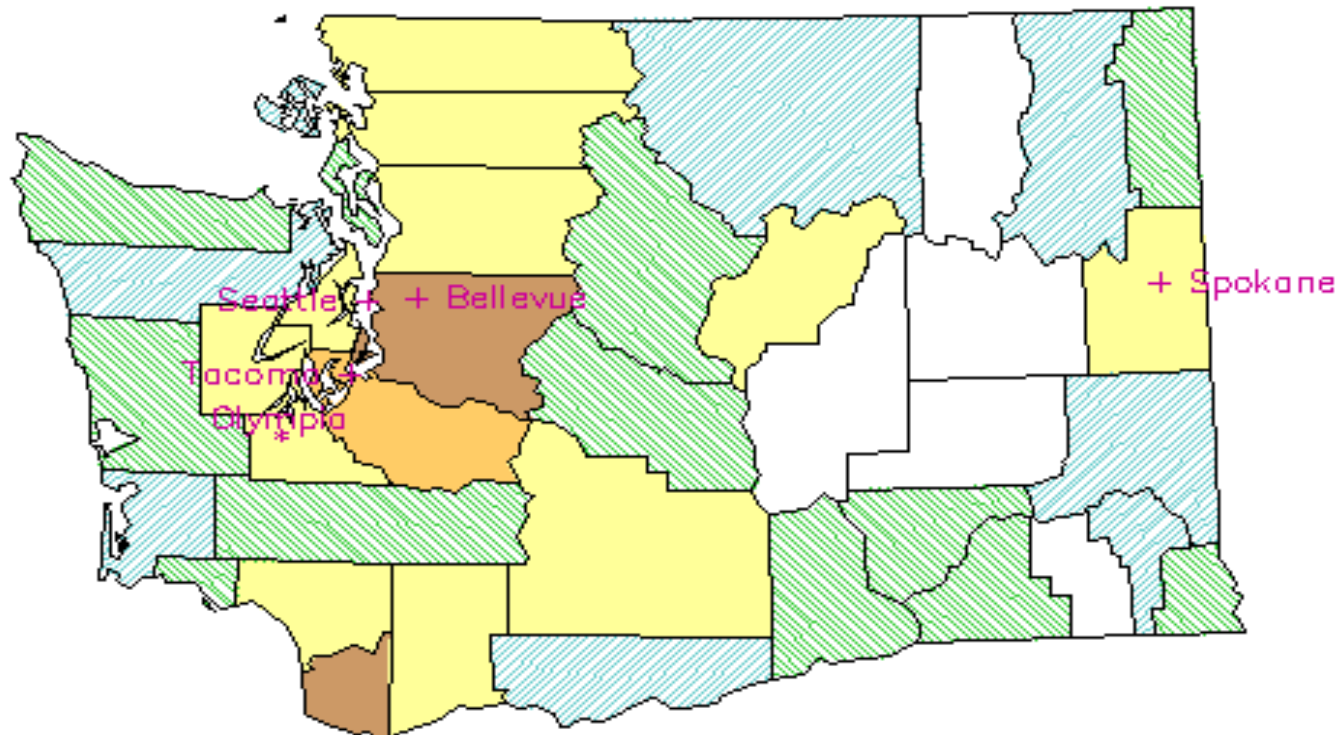
Percentile	Concentration (micrograms / cubic meter)
Highest in U.S.	4.75
95	1.43
90	1.14
75	0.81
50	0.65
25	0.57
Lowest in U.S.	0.48

County Median Ambient Pollutant Concentration
(micrograms / cubic meter)

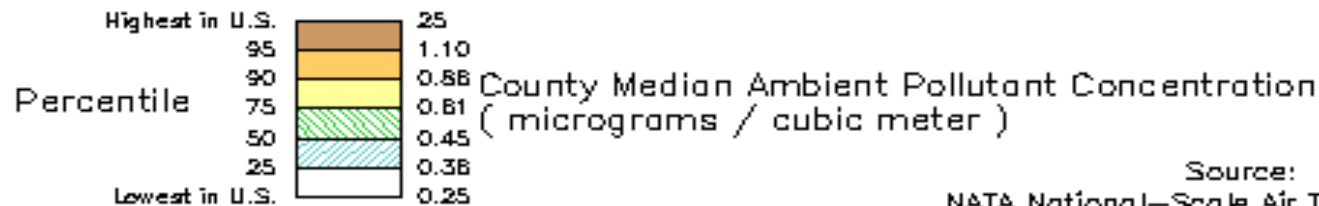
Source: U.S. EPA / OAQPS
NATA National-Scale Air Toxics Assessment

Formaldehyde Concentrations Washington Counties

1996 estimated county median ambient concentrations



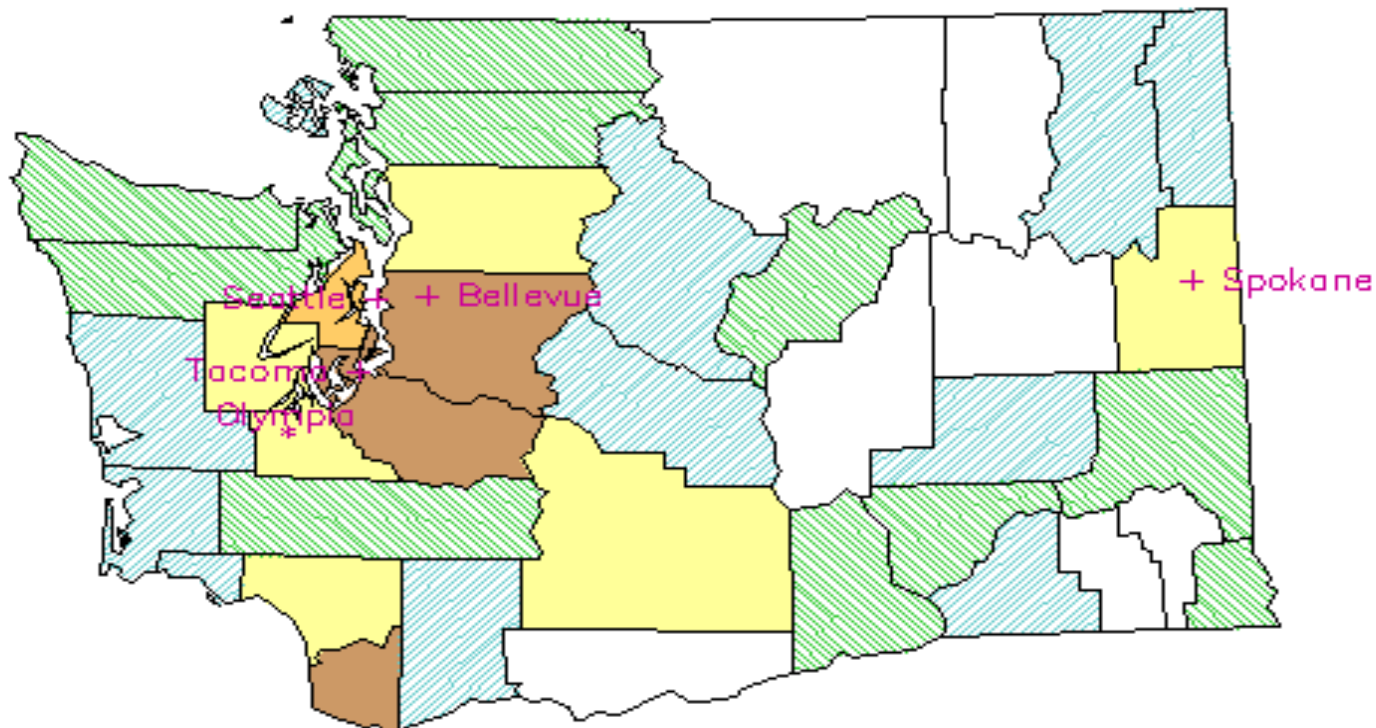
Distribution of U.S. Ambient Concentrations



Source: U.S. EPA / OAQPS
NATA National-Scale Air Toxics Assessment

Acetaldehyde Concentrations Washington Counties

1996 estimated county median ambient concentrations



Distribution of U.S. Ambient Concentrations

Percentile	Concentration (micrograms / cubic meter)
Highest in U.S.	4.14
95	0.68
90	0.48
75	0.24
50	0.12
25	0.059
Lowest in U.S.	0.000 87

County Median Ambient Pollutant Concentration
(micrograms / cubic meter)

Source: U.S. EPA / OAQPS
NATA National-Scale Air Toxics Assessment

Sources of Mobile Source Air Toxics

- Fuel evaporation
- Engine combustion processes
- Diesel exhaust creates dominant risk because of Chemicals involved



Diesel Exhaust is a Major Source of Fine Particles



- **Ultra-fine particles act like a gas rather than a solid**
- **Invisible and bypass lung defenses**
- **Diesel exhaust contains ultra-fine particles bound up with toxic substances**

Health Effects from Ultra-Fine Particles

- **Excess deaths**
- **Increased incidences of asthma**
- **Increased hospital admissions, emergency room visits**
- **Large numbers of lost work days**
- **Lung, eye and throat irritation**

Diesel Exhaust is a Major Target

- **Cancer risk greater than 500 in a million, *based on California risk numbers***
- **Risk numbers within range identified by EPA**
- **Ultra-fine particles in diesel exhaust create both cancer and non-cancer risk**
- **Recent studies show kids on school buses are exposed to 5 to 15 times the concentration of diesel exhaust in the ambient air**
- **Pilat Comment: EPA ignored this cancer risk until California research proved the cancer risk of diesel exhaust air pollutants.**

Puget Sound Diesel Solutions Program

**Diesel
Solutions**

Cleaner air for tomorrow, today



Overview

- **A voluntary program with many partners**
- **In collaboration with EPA's voluntary retrofit program**
- **Bringing ultra-low sulfur diesel fuel and retrofits to the four-county Central Puget Sound area**
- **Conoco/Phillips, EPA, King County, Boeing, engine manufacturers & others have provided support for the program**





The Leadership Group



United States Environmental Protection Agency



King County Metro



the City of Seattle

The City of Seattle



The Boeing Company



Everett Public Schools & Durham School Services



Kitsap Transit



Cummins



Washington State Department of Transportation



Port of Seattle



Phillips Petroleum (76 brand)



Detroit Diesel



Washington State Department of Ecology



The Diesel Technology Forum



MECA (Manufacturers of Emission Controls Association)



Johnson Matthey

Johnson Matthey



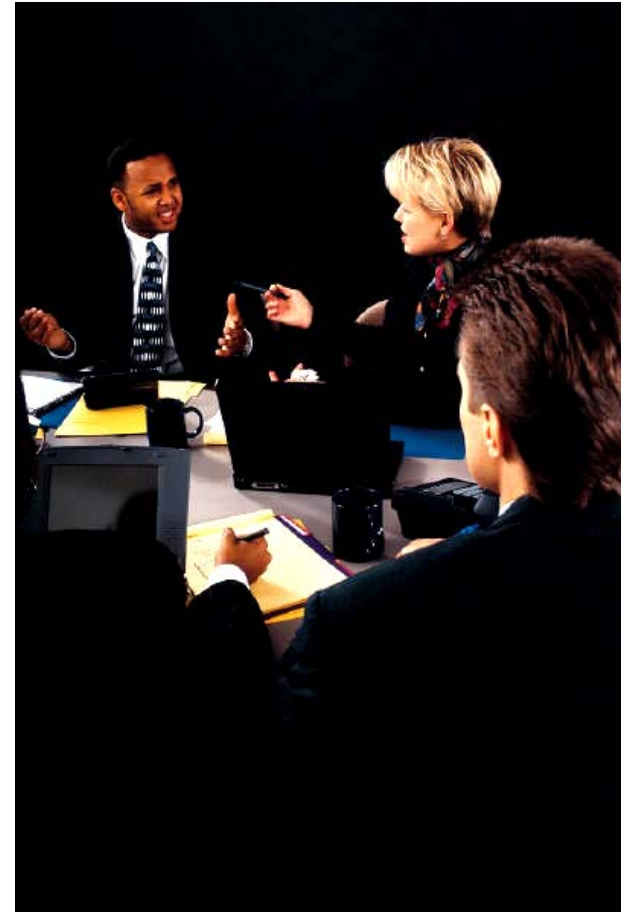
CleanAIR Systems



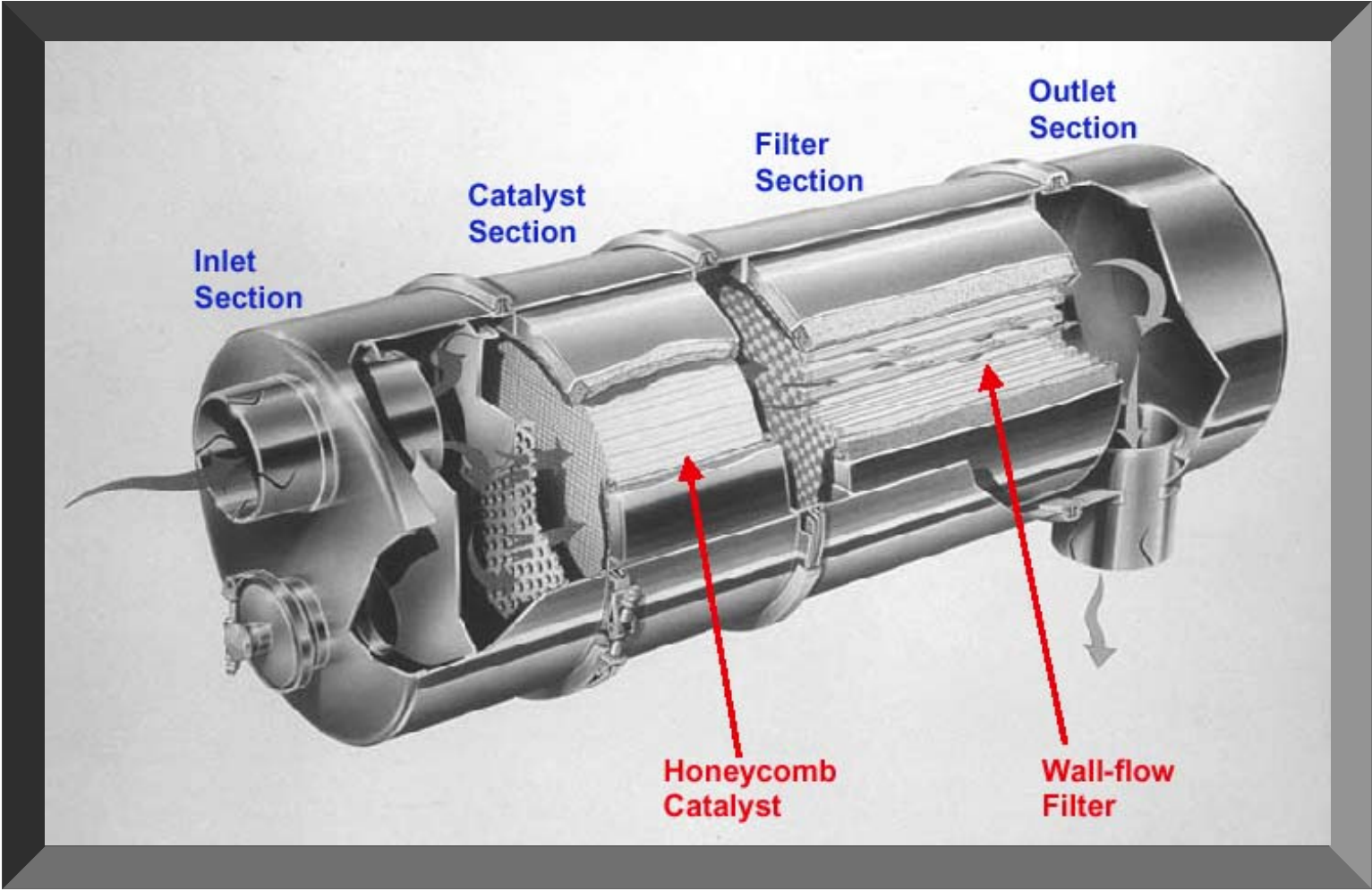
Community Transit



Puyallup Tribe of Indians

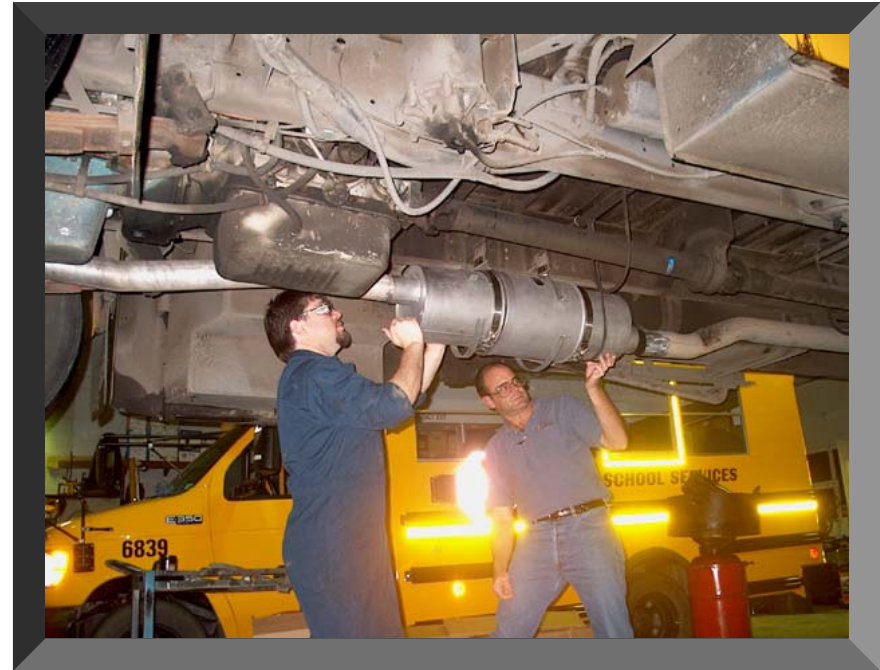


CRTTM Particulate Filter Johnson Matthey System



School Bus Retrofit Program

- **Significant focus on cleaning up school bus emissions**
- **Everett School District has equipped 20 buses with retrofits & uses ultra-low sulfur diesel**
- **Puyallup tribal school buses**
- **Obtained \$1 million from EPA for 5 new school bus projects**
- **National program on horizon**





Annual Benefits from Puget Sound Diesel Solutions Program

- **400 - 800 tons of fine particles reduced**
- **14-25% reduction of total regional fine particle emissions**
- **30 - 63 fewer early deaths annually**
- **68 - 126 fewer chronic bronchitis cases annually**
- **1500 - 2765 fewer cases of respiratory symptoms in asthmatic children**
- **5805 - 10,665 fewer lost work days**

Additional Benefits



- Ability to meet national air standards for particulates
- Improved regional visibility
- Improved quality of life

Visibility Concerns

- **Washington residents cherish views of Cascade and Olympic Mountains**
- **National parks and scenic areas in our state are impacted by urban pollution**
- **Ozone precursors and fine particles reduce visibility**
- **Air quality improvements also improve visibility, but keeping up with combustion growth is a challenge**

Visibility: going, going, gone

$PM_{2.5} = 33 \mu\text{g}/\text{m}^3$



Climate Change

- **We are developing a regional climate change program**
 - **Will conduct a regional stakeholder process**
 - **Identify a goal and consensus-based strategies**
- **Early action strategies include:**
 - **Educating the public, regulated sources, local governments**
 - **Conducting greenhouse gas emission inventories**
 - **Reducing idling**
 - **Mitigating energy projects**
 - **Integrating energy efficiency into our permitting**
- **Clean energy sources offer significant economic development opportunities**

Dennis McLerran Conclusions

- **We still have significant air quality problems in our region**
- **We will continue to work with regulated sources to prevent backsliding and implement federally delegated programs for point and area sources**
- **We are eliminating activities that no longer add value to take on new programs that do, like climate change**
- **We are sharpening our focus on motor vehicles, fuels, wood burning and diesel to target the largest unaddressed issues**
- **We have some outstanding opportunities to make a difference**

Dennis McLerran is the Director of the Puget Sound Clean Air Agency which is the regional governmental agency over the air quality in 4 counties; King, Kitsap, Pierce, and Snohomish counties.



P U G E T S O U N D

Clean Air Agency