

**AIR POLLUTION PROBLEMS,  
POLICIES AND "PLAYERS":  
A PERSONAL PERSPECTIVE, 1941-2002**

**May 15, 2002 - Sacramento, CA**

**JAMES N. PITTS, JR.**

**Research Chemist**

**University of California, Irvine**

**Professor Emeritus and Past Director University of California**

**Statewide Air Pollution Research Center, UC Riverside**

**GRANTING AGENCIES  
SUPPORTING  
OUR RESEARCH AT SAPRC**

**California Air Resources Board  
Jack Suder and John Holmes**

**U. S.  
Environmental Protection Agency  
Ron Patterson**

**National Science Foundation  
Richard Carrigan**

**U. S. Department of Energy  
David Balentine**

**MY**

**“ENRON DEFENSE”**

**“To the best of my recollection, the  
statements I make in this talk are  
accurate.”**

2



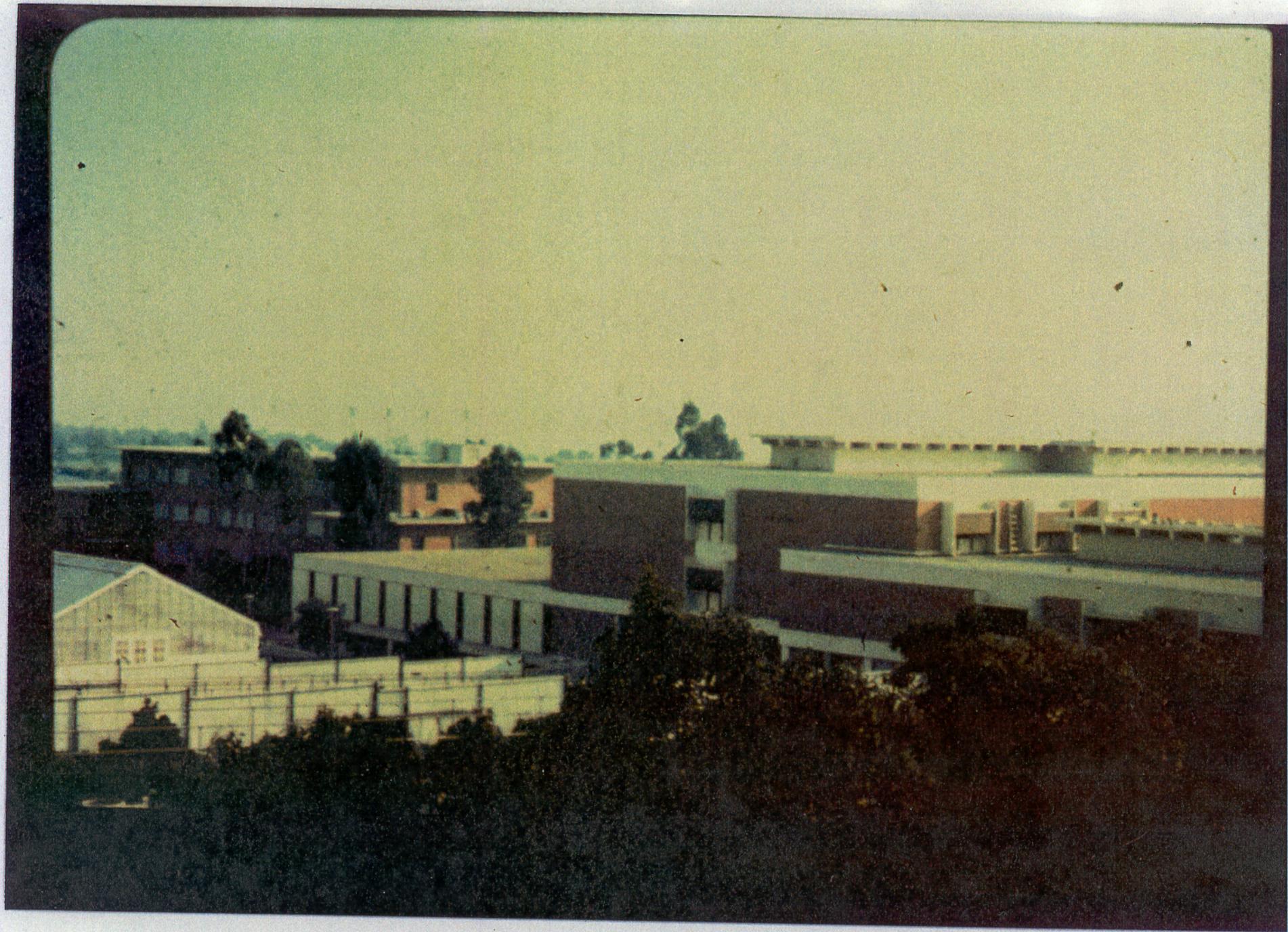
**LANDING OF SPANISH EXPLORER JUAN RODRIQUEZ  
CABRILLO AT LOS ANGELES HARBOR**

**October 8, 1542**

Mountain peaks were visible in the distance, but their bases were obscured. Smoke from Indian campfires rose vertically for only a few hundred feet and spread like a pall over the entire area. Cabrillo named the site "La Bahia de los Fumos," or the Bay of Smokes.

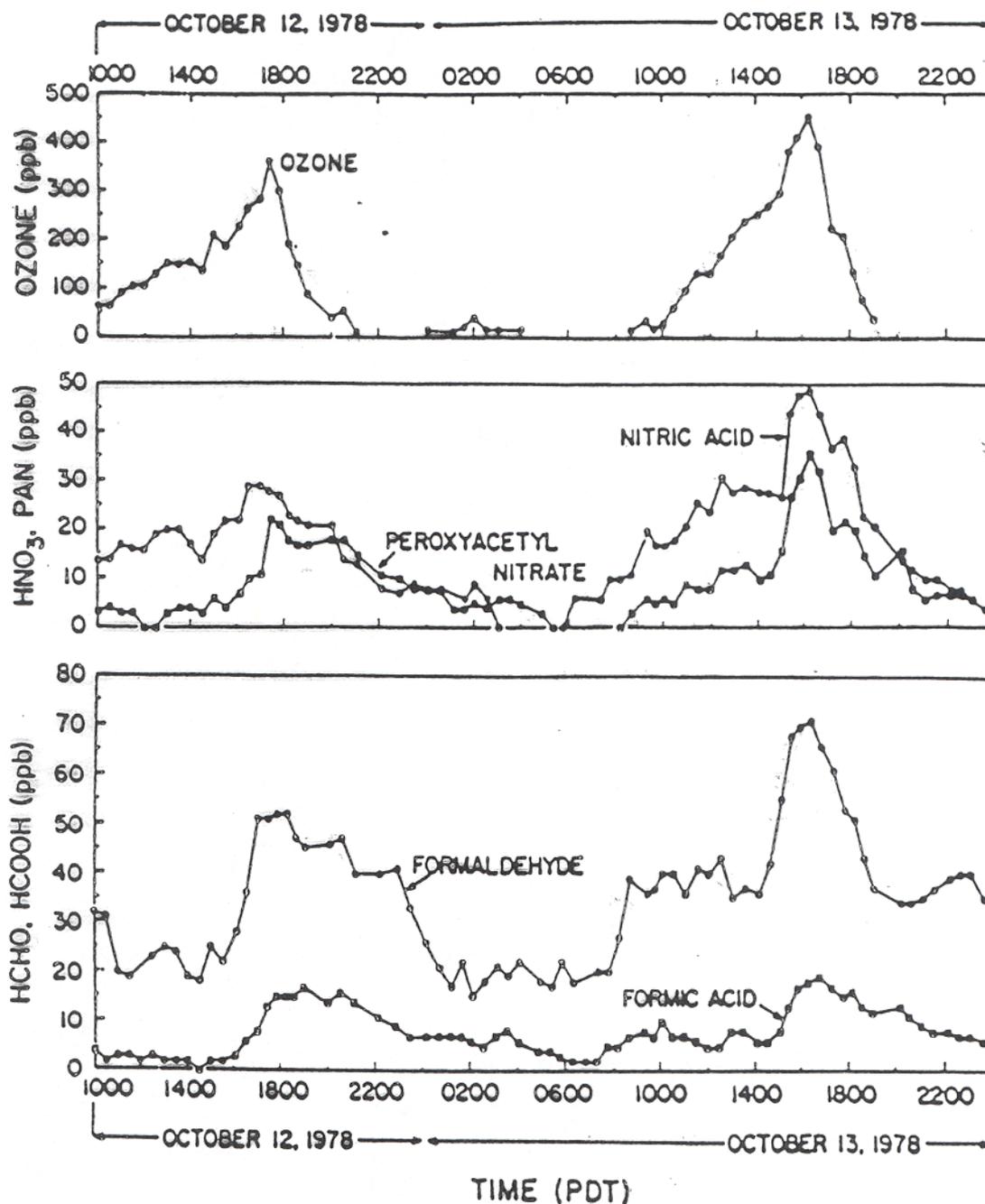
⑤





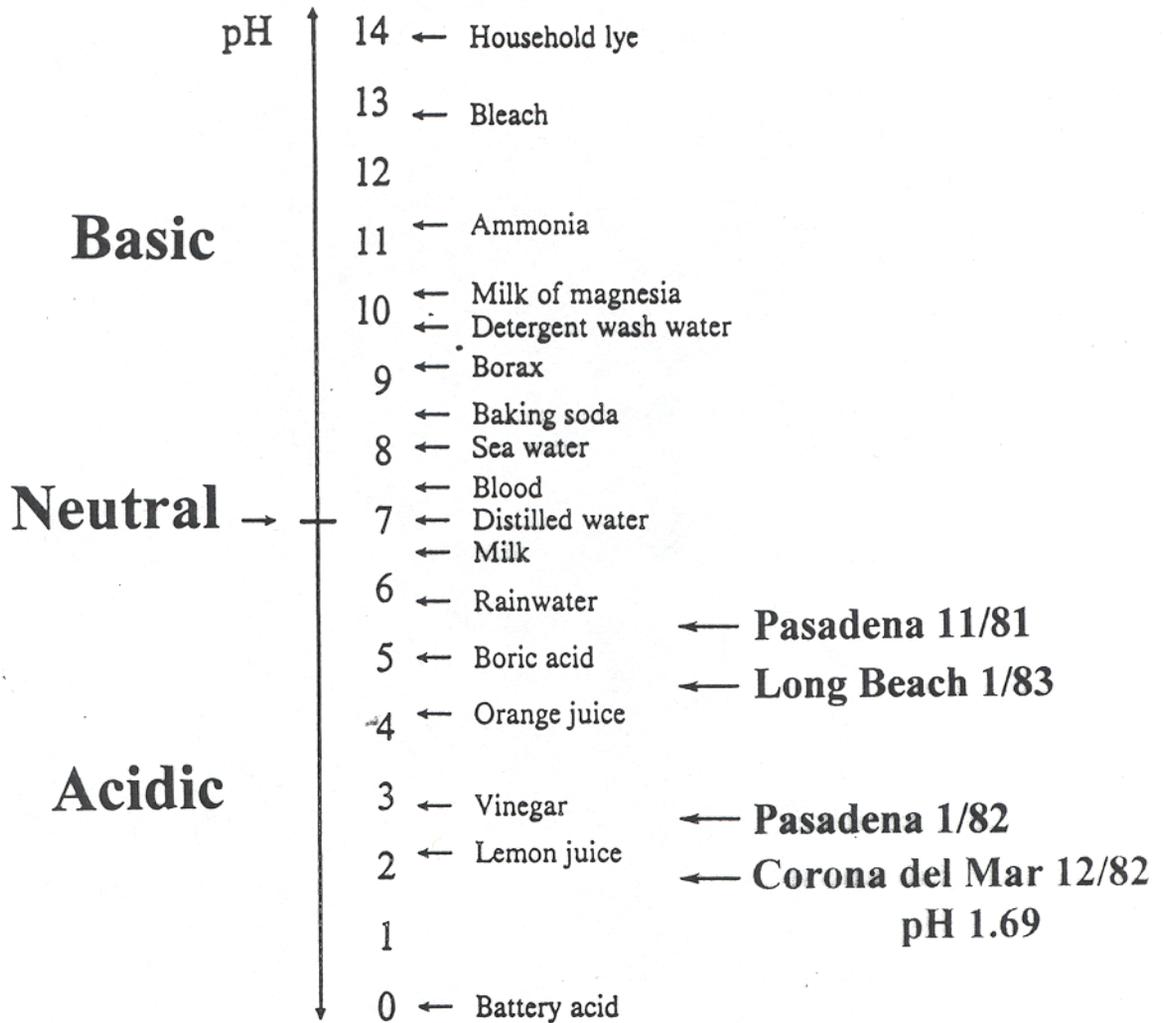
6

# Time-Concentration Profiles of Ozone and Toxic/Acidic Noncriteria Pollutants Present During an Intense Episode of Photochemical Smog in Claremont, CA, October 12-13, 1978, Determined with a 1 km Optical Pathlength, FT-IR Spectroscopic System



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# Acidities of Episodes of Ambient Fogs in Coastal Areas of Southern California in the 1980s vs. pH Values of Some Common Acidic Solutions



Jacobs and Hoffman, 1983; Munger et al., 1983; Hoffman and Jacob, 1984; Jacob et al., 1985

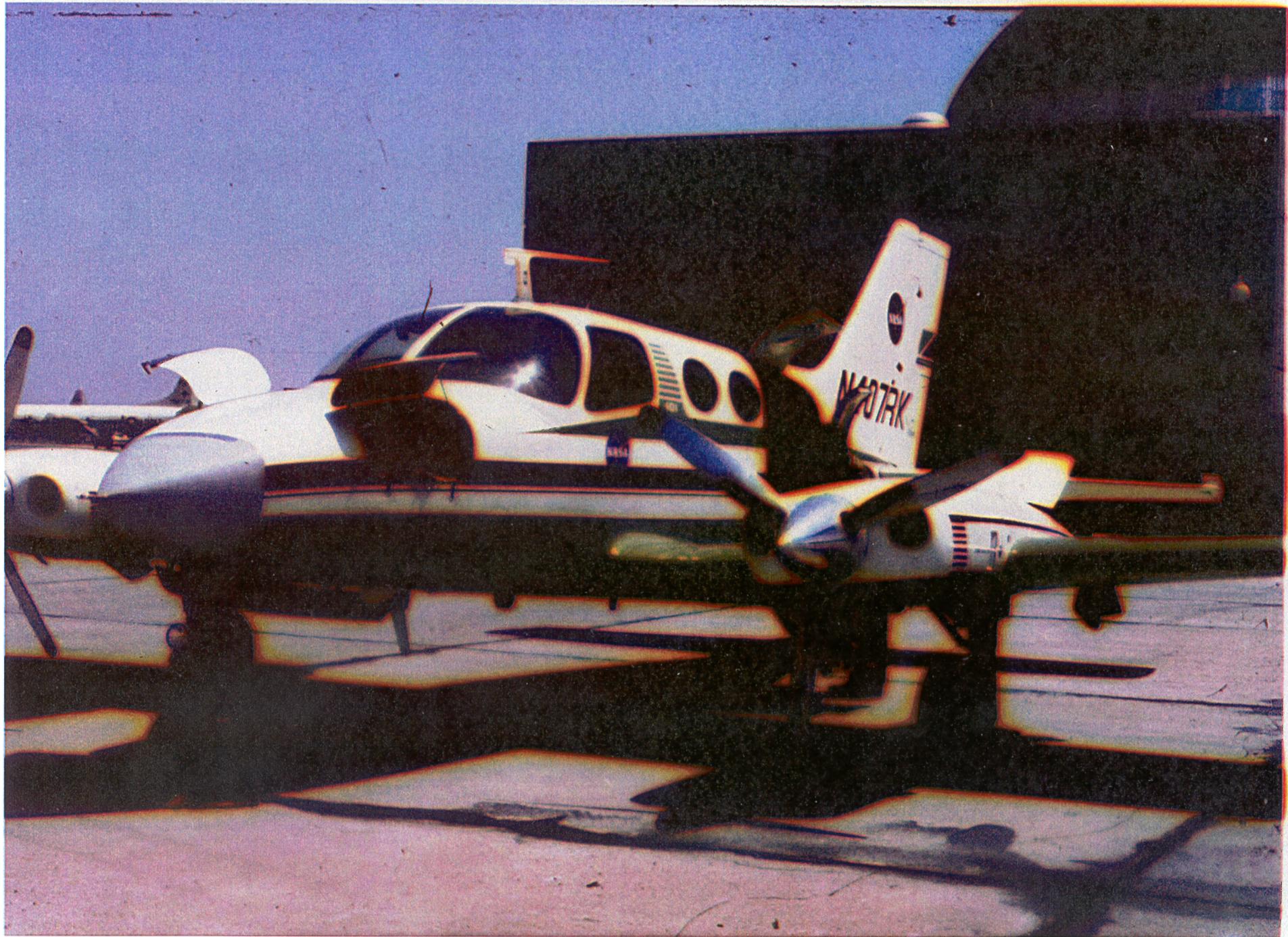




# AIRBORNE SURVEY OF MAJOR AIR BASINS IN CALIFORNIA

H. R. Gloria, G. Bradburn, R. F. Reinisch, NASA Ames Research Center, and  
J. N. Pitts, Jr., J. V. Behar, and L. Zafonte, Statewide Air Pollution Research  
Center, UCR

APCA, 24, 645 (1974)





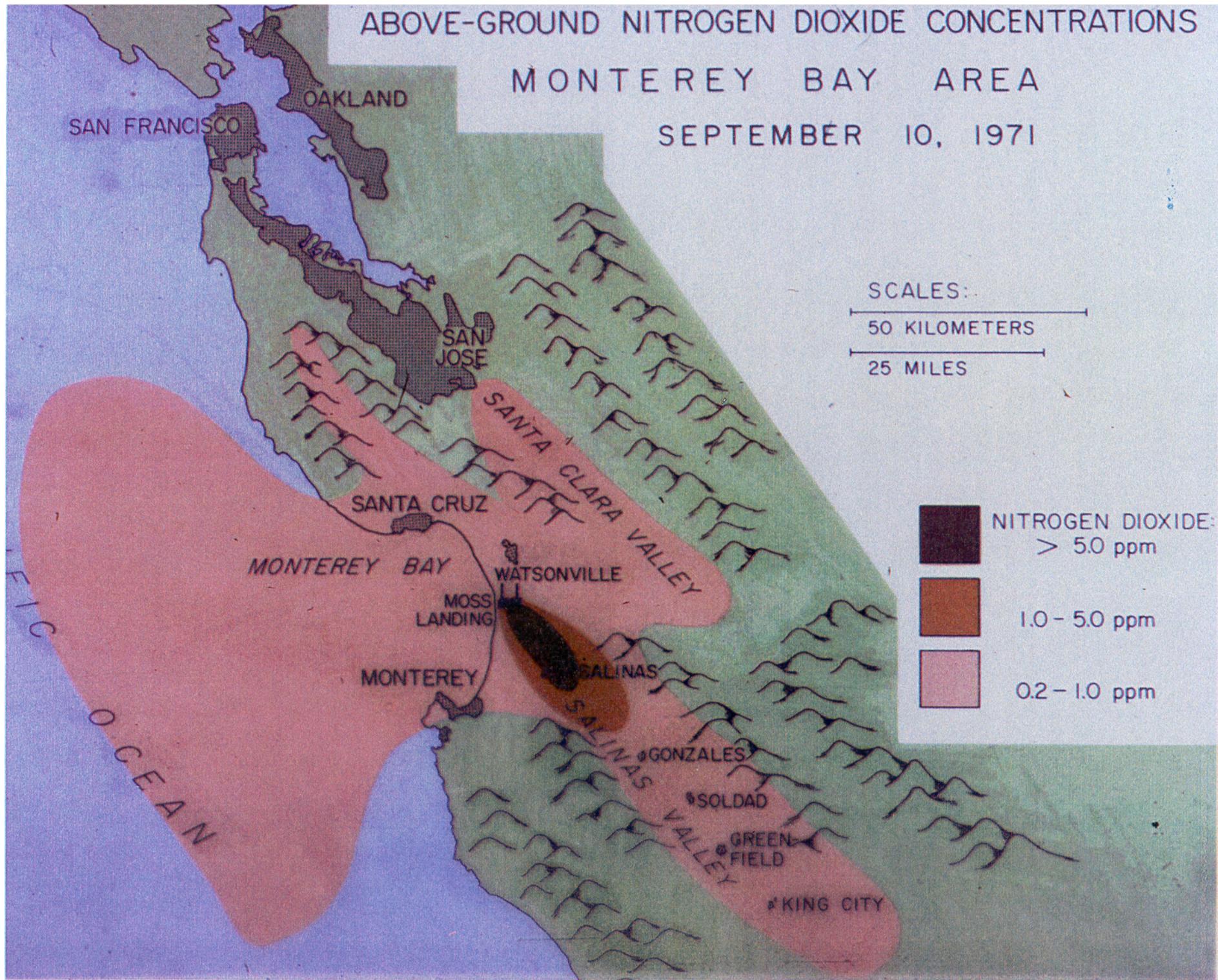




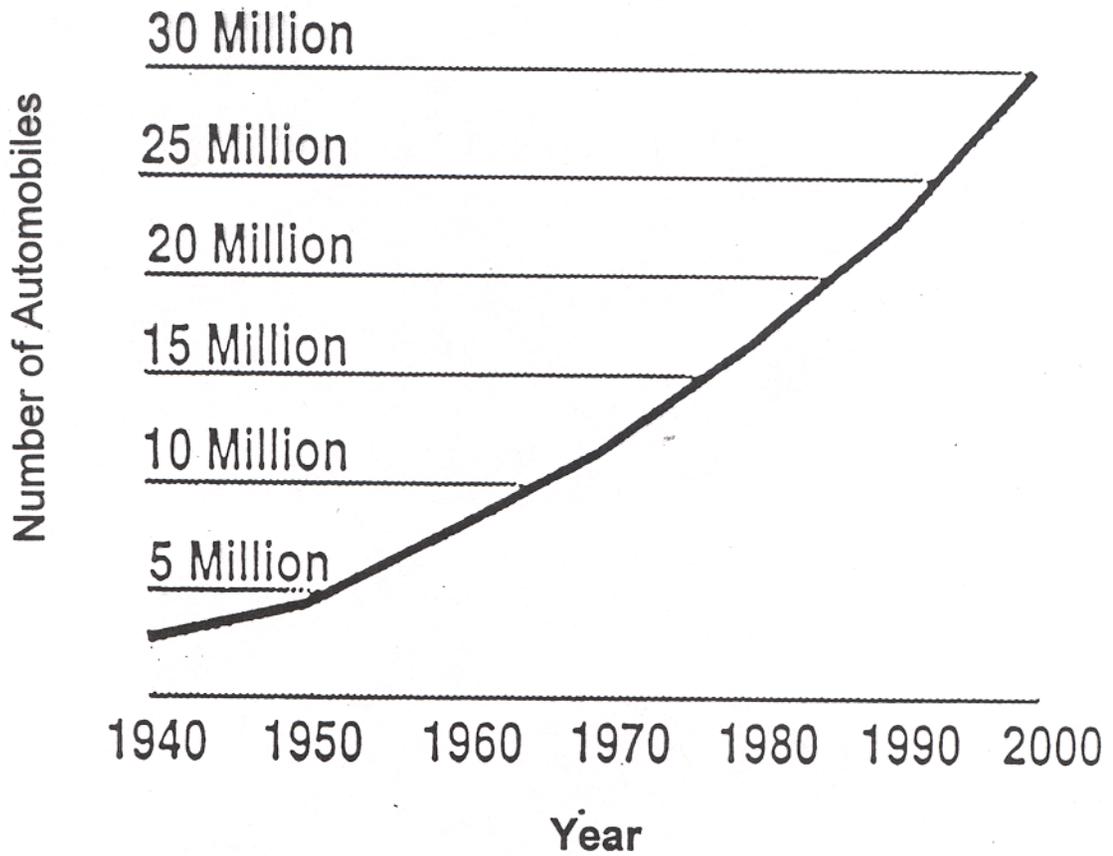
# ABOVE-GROUND NITROGEN DIOXIDE CONCENTRATIONS

## MONTEREY BAY AREA

SEPTEMBER 10, 1971



# "POPULATION EXPLOSION" OF AUTOMOBILES IN CALIFORNIA OVER 60 YEARS



California Air Resources Board

**When the world-famous  
HELEN KELLER,\*  
blind author and lecturer, was  
asked,**

**“What could be worse than losing  
your sight?”**

**she replied,**

**“LOSING YOUR VISION!”**

**\*(1880-1968). In her infancy, Helen Keller lost her sight, hearing, and most of her ability to utter sounds. Nevertheless, she learned to speak, read, and write, and graduated from Radcliff College in 1904.**

**A Factual Record of Correspondence**

**between**

***Kenneth Hahn***  
**Los Angeles County Supervisor**

**and the Presidents of**  
***General Motors, Ford and Chrysler***

**Regarding the Automobile Industry's**

**Obligation to Meet**

**Its Rightful Responsibility in Controlling**

**Air Pollution from Automobiles**

**February 1953 – January 1966**

19

**FROM COUNTY SUPERVISOR KENNETH HAHN  
CORRESPONDENCE:**

*February 19, 1953*

**TO: Mr. Henry Ford II,**  
*President, Ford Motor Co.*

"... with a population of approximately 4 million. Los Angeles County has about 2 million automobiles. While the exhaust fumes from these vehicles may not be the major cause of smog, it definitely appears that these gases contribute to the problem."

*March 3, 1953*

**FROM: Dan J. Chabek**  
*Ford Motor Co.*

"The Ford engineering staff, although mindful that automobile engines produce exhaust gases, feels these waste vapors are dissipated in the atmosphere quickly and do not present an air-pollution problem".

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# PHOTOCHEMISTRY *and* SMOG

A. J. Haagen-Smit

"While we have to wait for more experimental data for the construction of a reaction mechanism which explains fully all of the complicated phenomena, the control efforts do not have to be delayed.....

.....There is no reasonable doubt that control of olefins and other reactive organic pollutants as well as oxides of nitrogen is the most practical way for returning air of acceptable quality to our cities".

JAPCA , 13, 444 (1963)

# KEY POLICY DECISIONS EARLY ON

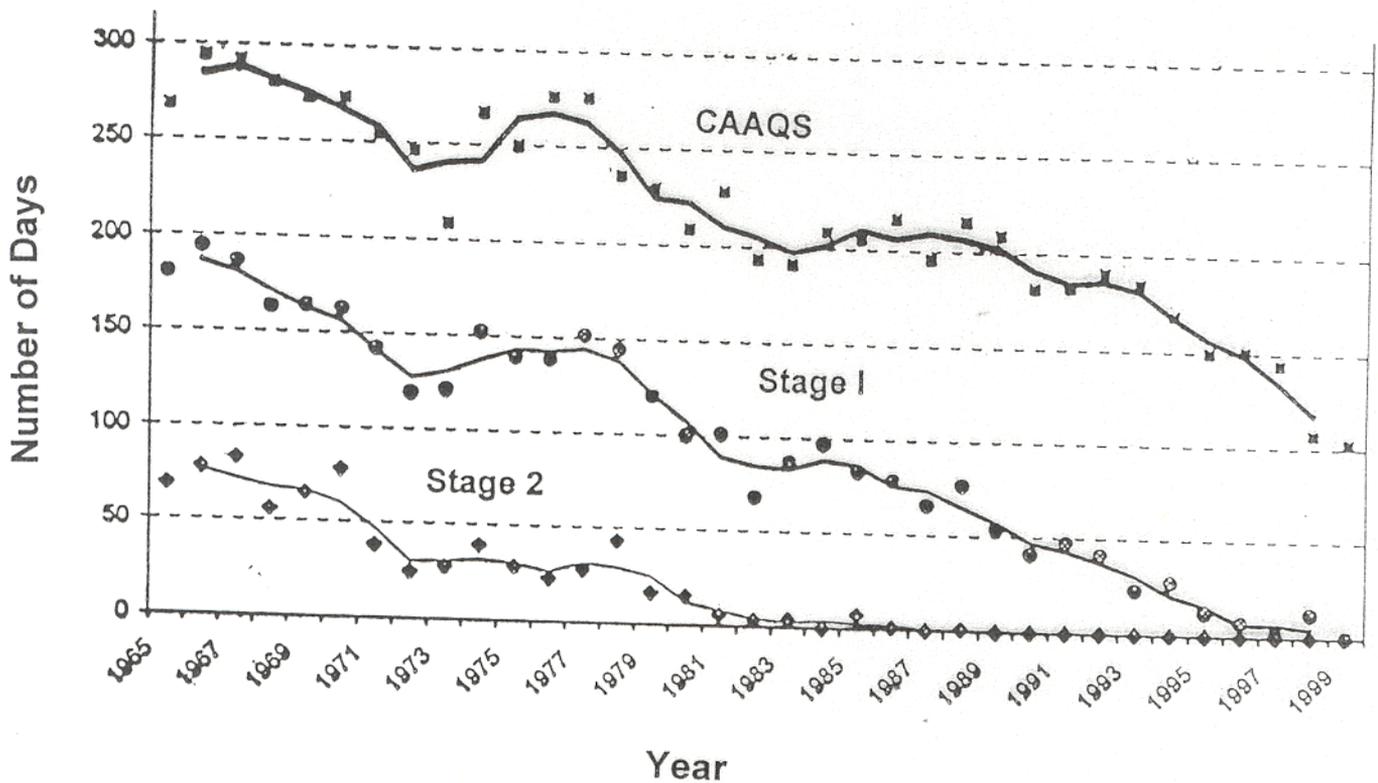
- 1960's: The State of California mandates Health Related Quality Standards as the foundation for developing air pollution emission control strategies, regulations, etc.
- This was in direct contrast to the approach of many other countries. They stipulate use of *The Best Available Control Technology (BACT)* in developing their air quality standards, emission controls, etc.





Professor James N. Pitts, Jr. (left) with Governor Jerry Brown of California (right)

# A REMARKABLE SUCCESS STORY: IMPACT ON THE SOUTH COAST AIR BASIN OF INCREASINGLY STRICT CONTROLS ON *BOTH* VOC AND NO<sub>x</sub> EMISSIONS, 1965-1999



- Exceedences of California hourly ambient Air Quality Standard (95 ppb) were decreased > 60%.
- Stage 1 episodes (max-hr O<sub>3</sub> 200 ppb) decreased > 95%.
- Stage 2 episodes (max-hr O<sub>3</sub> 350 ppb) eliminated in 1989.

**SOME GUIDING PRINCIPLES FOR RESEARCH  
IN ATMOSPHERIC CHEMISTRY AND  
APPLICATION OF RESULTS TO  
DEVELOPMENT OF AIR POLLUTION  
CONTROL STRATEGIES**

- ◆ **“The fundamental things apply as time goes by”  
Sam, *Casablanca*, circa 1941**
- ◆ **“Theories come and theories go but good data stand forever.”  
F. E. Blacet personal communication to J. G. Calvert and  
J. N. Pitts, Jr., 1946**

# ***PHOTOCHEMISTRY OF GASES***

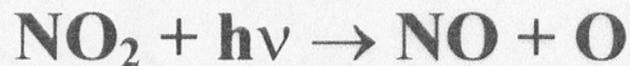
**W. A. Noyes, Jr. and P. A. Leighton**

**Reinhold, NY, 1941**

**The classic monograph for initial  
understanding of photochemical processes  
in L.A. smog.**

# **“PHOTOCHEMISTRY IN THE LOWER ATMOSPHERE”**

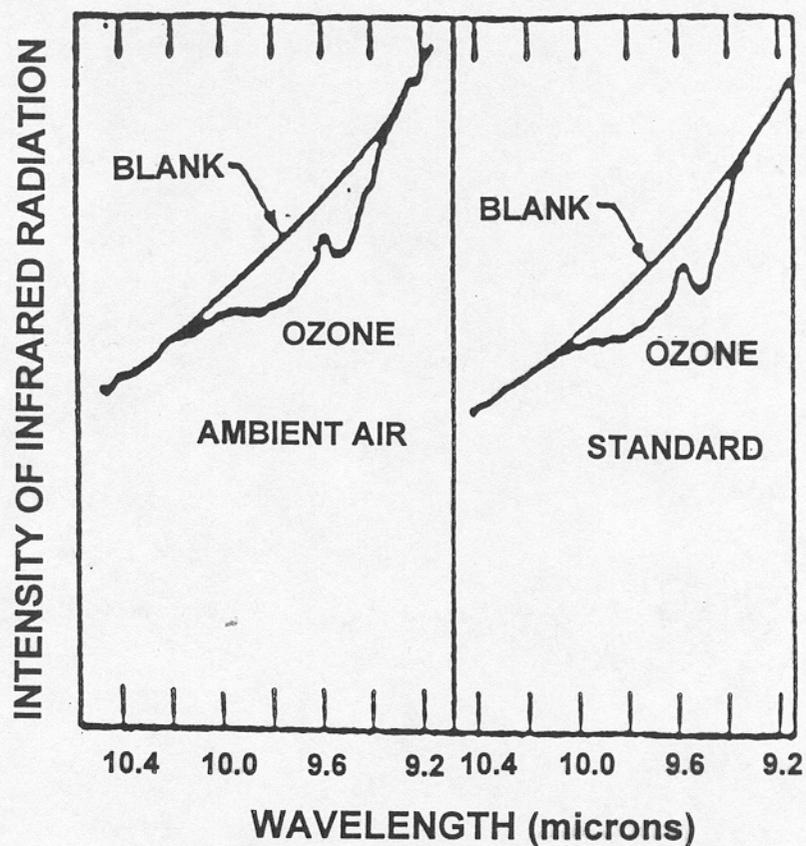
**F. E. Blacet,  
Department of Chemistry,  
University of California, Los Angeles**



**“However, the postulated steps are reasonable and indicate a way in which nitrogen dioxide may serve as an intermediate in making solar radiation available for use in the synthesis of ozone from atmospheric oxygen.”** [Indust. Eng. Chem., 44, 1339 (1952)]

# First Spectroscopic Identification and Measurement of Ozone in Polluted Ambient Air. Long Pathlength Infrared Technique

South Pasadena, 3:00 p.m., September 28, 1956



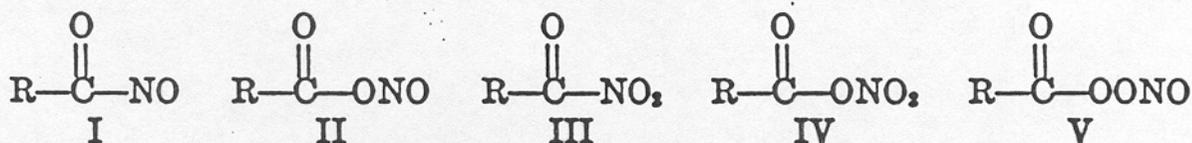
(a) Ambient Ozone - 0.4 ppm  
(Pathlength: 336 m)

(b) Standard Ozone - 1.34 ppm  
(Pathlength 120 m)

Stephens, Scott, Hanst and Doerr, 1956-57

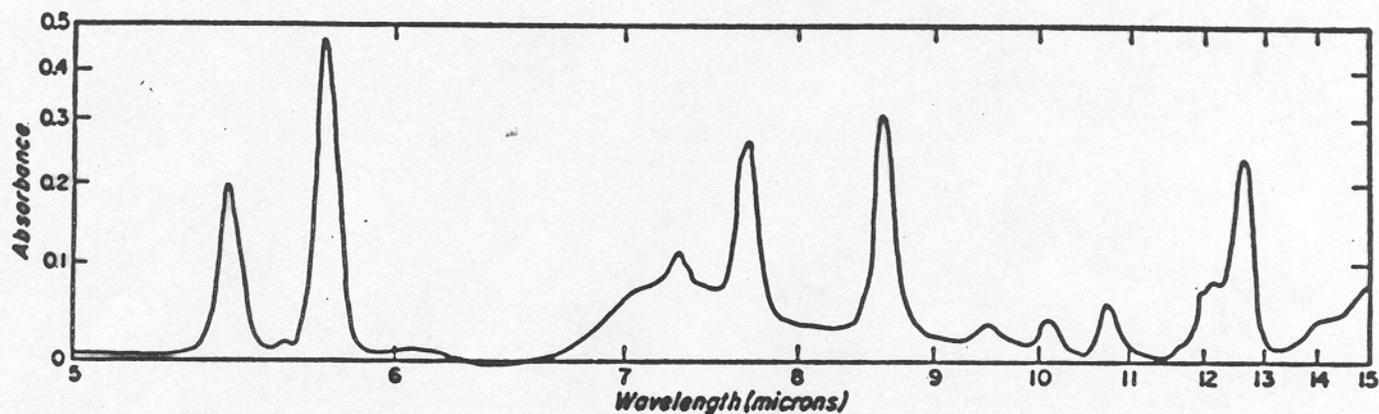
# Determination of structure of "Compound X" using long path infrared absorption spectroscopy

Stephens, Scott, Hanst, and Doerr, *JAPCA*, 6, 159 (1956)



Possible Structures

---



Infrared spectrum of "Compound X" confirming  
that it is Peroxyacetyl Nitrate (PAN), Structure IV

Stephens, Darley, Taylor, and Scott, *Proc. Am. Petrol Inst.*, 40, III (1960)

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**THE CLASSIC MONOGRAPH, 1961**

***PHOTOCHEMISTRY  
OF  
AIR POLLUTION***

**Philip A. Leighton**

**Department of Chemistry**

**Stanford University**

**Stanford, California**

**Academic Press**

# KEY ROLE OF OXIDES OF NITROGEN

- Sole known anthropogenic source of ozone:



- Forms the nitrate radical (nighttime oxidations):



- Precursor to PAN, HNO<sub>3</sub>, nitro-PAH etc.



**BEEFEATER**



Special  
London Dry  
**GIN**

**MARTINI ROSSI**



## HOW MUCH IS A PART-PER-THOUSAND ( $\cong$ Torr)?

- Add 6000 drops (5 jiggers) of vermouth to 1 bathtub of gin

## HOW MUCH IS A PART-PER-MILLION (ppm)?

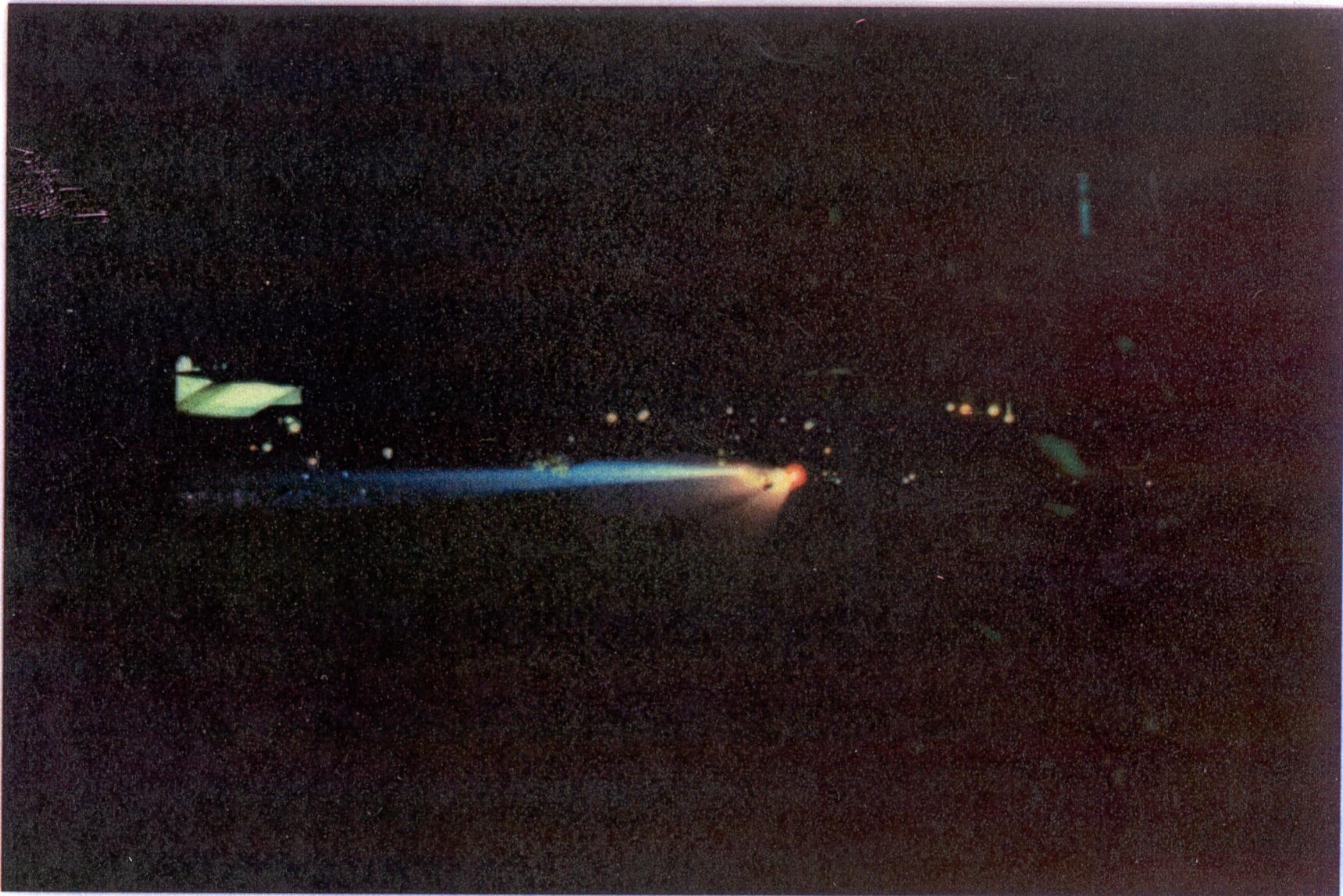
- Add 6 drops of vermouth to 1 bathtub of gin

## HOW MUCH IS A PART-PER-BILLION (ppb)?

- Add 1 drop of vermouth to 154 bathtubs of gin

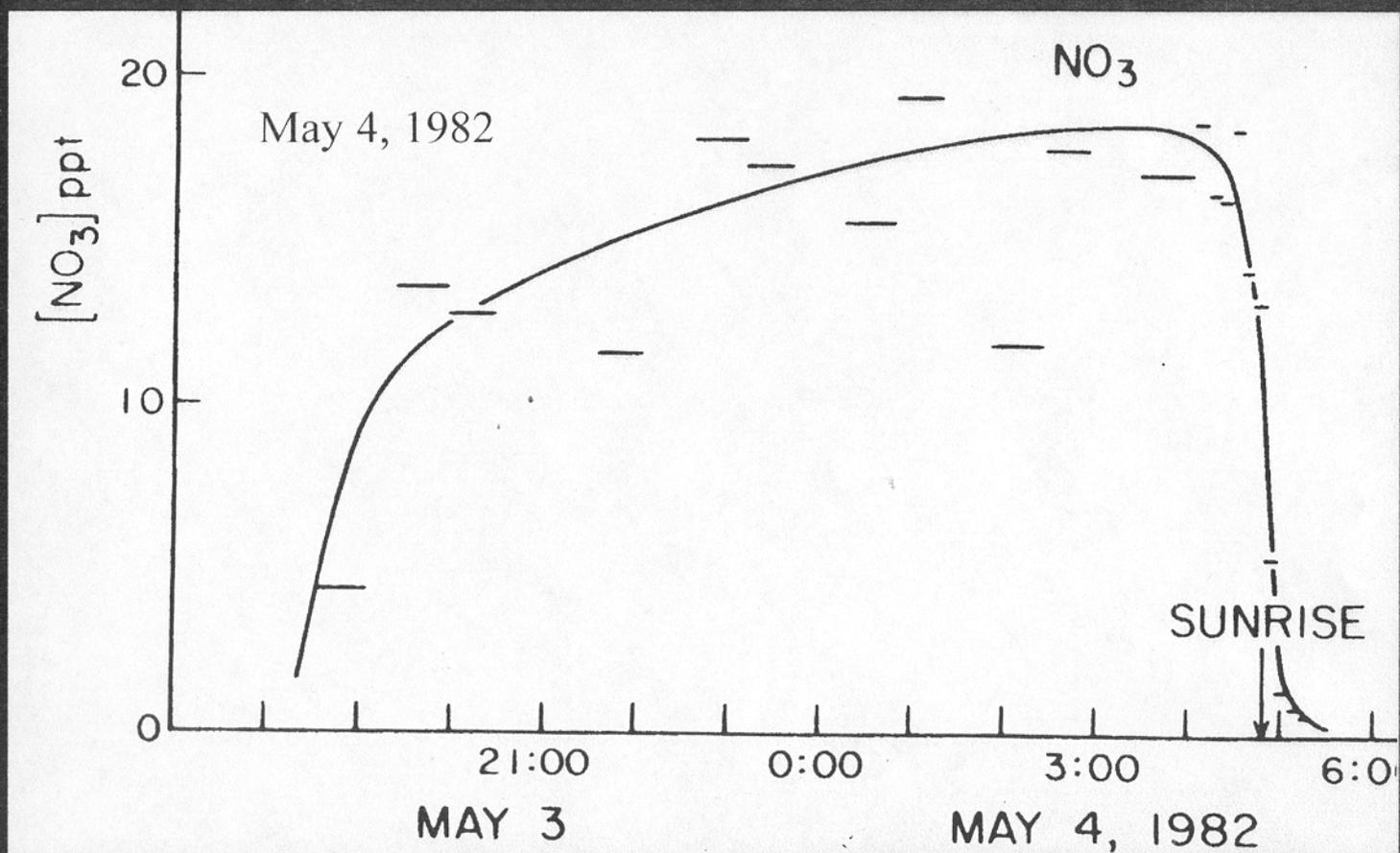
## HOW MUCH IS A PART-PER-TRILLION (ppt)?

- Add 1 drop of vermouth to 154,000 bathtubs of gin





# Nighttime Gas Phase Nitrate Radical ( $\text{NO}_3$ ) at Death Valley



**MEASUREMENTS OF THE VERTICAL  
DISTRIBUTIONS OF VARIOUS TRACE  
GASES IN URBAN AREAS BY  
DIFFERENTIAL OPTICAL ABSORPTION  
SPECTROSCOPY (DOAS)**

Milan Italy 1998 and Phoenix, AZ 2001

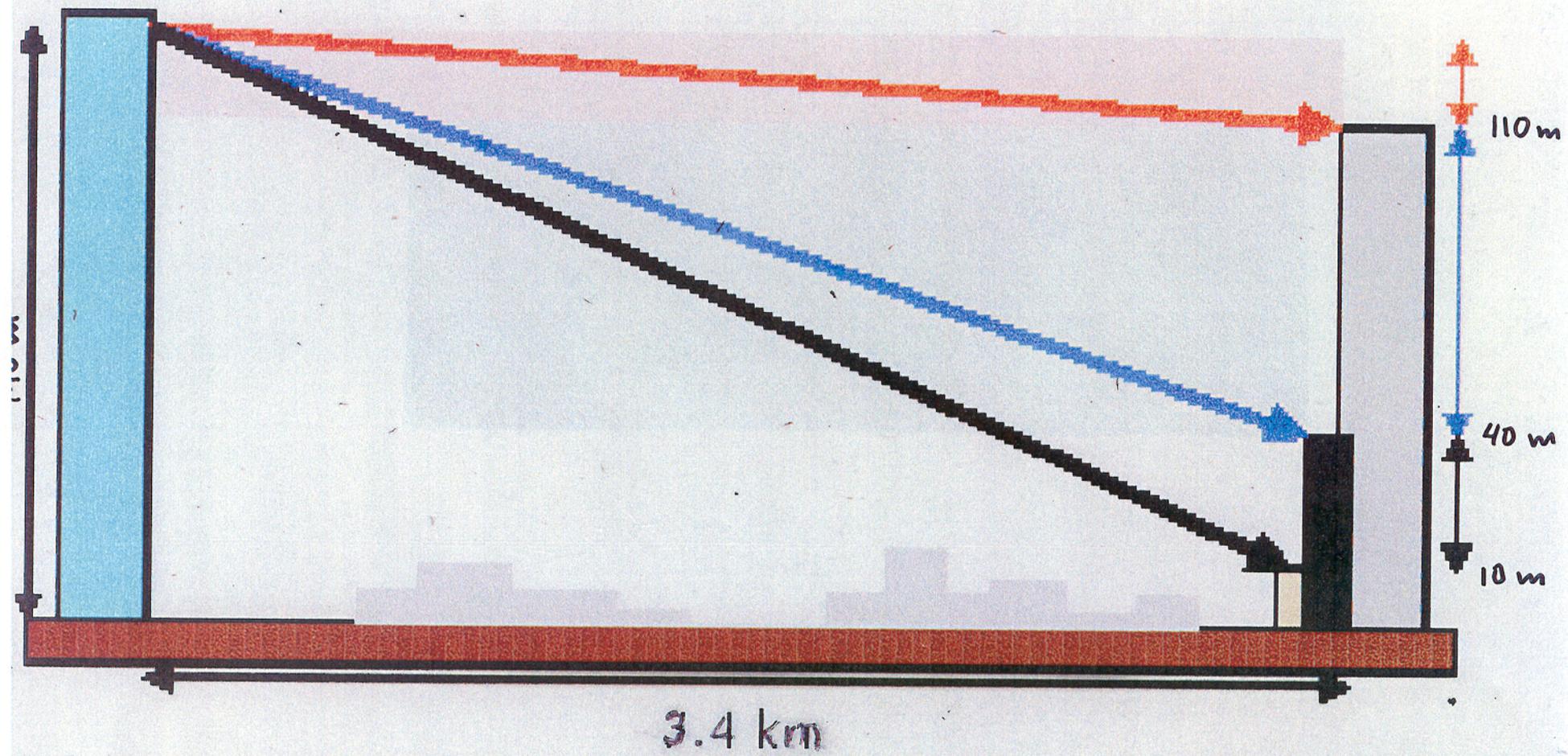
JOCHEN STUTZ

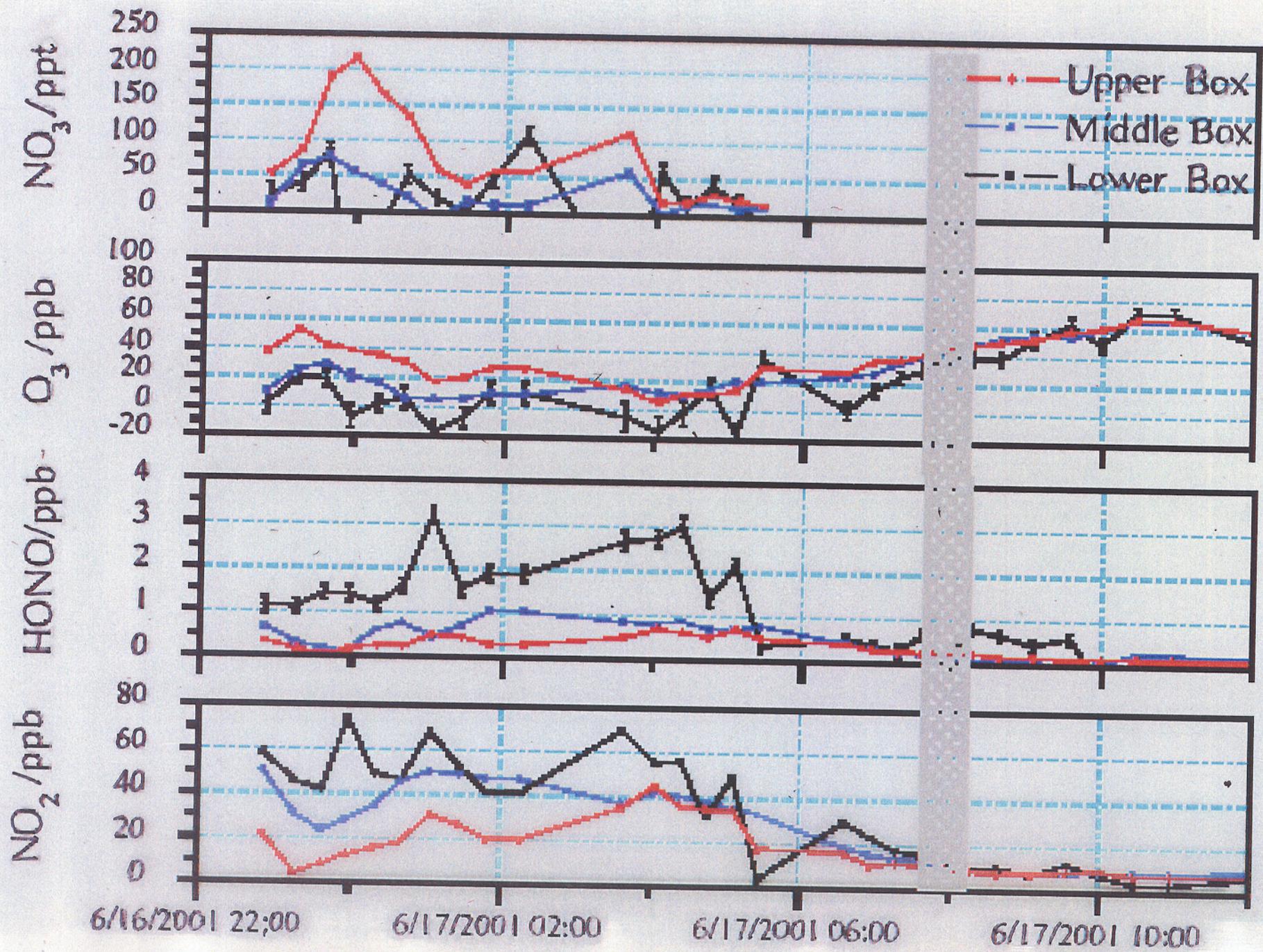
“The composition of the troposphere at night is strongly dependent on vertical mixing, which often manifests itself in the form of a shallow nocturnal boundary layer. This boundary layer inhibits transport of trace gases from the lowest part of the troposphere, where most of the sources are located, to the air aloft.

“While  $\text{NO}_x$  emissions are typically efficiently mixed throughout the boundary layer during the day, their vertical transport at night is slow, leading to strong gradients of species such as ozone.”

Dept. Atmospheric Sciences, UCLA

email: [jochen@atmos.ucla.edu](mailto:jochen@atmos.ucla.edu)





Computer

## CONCLUSION

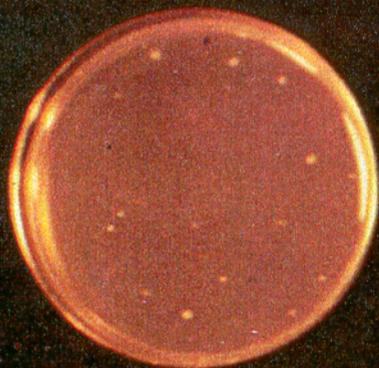
“These results show the strong change in the composition of the nocturnal atmosphere with altitude. This change in composition will also be reflected in the chemistry at different altitudes.

- ◆ “The picture of a ‘well-mixed’ nocturnal boundary layer is therefore not valid. Significant changes occur in a vertical scale of 10 m or even less.”

- ◆ “How representative are nocturnal and daytime measurements of pollutants taken close to the ground?”

- ◆ “Are the strong vertical changes reproduced in *chemical models for urban areas*? If not, do they have an influence?”

- ◆ “What happens during the early morning when photochemistry and vertical mixing begin simultaneously to change the composition of the atmosphere?”



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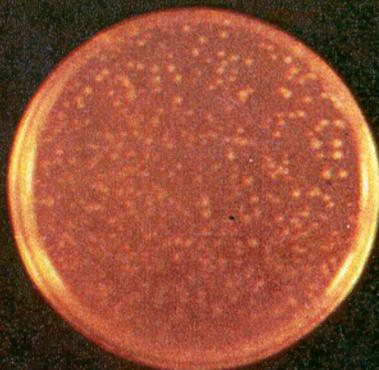
TA98  
ALONE

POLAR NEUTRALS  
L.A. FEB. '78



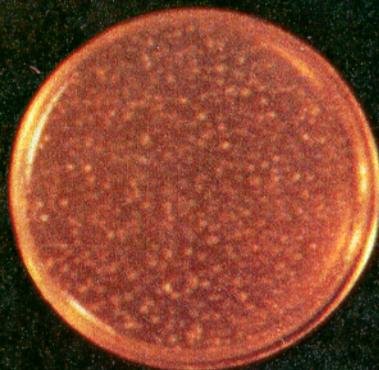
215

10µl  
SAMPLE



720

100µl  
SAMPLE



950

100µl  
SAMPLE  
+S9

# “ATMOSPHERIC REACTIONS OF POLYCYCLIC AROMATIC HYDROCARBONS: FACILE FORMATION OF MUTAGENIC NITRO DERIVATIVES”

## ABSTRACT:

(1) Directly active mutagens are formed on exposure of the promutagen benzo[a]pyrene to gaseous pollutants in ambient smog.

(2) In simulated atmospheres containing 1 part per million nitrogen dioxide and traces of nitric acid, *directly mutagenic* nitro-derivatives are readily formed from both benzo[a]pyrene and perylene (a nonmutagen in the Ames reversion assay).

(3) Possible formation of direct mutagens by such reactions:

- On sample collection filters
- In exhaust effluents and
- In the atmosphere,

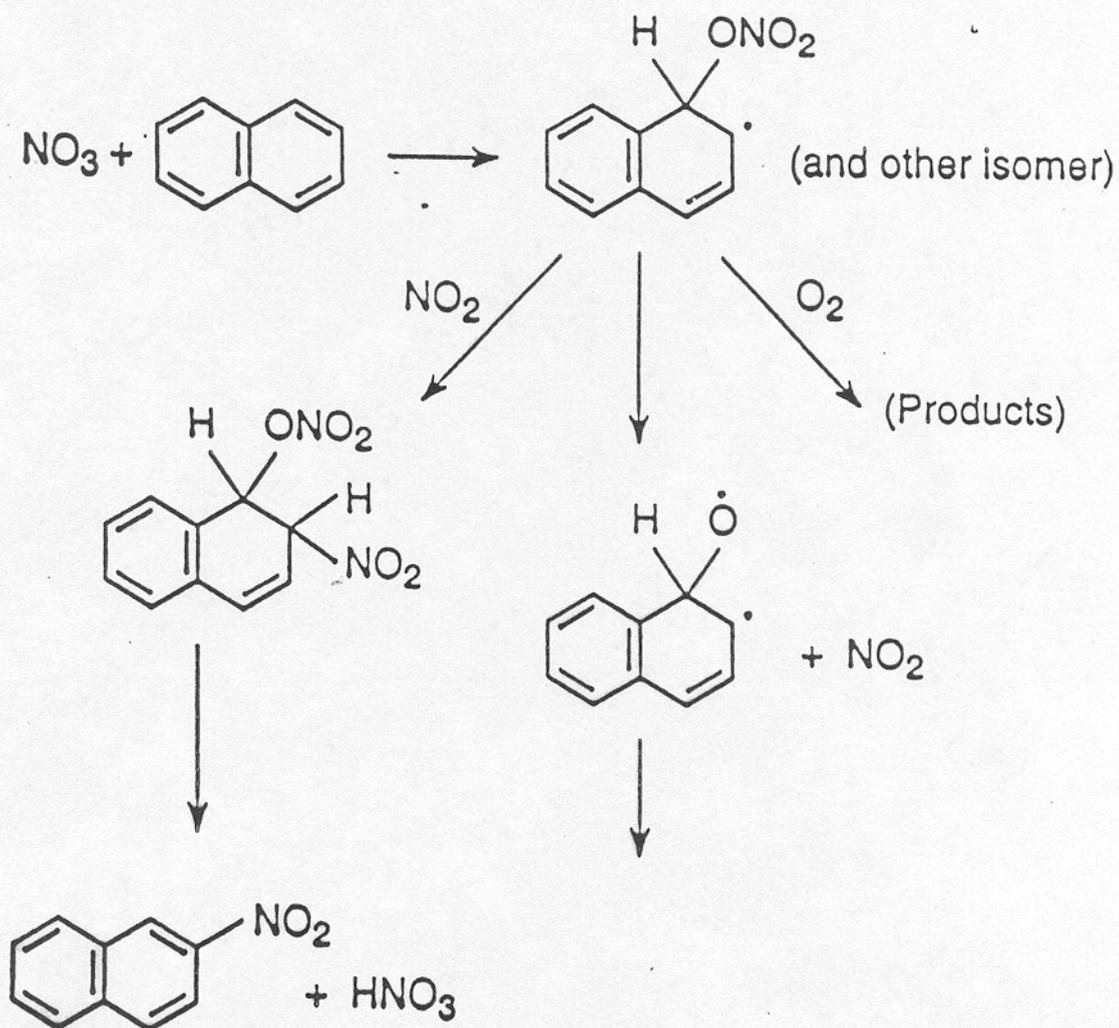
should be recognized.

# **HALF OF THE MUTAGENIC ACTIVITY OF AMBIENT AIR IS FROM DERIVATIVES OF EMITTED PAHs**

- This study, which examined ambient particulate matter, ambient vapor-phase samples, and urban dust, determined that *roughly half of direct-acting ambient air mutagenicity could be ascribed to atmospheric transformation products of PAHs.*
- The research adds significantly to the knowledge of the chemical nature of mutagens in ambient air, and provides a basis for determining the effects of various PAH emission control options on public health in California.

[Study performed by the Statewide Air Pollution Research Center, UCR.  
"Research Notes," California Air Resources Board,  
November 1994, No. 94-22.]

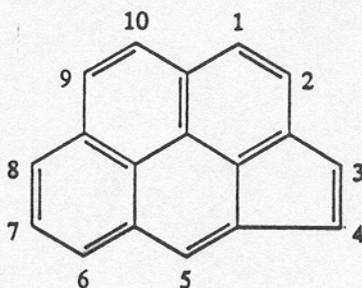
**MECHANISM OF NO<sub>3</sub> RADICAL REACTION WITH  
NAPHTHALENE IN AIR: NIGHTTIME FORMATION OF  
BACTERIAL AND HUMAN CELL MUTAGEN,  
2-NITRONAPHTHALENE**



**Lifetime, in daylight,  $\tau = 2.9$  hr vs. 0.4 hr for nonmutagenic 1-isomer**

# A "RESEARCH PRIORITY"

**“Given its demonstrated toxicology, relatively high levels in diesel exhaust and non-catalyst-equipped motor vehicles, widespread distribution in ambient air, and unique structure-reactivity aspects, further research on the fundamental and applied atmospheric chemistry and toxicology of cyclopenta[cd]pyrene would seem useful.**



**Cyclopenta[cd]pyrene**

**PARTICLE MASS vs.  
PARTICLE NUMBERS IN  
EXHAUST FROM 1988 vs.  
IMPROVED 1991 HEAVY-DUTY  
DIESEL ENGINES**

**RESULTS**

**Particle Mass**

**Emissions of particles in the  
accumulation mode (0.046 to 1.0  $\mu\text{m}$ ),  
as well as the total particulate mass,  
from a 1991 heavy-duty engine  
operating on a low-sulfur fuel**

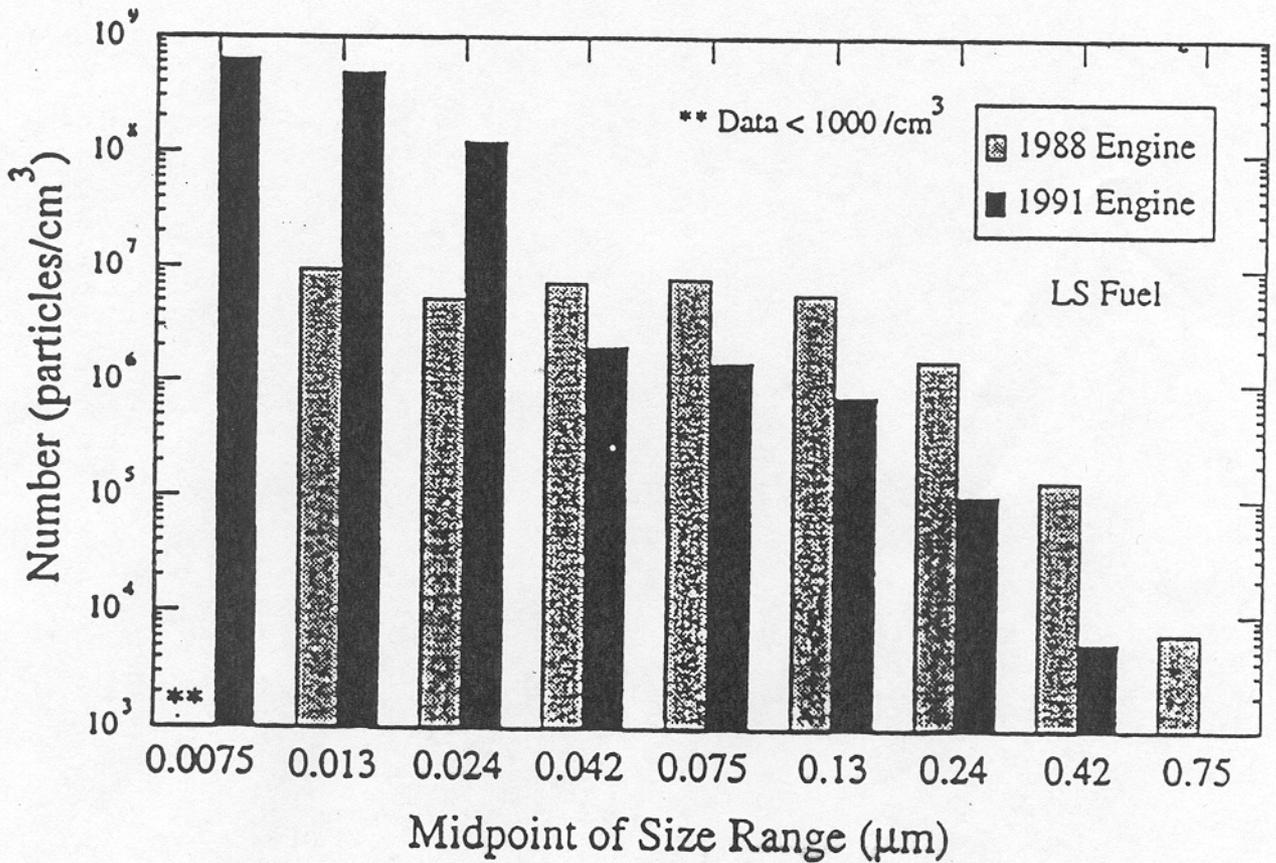
(0.01 weight % S) were much lower than from a less sophisticated 1988 model operating on the same fuel. Both were running under steady-state conditions.

### Particle Numbers

However, there was a *30-fold or greater increase in the number of ultra-fine particles (0.0075 to 0.046  $\mu\text{m}$ ) emitted by the 1991 engine with its newer technology.*

K. J. Baumgard and J. H. Johnson,  
*Soc. Automot. Eng.*, 960131  
(Spec. Publ. 1140, 1996, p. 37)

NUMBER DISTRIBUTION COMPARISONS BETWEEN A 1988 AND A MORE SOPHISTICATED 1991 HEAVY-DUTY DIESEL ENGINE RUNNING ON LOW SULFUR FUEL. A 30- TO 60-FOLD INCREASE IN ULTRAFINE PARTICLES IS OBSERVED.



# SOME DIESEL EMISSION CONTROL ISSUES

Heavy duty diesel exhaust emissions passing through a “Diesel Particulate Filter” (DPF) and entering ambient air:

- Have a significantly higher percent conversion of NO to NO<sub>2</sub> in the emitted NO<sub>x</sub>--- e.g., from ~10% NO<sub>2</sub> *without* a DPF to as high as 50-70% *with* the filter
- Show an increase in bacterial mutagenicity.
- Show a major *decrease in total particle mass* but contain a *significantly higher number of ultrafine particles*.

“The Road to Hell is Paved with Good Intentions.”

# LUNG CANCER, CARDIOPULMONARY MORTALITY, AND LONG-TERM EXPOSURE TO FINE PARTICULATE AIR POLLUTION

C. Arden Pope III, et al.

**OBJECTIVE:** To assess the relationship between long-term exposure to fine particulate air pollution and (1) all-cause, (2) lung cancer, and (3) cardiopulmonary mortality.

**DESIGN, SETTING, AND PARTICIPANTS:** Vital status and cause of death data were collected by the American Cancer society as part of the Cancer Prevention II study, an ongoing prospective mortality study, which enrolled approximately 1.2 million adults in 1982.

## RESULTS

◆ Each 10- $\mu\text{g}/\text{m}^3$  elevation in fine particulate air pollution was associated with approximately a 4%, 6%, and 8% increased risk of all-cause, cardiopulmonary, and lung cancer mortality, respectively.

◆ Measures of coarse particle fraction and total suspended particles were not consistently associated with mortality.

## CONCLUSION

Long-term exposure to combustion-related fine particulate air pollution is an important environmental risk factor for cardiopulmonary and lung cancer mortality.

# A "TIMELY" NEW CALIFORNIA AMBIENT AIR QUALITY STANDARD

**March 12, 2002: An ARB-OEHHA draft document entitled:**

- ◆ **"Proposal to Establish a 24-hr Standard for PM<sub>2.5</sub> – Report to the Air Quality Advisory Committee"**

- ◆ **Recommendation: A PM<sub>2.5</sub> 24-hr standard of 25 micrograms/m<sup>3</sup> not to be exceeded.**

- ◆ **Conclusion of the Air Quality Advisory Committee: "The scientific basis for the proposed PM<sub>2.5</sub> 24-hr standard was acceptable to the Committee, with no required changes."**



**IMPACTS OF TWO CLASSES OF  
TOXIC PESTICIDES: SOME  
CONTEMPORARY HEALTH,  
ECONOMIC, AND  
ENVIRONMENTAL ISSUES**

# AB 1807: "THE TANNER BILL"

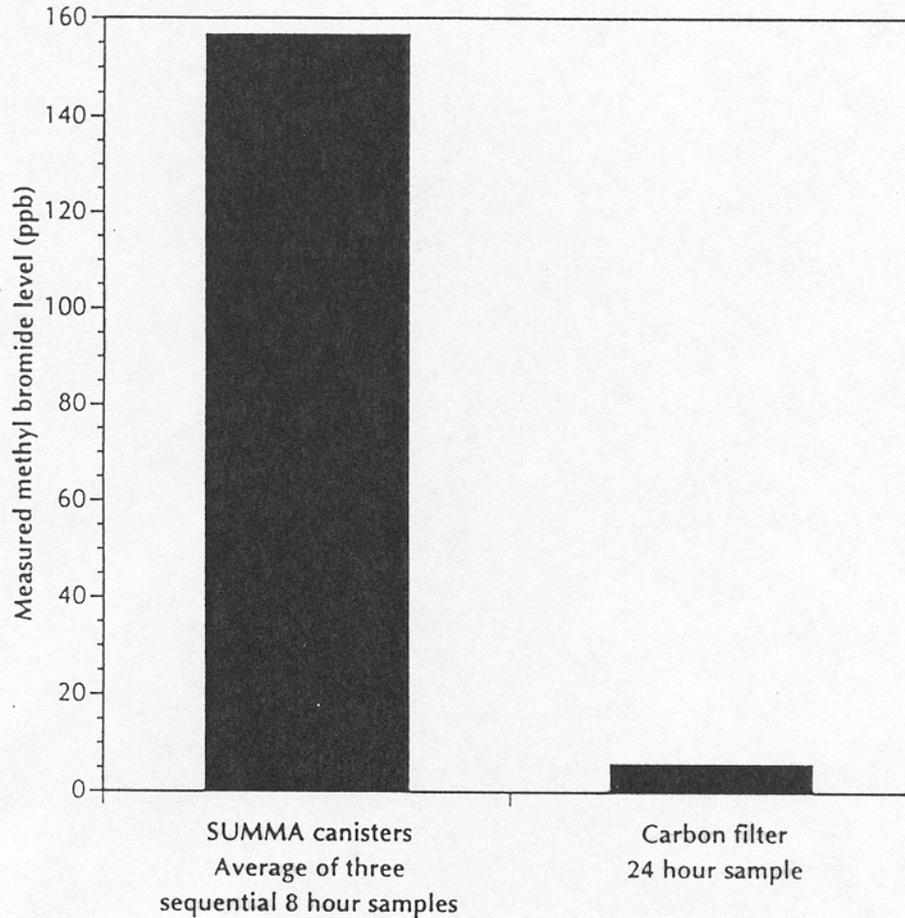
1984: California enacts legislation that created a statutory mandate for a program dedicated to:

- ◆ The *identification* of air toxics and
- ◆ Their control to levels that *prevent harm to public health*.

A cornerstone of this legislation is the key policy:

◆ "While undisputed scientific evidence may not be available to determine the exact nature and extent of risk from toxic air contaminants, *it is necessary to take action to protect public health.*"

Simultaneous Sampling of Methyl Bromide in Ambient Air by SUMMA  
Evacuated Canister and Carbon Filter Techniques 100 Ft from the Edge  
of Fumigated Strawberry Field, November 10, 1996 Near  
Watsonville, CA



SUMMA and carbon filter gear were mounted together on a tripod 5 ft above the ground. Source:  
Environmental Working Group, Methyl Bromide Monitoring Project, Watsonville, CA, November 1996.

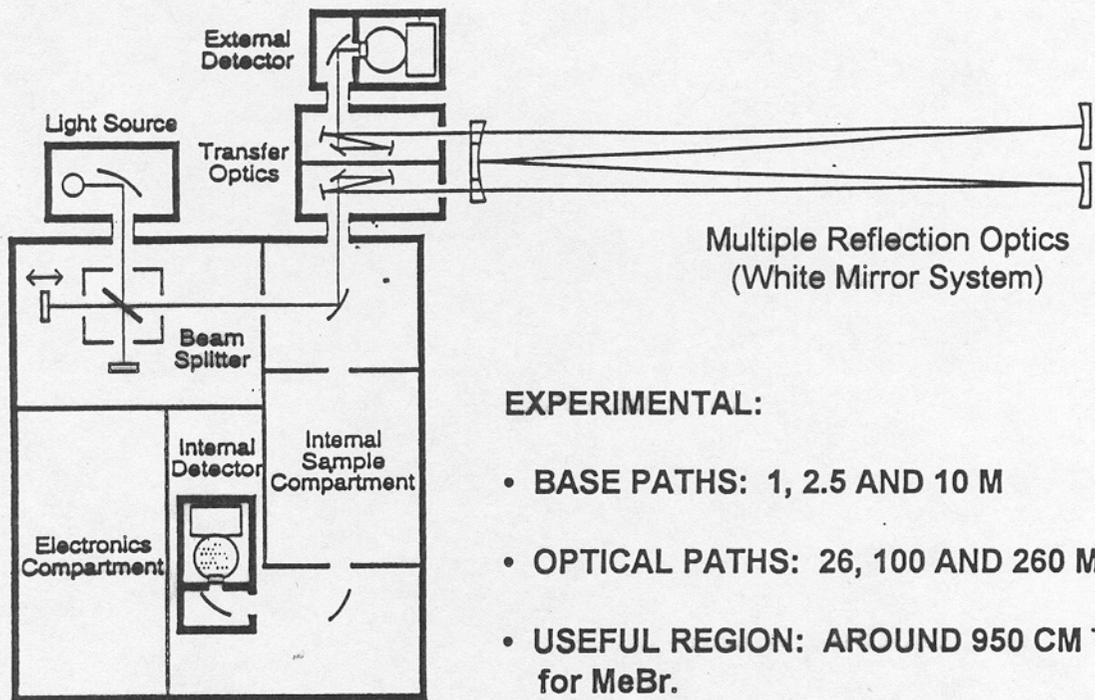
lv9712

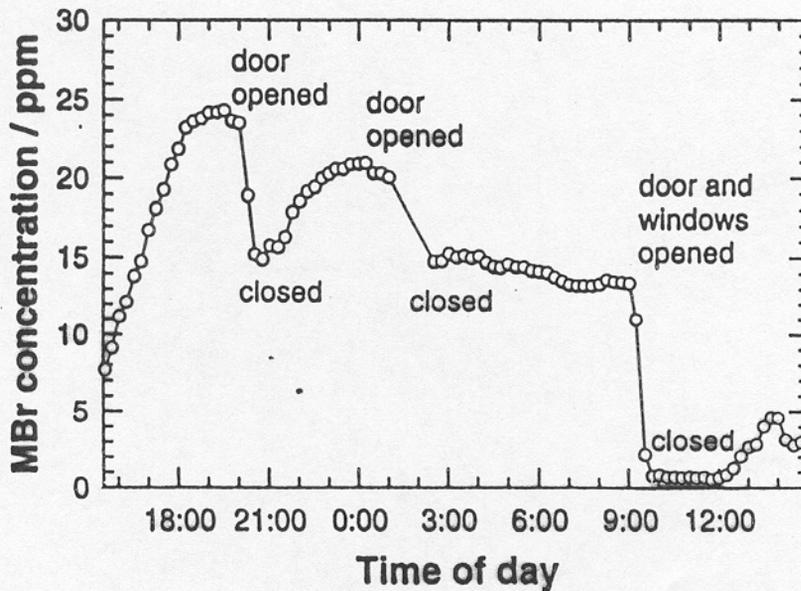
**INDOOR TIME-CONCENTRATION PROFILES  
METHYL BROMIDE DETERMINED BY LONG  
PATHLENGTH FT-IR SPECTROSCOPY**

**FOLLOWING:**

- **STRUCTURAL FUMIGATION OF A RESIDENTIAL HOME**
- **COMMODITY FUMIGATION IN WAREHOUSE**

**Source:** H. W. Biermann, "Time-Resolved Air Monitoring Using Fourier Transform Infrared Spectroscopy," in *Fumigants - Environmental Fate, Exposure, and Analysis*, James N. Seiber, et al., ACS Symposium Series 652, pp 202-211 (1996). ess97-1





**TIME-CONCENTRATION PROFILE<sup>a</sup> FOR METHYL BROMIDE.  
 IN RESIDENTIAL HOME, FOLLOWING “STRUCTURAL  
 FUMIGATION.” DATA TAKEN STARTING ~ 6 HR AFTER DECLARED  
 “SAFE FOR RE-ENTRY.”<sup>b</sup>**

<sup>a</sup>Time resolution ~ 15 minutes

<sup>b</sup>(< 3 ppm by “Drager tube”)

<sup>c</sup>H. Biermann, 1995

ess97-4

# HEALTH RISK ASSESSMENT OF AERIAL APPLICATION OF MALATHION-BAIT

## Summary Report

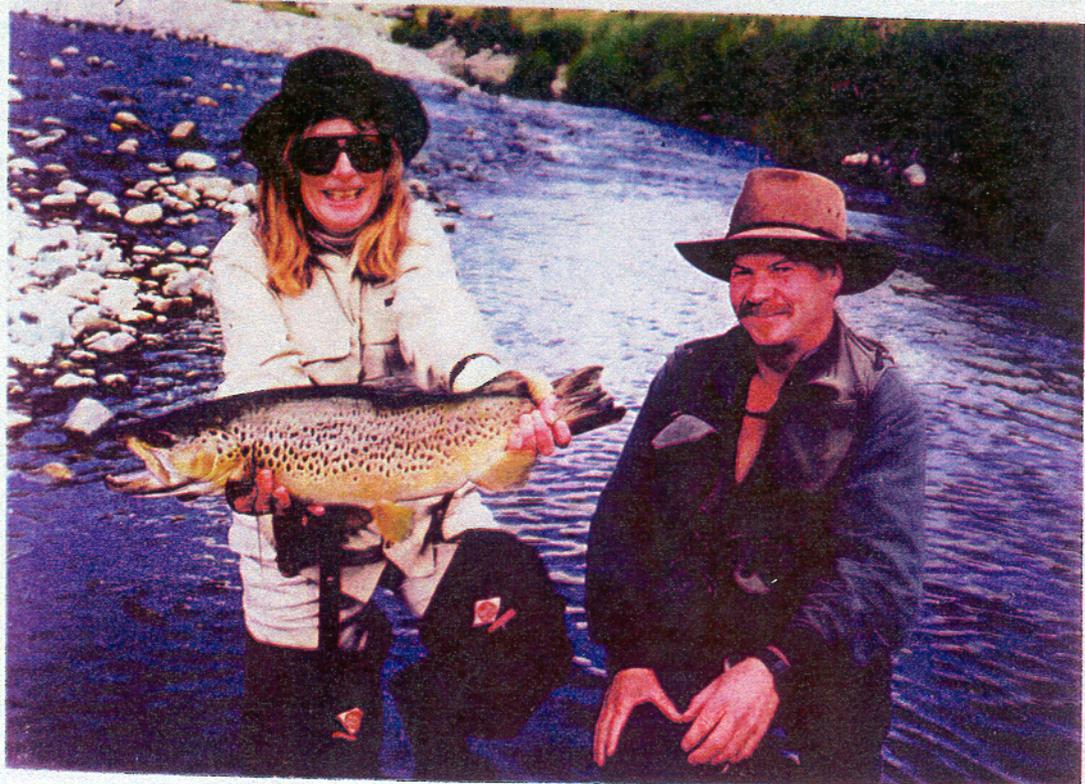
### HEALTH IMPACTS

#### “Acetylcholinesterase (AChE) Depression

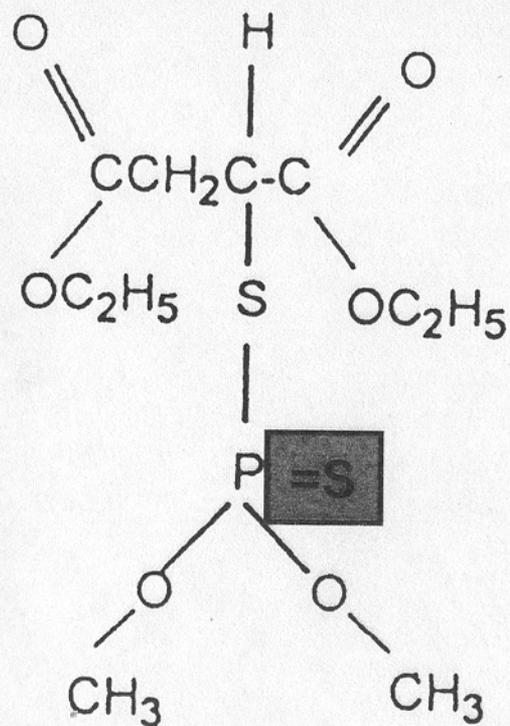
*“The possibility of AChE depression of more than 20% was found to be the most sensitive effect of toxicological concern from exposure to malathion-bait in the Medfly eradication program. A 20% depression of AChE is unlikely to cause clinical symptoms but is a marker of exposure to malathion.”*

**“Acetylcholinesterase is an enzyme needed for proper functioning of the nervous system. Its specific role is to neutralize acetylcholine immediately after the acetylcholine transmits a nerve signal across the nerve synapses. This prepares for the next signal to follow.**

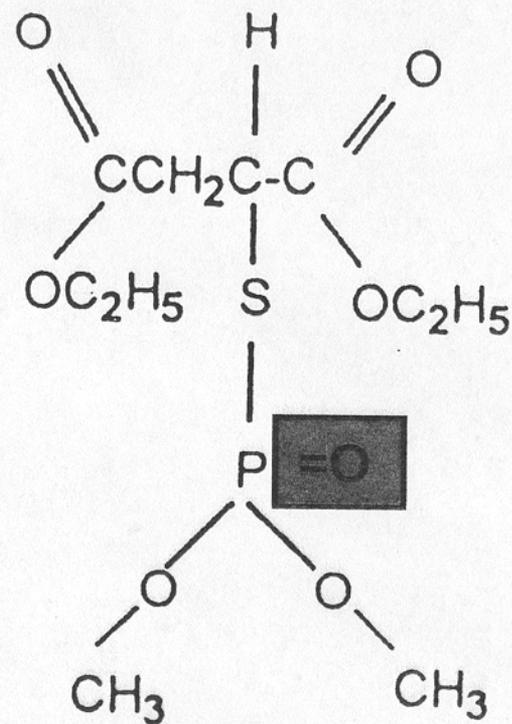
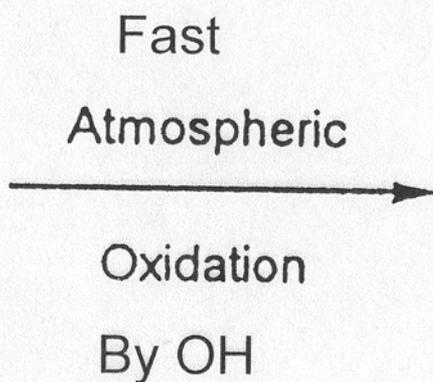
***“Humans and other mammals have a liver enzyme that detoxifies malathion. Insects and fish lack this enzyme, which is why malathion is highly effective against insect pests but far less toxic to humans. (This is also why people were advised to cover their fish ponds during malathion spraying.)”***



# Oxidation of Malathion to Malaoxon



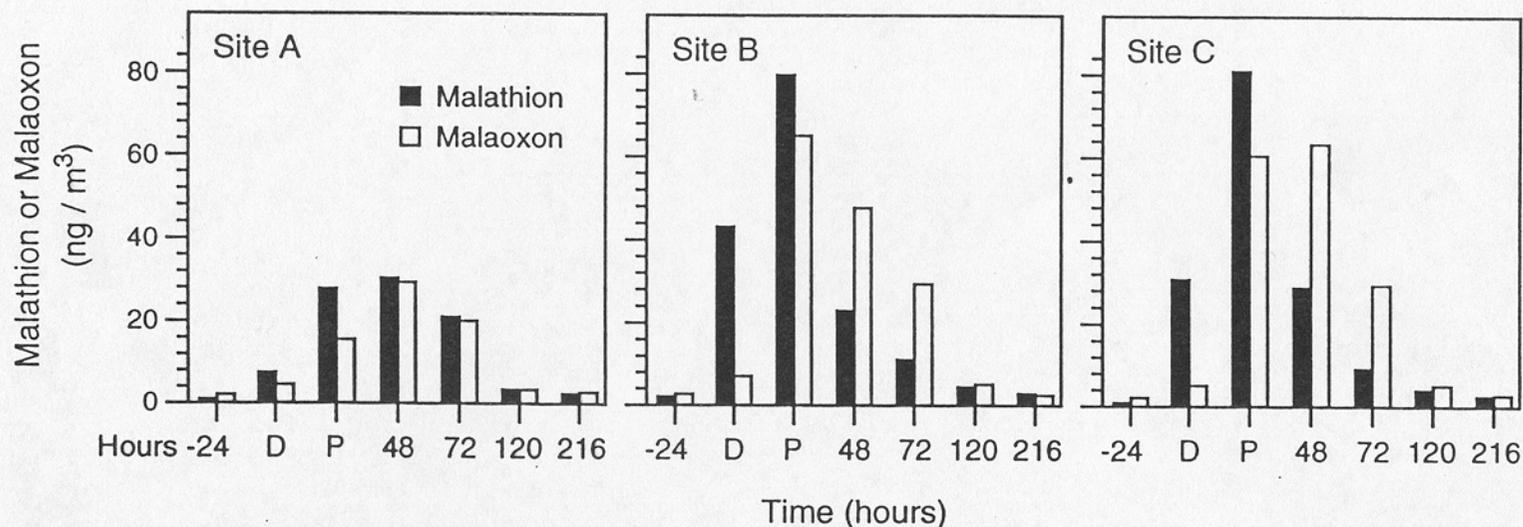
Malathion



Malaoxon

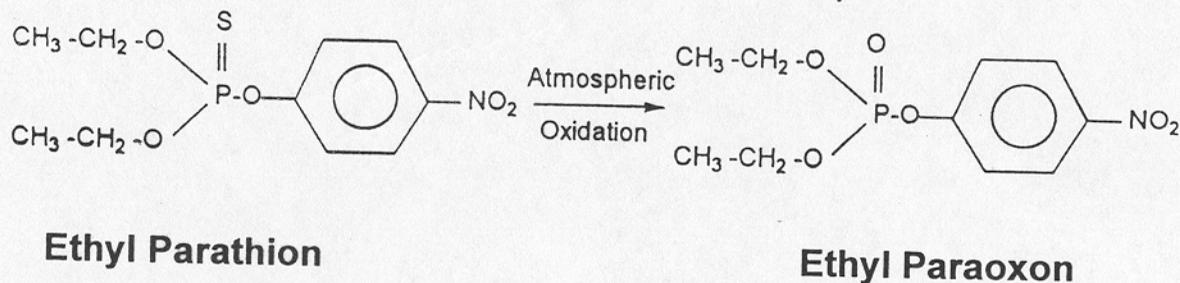
# MALATHION → MALAOXON

## AN "ATMOSPHERIC" ACTIVATION



Concentrations of malathion and malaoxon measured at three sites in Garden Grove, southern California in 1990 (adapted from Brown et al., 1993); before aerial spraying (-24 hr); during spraying (D); and immediately postspraying (P), and up to 216 hr later.

# ATMOSPHERIC TRANSFORMATION OF THE PESTICIDE ETHYL PARATHION TO ETHYL PARAOXON, AN ANALOG OF A NERVE AGENT



Half-life due to reaction with OH radicals

$$\tau_{1/2} = 2.6 \text{ hr}$$

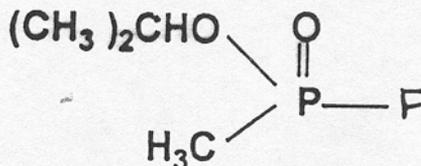
Half-life, solar noon in the summer months

$$\tau_{1/2} = < 1 \text{ hr}$$

# SARIN (GB)

## Nerve Gas

**"HUMAN TOXICITY: EXTREMELY ACTIVE CHOLINESTERASE INHIBITOR. TOXIC EFFECTS SIMILAR TO, BUT MORE SEVERE THAN, PARATHION."**



**METHYLPHOSPHONOFUORIDIC ACID;**

**I-METHYLETHYL ESTER,  $\text{C}_4\text{H}_{10}\text{FO}_2\text{P}$ ; MW 140.99140.09.**

*Merck Index, 8127, 1976*

# **THE DETERMINATION OF ACUTE TOXICITY EXPOSURE LEVELS FOR AIRBORNE TOXICANTS**

**OFFICE OF ENVIRONMENTAL HEALTH HAZARD ASSESSMENT  
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY**

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**DRAFT TECHNICAL SUPPORT DOCUMENT FOR PUBLIC COMMENT**

# ACUTE TOXICOLOGY EXPOSURE LEVELS FOR 1-HOUR EXPOSURE DURATIONS OF AIRBORNE TOXICANTS

	Level I*	Level II*	Level III*
<b><u>CW Agents</u></b>			
Arsine, AsH <sub>2</sub>	--	220 ppb	--
Chlorine, Cl <sub>2</sub>	70 ppb	--	--
Hydrogen Cyanide, HCN	30 ppb	--	50 ppm
Phosgene, COCl <sub>2</sub>	1 ppb	200 ppb	1 ppm

\*Level I = The discomfort or mild effect level

Level II = The disability or serious effect level.

Level III – The life-threatening effect level.

	Level I	Level II	Level III
<b><u>Pesticides</u></b>			
Methyl Bromide, CH <sub>3</sub> Br*	--	1 ppm	21 ppm
<b><u>Criteria Pollutants</u></b>			
Nitrogen Dioxide	--	1 ppm	--
Ozone	--	600 ppb	--
Sulfur dioxide	--	3 ppm	15 ppm

\*Calculated assuming  $C^n \times \text{Time} = K$ . This value assumes  $n = 2$ . A 1999 study assumes  $n = 1.33$ .

Draft Technical Support Document for "The Determination of Acute Toxicity Exposure Levels for Airborne Toxicants," Office of Environmental Health Hazard Assessment, California EPA, January 1995

# **MISSION STATEMENT OF THE NATIONAL DEFENSE RESEARCH COMMITTEE**

**“The Committee shall correlate and support scientific research on the mechanisms and devices of warfare, except those relating to problems of flight included in the field of activities of the National Advisory Committee on Aeronautics.**

**“The NDRC shall aid and supplement the experimental and research activities of the War and Navy Departments, and may conduct research for the creation and improvement of instrumentalities, methods, and materials of warfare.”**

**President Franklin D. Roosevelt**

**June 27, 1940**



Figure 3. *Central area of the CWS test installation at Dugway Proving Ground, Tooele, Utah.*

From "The Chemical Warfare Service in World War II: A Report of Accomplishments," Reinhold, 1948

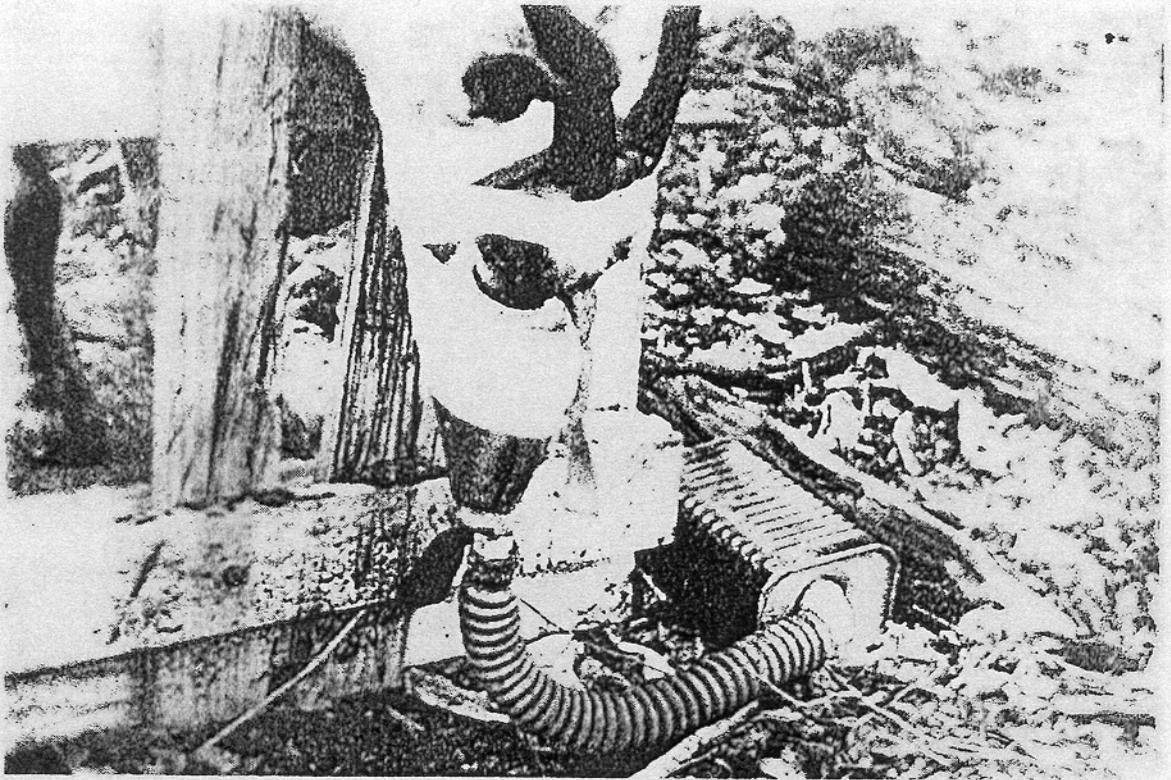
# **CHEMICAL WARFARE IN A TROPICAL JUNGLE “ENVIRONMENT”**

**“San Jose Island about 60 miles out in the Pacific Ocean from Balboa was chosen, largely because the island was uninhabited. Brigadier General E. F. Bullene commanded the expedition, and Dr. F. E. Blacet was placed in charge of the Division 10 group. This consisted of over 20 very able men who, by this time, had had more than a year’s experience in field experimentation.**

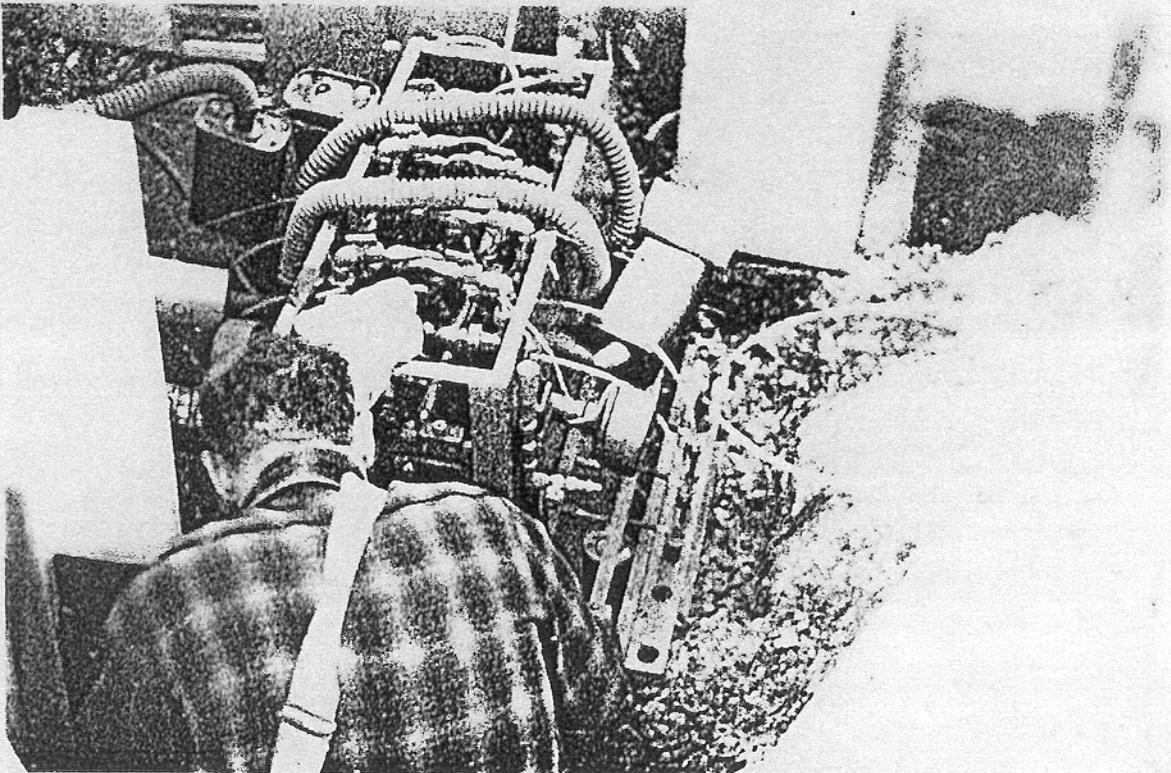
**“The entire expedition sailed from New Orleans in February 1944, and finally arrived in the Canal Zone after a lengthy trip which covered most of the Caribbean Sea not once but several times.”**

For example, in August and September 1944 several attacks were performed *under operational conditions with the aid of the 6<sup>th</sup> Air Force on a scale which, as far as we were aware, was never equaled in gas experiments during this war.* The data obtained were more than those ever obtained before.

A large amount of credit for organizing the nonpersistent phase of the program is due to Dr. Blacet, but the entire group with him performed outstanding service under conditions which were at times exceedingly trying.



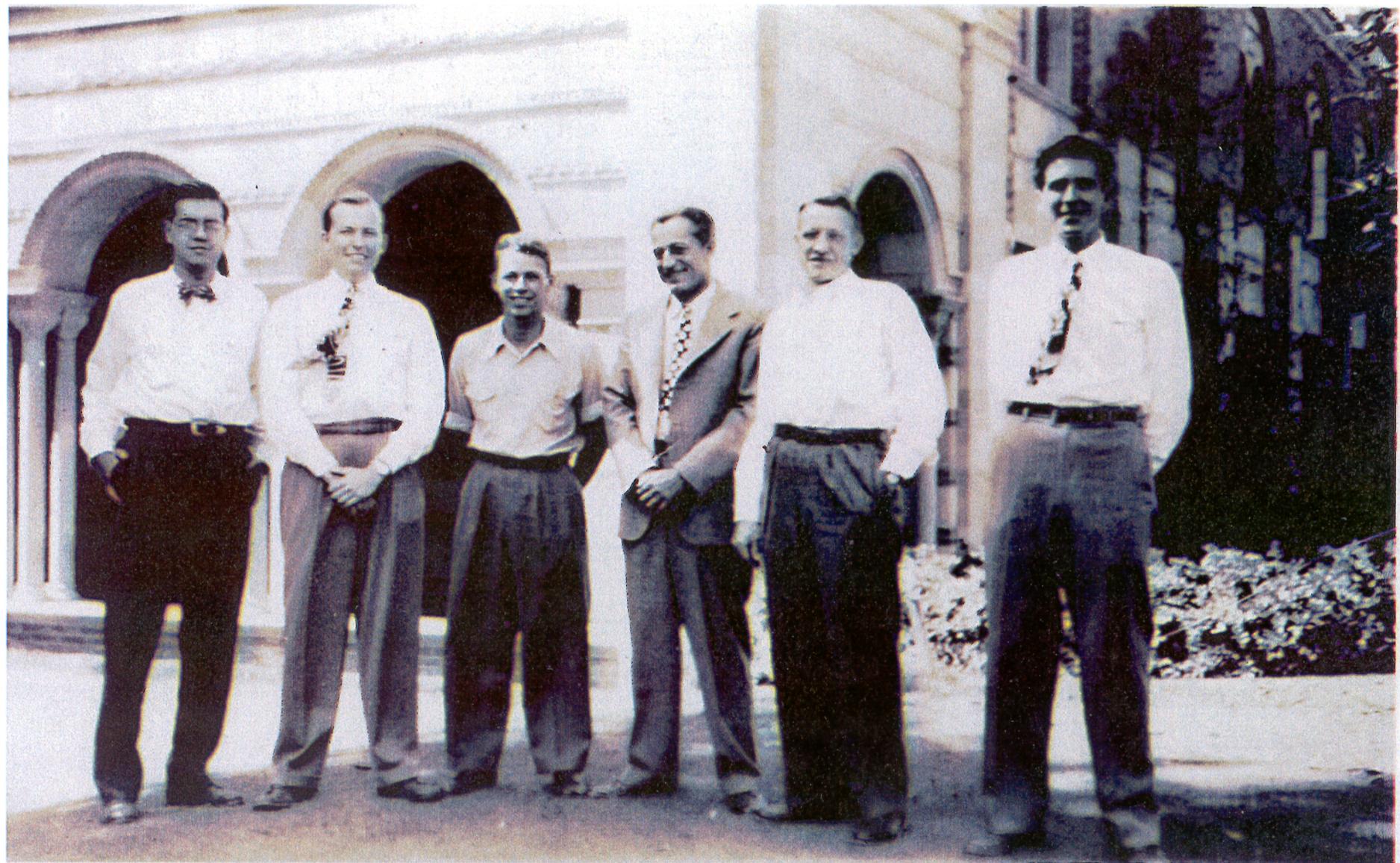
Goat fitted with gas mask for field tests



"Mechanical Goat" for field tests of gas mask canisters







## SOME “FUNDAMENTAL THINGS APPLY AS TIME GOES BY”

- ❑ *Basic science* is absolutely essential for answering key questions and developing sound control strategies.
- ❑ Ask the *right questions*...not only in research but also in its application to public policies.
- ❑ One *never has complete information* about complex environmental phenomena ..... *but* that should not prevent development and implementation of effective policies and controls.