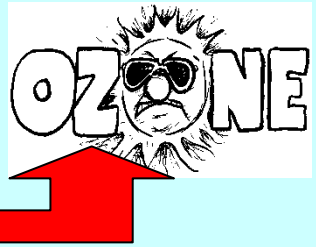
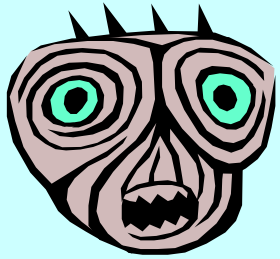
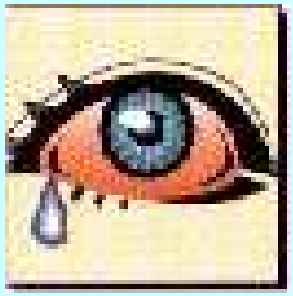
Respiratory effects of indoor generated ”smog”





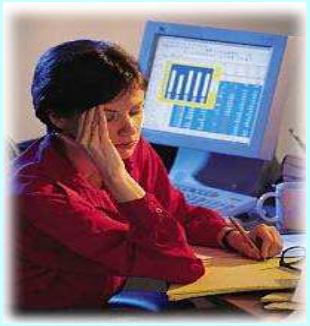


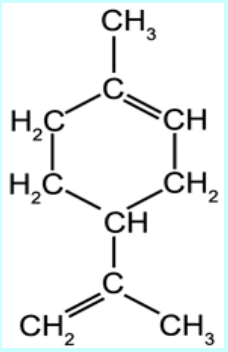
”Sick buildings”
Eye and respiratory symptoms

Fragrances
consumer products

Lung effects
cleaning personel

Children



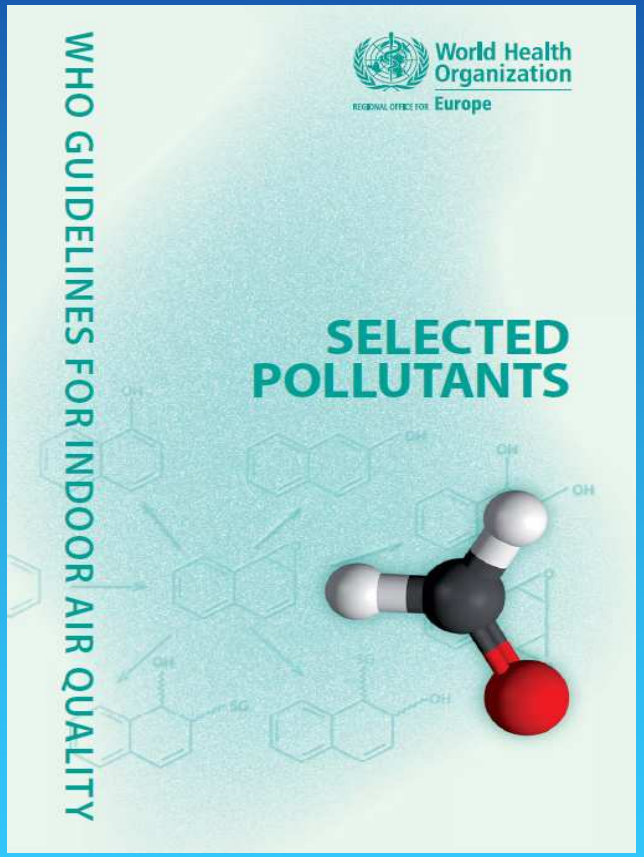


Peder Wolkoff

FORSKNINGSCENTER FOR ARBEJDSMILJØ
NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Indoor Air Guidelines
WHO 2010

Pollutant	mg/m^3	Criteria
Benzene	0.001	Life time risk = 6x10^{-6}
Carbon monoxide	100 35 10 7	15 min 1 hour 8 hours 24 hours
Formaldehyde	0.1	All 30 min periods, 24 hours
Naphthalene	0.01	Yearly average
Nitrogen dioxide	0.200 0.040	1 hour Yearly
PAH (BaP)	0.000001	Life time risk: 8,7x10^{-5} for BaP
Radon	Per Bq	Life time risk: 0,6x10^{-5} (non-smoker) Life time risk: 15x10^{-5} (smoker)
Trichloro ethylene	0.0023	Life time risk = 10^{-6}
Tetrachloro ethylene	0.25	Yearly exposure



EUROPEAN COLLABORATIVE ACTION

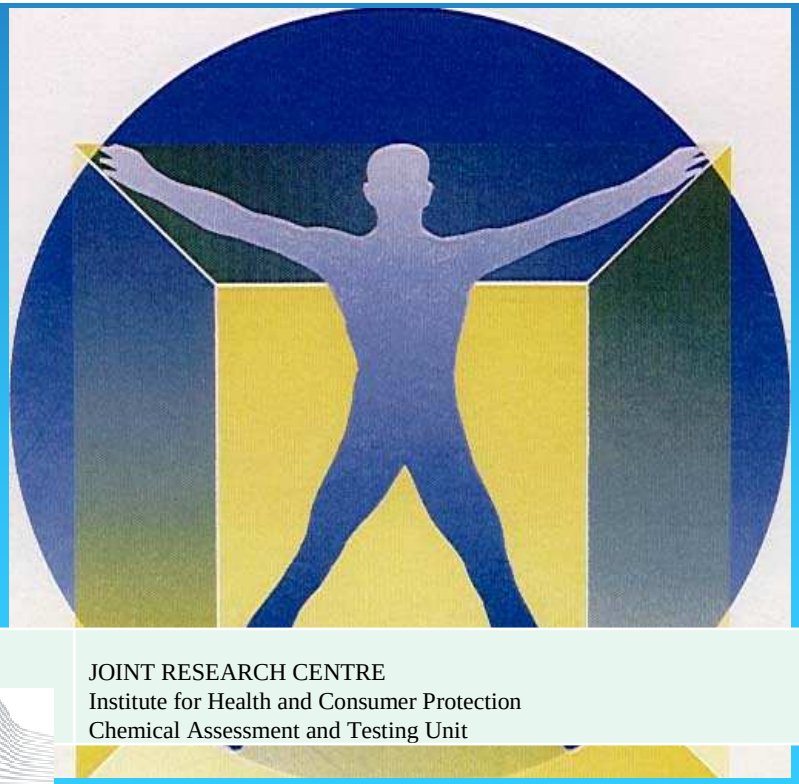
URBAN AIR, INDOOR ENVIRONMENT AND HUMAN EXPOSURE

Environment and Quality of Life

Report No 29

Harmonisation framework for health based evaluation of indoor emissions from construction products in the European Union using the EU-LCI concept

Construction product directive 89/106



Expected release
Medio October 2013

JOINT RESEARCH CENTRE
Institute for Health and Consumer Protection
Chemical Assessment and Testing Unit

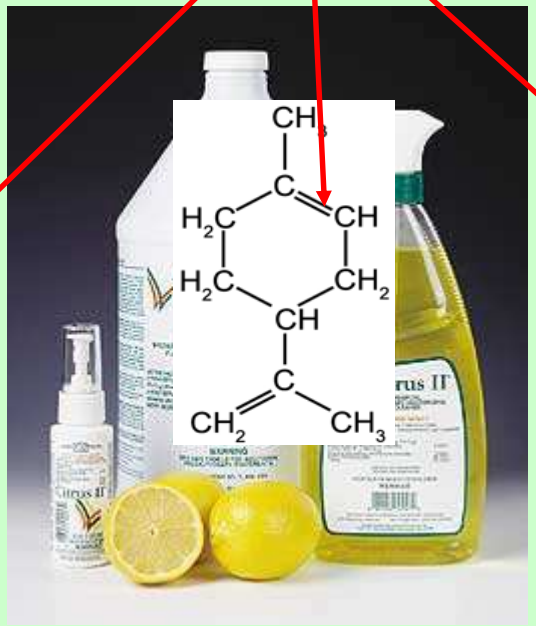
2013

EUR xxxxx EN

Is ozone-initiated terpenoid reactions a harmful cocktail?

”Reactive chemistry hypothesis”

20-70% infiltration



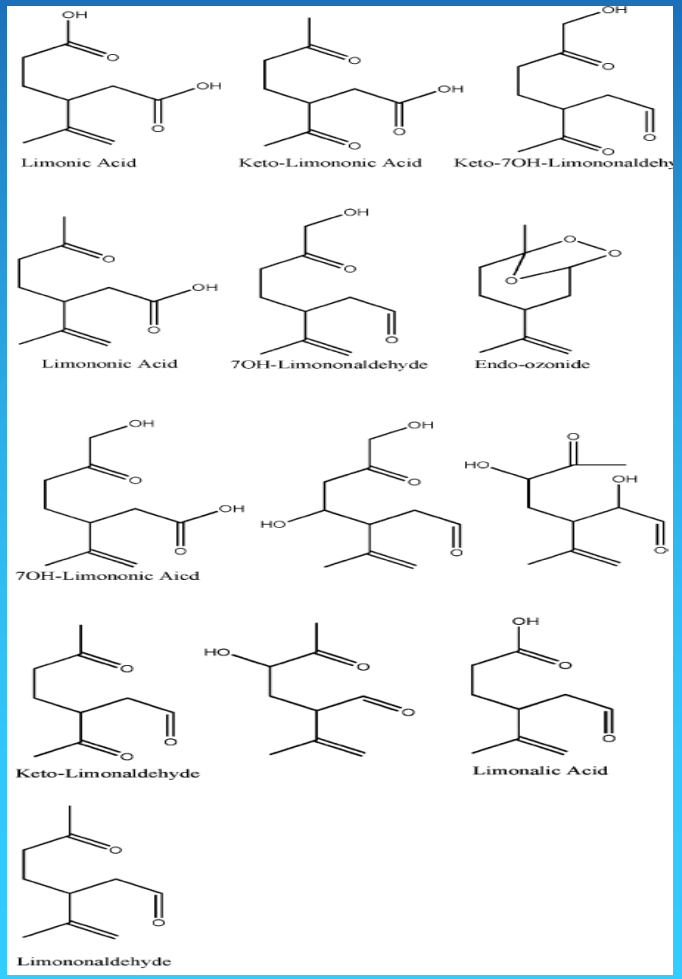
Oxidation products ozone-limonene

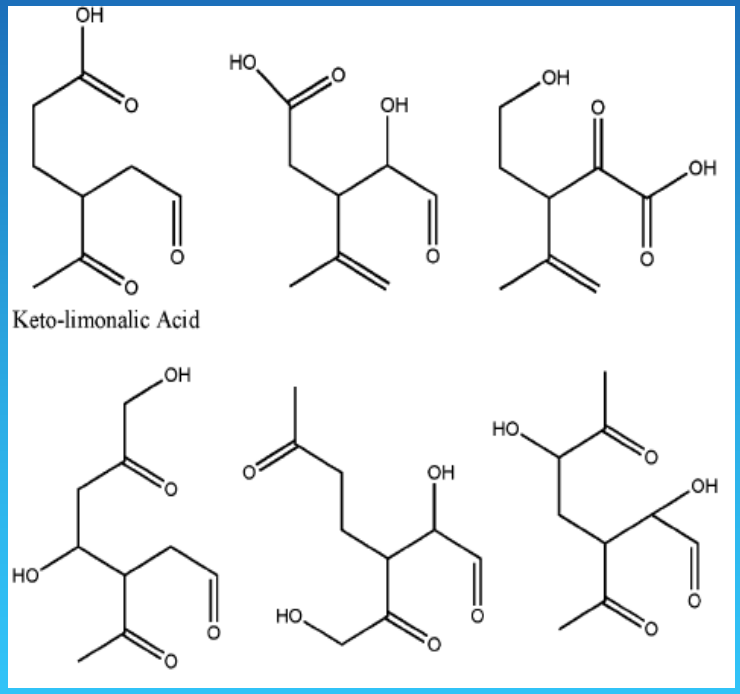
PAPER www.rsc.org/pccp | Physical Chemistry Chemical Physics

High-resolution mass spectrometric analysis of secondary organic aerosol produced by ozonation of limonene†

Phys. Chem. Chem. Phys., 2008, **10**, 1009–1022

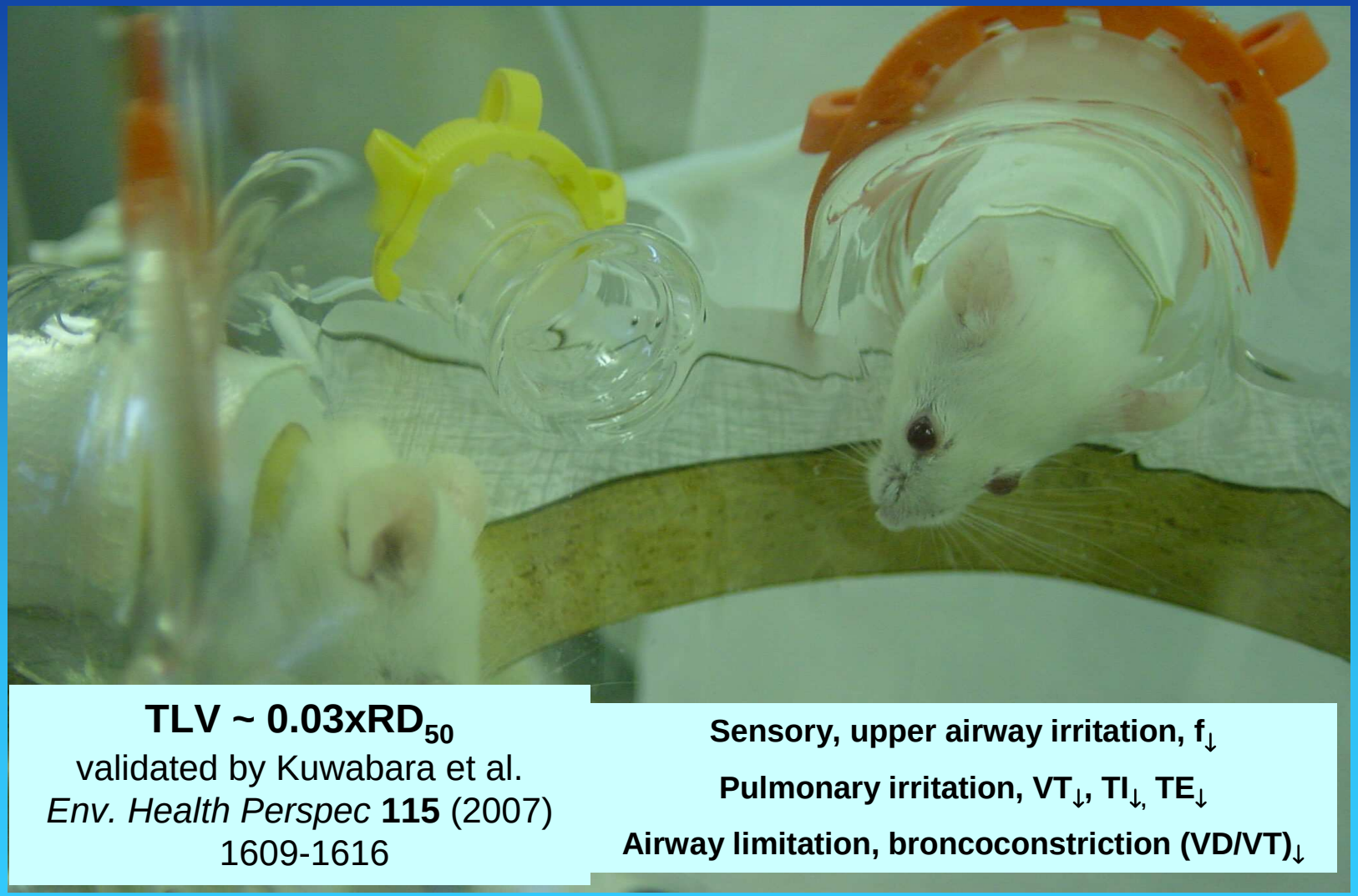
Maggie L. Walser,[a] Yury Desyaterik,[b] Julia Laskin,[c] Alexander Laskin[b] and Sergey A. Nizkorodov*[a]





Gas-phase and Particle-phase products (ultrafines)

Airway effects by mouse bioassay at NRCWE



TLV ~ 0.03xRD$_{50}$
validated by Kuwabara et al.
Env. Health Perspec **115** (2007)
1609-1616

Sensory, upper airway irritation, $f_{\downarrow}$

Pulmonary irritation, $VT_{\downarrow}$, $TI_{\downarrow}$, $TE_{\downarrow}$

Airway limitation, broncoconstriction $(VD/VT)_{\downarrow}$

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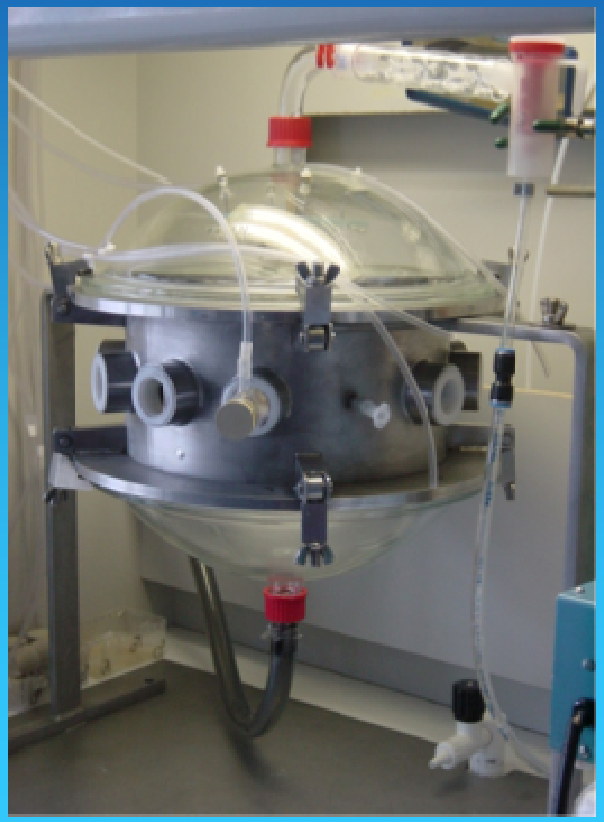
FOR THE WORKING ENVIRONMENT

Mouse bioassay

analysis of respiratory pattern



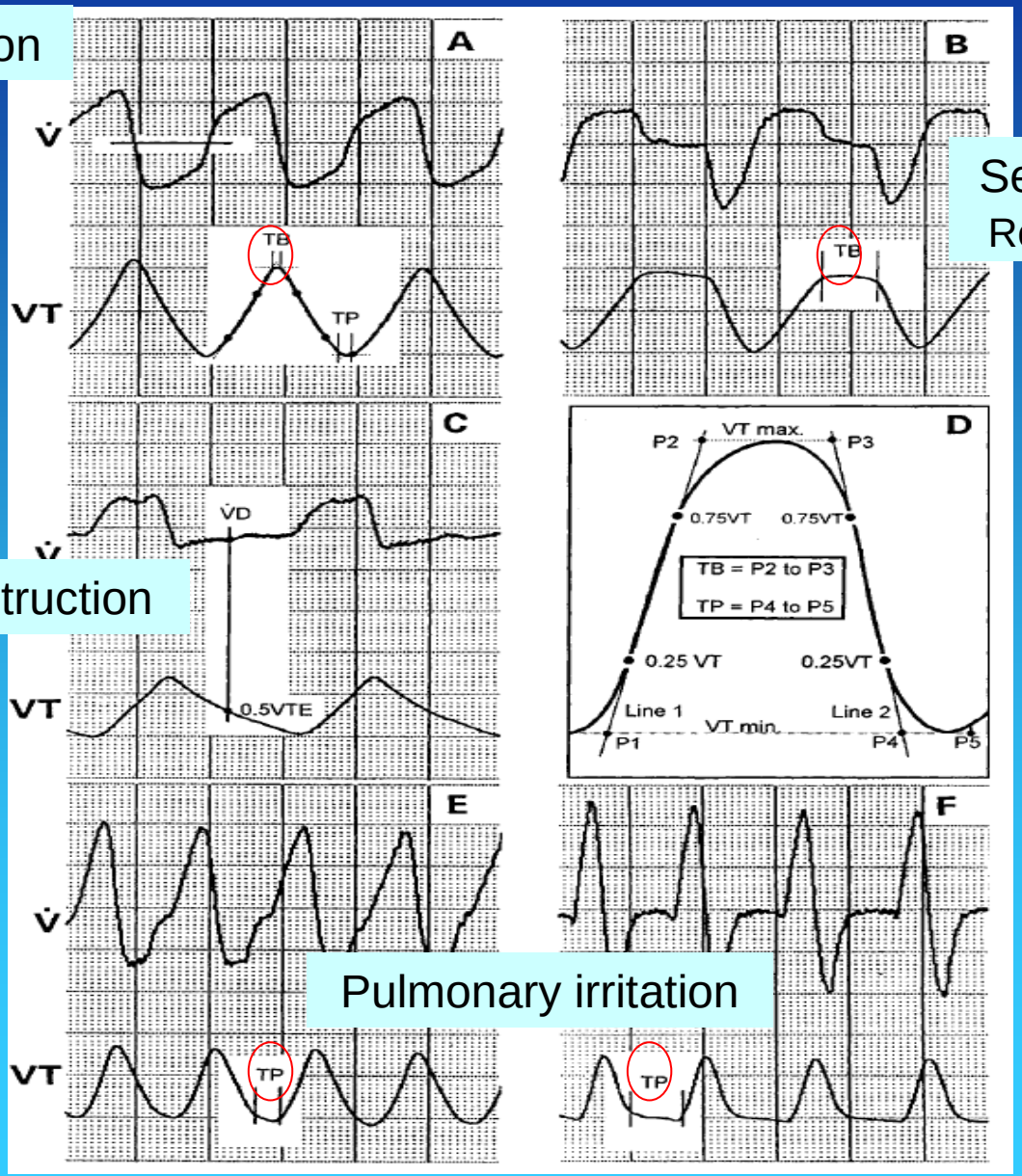
Mouse-assay
respiratory pattern analysis

Inspiration

Sensory irritation
Respiratory rate ↓

Airway obstruction

Pulmonary irritation



BAL/NAL in exposed mice

Broncho Lavage and Nasal lavage:

- **Inflammatory markers**
  - **Eosinophils**
  - **Machrophages**
  - **Epithelial cells**

- **Cardio/pulmonary markers**

NATIONAL RESEARCH CENTRE
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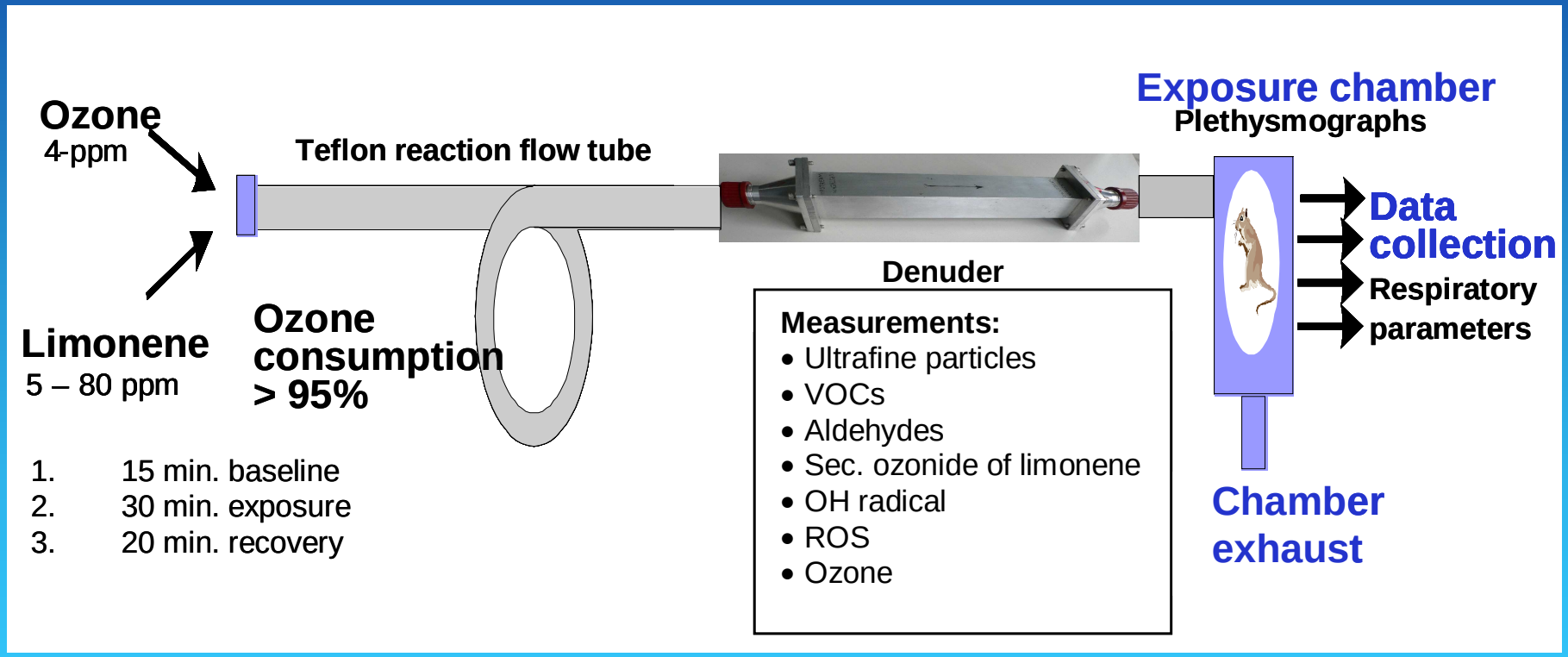
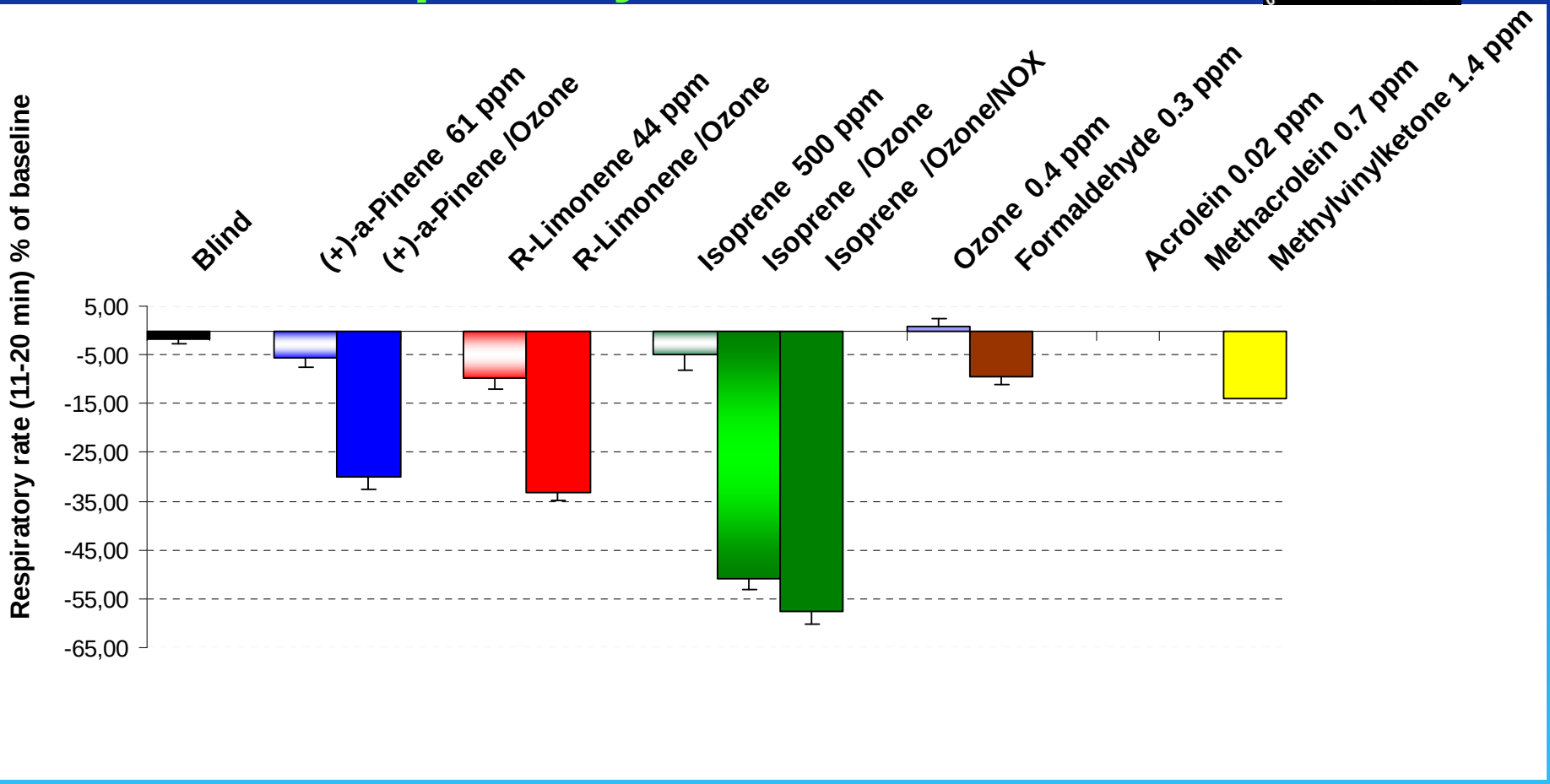
Experimental set-up
Ultrafines *versus* gaseous products



Wolkoff et al. *Tox Lett* 81 (2008) 171-176.

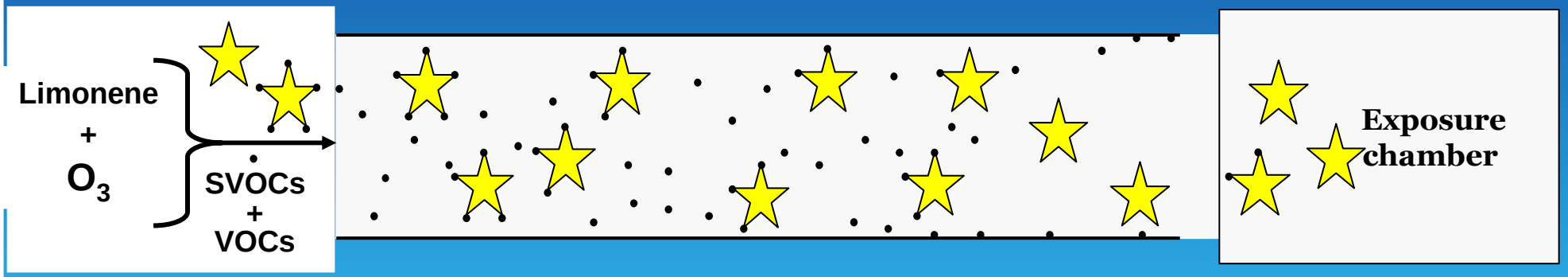
Terpene oxidation products
Respiratory rate reduction % in

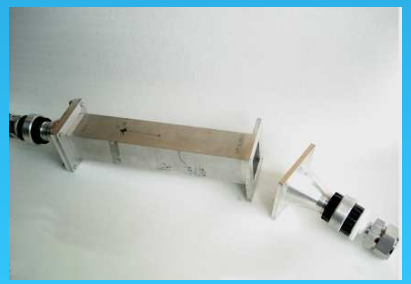


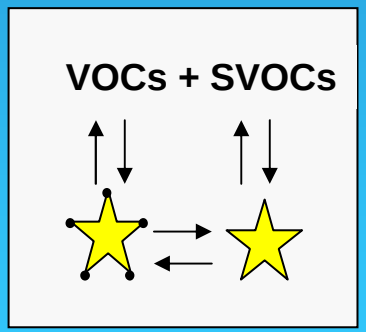
Substantial bioresponse!

Wolkoff et al. *Indoor Air* 10 (2000) 82-91.

Parallel plate diffusion denuder







Bioassay results
4 ppm O_3 + ~40 ppm limonene

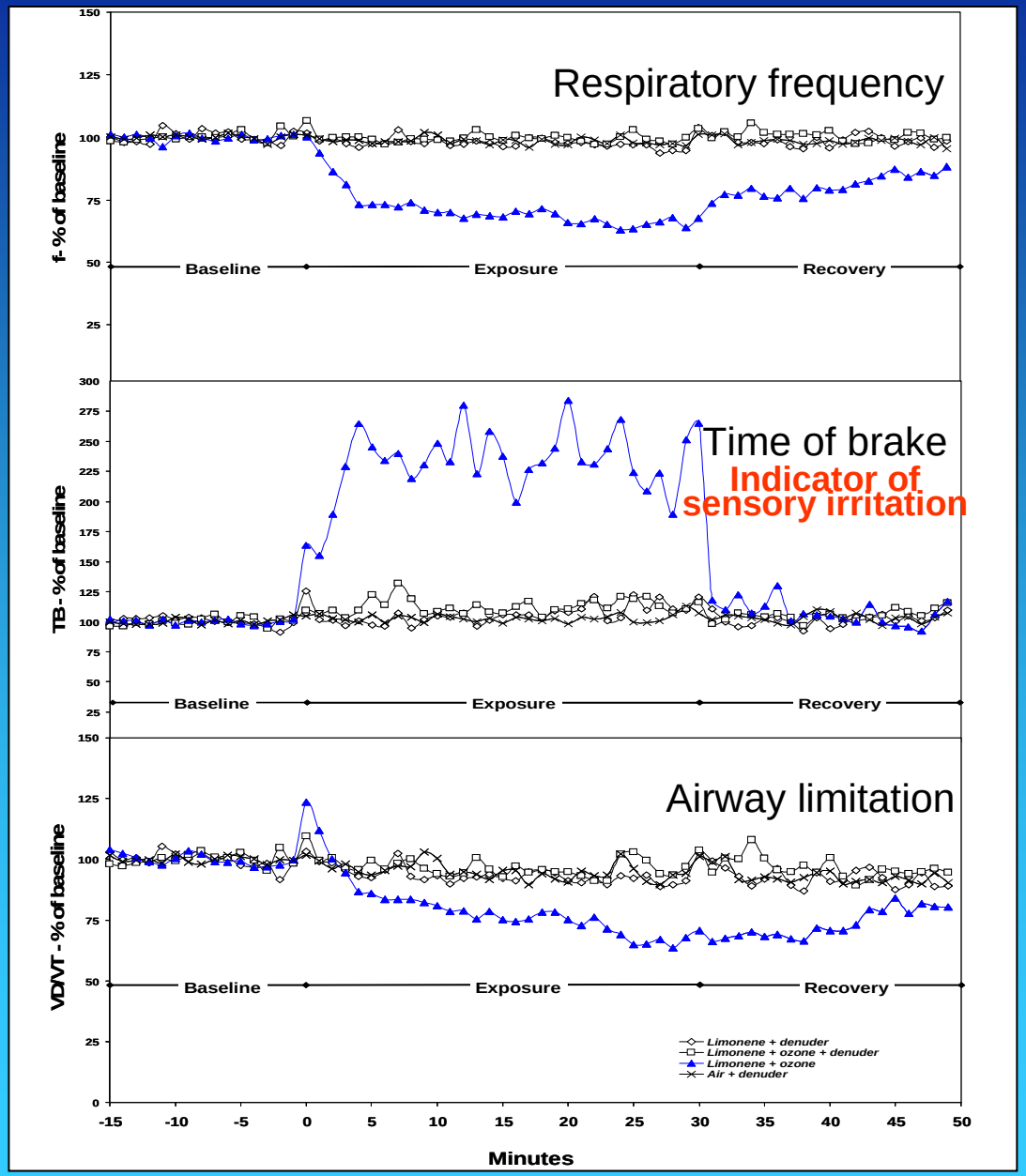
Airway irritation

75% by

CH_2O + LIM

Airway limitation (bronconstriction) not explained

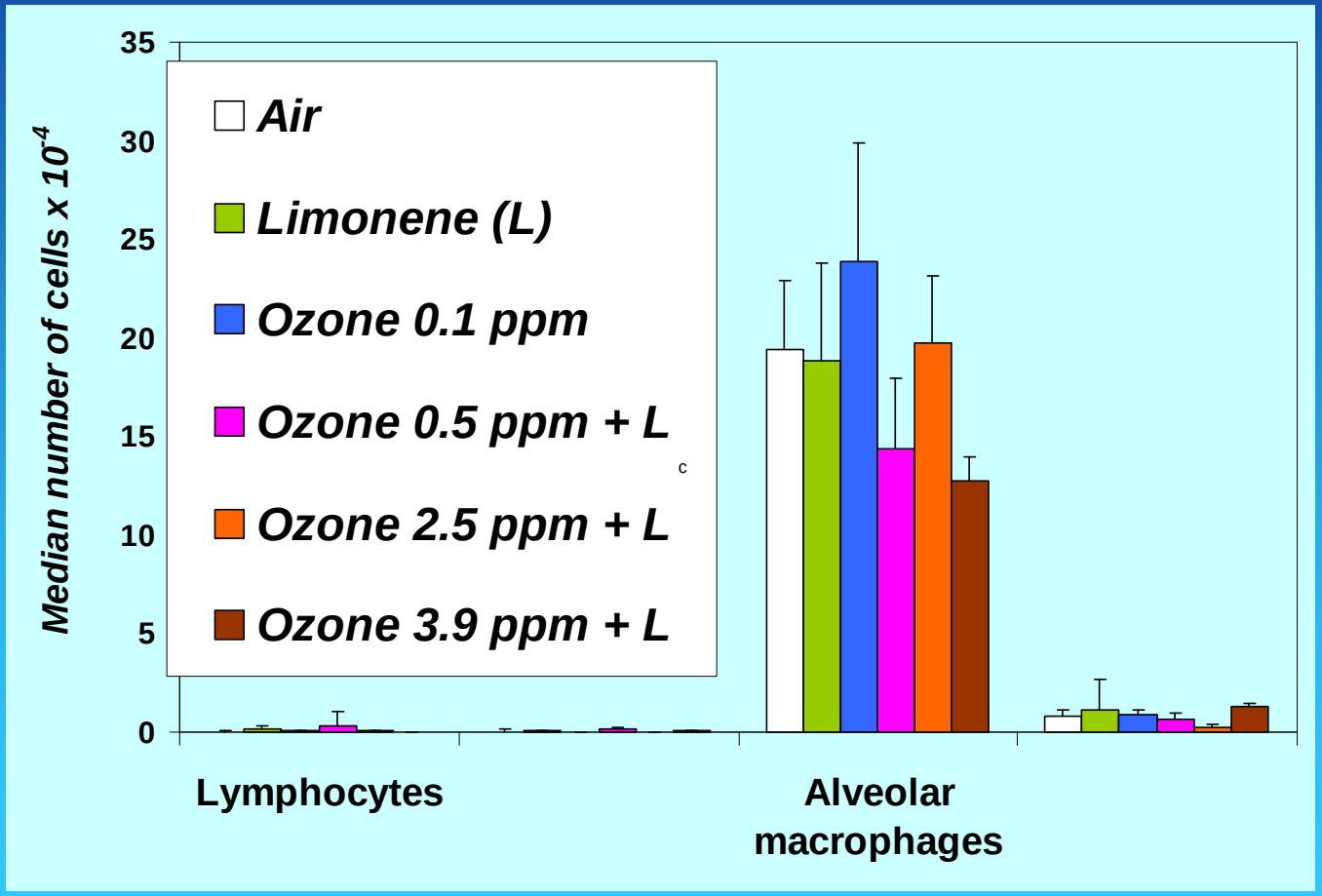
Denuded ultrafines not causative



Airway limitation may contribute to the respiratory rate

Wolkoff et al. *Tox Lett* 81 (2008) 171-176.

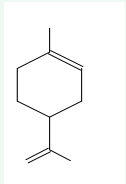
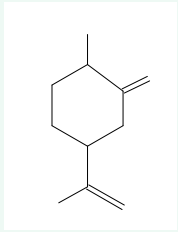
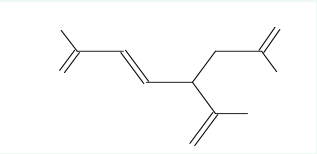
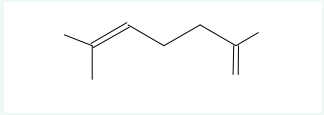
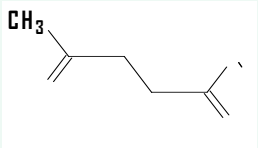
10 repeated exposures to O_3 + limonene
Bronchoalveolar lavage



No indication of inflammation in the airways

Wolkoff et al. *Tox. Lett.* 209 (2012) 166-172.

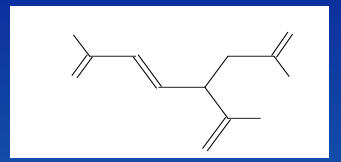
Ozone/terpene oxidation products

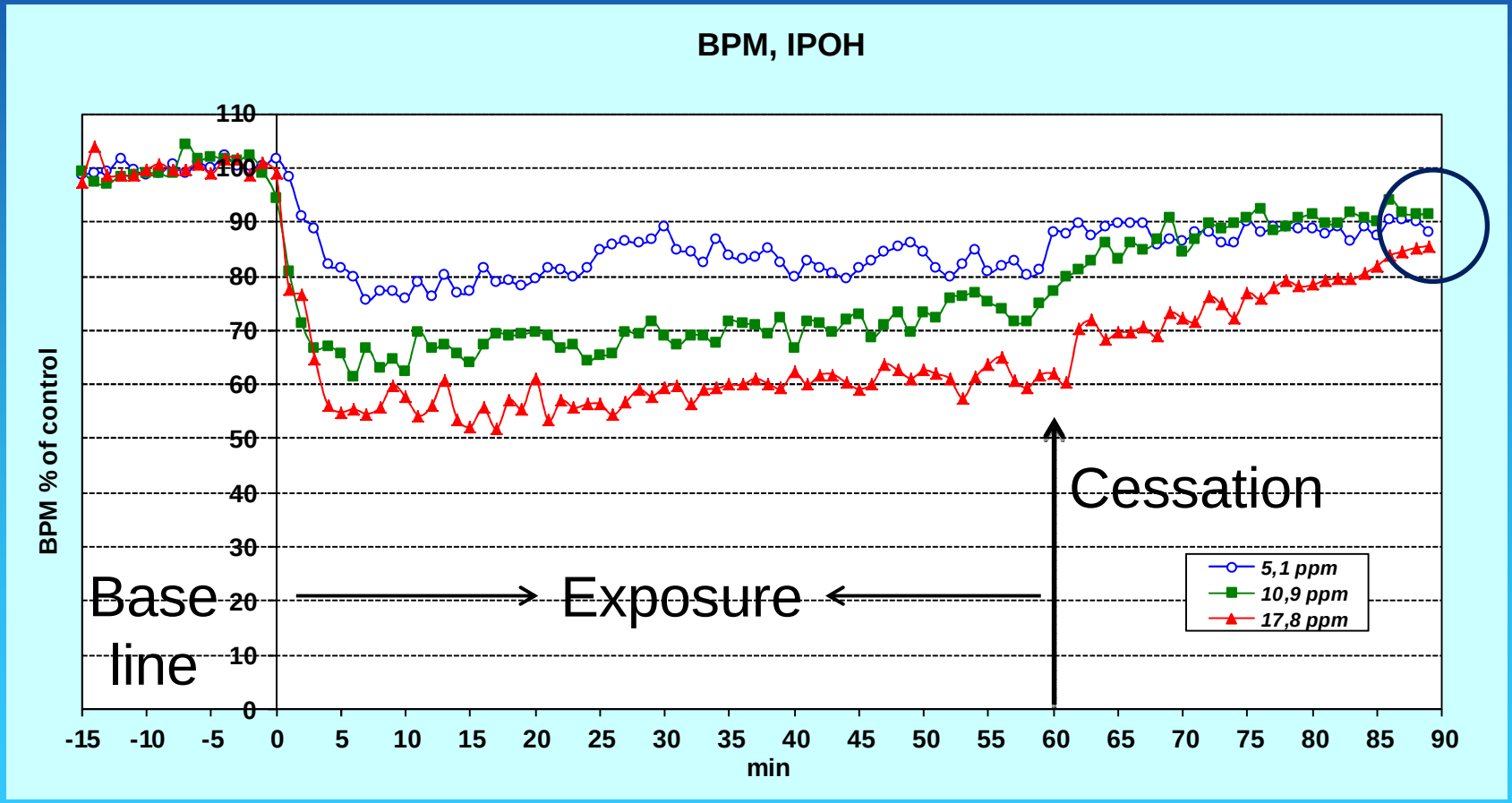
Ozone-initiated reaction products	Structure	Limonene	α-terpineol	Geraniol	Squalene Skin oils	Cabin air/ Office air	Ventilation filters
		Fragrances					
4-AMCH 4-acetyl-1-methyl cyclohexene		+					
DHC: dihydrocarvone 2-methyl-5-isopropenyl-cyclohexan-1-one		+					
IPOH 3-isopropenyl-6-oxo-heptanal		+				+	
6-MHO 6-methyl-5-heptene-2-one		+		+	+	+	
4-OPA 4-oxopentanal		+	+	+	+	+	+

Respiratory pattern of IPOH

A pure sensory irritant

Breath per min reduction %





Developed human reference values for ozone/terpene oxidation products* Life-long exposure

Ozone/terpene reaction products	Human reference values ppm	
	Sensory irritation	Airway limitation
IPOH	**0.16**	-
DHC	9	9
4-AMCH	1.3	0.45
4-OPA	0.3	**0.03**
6-MHO	0.3	0.5
Formaldehyde**	0.08	
Ozone**		0.08

*) Wolkoff et al., *Toxicol Lett* 216 (2013) 54-64.

**) Nielsen et al. *Hum Exp Toxicol* 19 (1999) 400-409.

Conclusion

- A well-established animal model can provide information about:
  - Respiratory effects (sensory irritation, airway limitation, lung irritation)
  - Inflammatory reactions
  - Cardiovascular effects
- Gas-phase chemicals and/or respirable particles can be tested
- Chemical cocktails can be tested
- Consumer products can be tested

Environment International 60 (2013) 145–162

Contents lists available at ScienceDirect

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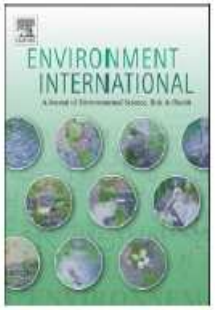
journal homepage: www.elsevier.com/locate/envint



Review

The health significance of gas- and particle-phase terpene oxidation products: A review

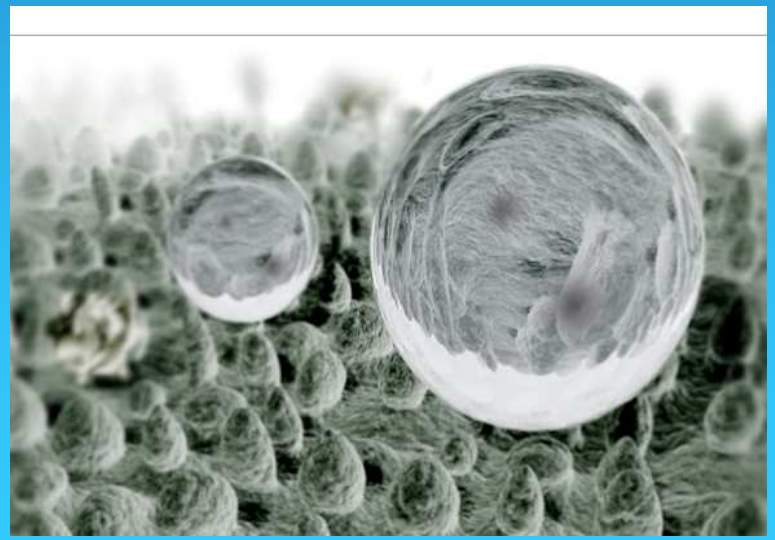
Annette C. Rohr *

Electric Power Research Institute, Palo Alto, CA, United States

Calls for:
Collaboration between the ambient and indoor air communities

Thank you

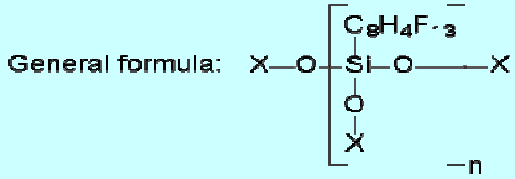
Nanospray sealing/coating products



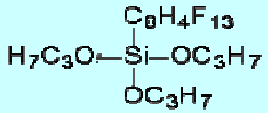
Nørgaard et al. *Tox Sci* 116 (2010) 216-224.

Nanospray sealing/coating products
QTOF mass spectrometry analysis

NFP 1

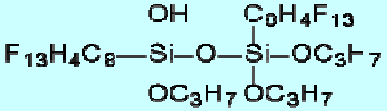


Silane



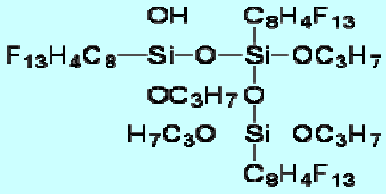
1H,1H,2H,2H-perfluorooctyl triisopropoxysilane

Disiloxane



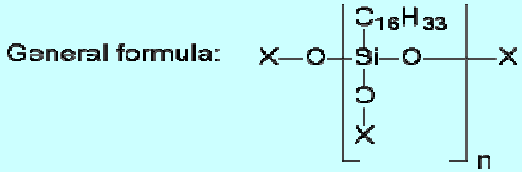
$[M+NH_4]^+$ at m/z 978

Trisiloxane

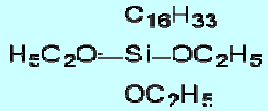


$[M+NH_4]^+$ at m/z 1428

NFP 2

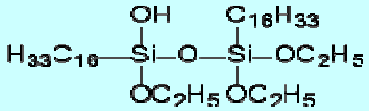


Silane



Hexadecyl triethoxysilane, $[M+H]^+$ at m/z 389

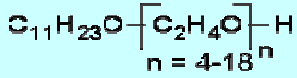
Disiloxane



$[M+H]^+$ at m/z 675

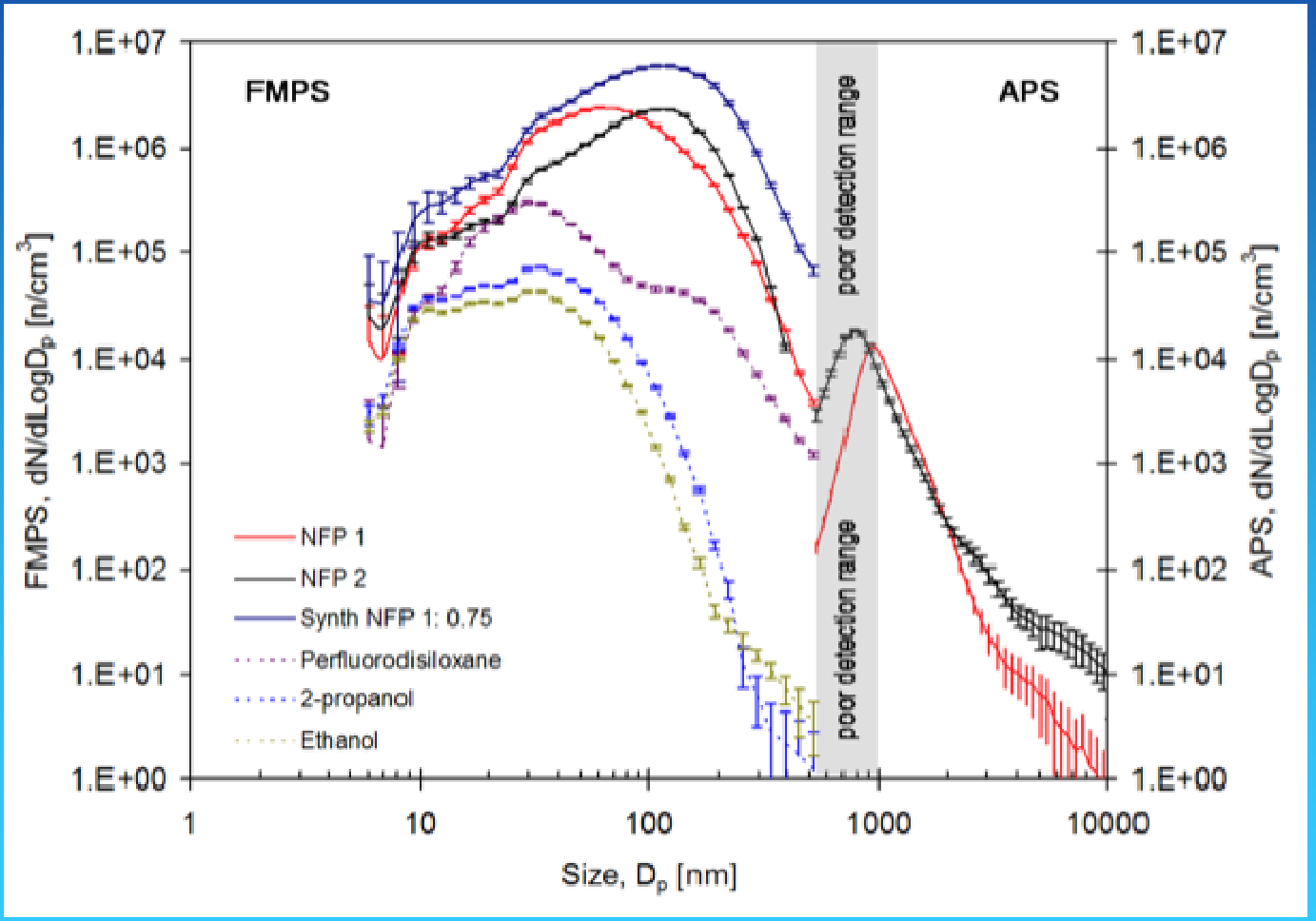
NFP 3

Non-ionc detergent



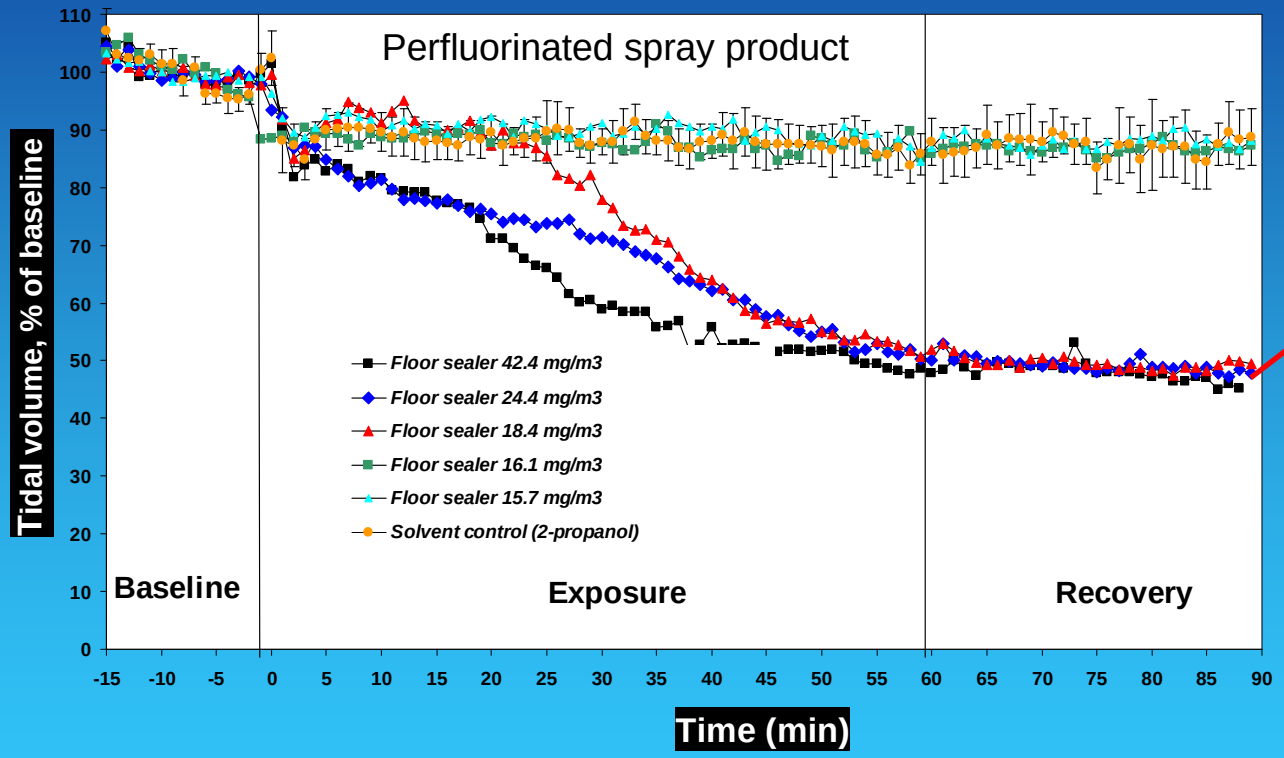
Nørgaard et al. *Tox Sci* 116 (2010) 216-224.

Nanospray sealing products
Particle characterization



Nørgaard et al. *Tox Sci* 116 (2010) 216-224.

Nanospray sealing products
Lung effects in mice

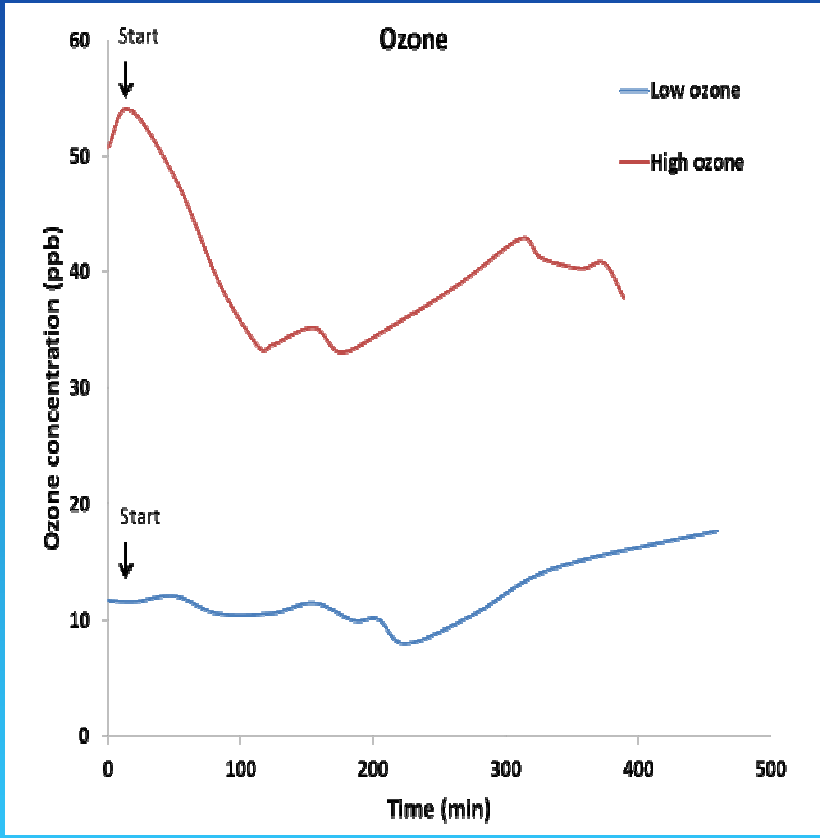


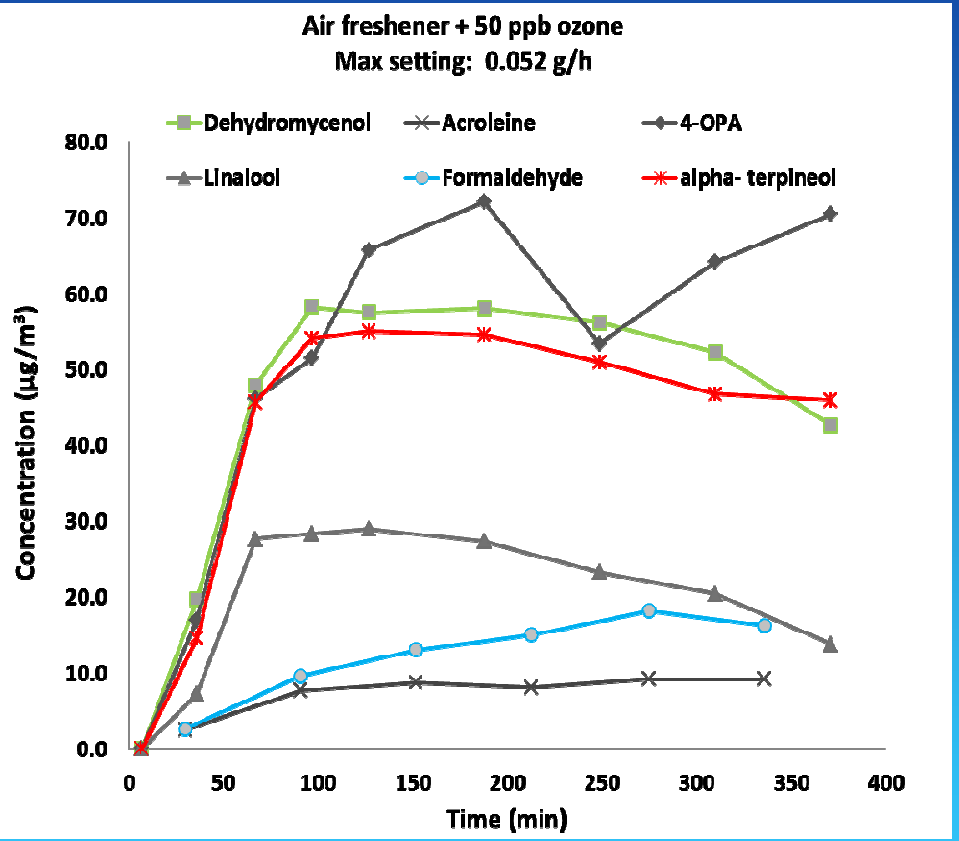
Atelectasis

Critical effects:
Fluorination + free OH groups
solvent

Nørgaard et al. *Tox Sci* 116 (2010) 216-224.

Plug-in air freshener (max setting) in 20 m^3 climate chamber, 0.5 h^{-1}





Nørgaard et al, in prep.

Steady state ozone concentration before turning on air freshener in chamber