

NO₂ Underground: What Exposure Level is Safe?

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Permissible Exposure Limit

5 ppm



Recommended Exposure Limit

1 ppm



Time Weighted Average Guideline

0.2 ppm

**How did the ACGIH arrive at their 0.2 ppm guideline value?
Is the ACGIH's guideline exposure value for NO₂ reasonable?**

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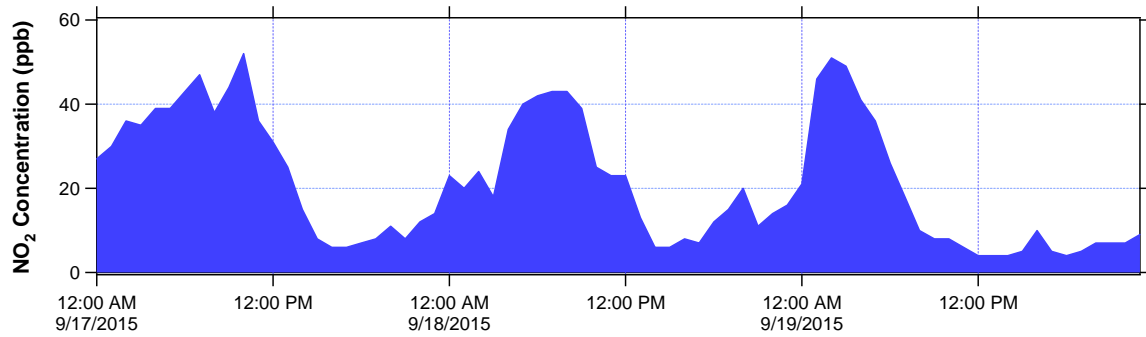
Ambient NO₂ Levels

Toronto Mean Concentration = 0.02 ppm

ACGIH Suggested TWA = 0.2 ppm

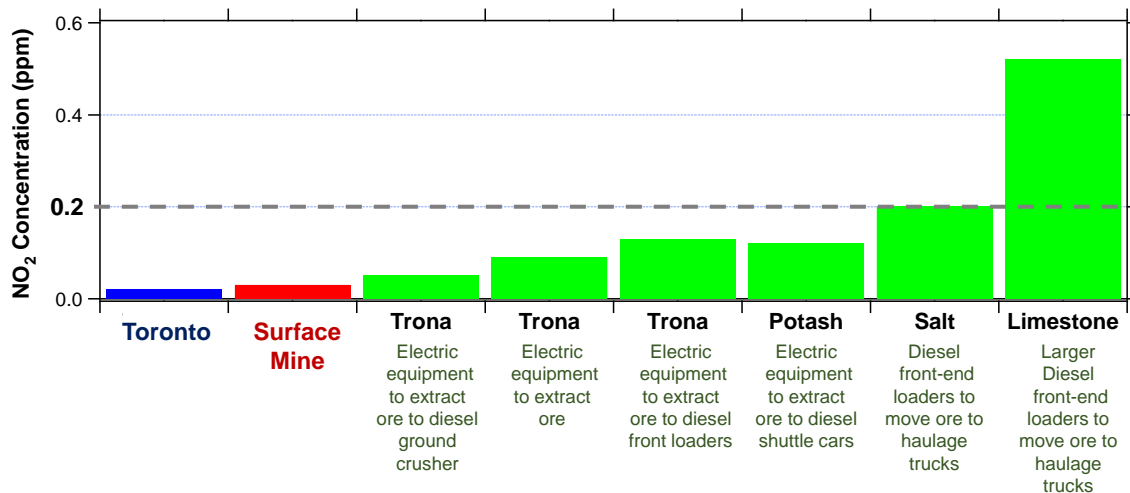


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Underground NO₂ Levels



Coble et al (2010) Annals of Occupational Hygiene

Underground Mines

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How can we test what exposure is safe?

Toxicological Study



Targeted Subjects OR Animals

- Expose each subject to a *known* concentration of NO₂
- Measure the subject's response (cellular response, symptom)
- Conclude about cause and effect relationship
- *Exposure concentrations are limited by ethics*
- *Cannot evaluate effects of long-term NO₂ exposure, only short-term.*

Epidemiological Study



Population-Scale

- *Estimate* NO₂ exposure for a population
- Evaluate the association of the exposure concentration with a health outcome (death, hospital admissions disease, symptoms)
- *Cannot control the exposure concentration*
- *Cannot establish causality*

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Toxicological Studies



Targeted Subjects

MAIN FOCUS by the ACGIH

Healthy Adults

8 studies
0.4 to 2 ppm NO₂



Asthmatic Adults

6 studies
0.1 to 0.6 ppm NO₂

Emphasis on asthmatics as they are more sensitive to exposure. Guideline value should protect both asthmatic and non-asthmatic workers.

Epidemiological Studies



Population-Scale

Considered by the ACGIH but findings did not contribute to the TWA guideline value.

These studies cannot isolate the effects of NO₂ or form conclusions about cause-effect relationships.

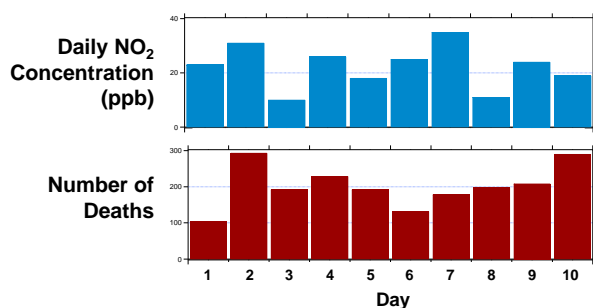
Useful to understand the effects of background levels to workers (ie. exposure during non-working hours).

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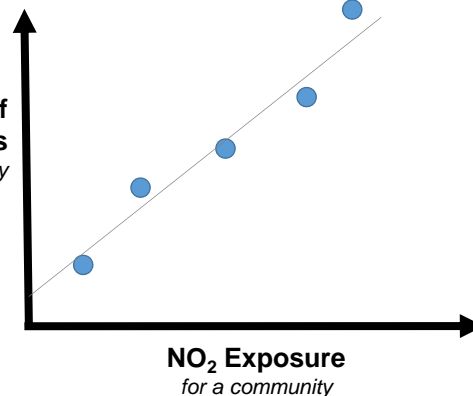
Short-term exposure to ambient NO₂

Effects on mortality

Epidemiological Study



Number of Deaths
in a community



We cannot comment if NO₂ caused these deaths! It may have been NO₂ or some other related pollutant or parameter.

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Short-term exposure to ambient NO₂

Effects on mortality related to respiratory disorders

Epidemiological Study



*Exposure to increased daily NO₂ concentrations is **associated** with increased mortality due to respiratory diseases.*

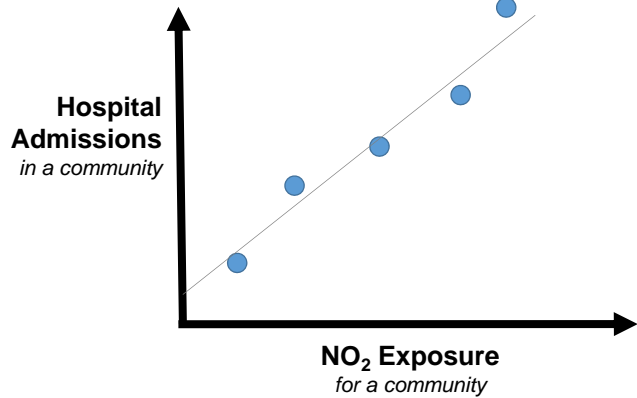
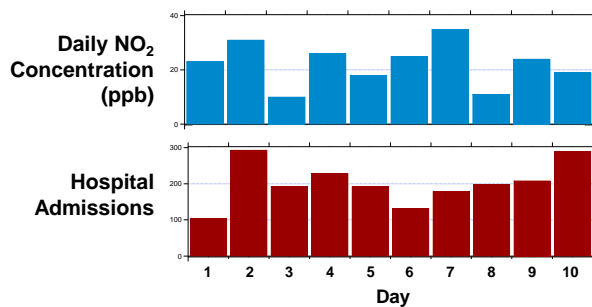
*A 5 ppb increase in NO₂ over a 24 hour averaging period is associated with 1.8% increase in respiratory mortality
Evaluation of ambient NO₂ concentrations from 181 cities*

***We cannot comment if NO₂ caused these deaths! It may have been NO₂ or some other related pollutant or parameter.
Studies suggest it is likely NO₂ that is driving this outcome.***

Short-term exposure to ambient NO₂

Effects on hospital admissions

Epidemiological Study



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Short-term exposure to ambient NO₂

Effects on hospital admissions related to respiratory disorders

Epidemiological Study



Exposure to increased daily NO₂ concentrations is **associated** with increased hospital admissions for **adults with asthma**.

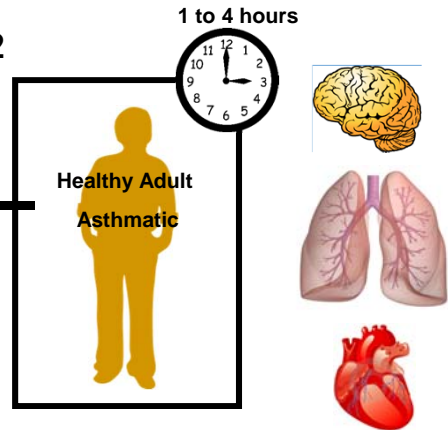
A 5 ppb increase in NO₂ over a 24 hour averaging period is associated with a 1.4% increase in hospital admissions for respiratory conditions.

The max NO₂ concentration considered was 0.08 ppm.

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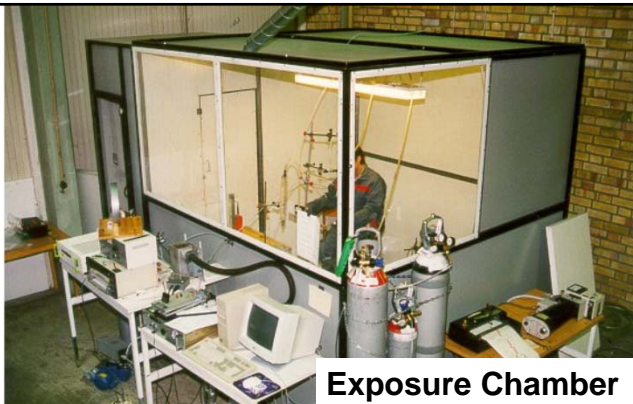
Short-term exposure to NO₂

Toxicological Study
Targeted Subjects
Chamber Exposure

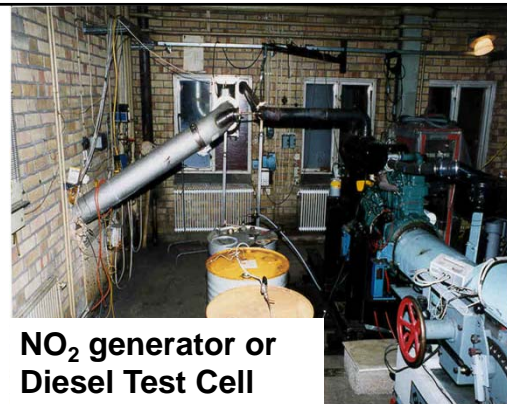


- 1 Expose a subject to known concentration of NO₂ for some time period in a well-defined environment.
- 2 Measure a response following the exposure.
- 3 If a response is found following the exposure, it is possible to conclude NO₂ caused the response.

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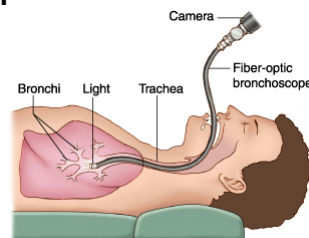
Exposure Chamber



NO₂ generator or Diesel Test Cell



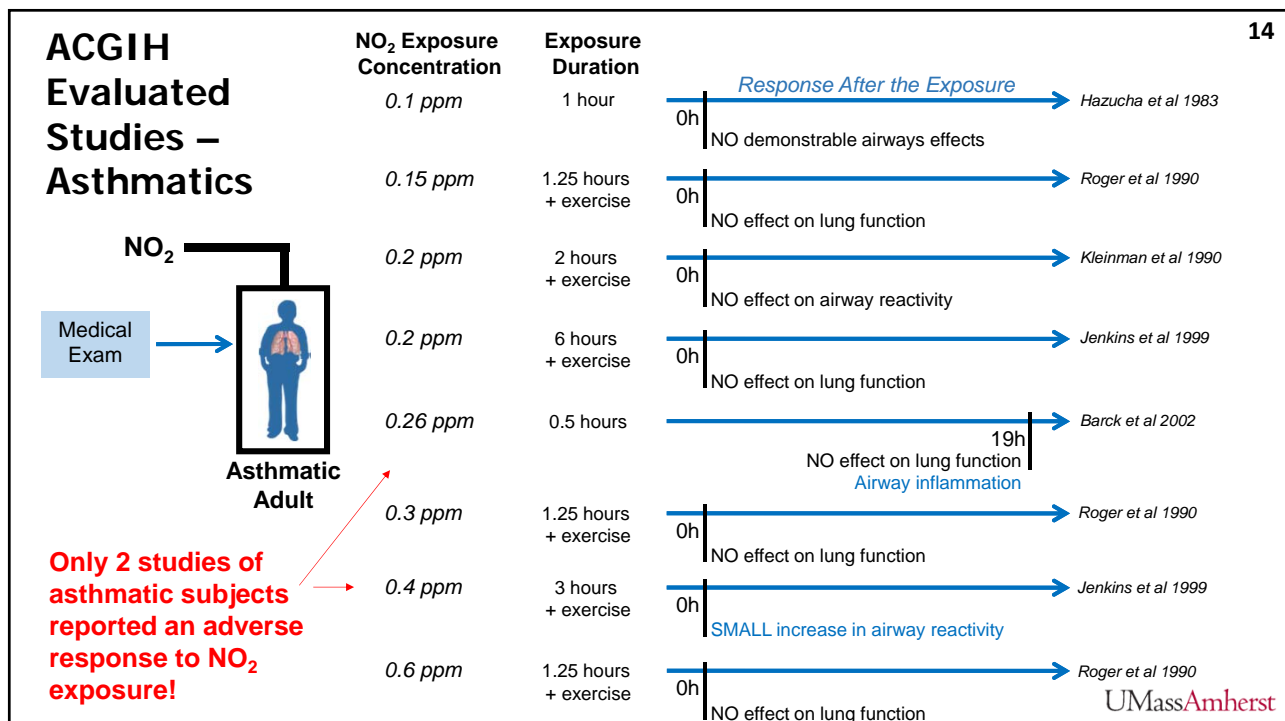
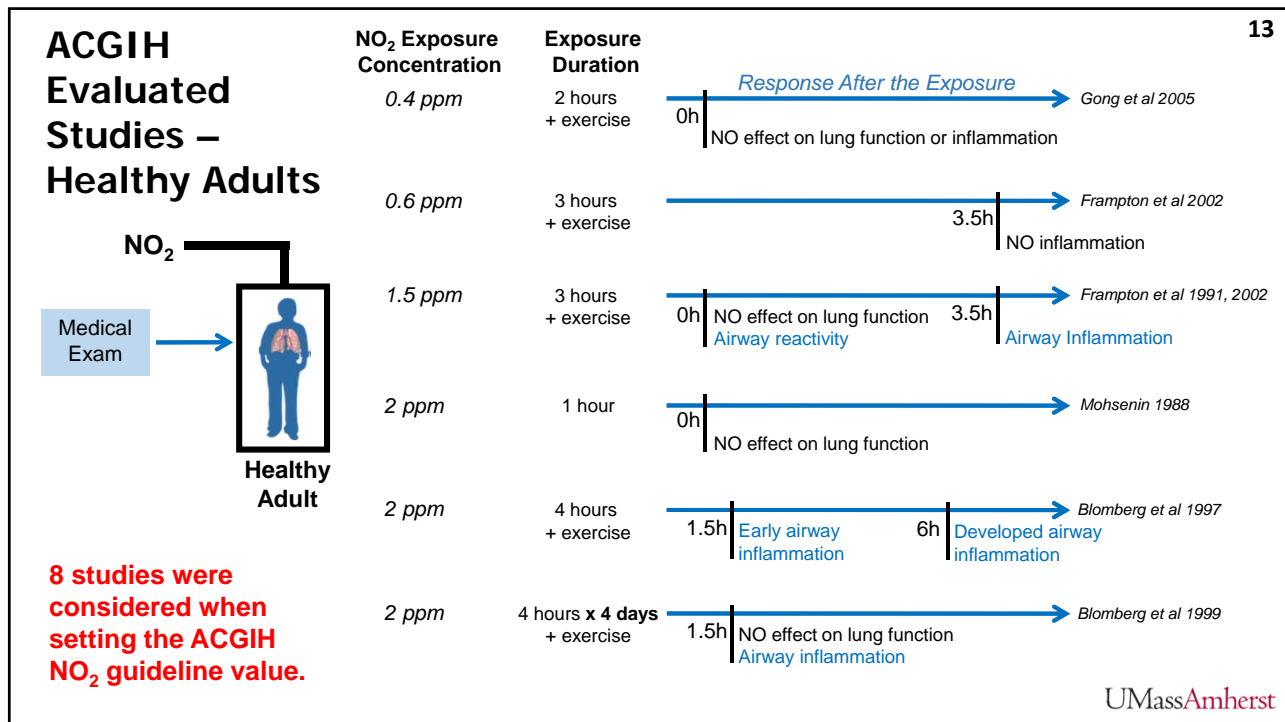
Assessment of an airway response following the exposure

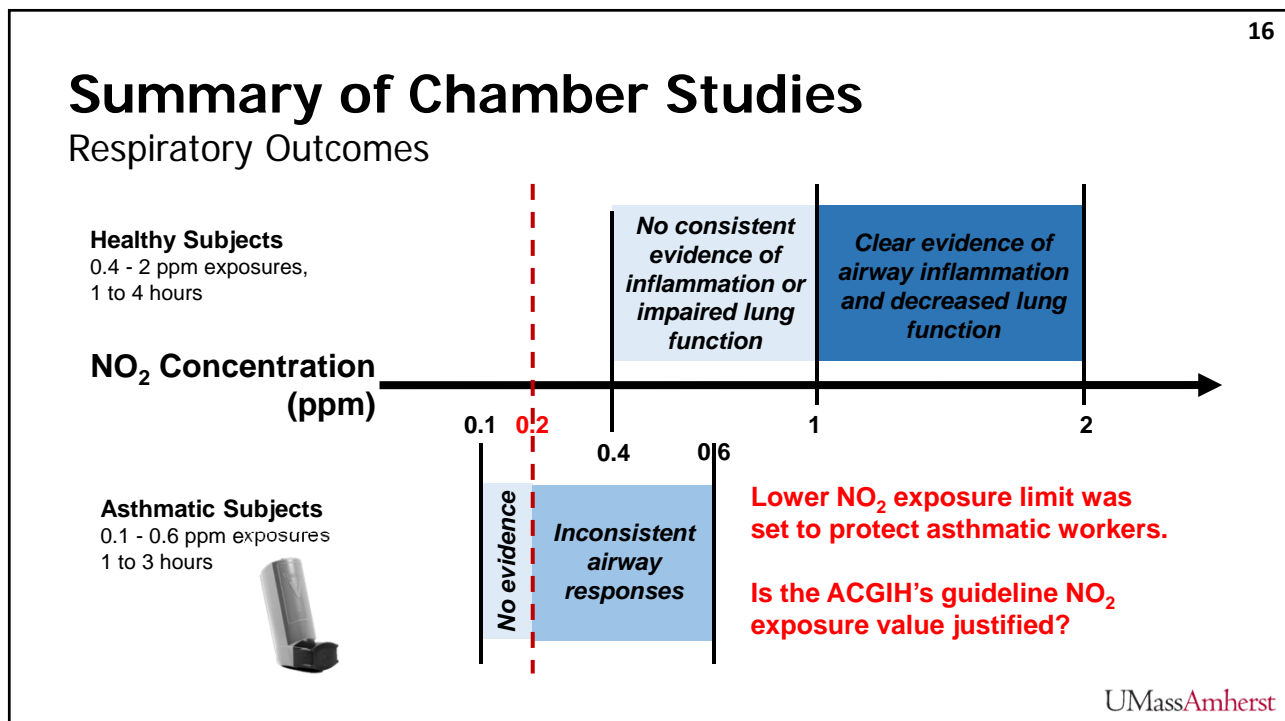
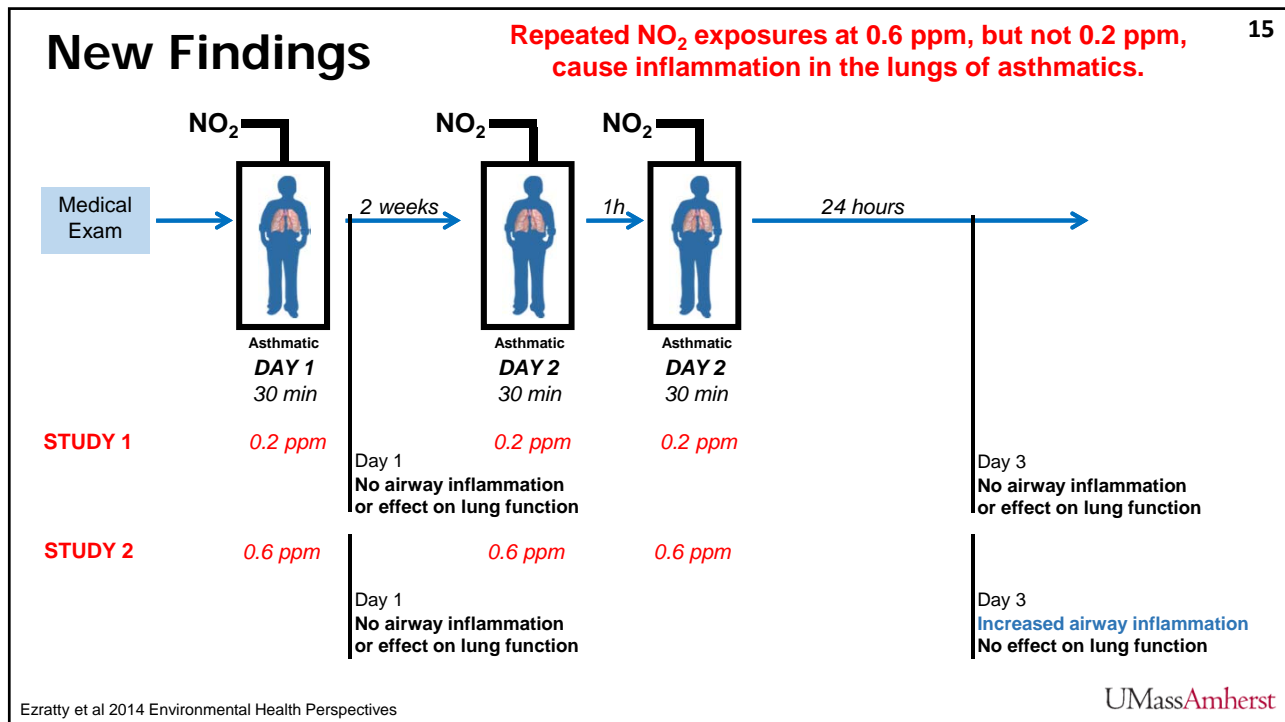


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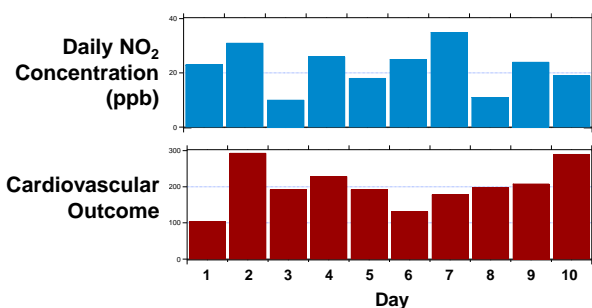
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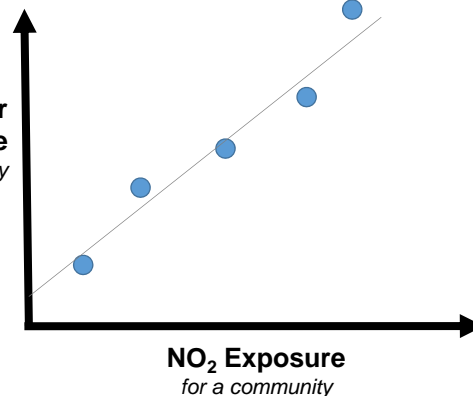


NO₂ effects on Cardiovascular Outcomes

Epidemiological Studies



Cardiovascular
Outcome
in a community



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NO₂ effects on Cardiovascular Outcomes

Epidemiological Studies



*Exposure to increased daily NO₂ concentrations is associated with increased **mortality** and **hospital admissions** due to cardiovascular disorders.*

*A 5 ppb increase in NO₂ over a 24 hour averaging period is associated with:
1.2% increase in cardiovascular mortality
1.4% increase in hospital admissions for cardiac disease
Evaluation of ambient NO₂ concentrations from 181 cities*

We cannot comment if NO₂ caused these deaths! It may have been NO₂ or some other related pollutant or parameter. Studies suggest a related pollutant is driven this effect.

Anderson et al (2007): http://tiny.cc/short_term_no2

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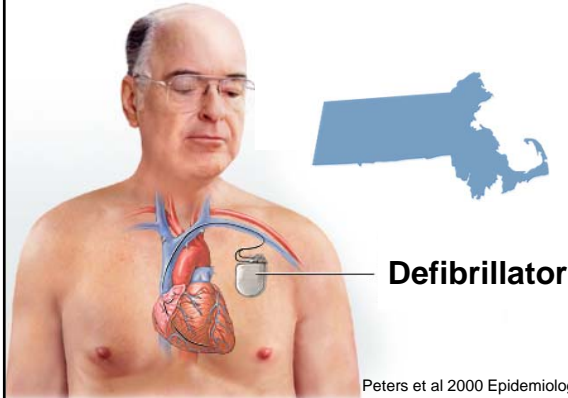
NO₂ effects on Cardiovascular Disorders

Epidemiological Studies



100 subjects with implantable defibrillators followed for 3 years in Massachusetts

Median age = 62; Mostly men.



Defibrillator

A 26 ppb increase in NO₂ was associated with increased defibrillator interventions 2 days later.

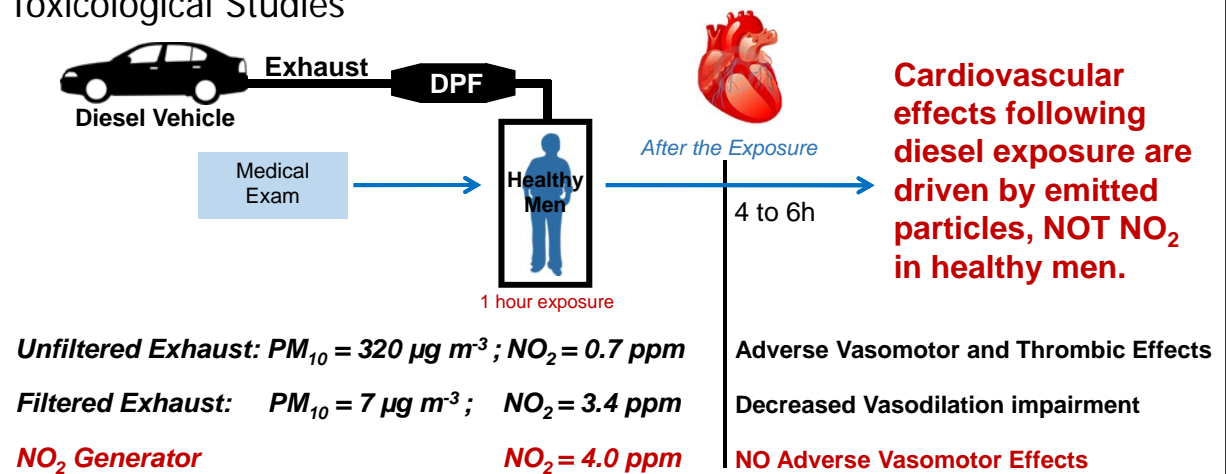
Given adults surviving serious cardiac events return to work with pacemakers and defibrillators, it is possible the ACGIH will revise its NO₂ guidelines based on responses in adults with cardiovascular disorders.

Peters et al 2000 Epidemiology

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Cardiovascular effects of NO₂ exposure

Toxicological Studies

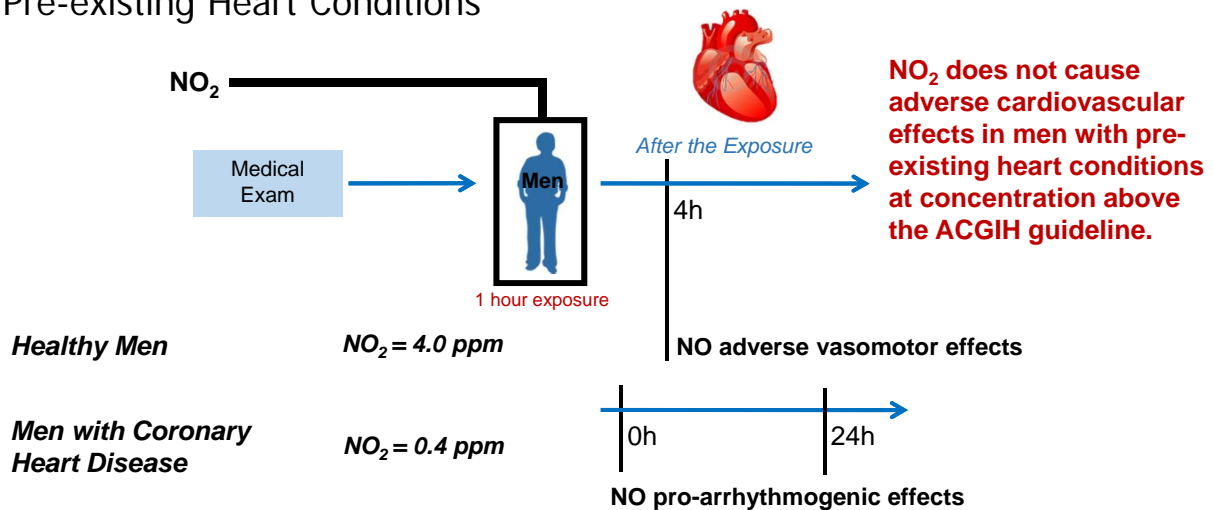


Lucking et al 2011; Langrish et al 2010

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Cardiovascular effects of NO₂ exposure

Pre-existing Heart Conditions



Langrish et al 2010; Scaife et al 2012

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Final Thoughts on safe NO₂ levels

- The ACGIH's TWA value for NO₂ was set to ensure sensitive individuals were protected from adverse effects
 - *The exposure limit was set based on short-term controlled NO₂ exposures conducted with asthmatics*
 - *Concern raised for adults surviving cardiac events*
- Guideline value based on controlled laboratory studies with human subjects
 - *Only two of the six studies that evaluated asthmatic subjects reported sub-clinical response following NO₂ exposure*
 - *Is this guideline aggressive given the available literature?*
- Considerations that may influence future changes to the NO₂ TWA guideline
 - *Effects of long-term exposure characteristic of occupational environments*
 - *Workers with pre-existing health conditions*
 - *What is an adverse response?*

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Thank you.

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