Human Health Effects of Ozone (O$_3$)

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Topics

• Introduction – Background on the respiratory tract
• Human health effects of ozone
  – Those known
  – Susceptible subpopulations
• Can Pinedale’s altitude influence potential $O_3$ effects?
• Things you can do during an $O_3$ air pollution episode
Complexities for Understanding $O_3$ Health Effects
Ozone Plays no Favorites in Humans and Animals

- Attacks carbon – carbon double bonds
- Reacts with amino acids
- Starts a cascade of reactions
- Reactions are extremely fast
- Reactions are not reversible
What Happens When $O_3$ is Taken up in Fluids Lining the Respiratory Tract?

- Mucus lines the nose, trachea, and conducting airways
  - Mucous layer contains many substances that react with $O_3$
  - Reactions lessen the amount of $O_3$ that can penetrate to lung tissues
- Surfactant lines the alveolar region where gas exchange occurs
  - Surfactant contains few substances that react with $O_3$
  - Result is greater penetration of $O_3$ to alveolar tissue
- $O_3$ is highly reactive but poorly soluble
  - Carries deeper into the lungs compared to other gaseous pollutants
Major Respiratory Tract Regions

Drawing courtesy of J. Harkema
Human: Bronchial Tree and Circulation

New $O_3$ Standard -- How Much is 75 ppb?

100 circles with each circle containing 75 smaller circles

Need 133,332 more slides with only green circles on them

Then the single red circle reflects how much ozone mass there needs to be to represent 75 ppb of ozone.
Types of Health Effects Seen After Short-term O₃ Exposure

- **Respiratory Morbidity**
  - Respiratory symptoms
  - Lung function
  - Airway inflammation
  - Airway responsiveness
  - Respiratory hospital admissions and ER visits

- **Cardiovascular Morbidity**

- **Mortality**
Ozone Irritates Airways

• Symptoms
  – Cough
  – Sore or scratchy throat
  – Pain with deep breath
  – Fatigue
• Rapid onset
• Similar symptoms, with or without asthma
Respiratory Symptoms Seen in Children in Epidemiological Studies

• Asthmatics
  – Significant association between O₃ exposure and
    • Cough
    • Wheeze
    • Production of phlegm
    • Shortness of breath
  – Increased use of asthma medication

• Non-asthmatics
  – No effects on respiratory symptoms seen
  – Consistent with diminished responses seen in healthy children in human clinical studies
Exercise Greatly Increases O$_3$ Doses

- With Exercise, the site of maximal tissue dose shifts distally
  - 1$^{st}$ generation of respiratory bronchioles at rest
  - 1$^{st}$ generation of alveolar ducts with heavy exercise
Exercise Greatly Increases O₃ Doses (Cont.)

• Max tissue dose ↑ 19-fold with heavy exercise compared to normal respiration at rest
• With heavy exercise, there is an overall 10-fold ↑ in total mass uptake
  – Conducting airways ↑ by a factor of 1.4
  – Alveolar region tissue dose ↑ by a factor of 13.6
What it is and How it is Determined

• What it is
  – The volume of air a person can forcefully expel from their lungs in 1 second.

• How it is determined
  – At the end of a breath, if a person inhales as much air as they can, total lung capacity (TLC) is considered to be the attained volume.
  – The person then exhales rapidly and maximally from TLC. The volume that is exhaled in 1 sec is termed the FEV$_1$
FEV$_1$ Changes in Healthy Humans Exposed 1-2 Hours to Various O$_3$ Concentrations

- **Rest**
  - No statistically significant effects on FEV$_1$ below 500 ppb
  - 7% decline in FEV$_1$ at 500 ppb

- **Exercise: Moderate to Heavy and Intermittent to Continuous**
  - Heavy intermittent exercise (minute ventilation = 65 Liters/min) to 180 ppb of O$_3$ caused a 9.5% ↓ in FEV$_1$
  - Heavy exercise for 1 hr to 120 – 200 ppb can significantly reduce FEV$_1$
  - Significant changes in FEV$_1$ result from various combinations of O$_3$ concentration and level of minute ventilation
Effects on FEV$_1$ with 6.6 hrs Exposure to 120 ppb O$_3$ and Moderate Exercise

Mean age of healthy young adults ranged from 22 to 25 years

* Exposures ranged from 115 to 130 ppb in the Adams & Ollison study
Variability in FEV\textsubscript{1} Decrements with 6.6 Hours of Exposure to Various O\textsubscript{3} Concentrations While Exercising Moderately

Red numbers are the percentage of persons having FEV1 decrements > 10 %.
Daily 6.6 hr Exposures of Healthy Young Adults to 120 ppb O\textsubscript{3}

Exercise 50 min out of each hour at an average minute ventilation level of 39 Liters/min except during 35 min lunch break

No change from controls
Airway Inflammation

- Inflammatory responses seen even at lowest level tested (80 ppb O₃) with 6.6 hr exposures
  - Effects may be seen even in those that show no lung function changes
- With repeated exposure over several days, inflammatory markers are attenuated
  - Markers of lung injury and permeability show no attenuation
Homology of the Lung Lavage Fluid Protein Response
Airway Inflammation (Cont.)

• Some epidemiological studies show an association between acute exposure and airway inflammation in children when the 1-hr max is about 100 ppb
Airway Responsiveness – Short-term O₃ Exposure

• ↑ in nonspecific airway responsiveness (methacoline or histamine challenge)

• For those with preexisting allergic airway disease, with or without asthma
  – Repeated daily exposure to 125 ppb for 4 days exacerbated (i.e., made worse) lung function decrements in response to bronchial allergen challenges

• Animal studies show O₃-induced worsening of airway responsiveness persists longer and attenuates more slowly than O₃-induced pulmonary function decrements and respiratory symptoms
Respiratory Hospital Admissions and ER Visits

- Positive and robust association between ambient O$_3$ levels and respiratory-related hospitalizations
- Also true for asthma ER visits
- Both of the above seen during warmer months
  - So there may not be a direct translation to Pinedale during winter months
Cardiovascular Morbidity

• Some field/panel studies suggest a potential association between acute $O_3$ exposure and
  – ↓ in heart rate variability
  – Ventricular arrhythmias
  – Incidence of myocardial infarctions

• The limited body of evidence is suggestive that $O_3$ directly and/or indirectly contributes to cardiovascular-related morbidity
  – But the case is far from substantiated
Mortality

- Recent epidemiological studies provide relatively strong evidence for associations between short-term $O_3$ exposure and all causes of mortality
  - Adjustments made for season and levels of particulate matter
- Numerous studies show small but statistically significant positive associations between $O_3$ and cardiovascular mortality
- Mechanistic basis for contributing to non-accidental and cardiopulmonary-related mortality has yet to be determined
What About Pinedale’s Altitude?

• Breathing at altitude
  – Regulated by carbon dioxide ($CO_2$) production
  – There is less oxygen in the air compared with sea level
  – People take in less oxygen but keep the same minute ventilation in order to get rid of the $CO_2$

• No studies specifically examining effects of $O_3$ at altitude
• Calibration method for monitors is altitude independent
• Given the above, one would expect the effects of exposure to $O_3$ to be essentially the same as at sea level
Things to do During an O₃ Air Pollution Episode

Inhaled O₃ dose = O₃ concentration x ventilation rate x length of exposure

- Reducing these factors reduces inhaled dose
  - Stay indoors as much as possible
  - If working outdoors, try to work earlier in the morning and avoid the afternoon
  - If exercising outdoors, do it in the morning & stay away from roadways
- Know your body – pay attention to symptoms
- Children or adults with asthma – follow asthma action plan
- Coaches of outdoor sports – rotate players frequently
- If you have heart disease, check with your doctor