

Ground-level Ozone and Human Health

James L. Crooks, Ph.D., M.S.
Associate Professor, National Jewish Health
Clinical Associate Professor, Colorado School of Public Health

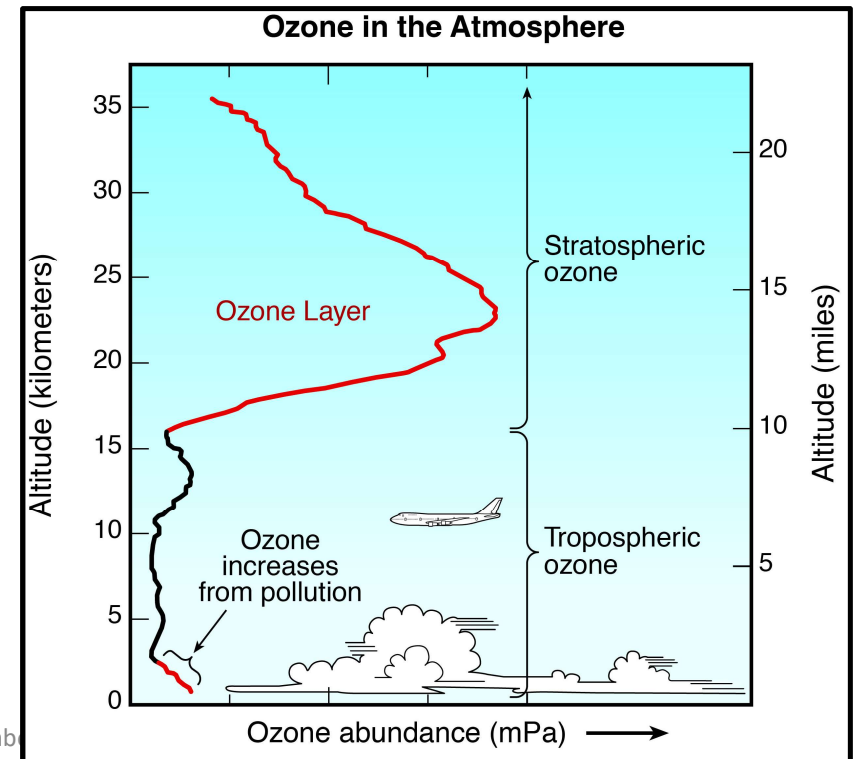


Ozone Basics

JL Crooks | Ozone and Health | September 21, 2023

Ozone (O₃): High vs. Low

- Stratospheric ozone = “good” ozone
 - The “ozone layer”
 - Reflects harmful UV from the sun
- Tropospheric ozone = “bad” ozone
 - Reactivity is hard on your lungs
 - Harmful to breathe



Ozone structure

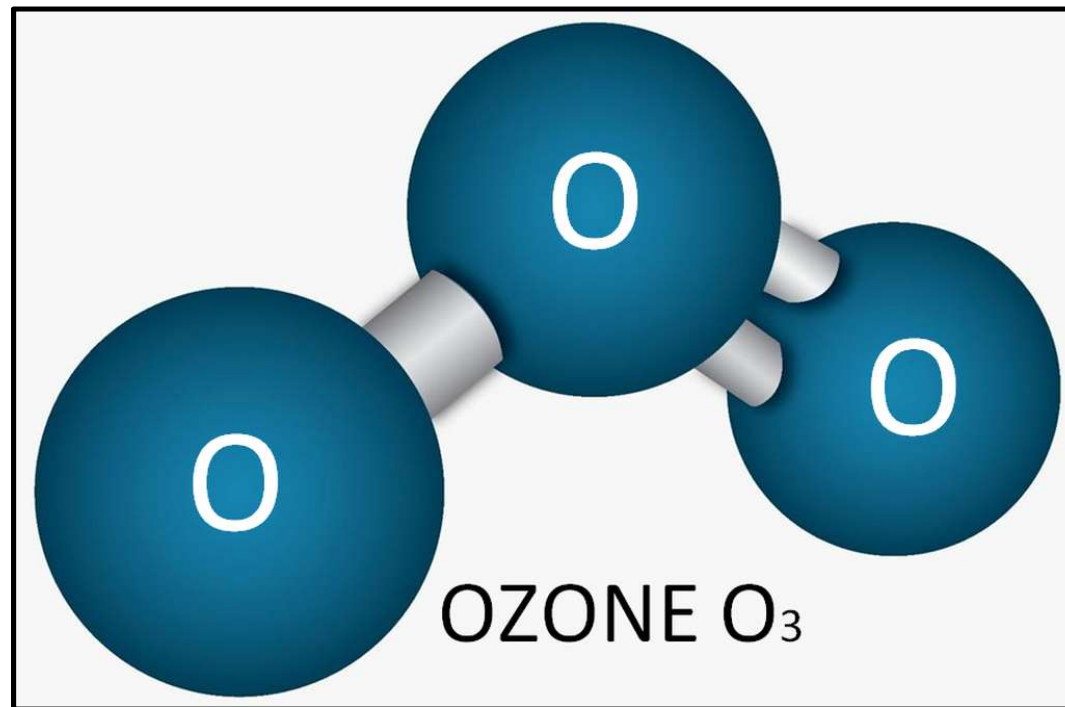
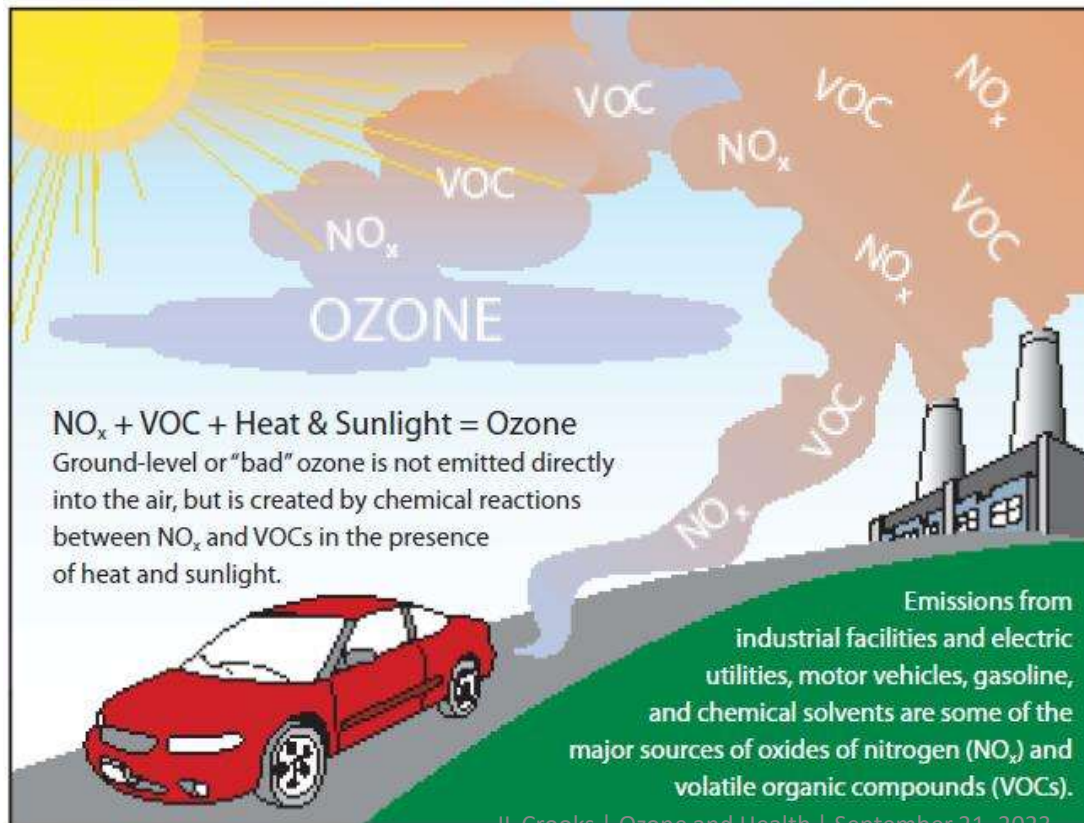


FIGURE 1. Illustration of Ground-Level Ozone Formation



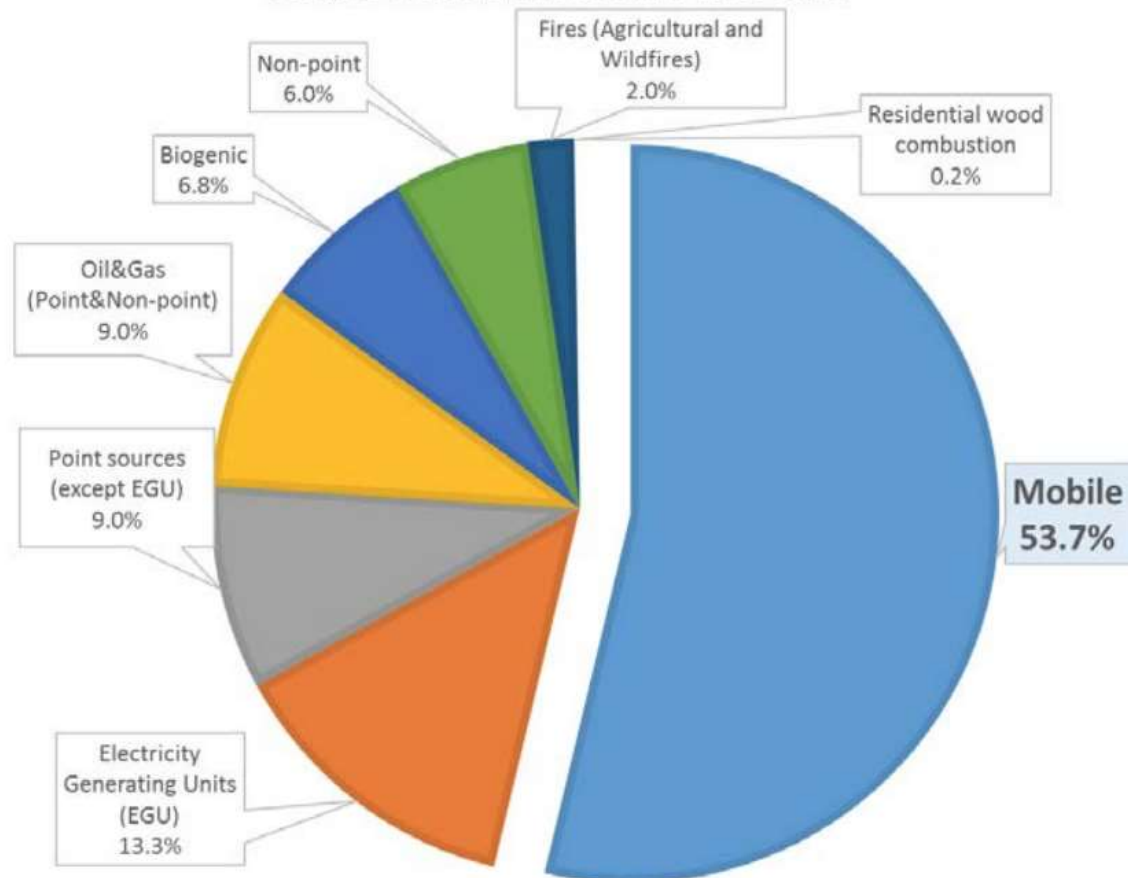
Source: Adapted from EPA 2010.

JL Crooks | Ozone and Health | September 21, 2023

"Bad" ozone can be distinguished from "good" ozone, which is present at high altitudes in the atmosphere and beneficial because it protects the earth from excessive ultraviolet radiation. But bad, or ground-level, ozone—the primary component of smog—is harmful to health. Human activities such as driving cars and generating electricity are major sources of the ingredients that form smog.



TOTAL NOX EMISSIONS 2014NEI



VOC sources

Compound	Atmospheric lifetime (approx.)	Characteristic sources
Ethane	1.5 months	Natural gas, biomass burning
Acetylene	15 days	Vehicle emissions, biomass burning
Methanol	12 days	Plants, VOC oxidation
Propane	11 days	Liquefied petroleum gas, natural gas
Benzene	10 days	Industrial emissions, vehicle emissions, biomass burning
<i>iso/n</i> -Butane	5 days	Vehicle emissions, liquefied petroleum gas
Ethanol	4 days	Plants, biofuel
<i>iso/n</i> -Pentane	3 days	Vehicle emissions, gasoline evaporation
Toluene	2 days	Solvents, vehicle emissions
Ethene	1 day	Vehicle emissions
Formaldehyde	1 day	VOC oxidation, biomass burning
Isoprene	3 hours	Plants

<https://public.wmo.int/en/resources/bulletin/changing-volatile-organic-compound-emissions-urban-environments-many-paths>

A photograph of the Denver skyline at sunset, with a light blue and yellow sky and a hazy cityscape in the foreground. A white rectangular box with a black border is centered in the middle of the image, containing the title text.

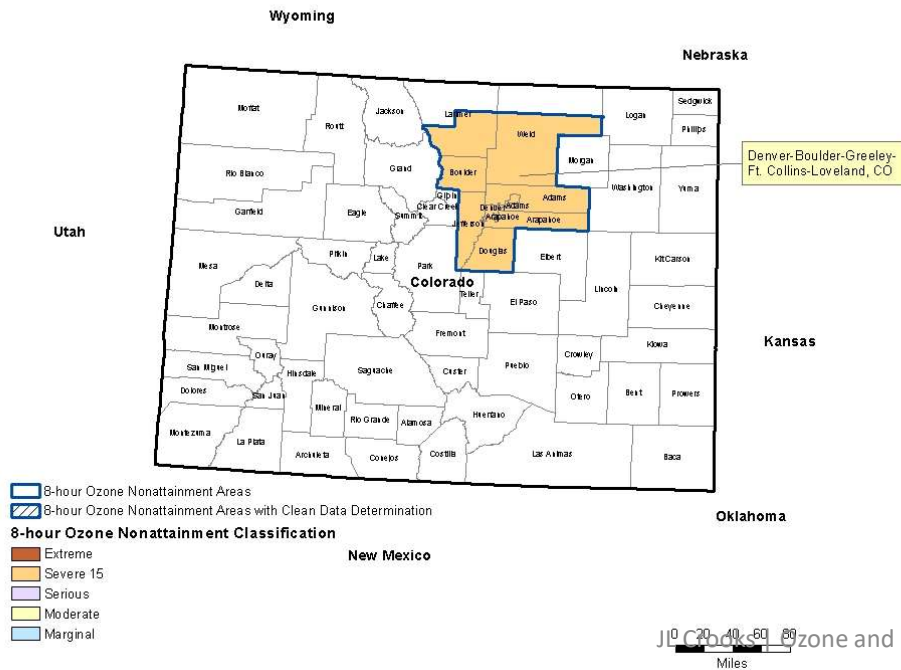
Ozone in Denver

JL Crooks | Ozone and Health | September 21, 2023

Denver Metro Ozone Nonattainment Status

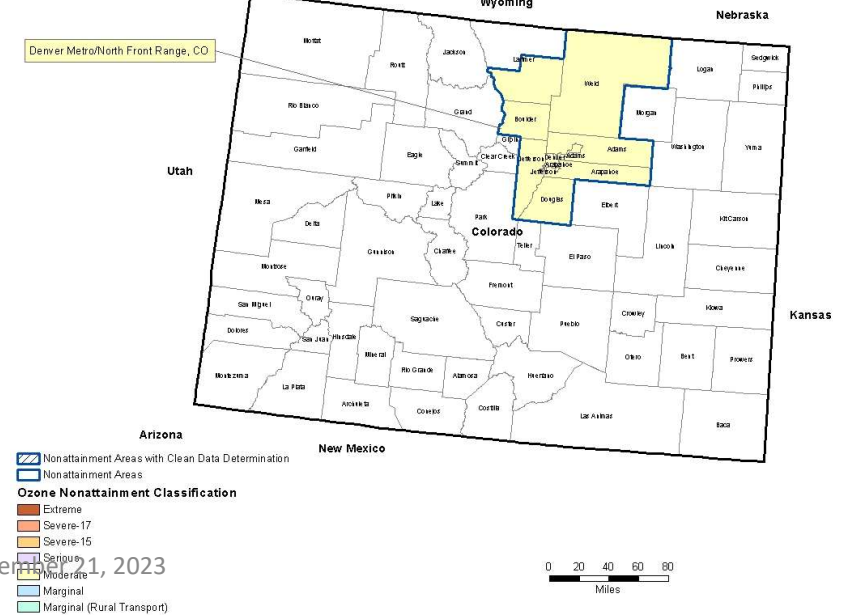
Colorado 8-hour Ozone Nonattainment Areas (2008 Standard)

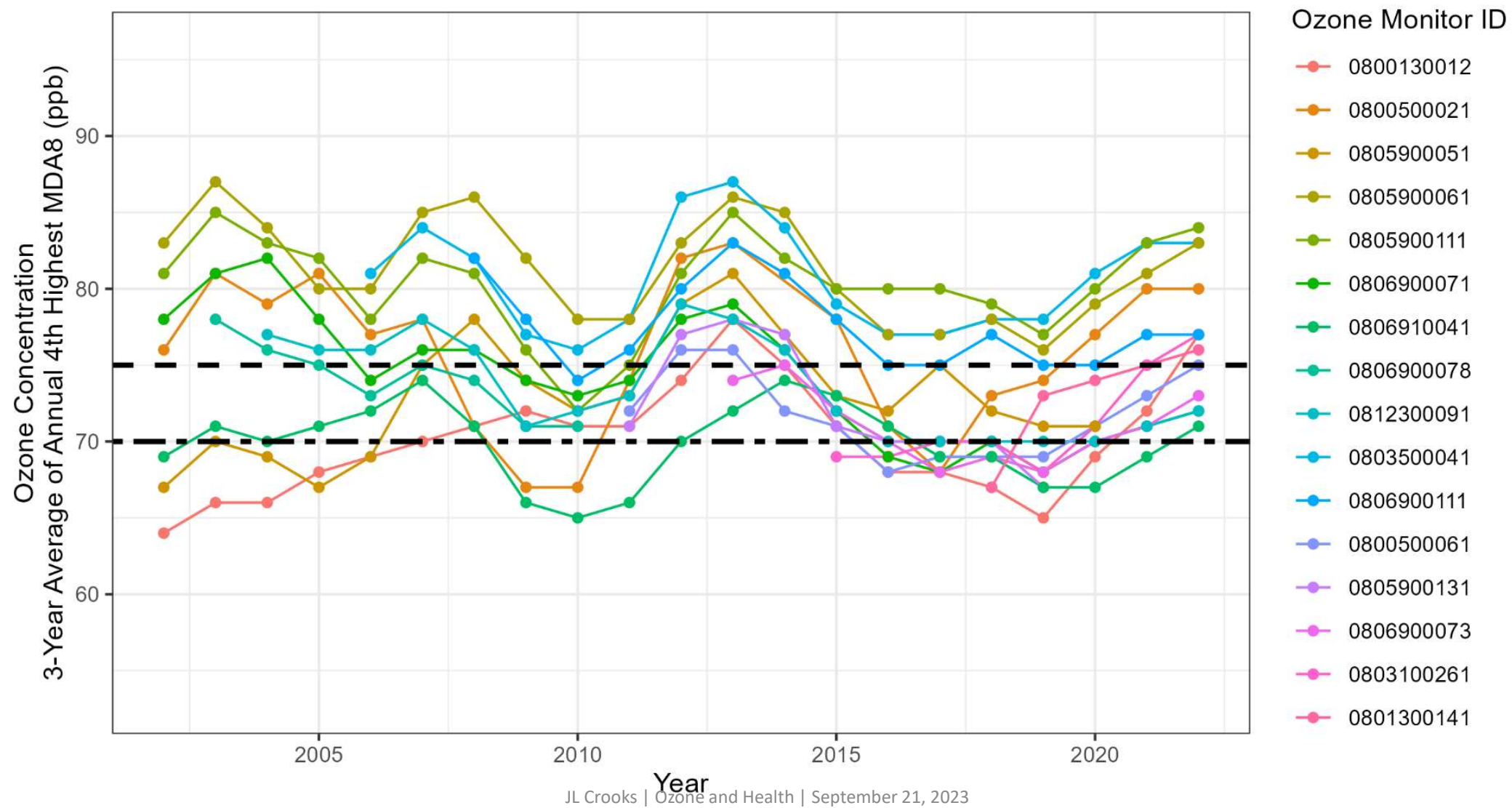
08/31/2023

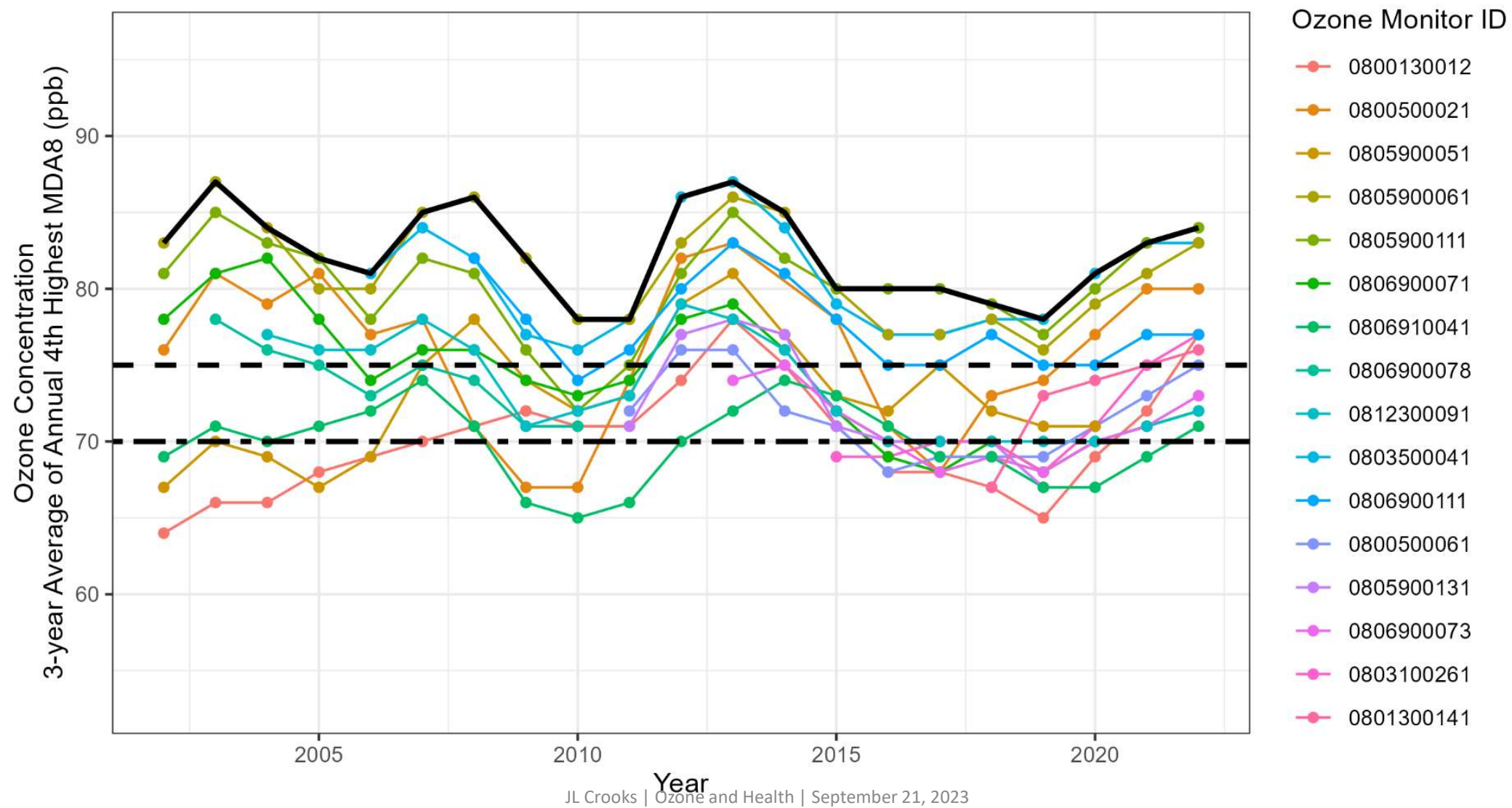


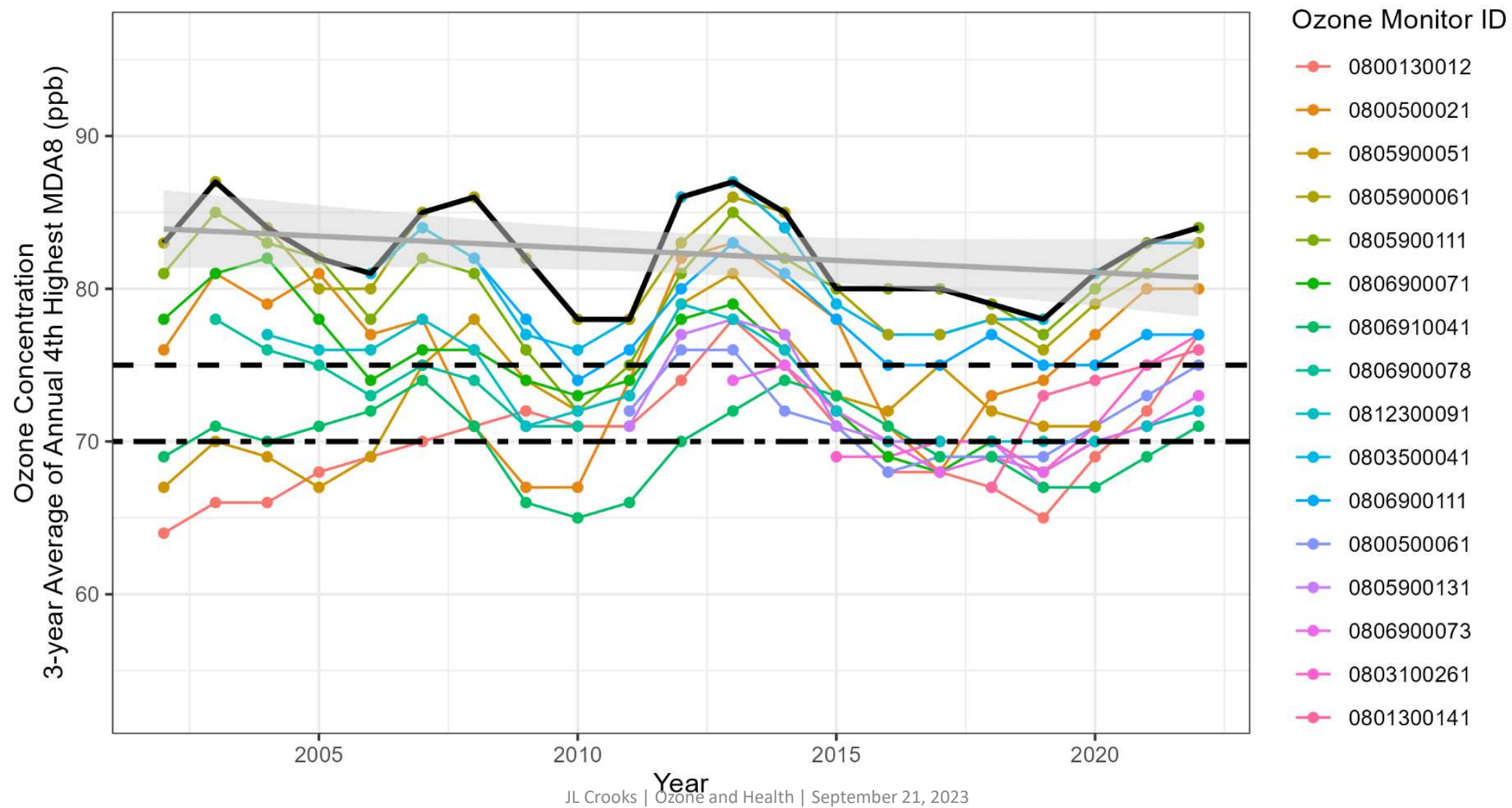
Colorado 8-hour Ozone Nonattainment Areas (2015 Standard)

08/31/2023











Ozone and Health

JL Crooks | Ozone and Health | September 21, 2023

Health effects of ozone

- 1970s-2000s – Ozone affects respiratory disease
 - Asthma
 - Emphysema
 - COPD
- 2010s – Ozone affects lots of other health outcomes too, via inflammatory and metabolic pathways
 - Heart attack
 - Stroke
 - Cardiovascular disease
 - Type 2 diabetes
 - Alzheimer’s Disease and cognitive decline
 - Adverse birth outcomes
 - ...

Integrated Science Assessment for Ozone and Related Photochemical Oxidants

Table ES-1 Summary of causality determinations by exposure duration and health outcome.

Health Outcome ^a	Conclusions in the 2020 ISA
Short-term exposure to ozone	
Respiratory effects	Causal relationship
Cardiovascular effects	Suggestive of, but not sufficient to infer, a causal relationship ^c
Metabolic effects	Likely to be causal relationship ^b
Total mortality	Suggestive of, but not sufficient to infer, a causal relationship ^c
Central nervous system effects	Suggestive of, but not sufficient to infer, a causal relationship
Long-term exposure to ozone	
Respiratory effects	Likely to be causal relationship
Cardiovascular effects	Suggestive of, but not sufficient to infer, a causal relationship
Metabolic effects	Suggestive of, but not sufficient to infer, a causal relationship ^b
Total mortality	Suggestive of, but not sufficient to infer, a causal relationship
Reproductive effects	Effects on fertility and reproduction: suggestive of, but not sufficient to infer, a causal relationship ^b Effects on pregnancy and birth outcomes: suggestive of, but not sufficient to infer, a causal relationship ^b
Central nervous system effects	Suggestive of, but not sufficient to infer, a causal relationship
Cancer	Inadequate to infer the presence or absence of a causal relationship ^e

Health Effects Institute

Trusted science for cleaner air and better health.

Ozone and Oxidants

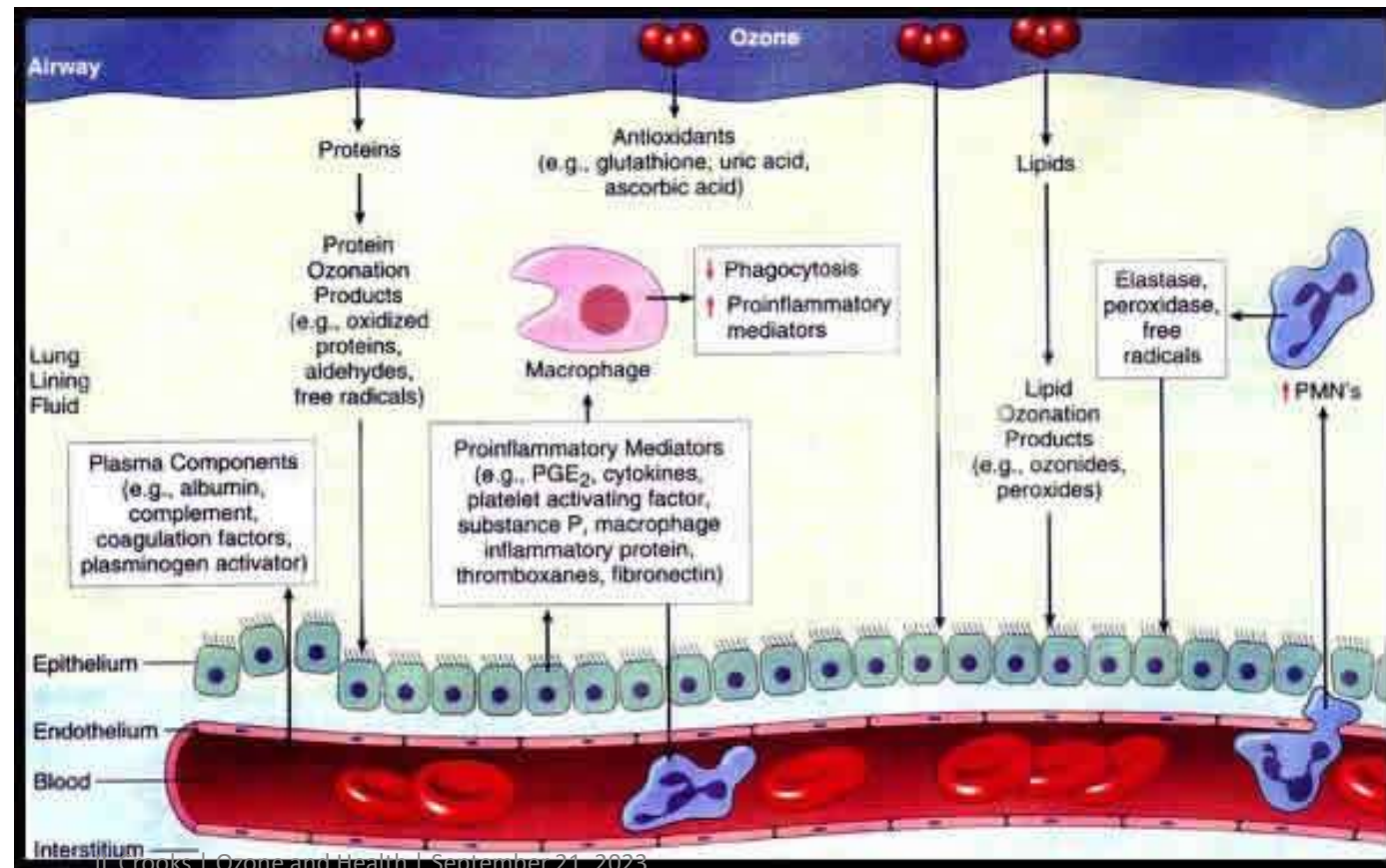
“Ozone (O₃) is a reactive gas that has been associated with adverse health effects in children and adults. Effects on the respiratory system are well established and include exacerbation of asthma (acute effects) and effects on lung growth (chronic effects). More recently, long-term exposure to ozone has been associated with adverse cardiovascular outcomes, including increased mortality.”

JL Crooks | Ozone and Health | September 21, 2023

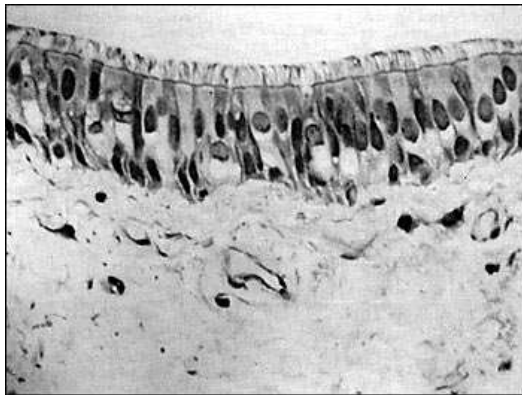
How do we know ozone is harmful?

Study Type	Scale	Common Outcomes	Purpose
Population	Large administrative databases	Respiratory mortality, hospitalizations, ER visits	Demonstrative relevance in the overall population
Cohort	Groups recruited for a specific purpose studied over time	Respiratory mortality, hospitalizations, ER visits, lung function changes	Demonstrative health relevance in specific groups
Controlled Human Exposure	Small groups of volunteers exposed to outdoor air vs. clean air	Lung function changes, cardiac function changes, inflammation	Demonstrate health changes over a short time scale
Controlled Animal Exposure	Lab animals exposed to different ozone levels	Lung function changes, structural changes in the lung, changes in cell function, inflammation, oxidative stress	Demonstrate health changes over a longer time scale and/or higher concentration, establish biological foundation underlying disease processes
In vitro	Cultured cells exposed to different ozone levels	Changes in cell function, inflammation, oxidative stress	Establish biological foundation underlying disease processes

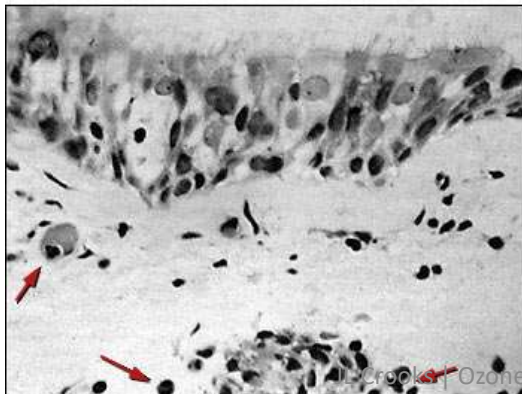
Scientists understand how ozone affects the lung



J. Crooks | Ozone and Health | September 21, 2023



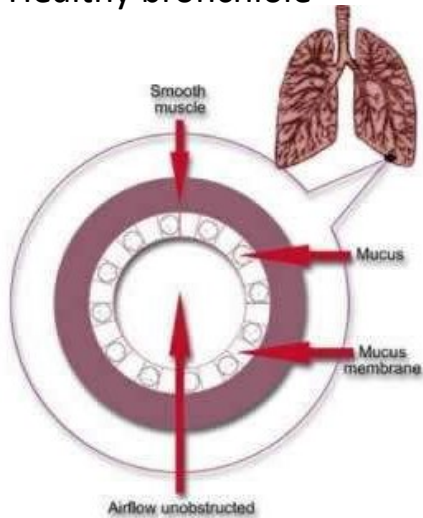
Healthy Lung Tissue



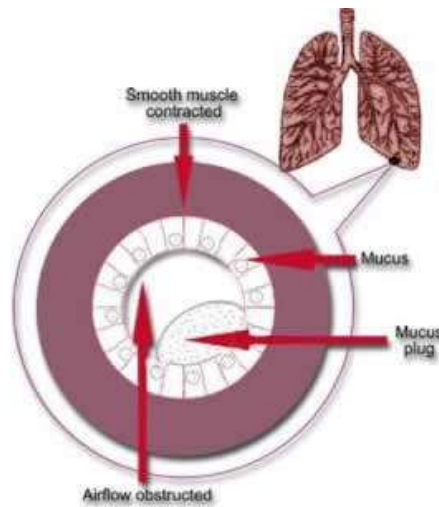
Ozone-damaged Lung Tissue

- Ozone reacts with molecules in the lining of our airways, and this causes acute inflammation.
- The lining of our airways loses some of its ability to serve as a protective barrier to microbes, toxic chemicals, and allergens.

Healthy bronchiole

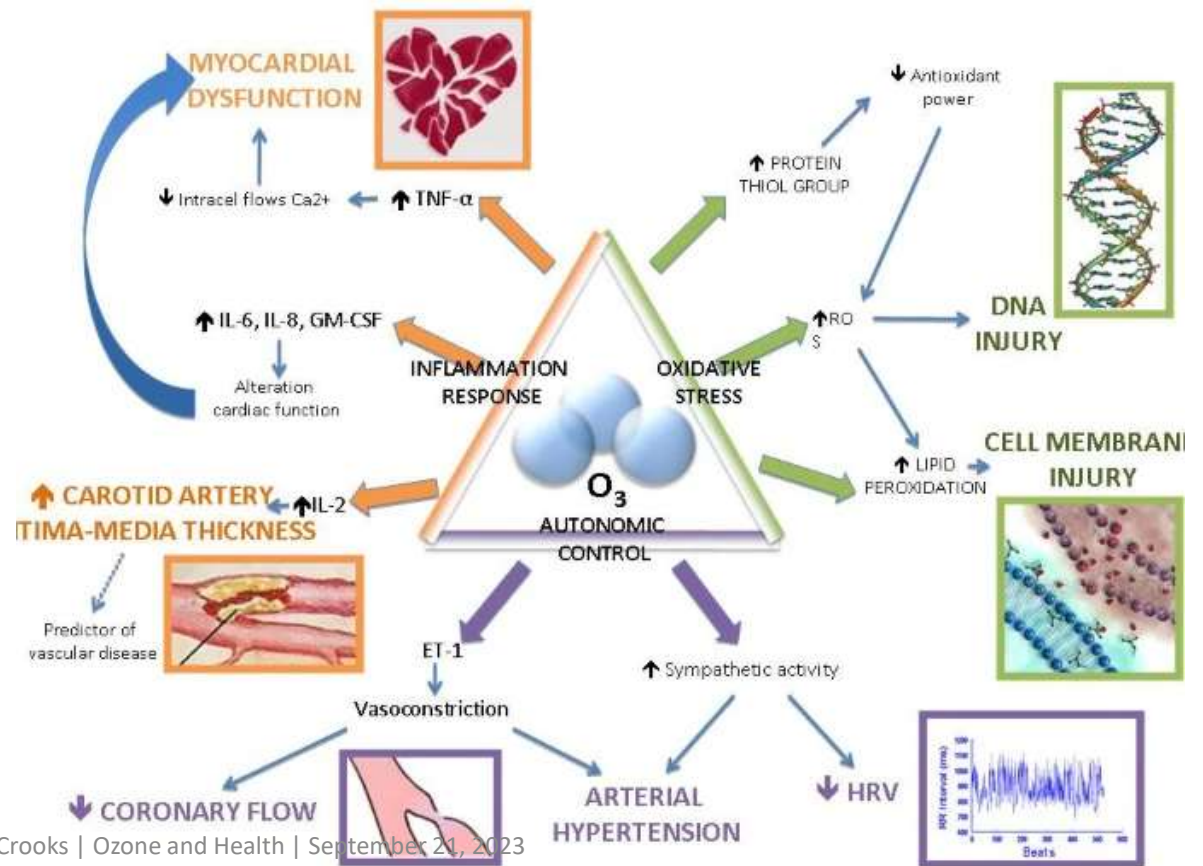


Ozone-exposed bronchiole



- Our airways respond by covering the affected areas with fluid and by contracting muscles. Breathing becomes more difficult.
- Common responses to ozone include shortness of breath, dry cough or pain when taking a deep breath, tightness of the chest, wheezing, and sometimes even nausea.
- Ozone triggers asthma and aggravates other respiratory illnesses such as pneumonia, bronchitis, emphysema, and COPD.

Scientists understand how ozone affects the heart



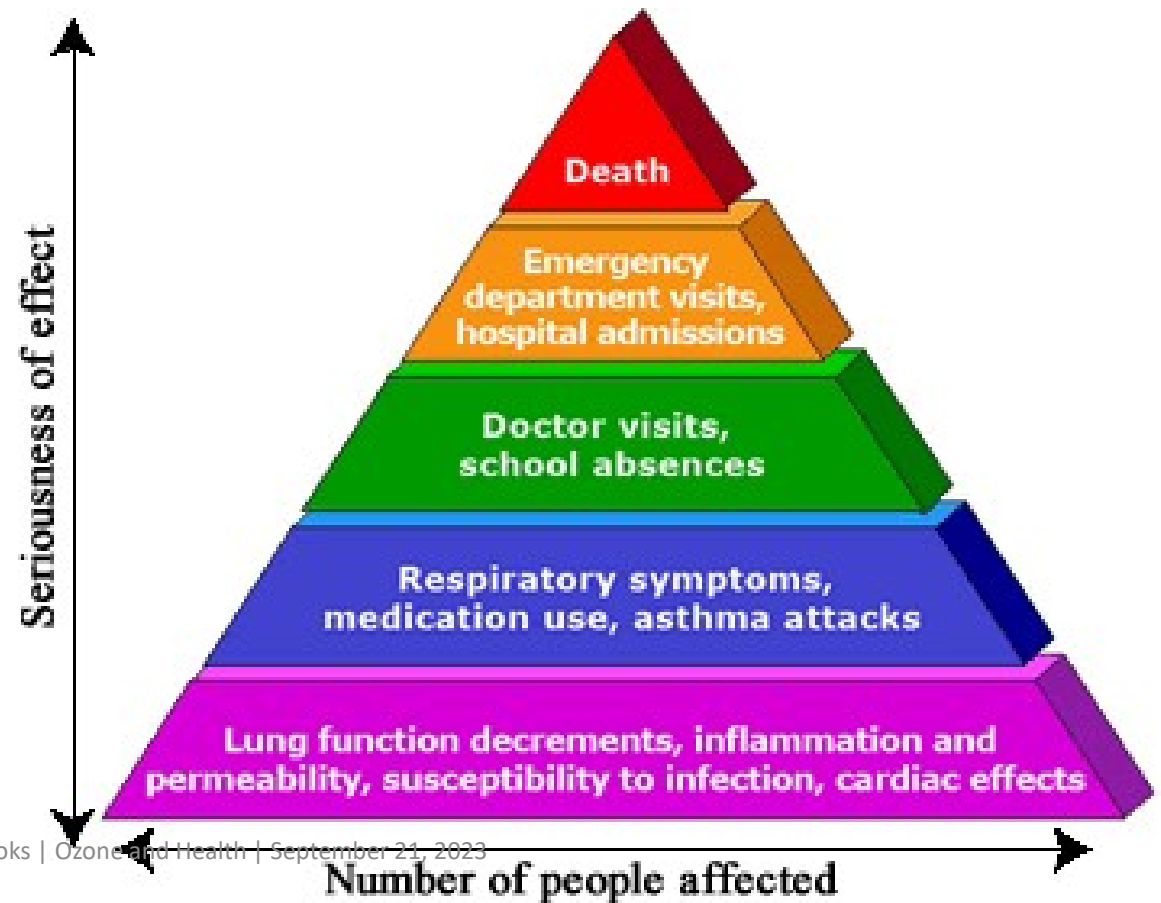
Srebot, V., Gianicolo, E.A., Rainaldi, G. *et al.* Ozone and cardiovascular injury. *Cardiovasc Ultrasound* 7, 30 (2009). <https://doi.org/10.1186/1476-7120-7-30>



Who Does Ozone Affect?

JL Crooks | Ozone and Health | September 21, 2023

Many people are affected a little, some people are affected a lot



Who is most vulnerable?

- Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. (IPCC AR5 2014)
- Individuals with pre-existing chronic disease
- Children
- Older Adults
- People who work outside
- The unhoused





Thank you