Ground Level Ozone (O_3)

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101 Fact Sheet

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Introduction

Ozone (O_3) is one of several serious air pollutants. The Denver Metro area, in particular, frequently has ozone levels determined to be hazardous. This has been a problem for years. Ozone levels are higher on weekends than weekdays and higher in urban areas, mainly due to more significant hydrocarbon and nitrogen oxide emissions associated with greater vehicular traffic. (https://courses.washington.edu/cee490/Lawson.PDF).

This Together Colorado Climate Justice Committee 101 Information Sheet is an "Introduction to Ozone." Legislation is being proposed in the 2023 session of the Colorado State Legislature to address some of our ozone problems, and we hope this document helps people understand these issues.

What is ozone, and when is it "beneficial" or "harmful?"

Ozone (O_3) is a form of oxygen (an allotrope) that, in the stratosphere (about 15 miles up in the atmosphere, Figure 1), protects us from harmful shortwave ultraviolet (UVC) light from the sun. However, when O_3 is near the ground, it is a toxic air pollutant (Figure 2).

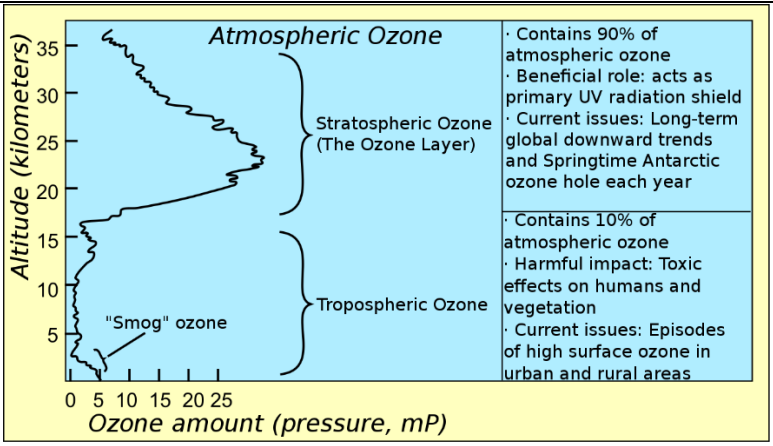
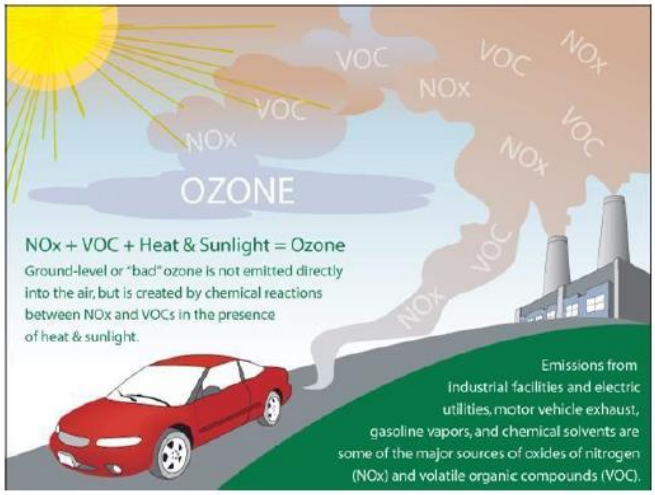


Figure 1. Ozone concentration in the atmosphere versus altitude.

The oxygen we breathe that is necessary for life contains two oxygen atoms (O_2), making up about 21% of Earth's atmosphere. Most of the rest is nitrogen (N_2). There are also smaller amounts of other gases, including water vapor, greenhouse gases (mainly CO_2), and air pollution. While O_3 protects us from the sun's harmful, shortwave UVC light, it is a very reactive molecule because it readily "gives up" its "extra" oxygen atom, making O_3 a powerful oxidizer.

Both stratospheric (beneficial) ozone and ground-level (harmful) ozone are made by what chemists call photochemical reactions. In photochemical reactions, sunlight provides the energy needed to make the chemical reactions "go."



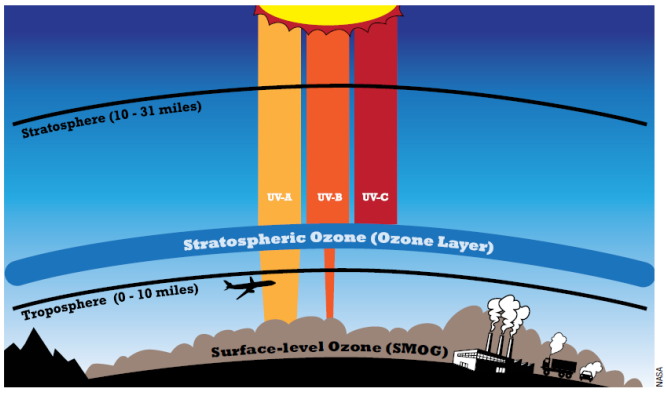
Source: EPA Ground-level Ozone Basics

Figure 2. EPA's ground-level ozone cartoon

Longwave ultraviolet light (UVA and UVB) drives the chemical reactions (Figure 3) during ground-level O_3 formation, and fossil fuel emissions play an important role.

When people think about burning fossil fuels, they generally picture carbon dioxide (CO_2) because it is the largest by volume greenhouse gas, or in the case of incomplete combustion, poisonous carbon monoxide (CO).

What most people don't consider is that at the *temperatures where fossil fuels burn* (up to 2000°F), nitrogen (N_2) in the air is chemically reactive, and at these temperatures, reacts with O_2 to form NO and NO_2 (nitrogen oxides collectively referred to as NO_X). Aside from being unhealthy to breathe, NO_X reacts with unburned hydrocarbons to form ground-level ozone in sunlight. The highest concentrations of NO_X and volatile organic compounds (VOCs), such as unburned gasoline and diesel and industrial solvent emissions from factories, occur in cities, ports, and similar places. Therefore, the highest concentrations of ground-level O_3 are in these locations.



While ozone can be found through the entire atmosphere, it is mostly concentrated at an altitude of about 15 miles. This band of ozone-rich air, called the ozone layer, protects all life forms on Earth by filtering two harmful forms of ultraviolet light called UV-B and UV-C.

Figure 3. Ozone filtering by the atmosphere. https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/articlesbytopic/chemicalreactions/chemmatters-april2013-ozone.pdf

But I thought ozone *depletion* was a problem.

Most people have heard of ozone depletion, but this is a separate issue that has nothing to do with ground-level ozone air pollution. Instead, ozone depletion refers to how certain volatile chemicals (such as some refrigerants and old spray propellants) can make stratospheric (beneficial) O_3 decompose faster than natural processes can replenish it. When this happens, more harmful shortwave UVC reaches the Earth's surface. As a result, the EPA banned several refrigerants and propellants, and the "ozone holes" in the upper atmosphere appear to be "healing."

Adverse Health Effects of Ground Level Ozone (the consequences of non-compliance)

"Respiratory disease: reduced lung function, increased hospital admissions and emergency department visits for asthma and respiratory infections, and possibly increased rates of asthma development. School-aged children are particularly vulnerable."

Cardiovascular disease: specifically increased rates of strokes. There is also evidence supporting ozone's effects on cardiac arrhythmia in persons with preexisting heart disease."

"Studies reviewed indicate that ozone is responsible for [approximately] 5000 deaths per year in the US. New studies add to evidence that long-term ozone exposure also increases mortality rates." Here is the link to the report https://blogs.edf.org/climate411/files/2019/09/EDF_Summer_Ozone_Analysis_FINAL-9_10.pdf

What Can Be Done?

As you might imagine, there is an enormous amount of literature about ground-level ozone, how, why, and when it forms, and how to decrease its presence. In addition, the EPA has many resources linked to its website. For example, driving less by carpooling and using public transport reduces the amounts of NOx and unburned hydrocarbons emitted per person per mile. Still, there are changes in fuel standards and industrial regulations that offer promise.

According to the EPA, *"The Clean Air Act requires each state containing an ozone nonattainment area* [e.g., Colorado] *to develop a written plan for cleaning the air in that area. This plan called the State Implementation Plan (SIP)* [this is one of the goals of a 2023 bill supported by Together Colorado], *details the steps the state must take to improve air quality and meet applicable air quality standards. We help the states develop strategies and enact regulations to include in the SIP. Strategies currently being implemented include:"*

- Vapor recovery nozzles at the gasoline pump to reduce refueling emissions.
    - CA and some other states have vapor recovery attachments on gasoline nozzles. Look at the fumes flowing around the nozzle out into the air the next time you fill up. These gasoline vapors will react with NOx in sunlight to produce ground-level O_3.
- Cleaner burning reformulated gasoline will reduce VOC, NOx, and other pollutants.
    - Reformulated gasoline burns cleaner, but Colorado has resisted a mandate for its use because it costs more. Of course, everybody complains when gasoline prices increase, but this may be the price we need to pay for cleaner air.
- Implement strict NOx emission limits for power plants and industrial combustion sources.
    - Reducing NOx might require installing costly, specialized control technology so the industry will resist it. One technology already used by many power plants is called

Selective Catalytic Reduction (SCR). In SCR, the flue gas containing NOx is mixed with small amounts of ammonia gas (NH_3) and passed through a layer of vanadium-based catalyst. With careful control of the process's operating conditions, NOx and NH_3 react with each other to form harmless nitrogen (N_2) and water vapor (H_2O). https://en.wikipedia.org/wiki/Selective_catalytic_reduction

- Enhance vehicle inspection programs in states.
    - Older cars pollute more than newer ones with the latest pollution control technology. Perhaps the government could help less-affluent people purchase newer cars with better pollution control. Perhaps with no-interest loans? Here is the link to a UN report about pollution and used cars. https://www.unep.org/resources/report/used-vehicles-and-environment-progress-and-updates-2021
- Implement strict limits on solvent usage in factories.
    - Companies that use industrial organic solvents for cleaning parts, conducting chemistry and other uses are generally permitted to vent limited amounts of vapor directly into the air without installing clean-up technologies. While an individual factory's emissions might not be significant, combining all factory emissions is a large VOC source. So again, government subsidies to install vapor clean-up systems could significantly reduce emissions.

"The states are required to submit the State Implementation Plan to EPA for approval. We at EPA then review the plan and approve it if it satisfactorily shows that attainment with the ozone National Ambient Air Quality Standard will be achieved as required by the Clean Air Act."

Ground-level ozone is one of many serious air pollutants (even when excluding greenhouse gas emissions). In addition, carbon monoxide, nitrogen oxides, volatile organics, sulfur dioxide, hydrogen sulfide, hydrogen chloride, and a long list of others, are hazardous pollutants. Finally, particulates such as $PM_{2.5}$ that can deeply enter the lungs are perhaps an even more severe threat. Hopefully, this document has explained some of the issues surrounding ozone.