Hot and Smoggy

The Ozone – Hot Weather Connection in Eight California Cities

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October 2007

Acknowledgments

The author would like to thank Bonnie Holmes-Gen of the American Lung Association of California, Janice Nolen and Paul Billings of the American Lung Association, Tom Plenys of the Coalition for Clean Air, and Tony Dutzik of the Frontier Group for their detailed and insightful comments on this paper. Thanks to the California Air Resources Board for providing the data for our analysis. Thanks also to Natasha Oxenburgh for her contribution to this report and to Bernadette Del Chiaro of Environment California Research & Policy Center for her editorial assistance.

The Environment California Research & Policy Center thanks the Kirsch Foundation whose financial support made this report possible.

The author alone bears responsibility for any factual errors. The recommendations in this report are those of the Environment California Research & Policy Center and do not necessarily represent the views of our funders or those who reviewed the report.

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Table of Contents

Executive Summary

Despite years of progress in cleaning up California's air, millions of Californians continue to breathe the dirtiest air in the nation. In fact, the Golden State is home to eight of the 10 most ozone-polluted counties in the United States. Unfortunately, scientists predict that rising temperatures from global warming will increase conditions conducive to ozone formation (often called "smog"). This report examines the correlation between higher temperatures and ozone pollution at eight locations in California, and concludes that, in order to protect the health of Californians, policy-makers must take aggressive steps to reduce pollution that leads to smog, while also continuing to lead national and international efforts to tackle global warming.

Ground-level ozone, the primary component of smog, is a severe respiratory irritant that can aggravate asthma and cause other respiratory problems, including permanent lung damage. Using temperature and air quality data from the California Air Resources Board, this report found that the warmer the weather the more likely that Californians are breathing dirty air.

Key findings include the following:

- In Bakersfield, ozone levels exceeded the state 8-hr health standard 91 percent of the days that the daily maximum temperature was 100°F or more. Ozone levels exceeded the state 1-hr health standard 58 percent of those days.

- In Burbank, ozone levels exceeded the state 8-hr health standard 42 percent of the days that the daily maximum temperature was 100°F or more. Ozone levels exceeded the state 1-hr health standard 41 percent of those days.

- In Folsom, ozone levels exceeded the state 8-hr health standard 83 percent of the days that the daily maximum temperature was 100°F or more. Ozone levels exceeded the state 1-hr health standard 58 percent of those days.

- In Fresno, ozone levels exceeded the state 8-hr health standard 84 percent of the days that the daily maximum temperature was 100°F or more. Ozone levels exceeded the state 1-hr health standard 75 percent of those days.

- In Riverside, ozone levels exceeded the state 8-hr health standard 79 percent of the days that the daily maximum temperature was 100°F or more. Ozone levels exceeded the state 1-hr health standard 69 percent of those days.

- In San Bernardino, ozone levels exceeded the state 8-hr health standard 75 percent of the days that the daily maximum temperature was 100°F or more. Ozone levels exceeded the state 1-hr health standard 67 percent of those days.

- In San Diego, ozone levels exceeded the state 8-hr health standard 16 percent of the days that the daily maximum temperature was 90°F or more. Ozone levels exceeded the state 1-hr health standard 15 percent of those days.

- In Sequoia National Park, ozone levels exceeded the state 8-hr health standard 75 percent of the days that the daily maximum temperature was 80°F or more. Ozone levels exceeded the state 1-hr health standard 59 percent of those days.

Unfortunately, with worldwide emissions of global warming pollution increasing each year, temperatures are expected to rise in the coming decades. Scientists predict that higher temperatures from global warming will lead to higher levels of ozone pollution in California by increasing emissions of ozone-forming pollutants and accelerating chemical processes that generate ozone.

Given California's existing air pollution problems and the expectation that global warming will increase ozone formation that leads to smog, state policy-makers and environmental agencies should work to significantly reduce ozone-forming pollutants while simultaneously reducing global warming emissions to levels that scientists have concluded are necessary to prevent a dramatic increase in temperature.

To reduce smog pollution state policy-makers and agencies should prioritize a variety of policy measures, including measures outlined in California's State Implementation Plan for federal ambient air quality standards. Measures to prioritize include:

- **Passenger vehicles** – Increase the sale and use of zero-emission and low-polluting passenger cars and light-duty trucks, accelerate vehicle retirement, and strengthen the state smog check program;

- **Trucks and off-road equipment** – Reduce emissions from medium- and heavy-duty diesel trucks and off-road equipment by strengthening emissions standards, increasing retrofits, and accelerating replacement with cleaner technologies;

- **Ports & goods movement** – Require cleaner marine engines and fuels, increase the number of ships with the ability to use shore-side power ("cold ironing"), increase retrofits, and accelerate the introduction of cleaner port trucks, harbor craft and locomotives;

- **Agriculture** – Accelerate the replacement of agricultural equipment through regulation and incentives; and

- **Strong enforcement of existing pollution control rules** – Enforce tough standards for cleaner construction equipment, airport ground support, and other off-road vehicles.

To reduce global warming emissions state policy-makers and agencies should prioritize successful implementation of the Global Warming Solutions Act of 2006 (Assembly Bill 32), which commits California to reducing global warming emissions to 1990 levels by 2020.

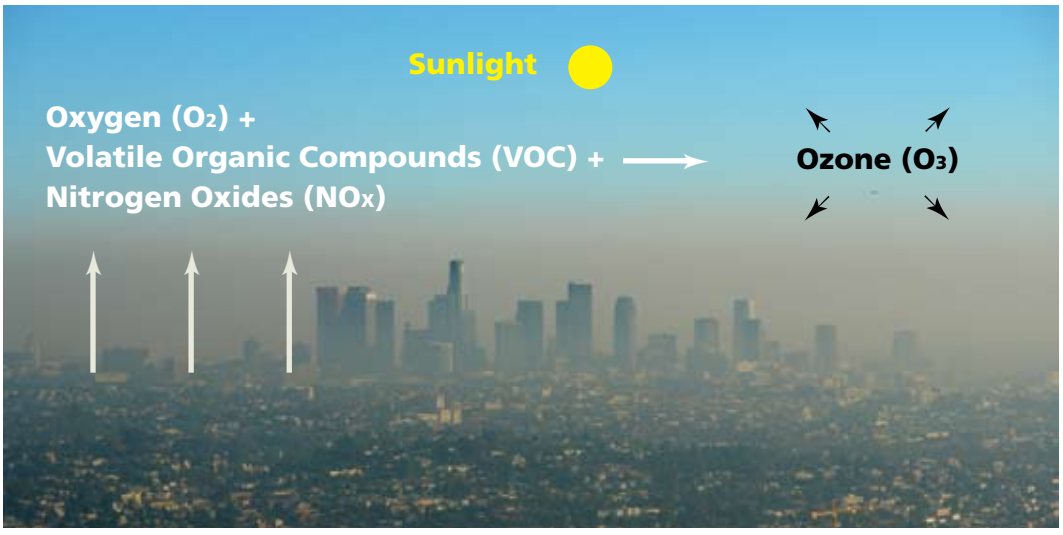
Sources of Ozone Pollution

Ozone is an odorless, colorless gas. In the upper atmosphere, ozone forms naturally and shields the planet from ultraviolet radiation. At ground level, however, ozone causes serious health problems.

Ozone is not emitted directly from pollution sources but rather forms when nitrogen oxide (NOx) emissions and volatile organic compounds (VOCs) react with heat and sunlight (see Figure 1). Ozone levels in California typically rise from May to October, when temperatures are generally higher, sunlight is more abundant, and atmospheric conditions can be stagnant.

The combustion of fossil fuels to power cars, SUVs, trucks, and other mobile sources such as ships and construction

Figure 1: Diagram of Ozone Formation[1]



equipment produces 84 percent of all NOx emissions in California (see Figure 2).[2] VOCs result from a wider range of sources, including motor vehicles, other mobile sources, consumer products and other miscellaneous processes (see Figure 3).[3]

Figure 2: Emissions of Nitrogen Oxides by Source, 2005

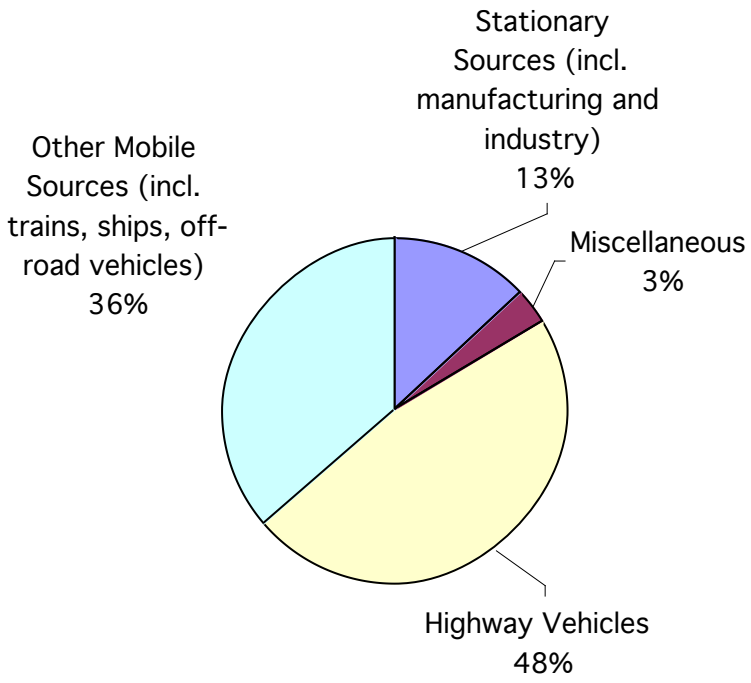
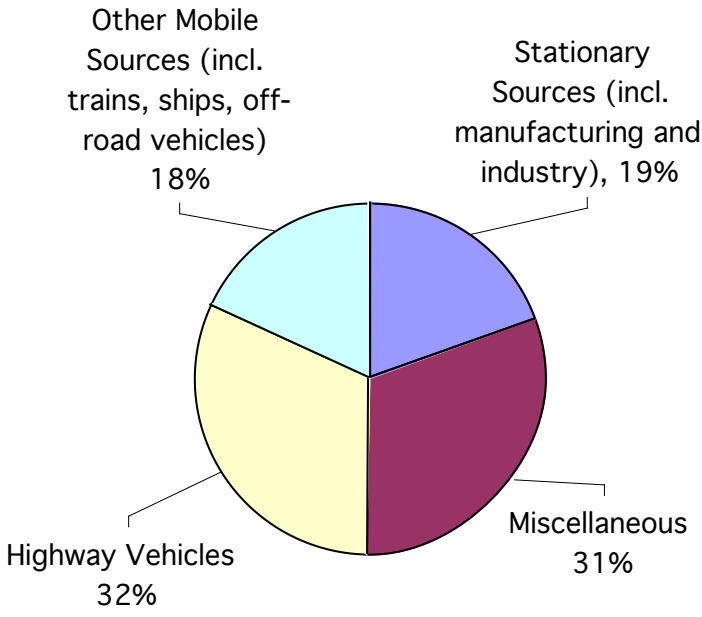


Figure 3: Emissions of Volatile Organic Compounds by Source, 2005



Health Effects of Ozone

Ozone is a powerful oxidant that burns our lungs and airways, causing them to become inflamed, reddened, and swollen. Children, senior citizens, and people with respiratory disease are particularly vulnerable to the health effects of ozone.

Exposure to even very low levels of ozone contributes to a wide range of adverse health effects. For example, the U.S. Environmental Protection Agency has concluded that even when ozone is inhaled at very low levels, it can cause chest pain and cough, aggravate asthma, reduce lung function, increase emergency room visits and hospital admissions for respiratory problems, and lead to irreversible lung damage.[4]

Meanwhile, scientific research continues to point to even more serious health and societal impacts associated with exposure ozone. Recent studies have linked ozone to these health effects:

California Tops Charts in Ozone Pollution

According to American Lung Association analysis of nationwide ozone pollution data between 2003 and 2005, California is home to eight of the ten most ozone-polluted counties in the United States.

The Ten Most Polluted Counties

1. San Bernardino (California)
2. Kern (California)
3. Riverside (California)
4. Los Angeles (California)
5. Tulare (California)
6. Fresno (California)
7. Harris (Texas)
8. Merced (California)
9. Tarrant (Texas)
10. Sacramento (California)

U.S. EPA Weighs Decision to Strengthen 8-hr Ozone Health Standard

In 1997, EPA set the national air quality standard for ozone at 0.08 parts per million (ppm) averaged over an eight-hour period. In 2006, the Clean Air Scientific Advisory Committee, a group of expert scientists who advise the EPA Administrator on air quality standards, reviewed a 2,000 page summary of the scientific research on the health effects of ozone and unanimously concluded:

§ There is no scientific justification for retaining the current ozone standard of 0.08 ppm;

§ The ozone standard must explicitly include the "margin of safety" required by the Clean Air Act;

§ Therefore, the new 8-hour ozone standard should be set in the range of 0.06 to 0.07 ppm.

On June 20, 2007, U.S. EPA proposed strengthening the national air quality standard for ozone to within a range of 0.07 to 0.075 ppm, weaker than what the agency's scientific advisors say is necessary to protect public health. Alarmingly, the new proposal also leaves the door open to retaining the current ozone standard, which scientists and even EPA Administrator Stephen Johnson have said is not strong enough to protect public health.

The EPA is expected to issue a final standard by March 2008.

- **Development of Asthma in Children –** Asthma is the most common chronic disease among children.[6] Nationwide, the prevalence of childhood asthma more than doubled between 1980 and the mid-1990s, and remains at historically high levels today.[7] A 2002 study of more than 3,500 children in twelve Southern California communities found that children who participated in several outdoor sports in high ozone communities were three times more likely to develop asthma than children who did not play sports. In contrast, children participating in sports in areas of low ozone concentration were not more likely to develop asthma.[8]

- **Premature Mortality** – Studies have found that exposure to ozone is associated with increased mortality.[9] Research is showing that ozone may directly affect the heart and cardiovascular system as well as the lungs.[10]

- **Missed School Days** – Ozone pollution causes many children to miss school. A study on the effects of air pollution on school absenteeism found that a small increase in ozone pollution (0.02 parts per million) is associated with a nearly two-thirds increase in missed school days as a result of illness.[11] Consequently, the California Air Resources Board estimates that statewide 1.3 million school absences could be avoided annually if ozone levels statewide were brought into attainment with the 1-hour standard of 0.09 ppm.[12]

- **Birth Defects** – Ozone may impact the development of a fetus in the womb. A 2002 study by UCLA researchers found that women in four Southern California counties who were exposed to ozone in their second month of pregnancy had an increased risk of giving birth to babies with serious heart defects, including aortic artery and valve defects.[13]

While high ozone concentrations pose pervasive health risks, research demonstrates that declines in ozone levels can reduce these effects. For instance, during the 1996 Summer Olympics, officials closed downtown Atlanta to traffic and increased public transit, which reduced ozone levels and significantly lowered rates of acute care visits and hospitalizations for asthma among children.[14]

The Ozone-Hot Weather Connection in Eight California Cities

This report examined the correlation between temperature and air quality at eight locations in California between 1997 and 2006. Using temperature and air quality data from the California Air Resources Board, this report found that the warmer the weather the more likely that Californians are breathing dirty air. In addition, the analysis showed that a small increase in the daily maximum temperature was often associated with a substantial increase in the likelihood that air quality exceeded health standards

The report assesses air quality based on the 1-hour and 8-hour California Ambient Air Quality Standard (CAAQS) for ozone pollution. The 1-hour CAAQS for ozone is 0.09 parts per million (ppm) and the 8-hour CAAQS for ozone is 0.070 ppm.

Bakersfield

The greatest likelihood that air quality in Bakersfield exceeded state health standards occurred when the daily high was at least 100°F. On those days, ozone levels exceeded the 8-hr health standard 91 percent of the time, and the 1-hr health standard 58 percent of the time. When the daily high was between 95 and 99°F, ozone levels exceeded the 8-hr and 1-hr health standards 77 and 28 percent of the time, respectively. Ozone levels exceeded the 8-hr health standard 67 percent of the days in which the daily high was between 90 and 94°F. Ozone levels exceeded the 1-hr health standard 21 percent of those days.

Burbank

The greatest likelihood that air quality in Burbank exceeded state health standards occurred when the daily high was at least 100°F. On those days, ozone levels exceeded the 8-hr health standard 42 percent of the time, and the 1-hr health standard 41 percent of the time. When the daily high was between 95 and 99°F, ozone levels exceeded the 8-hr and 1-hr health standards 31 and 25 percent of the time, respectively. Ozone levels exceeded the 8-hr health standard 22 percent of the days in which the daily high was between 90 and 94°F. Ozone levels exceeded the 1-hr health standard 19 percent of those days.

Figure 4: Bakersfield: Exceedances of Ozone Health Standards, 1997-2006

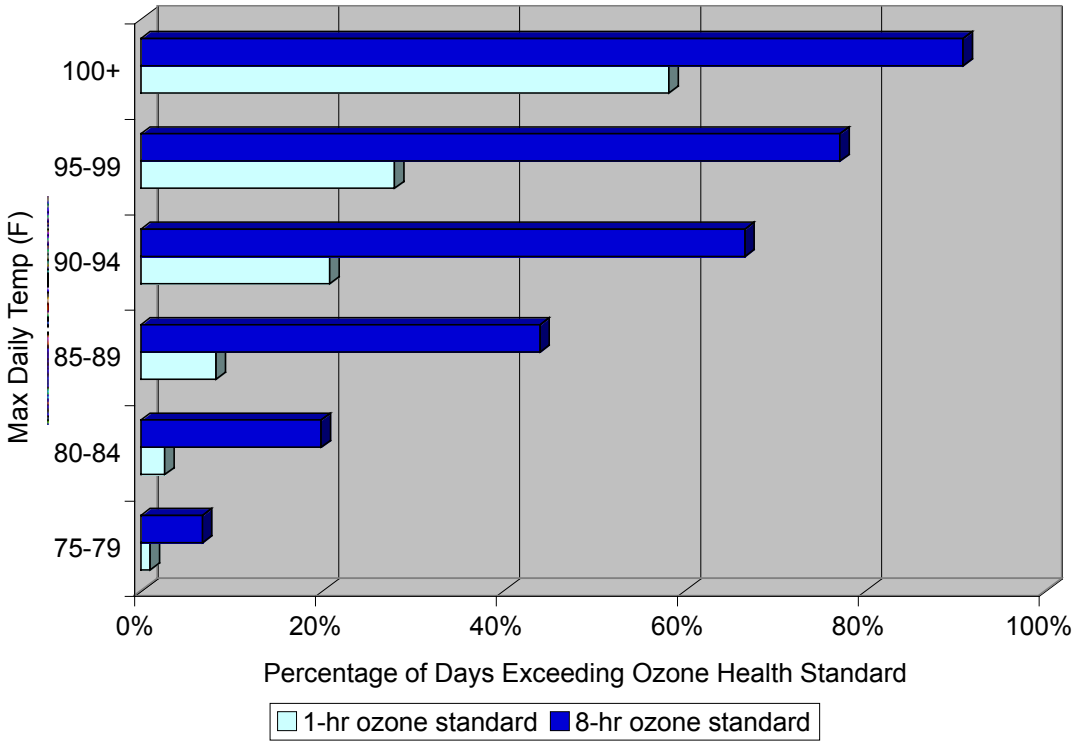
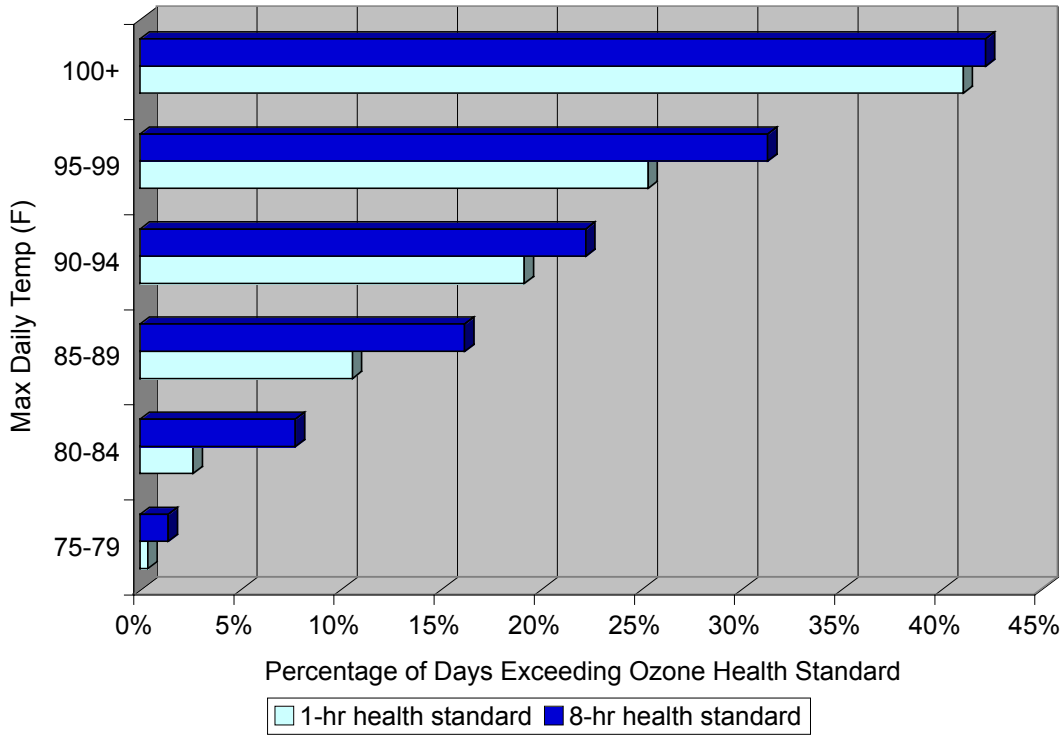


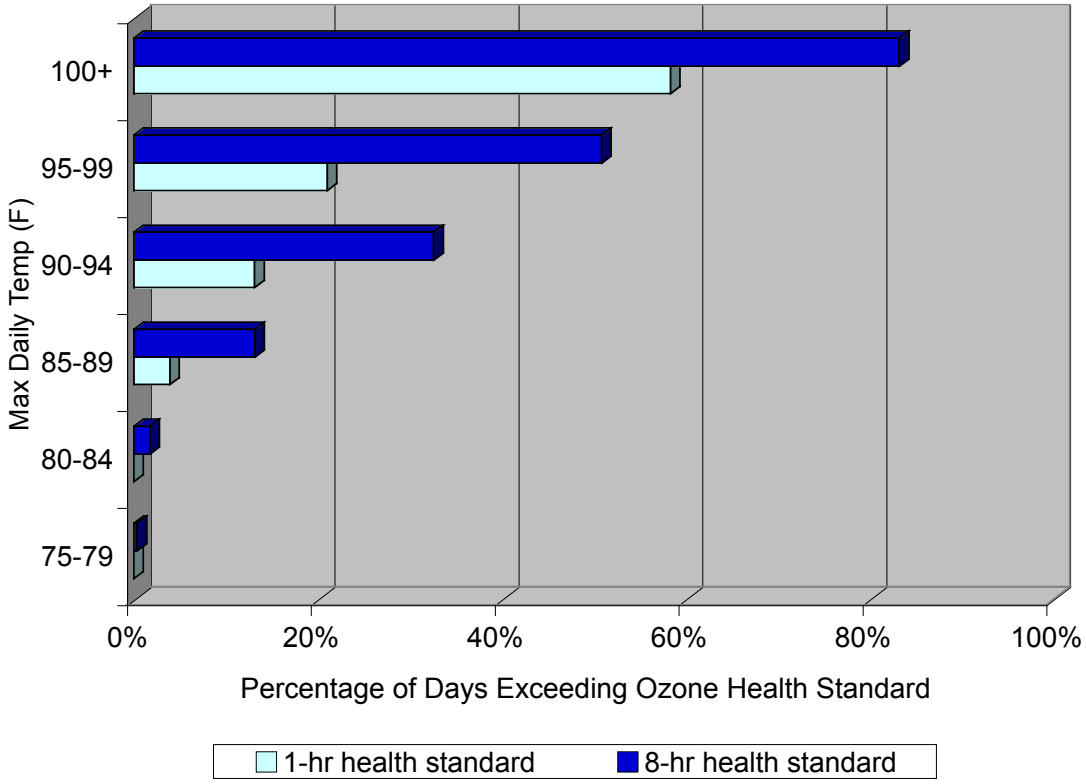
Figure 5: Burbank: Exceedances of Ozone Health Standards, 1997-2006



Folsom

The greatest likelihood that air quality in Folsom exceeded state health standards occurred when the daily high was at least 100°F. On those days, ozone levels exceeded the 8-hr health standard 83 percent of the time, and the 1-hr health standard 58 percent of the time. When the daily high was between 95 and 99°F, ozone levels exceeded the 8-hr and 1-hr health standards 51 and 21 percent of the time, respectively. Ozone levels exceeded the 8-hr health standard 33 percent of the days in which the daily high was between 90 and 94°F. Ozone levels exceeded the 1-hr health standard 13 percent of those days.

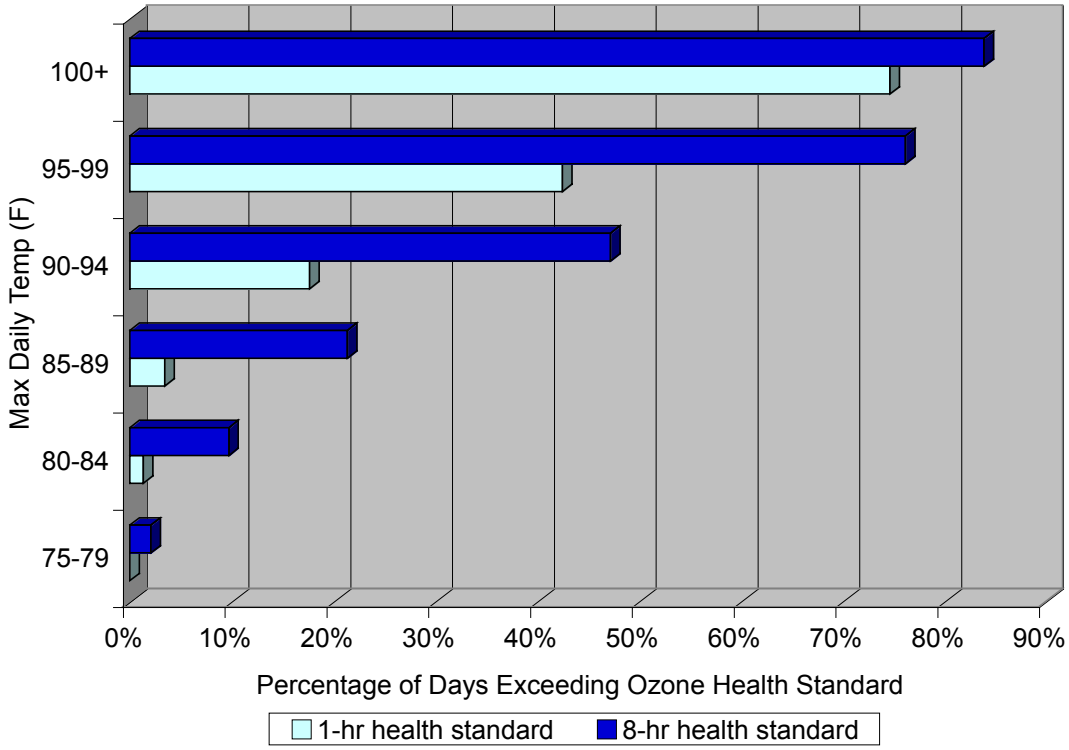
Figure 6: Folsom: Exceedances of Ozone Health Standards, 1997-2006



Fresno

The greatest likelihood that air quality in Fresno exceeded state health standards occurred when the daily high was at least 100°F. On those days, ozone levels exceeded the 8-hr health standard 84 percent of the time, and the 1-hr health standard 75 percent of the time. When the daily high was between 95 and 99°F, ozone levels exceeded the 8-hr and 1-hr health standards 76 and 43 percent of the time, respectively. Ozone levels exceeded the 8-hr health standard 47 percent of the days in which the daily high was between 90 and 94°F. Ozone levels exceeded the 1-hr health standard 18 percent of those days.

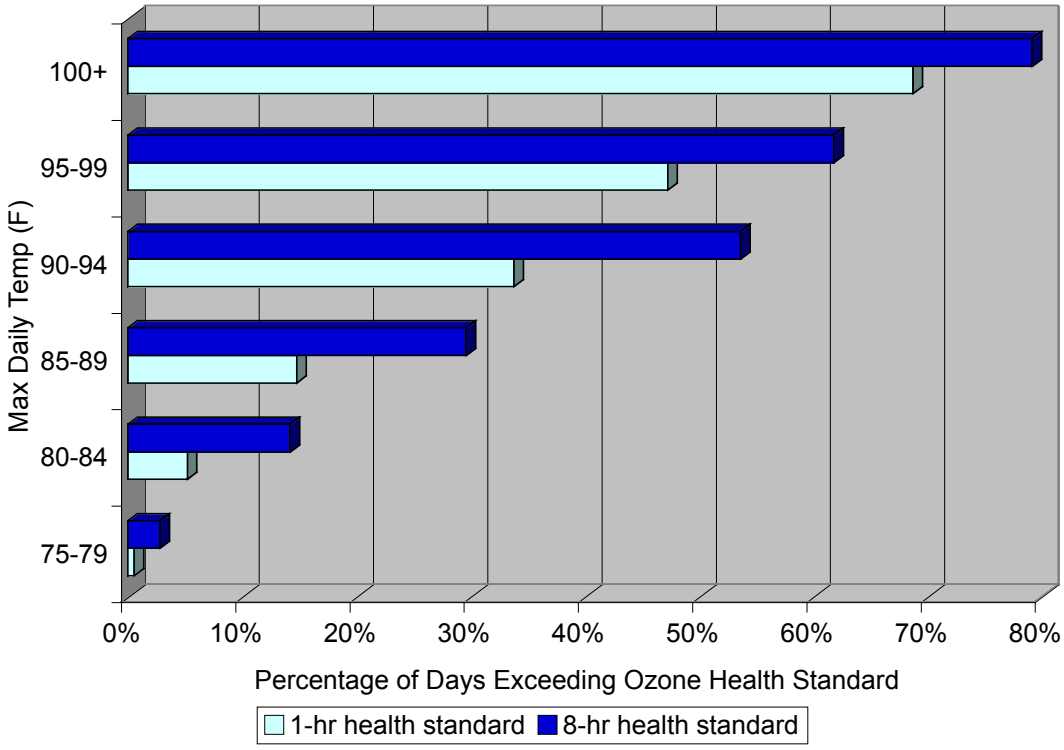
Figure 7: Fresno: Exceedances of Ozone Health Standards, 1997-2006



Riverside

The greatest likelihood that air quality in Riverside exceeded state health standards occurred when the daily high was at least 100°F. On those days, ozone levels exceeded the 8-hr health standard 79 percent of the time, and the 1-hr health standard 69 percent of the time. When the daily high was between 95 and 99°F, ozone levels exceeded the 8-hr and 1-hr health standards 62 and 47 percent of the time, respectively. Ozone levels exceeded the 8-hr health standard 54 percent of the days in which the daily high was between 90 and 94°F. Ozone levels exceeded the 1-hr health standard 34 percent of those days.

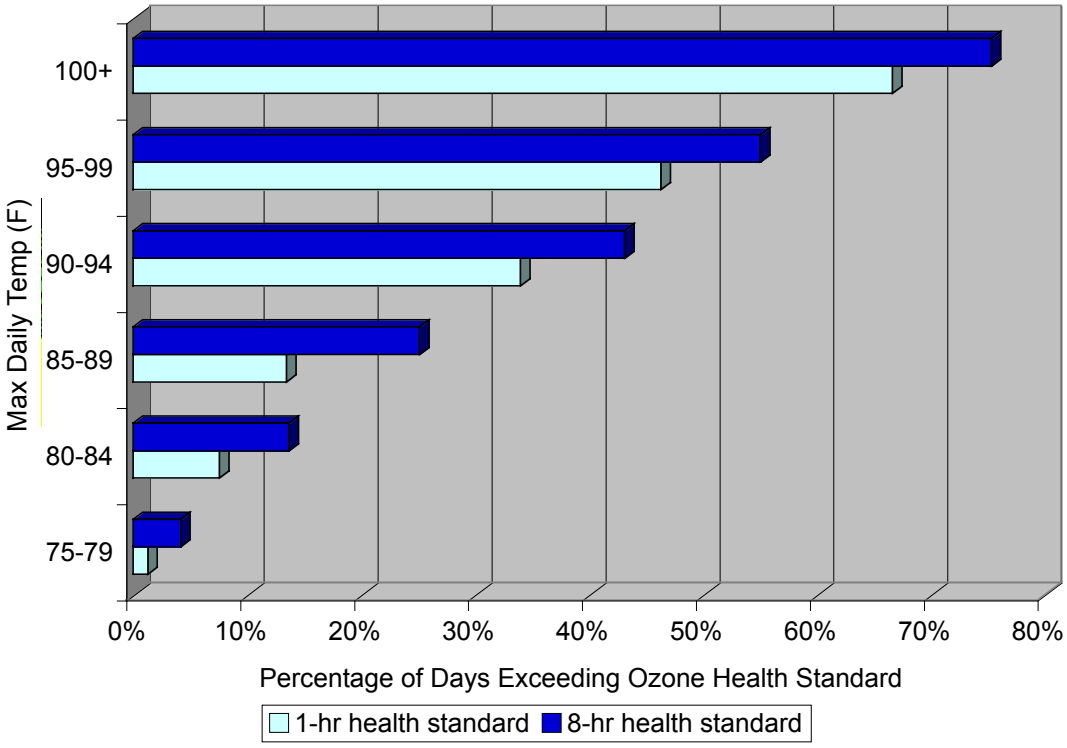
Figure 8: Riverside: Exceedances of Ozone Health Standards, 1997- 2006



San Bernardino

The greatest likelihood that air quality in San Bernardino exceeded state health standards occurred when the daily high was at least 100°F. On those days, ozone levels exceeded the 8-hr health standard 75 percent of the time, and the 1-hr health standard 67 percent of the time. When the daily high was between 95 and 99°F, ozone levels exceeded the 8-hr and 1-hr health standards 55 and 46 percent of the time, respectively. Ozone levels exceeded the 8-hr health standard 43 percent of the days in which the daily high was between 90 and 94°F. Ozone levels exceeded the 1-hr health standard 34 percent of those days.

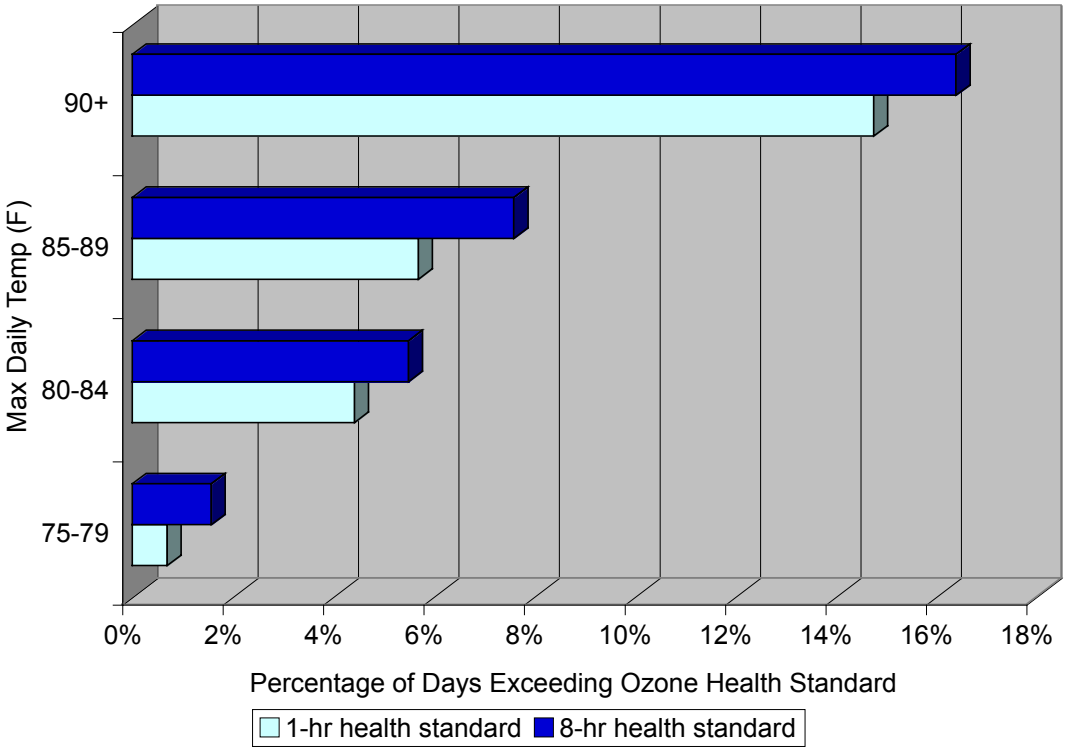
Figure 9: San Bernardino: Exceedances of Ozone Health Standards, 1997-2006



San Diego

The greatest likelihood that air quality in San Diego exceeded state health standards occurred when the daily high was at least 90°F. On those days, ozone levels exceeded the 8-hr health standard 16 percent of the time, and the 1-hr health standard 15 percent of the time. When the daily high was between 85 and 89°F, ozone levels exceeded the 8-hr and 1-hr health standards 8 and 6 percent of the time, respectively. Ozone levels exceeded the 8-hr health standard 6 percent of the days in which the daily high was between 80 and 84°F. Ozone levels exceeded the 1-hr health standard 4 percent of those days.

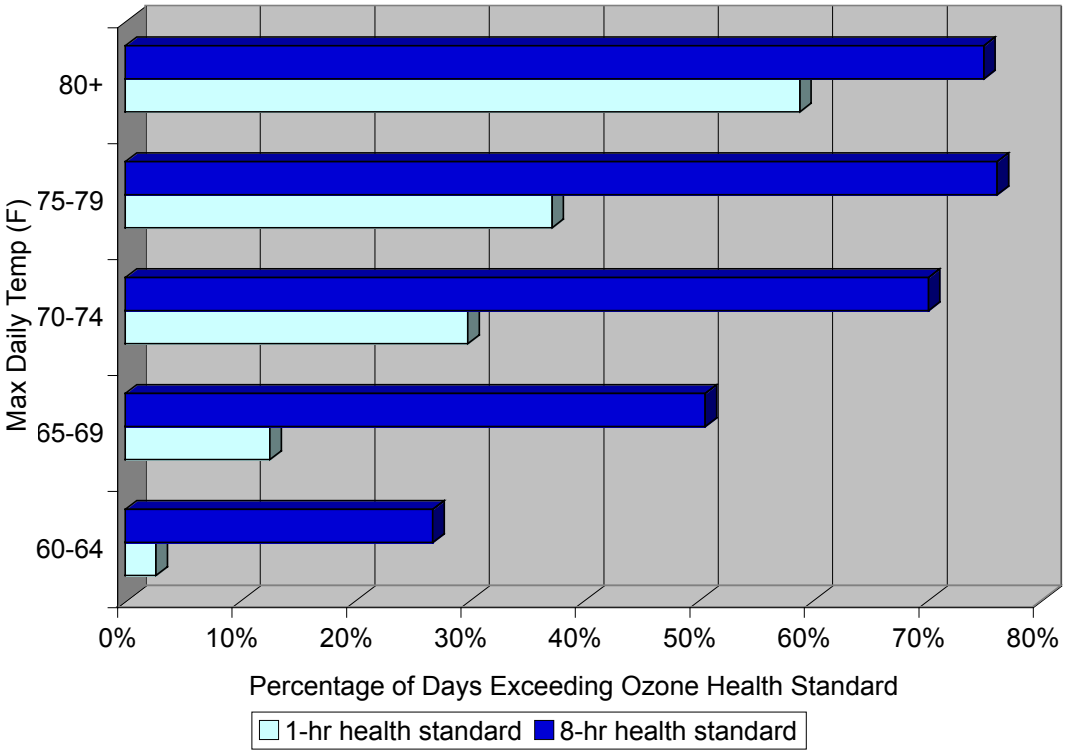
Figure 10: San Diego: Exceedances of Ozone Health Standards, 1997-2006



Sequoia National Park

When the daily high was at least 80°F, ozone levels in Sequoia National Park exceeded the 8-hr health standard 75 percent of the time – nearly as much as when the daily high was in the upper 70's – and the 1-hr health standard 59 percent of the time. When the daily high was between 75 and 79°F, ozone levels exceeded the 8-hr and 1-hr health standards 76 and 37 percent of the time, respectively. Ozone levels exceeded the 8-hr health standard 70 percent of the days in which the daily high was between 70 and 74°F. Ozone levels exceeded the 1-hr health standard 30 percent of those days.

Figure 11: Sequoia National Park: Exceedances of Ozone Health Standards, 1997-2006



Global Warming Forecasts More Hot Weather

In February 2007, the Intergovernmental Panel on Climate Change (IPCC), a United Nations body charged with assessing the scientific record on global warming, found that evidence of global warming is "unequivocal" and concluded, with more than 90 percent certainty, that human activities are responsible for most of the observed increase in global average temperatures since the mid-20th century.[15]

According to the IPCC, global average surface temperatures increased by more than 1.4°F since the second half of the 19th century.[16] Since 1975, temperatures have been increasing at a faster rate of about 0.36°F per decade.[17] And in the United States, the past nine years have all been among the 25 warmest on record, an unprecedented streak since records began in 1895.[18]

In the summer of 2006 California experienced a heat wave that rocked the state, setting numerous temperature records. For example, Fresno experienced its warmest July on record, averaging 87.8°F; Stockton recorded its highest temperature ever of 115°F on July 23; and Woodland Hills set a record for 21 days in July over 100°F and also recorded its highest temperature ever of 119°F on July 22.[19] Although no single weather event can be attributed to global

warming, rising global temperatures increase the likelihood that heat waves—like the one California experienced in July 2006—will occur.

With worldwide emissions of global warming pollution increasing each year, temperatures will continue to rise in coming decades. However, the extent to which temperature increases in California will be determined by how quickly and significantly global warming emissions are reduced through a transition to clean, non-fossil fuel technologies and a more efficient use of energy.

Through a study commissioned by the State of California, researchers adapted three separate climate models to determine the range of possible temperatures in California by the end of the 21st century. Using three different scenarios of possible global warming emissions pathways for the rest of the 21st century, researchers predict temperature increases in 2100 from 3.0° to 5.4°F – under a "low warming" scenario – to 8° to 10.4°F – under a "high warming" scenario.[20] Virtually all simulations demonstrate greater warming in the summer than in the winter, which would further increase the occurrence and severity of summer heat waves.[21]

Impact of Hot Weather on Ozone Formation

Scientists predict that higher temperatures in California will result in increased ozone pollution. It has long been known that higher temperatures increase rates of chemical reactions in the air that drive ozone formation. Furthermore, studies predict that a doubling of carbon dioxide levels in the atmosphere would result in a doubling of natural (biogenic) VOC emissions.[22] Along with increases in man-made (anthropogenic) emissions worldwide, "background" ozone levels by 2100 could increase by 0.04 ppm to 0.1 ppm with lower warming or by as much as 0.2 ppm with severe warming.[23]

Global warming may impact ozone formation in other ways as well. For example, the California Air Resources Board (ARB) estimates that if temperatures rise between 5.5° and 8°F by 2100, summertime VOC emissions from cars and trucks will likely increase by 13 percent, while NOx emissions may decrease slightly as a result of warmer early morning weather.[24] On the other hand, NOx emissions from power plants increase on hot summer days as a result of increased air conditioner use in the summertime; consequently, the ARB estimates a 3 percent increase in NOx emissions for every degree increase in temperature.[25]

As a result of these considerations, the prediction is for more ozone pollution as a result of global warming. University of California researchers estimate that by the end of the century the number of days conducive to ozone formation could increase 75 to 85 percent in Los Angeles and the San Joaquin Valley under a "medium warming" scenario. With less warming, ozone days are predicted to increase only 25 to 35 percent in those locations.[26]

Of course, ozone is the result of more than just meteorology. With stricter emissions standards new technologies, denser development, and improved transit, California can protect public health by reducing emissions of pollutants that lead to ozone formation.

Conclusion and Recommendations

Given California's existing air pollution problems and the expectation that global warming will make matters worse, state policy-makers and environmental agencies should work to significantly reduce ozone-forming pollutants while simultaneously reducing global warming emissions to levels that scientists have concluded are necessary to prevent a dramatic increase in temperature.

To reduce smog pollution state policy-makers and agencies should prioritize policies to significantly cut emissions of ozone-forming pollutants in California, including measures outlined in California's State Implementation Plan for federal ambient air quality standards. Measures to prioritize include:

- **Passenger vehicles** – Increase the sale and use of zero-emission and low-polluting passenger cars and light-duty trucks, accelerate vehicle retirement, and strengthen the state smog check program;

- **Trucks and off-road equipment** – Reduce emissions from medium- and heavy-duty diesel trucks and off-road equipment by strengthening emissions standards, increasing retrofits, and accelerating replacement with cleaner technologies;

- **Ports & goods movement** – Require cleaner marine engines and fuels, increase the number of ships with the ability to use shore-side power ("cold ironing"), increase retrofits, and accelerate the introduction of cleaner port trucks, harbor craft and locomotives;

- **Agriculture** – Accelerate the replacement of agricultural equipment through regulation and incentives; and

- **Strong enforcement of existing pollution control rules** – Enforce tough standards for cleaner construction equipment, airport ground support, and other off-road vehicles.

To reduce global warming emissions state policy-makers and agencies should prioritize successful implementation of the Global Warming Solutions Act of 2006 (Assembly Bill 32), which commits California to reducing global warming emissions to 1990 levels by 2020.

Appendix: Data Tables for Eight California Cities, 1997-2006

Bakersfield

Temperature (°F)	Avg. daily max. 1-hr ozone (ppm)	Percent of days exceeding 1-hr ozone standard	Avg. daily max. 8-hr ozone (ppm)	Percent of days exceeding 8-hr ozone standard
100+	0.096	58.37%	0.086	90.91%
95-99	0.087	28.06%	0.079	77.27%
90-94	0.084	20.88%	0.076	66.79%
85-89	0.077	8.32%	0.069	44.13%
80-84	0.069	2.63%	0.061	19.92%
75-79	0.062	1.02%	0.053	6.80%

Burbank

Temperature (°F)	Avg. daily max. 1-hr ozone (ppm)	Percent of days exceeding 1-hr ozone standard	Avg. daily max. 8-hr ozone (ppm)	Percent of days exceeding 8-hr ozone standard
100+	0.094	41.11%	0.068	42.22%
95-99	0.080	25.37%	0.060	31.34%
90-94	0.075	19.18%	0.057	22.26%
85-89	0.067	10.61%	0.050	16.22%
80-84	0.057	2.65%	0.044	7.76%
75-79	0.049	0.40%	0.038	1.41%

Folsom

Temperature (°F)	Avg. daily max. 1-hr ozone (ppm)	Percent of days exceeding 1-hr ozone standard	Avg. daily max. 8-hr ozone (ppm)	Percent of days exceeding 8-hr ozone standard
100+	0.100	58.37%	0.084	83.26%
95-99	0.082	21.05%	0.070	50.88%
90-94	0.077	13.14%	0.066	32.63%
85-89	0.069	3.92%	0.058	13.17%
80-84	0.059	0.00%	0.050	1.74%
75-79	0.054	0.00%	0.046	0.35%

Fresno

Temperature (°F)	Avg. daily max. 1-hr ozone (ppm)	Percent of days exceeding 1-hr ozone standard	Avg. daily max. 8-hr ozone (ppm)	Percent of days exceeding 8-hr ozone standard
100+	0.108	74.67%	0.091	83.92%
95-99	0.092	42.51%	0.080	76.20%
90-94	0.080	17.68%	0.070	47.23%
85-89	0.072	3.42%	0.063	21.37%
80-84	0.069	1.34%	0.058	9.73%
75-79	0.060	0.00%	0.050	2.07%

Riverside

Temperature (°F)	Avg. daily max. 1-hr ozone (ppm)	Percent of days exceeding 1-hr ozone standard	Avg. daily max. 8-hr ozone (ppm)	Percent of days exceeding 8-hr ozone standard
100+	0.107	68.75%	0.087	79.17%
95-99	0.095	47.27%	0.077	61.82%
90-94	0.086	33.80%	0.072	53.63%
85-89	0.073	14.80%	0.061	29.61%
80-84	0.061	5.22%	0.049	14.20%
75-79	0.053	0.56%	0.042	2.80%

San Bernardino

Temperature (°F)	Avg. daily max. 1-hr ozone (ppm)	Percent of days exceeding 1-hr ozone standard	Avg. daily max. 8-hr ozone (ppm)	Percent of days exceeding 8-hr ozone standard
100+	0.109	66.67%	0.087	75.33%
95-99	0.095	46.35%	0.076	55.06%
90-94	0.086	34.01%	0.069	43.15%
85-89	0.074	13.47%	0.058	25.15%
80-84	0.061	7.60%	0.048	13.68%
75-79	0.050	1.31%	0.039	4.18%

San Diego

Temperature (°F)	Avg. daily max. 1-hr ozone (ppm)	Percent of days exceeding 1-hr ozone standard	Avg. daily max. 8-hr ozone (ppm)	Percent of days exceeding 8-hr ozone standard
90+	0.070	14.75%	0.054	16.39%
85-89	0.064	5.70%	0.050	7.59%
80-84	0.057	4.42%	0.045	5.50%
75-79	0.052	0.69%	0.042	1.57%

Sequoia National Park

Temperature (°F)	Avg. daily max. 1-hr ozone (ppm)	Percent of days exceeding 1-hr ozone standard	Avg. daily max. 8-hr ozone (ppm)	Percent of days exceeding 8-hr ozone standard
80+	0.095	58.93%	0.082	75.00%
75-79	0.090	37.29%	0.080	76.17%
70-74	0.085	29.93%	0.076	70.17%
65-69	0.079	12.63%	0.070	50.66%
60-64	0.067	2.68%	0.060	26.87%

Notes

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