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# Review of the California Ambient Air Quality Standard For Ozone

Volume I

*Public Review Draft  
June 21, 2004*

***California Environmental Protection Agency***

**Air Resources Board  
and  
Office of Environmental Health and Hazard Assessment**

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<http://www.arb.ca.gov/research/aaqs/ozone-rs/ozone-draft-rpt.htm>

More information regarding the review of the California ambient air quality standard for ozone can be found at the ARB internet site at:

<http://www.arb.ca.gov/research/aaqs/ozone-rs/ozone-rs.htm>

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## Abbreviations

AQDA	Air Quality Data Action
AOT40	an ozone exposure metric defined as the accumulated exposure to O <sub>3</sub> over the threshold of 40 ppb
AVG	aminoethoxyvinyl glycine
BSA	Broader Sacramento Area
ARB	Air Resources Board
CEC	controlled environment chamber
CFR	Code of Federal Regulations
d	day
ESPACE	European Stress Physiology and Climate Experiment
FACE	Free Air Carbon Enrichment system, a chamber-free, open-air fumigation design
FEM	federal equivalent method
FRM	federal reference method
g	gram
GBVAB	Great Basin Valleys Air Basin
gdw	gram dry weight
GIS	geographic information system
gfw	gram fresh weight
hr	hour
ha	hectare (= 10,000 m <sup>2</sup> ; an area that is 100 m x 100 m)
hm	hourly mean
H&SC	Health and Safety Code
IPM	Integrated Pest Management.
k	allometric growth coefficient describing the distribution of dry weight gain between competing plant parts, defined as the ratio of the Relative Growth Rates of the competing plant parts
kg	kilogram (= 1,000 g = 2.205 lbs)
km	kilometer (= 1,000 m = 0.62 miles)
L	liter
LCAB	Lake County Air Basin
LST	local standard time

LTAB	Lake Tahoe Air Basin
m	meter (= 3.28 feet)
m <sup>2</sup>	square meter, an area that is 1 m x 1 m
MDAB	Mojave Desert Air Basin
MCAB	Mountain Counties Air Basin
mRNA	messenger RNA (ribonucleic acid)
n	sample size
NARSTO	a public/private partnership to coordinate research on tropospheric pollution, (formerly the North American Research Strategy for Tropospheric Ozone)
NCAB	North Coast Air Basin
NCCAB	North Central Coast Air Basin
NCLAN	National Crop Loss Assessment Network, a national study of O <sub>3</sub> impacts on crops, undertaken during the 1980s
NEPAB	Northeast Plateau Air Basin
nL	nanoliter (10 <sup>-9</sup> L).
nm	nanometer, or one billionth of a meter
ppm	parts per million
ns	not statistically significant at P = . 05.
OII	Ozone Injury Index
OTC	open top field exposure chamber
PAR	photosynthetically active radiation (400 – 700 nm)
ppb	parts per billion by volume
ppb-hr	parts per billion hours (i.e., sum of concentration times duration), a measure of exposure to O <sub>3</sub>
ppm-hr	parts per million hours (i.e., sum of concentration times duration), a measure of exposure to O <sub>3</sub>
QAS	Quality Assurance Section
R:S	ratio of root biomass (dry weight) to shoot biomass
RGR	relative growth rate, defined as the difference in the dry weight of a plant or plant part over a time period, divided by the initial dry weight and the length of the time period
RH	relative humidity
RuBisCO	ribulose biphosphate carboxylase-oxygenase
RuBP	ribulose biphosphate

SCCAB	South Central Coast AIR Basin
SCOIAS	Sierra Cooperative Ozone Impact Assessment Study
SDAB	San Diego Air Basin
SFBAAB	San Francisco Bay Area Air Basin
SIP	State Implementation Plan
SJVAB	San Joaquin Valley Air Basin
SoCAB	South Coast Air Basin
SSAB	Salton Sea Air Basin
SUM06	an ozone exposure metric involving concentration weighting, defined as the sum of all hourly mean ozone concentrations equal to or greater than 70 ppb
TREEGRO	a physiologically based computer simulation model of tree growth and development
UN-ECE	United Nations Economic Commission for Europe
USD	United States dollars
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USEPA	United States Environmental Protection Agency
USV	Upper Sacramento Valley
$V_d$	deposition velocity, defined as deposition flux of (e.g.,) $O_3$ divided by its concentration in air (usually in cm/s or m/s)
VPD	vapor pressure deficit, a measure of evaporative demand of air
wk	week
yr	year
ZAP	zonal application system, a chamber-free, open-air exposure system
$\mu\text{g}$	microgram

## Definitions

Abscission	the normal separation, involving a layer of specialized cells, of flowers, fruits and leaves of plants
AOT40	accumulated exposure over threshold of 40 ppb ozone
$\text{Ca}^{2+}$	calcium ion
Canopy	a cover of foliage that forms when the leaves on the branches trees in a forest overlap during the growing season

CO <sub>2</sub>	carbon dioxide
Edaphic	the physical, chemical, and biological characteristics of soil
Fine roots	roots with a diameter between 0.5 to 3 mm
Foliar	of or referring to a plant leaf
Full-sib	seedlings that have the same parents, but not necessarily from seed produced in the same year
Half-sib	seedlings that have one parent in common
HNO <sub>3</sub>	nitric acid
Homeostasis	the tendency toward maintaining physiological stability within an organism (plant or animal)
Jeffrey pine	<i>Pinus jeffreyi</i> Grev. and Balf.
K <sup>+</sup>	potassium ion
Mesophyll Cells	the internal cells of a leaf, distinct from cells at the leaf surface or from cell layers immediately adjacent to the leaf surface
Mixed conifer	forests with a tree-layer dominated by a mixture of conifer species
Montane	of or relating to a mountain or mountainous area
Mycorrhizae	a biological association of a fungus (e.g., <i>Pisolithus tinctorius</i> ) with the root cells of a plant (e.g., ponderosa pine tree)
Mycorrhizal Trees	trees with roots associated a mycorrhizae fungus
ng	nanogram (= 0.000000001 g = 10 <sup>-9</sup> g)
NH <sub>4</sub> NO <sub>3</sub>	ammonium nitrate
NO	nitric oxide (mol wt. = 30); the primary N-containing by-product of combustion
NO <sub>2</sub>	nitrogen dioxide
NO <sub>x</sub>	nitrogen oxides (or oxides of nitrogen)
O <sub>3</sub>	ozone (mol. wt. = 48)
Phloem	the plant tissue through which sugars and other organic materials are transferred to different parts of the plant
Sieve Cells	the primary type of cell found in the phloem of plants
Photosynthesis	the production by green plants of organic compounds from water and carbon dioxide using energy absorbed from sunlight

<i>Pisolithus tinctorius</i>	a mycorrhizae-forming fungus that forms root-associations with a wide variety of pine and other tree species
Process Rates	the degree or amount at which specific actions or activities occur (e.g., water vapor loss from leaves of plants)
Senescence	the onset of aging -- a phase in plant development from maturity to the complete loss of organization and function in plants
Shoot	the aboveground portion of the plant (e.g., leaves, stems, flowers, and fruits)
Sucrose	a disaccharide (with 12 carbon atoms) commonly found in plants
(Sucrose) Translocation	the movement of sucrose (or other soluble organic food materials) through plant tissues – most commonly from leaves to stems/roots
Terrain-effect winds	air currents influenced by the geographic features of the land that it passes over
<i>Ulmus americana</i>	the scientific name for “American Elm”
Whorl	the arrangement of leaves, petals, etc., at about the same place on a stem

# 1 Executive Summary

The staff of the Air Resources Board (ARB) and Office of Environmental Health Hazard Assessment (OEHHA) have reviewed the scientific basis for the California Ambient Air Quality Standard for ozone to determine its adequacy to protect public health, including the health of infants and children. Staff has reviewed the scientific literature on public exposure, atmospheric chemistry, welfare effects, and health effects of exposure to ozone. This staff report presents the results of the staff review and the staff recommendations to revise the standard in order to adequately protect public health.

This review is a requirement of California Health & Safety Code section 39606. In December 2000, as a requirement of the Children's Environmental Health Protection Act (Senate Bill 25, authored by Senator Martha Escutia, Stats. 1999, Ch. 731), the California Air Resources Board (ARB or Board), approved a report (ARB and OEHHA, 2000) that contained a preliminary review of all of the existing health-based California ambient air quality standards. The purpose for that review was: (1) to determine whether, based on public health, scientific literature, and exposure pattern data, the existing ambient air quality standards adequately protected the health of the public, including infants and children, with an adequate margin of safety [California Health & Safety Code section 39606(d)(1)]; and (2) to prioritize for full review any standards which might not adequately protect public health.

These reviews were not exhaustive, but rather were narrowly targeted to the two purposes noted above. The critical reviews suggested that adverse health effects might occur in infants, children, and other potentially susceptible subgroups exposed to pollutants at or near levels corresponding to several existing California ambient air quality standards. Staff recommended, the Air Quality Advisory Committee (AQAC) agreed, and the Board concurred, that among the standards deemed possibly inadequate, the standard for ozone should be the second to undergo full review, following those for particulate matter and sulfates. The ARB and OEHHA staff have now completed an exhaustive review of the scientific literature on the health effects of ozone.

In this report, the staff of the ARB and OEHHA present the findings of their full review of the public health, scientific literature, and exposure pattern data for ozone in California. Due to the extensive nature of the literature review and the hundreds of studies reviewed, the staff report is divided into two volumes. Volume I contains information on chemistry of ozone formation, ozone precursor sources and emissions, ozone exposure and background levels, measurement methods, and welfare effects of ozone exposure. A summary of ozone health effects and the staff recommendation is also included in Volume I. The health effects literature review is contained in Chapter 11, Health Effects of Ozone Exposure, and Chapter 12, Epidemiological Studies, in Volume II of the staff report.

The staff review found the following information. In controlled human exposure studies, exercising individuals exposed for 1 hour (hr) to an ozone concentration of 0.12 parts per million (ppm) or for 6.6 hr to a concentration of 0.08 ppm experienced lung function decrements and symptoms of respiratory irritation such as cough, wheeze, and pain upon deep inspiration. The lowest O<sub>3</sub> concentrations at which airway hyperreactivity (an increase in the tendency of the airways to constrict in reaction to exposure to irritants) has been reported are 0.18 ppm O<sub>3</sub> following 2-hr exposure in exercising subjects, 0.40 ppm following 2-hr exposure in resting subjects, and 0.08 ppm O<sub>3</sub> in subjects exercising for 6.6 hr. Airway inflammation has been reported following 2-hr exposures to 0.20 ppm O<sub>3</sub> and following 6.6-hr exposure to 0.08 ppm O<sub>3</sub>. Additional support for the exposure/response relationship for ozone health effects is derived from animal toxicological studies, which have shown that chronic ozone exposure can induce morphological (tissue) changes throughout the respiratory tract, particularly at the junction of the conducting airways and the gas exchange zone in the deep lung.

Epidemiological studies have shown positive associations between ozone levels and several health effects including decreased lung function, respiratory symptoms, and emergency room visits for asthma. Children may be more susceptible to the effects of ozone than the general population due to effects on the developing lung and to relatively higher exposure than adults. Also, asthmatics may represent a sensitive sub-population for ozone. Since most California residents are exposed to levels at or above the current State ozone standard during some parts of the year, the statewide potential for significant health impacts associated with ozone exposure is large and wide-ranging.

## **1.1 Staff Recommendations for the Ozone Standard**

Based on the results of the staff review and their findings, staff is recommending that the California ambient air quality standard for ozone be revised. California Ambient Air Quality Standards have four elements (California Health and Safety Code Section 39014, and Title 17, California Code of Regulations, Article 2, Section 70101): (1) definition of the air pollutant, (2) an averaging time, (3) a pollutant concentration, and (4) a monitoring method to determine attainment of the standard. Staff recommends the following revision be made to the California ambient air quality standard for ozone:

1. Retain ozone as the indicator for oxidant air pollution.
2. Ozone 1-hour-average Standard – Retain the 1-hour-average standard for ozone at **0.09 ppm**.
3. Ozone 8-hour-average Standard – Establish an 8-hour-average standard for ozone at **0.070 ppm**.
4. For both the 1-hour and 8-hour ozone standards, the concentrations for the standards noted above are established as “**not to be exceeded**”.
5. Ozone Monitoring Method – retain the current monitoring method for ozone which uses the ultraviolet (UV) absorption method for determining compliance with the state Ambient Air Quality Standard for ozone. Incorporate all

federally approved UV methods (listed at <http://www.epa.gov/ttn/amtic/criteria.html>) as California Approved Samplers for ozone. This will result in no change in air monitoring practices, but will align state monitoring requirements with federal requirements.

## **1.2 Other Recommendations:**

In light of the adverse health effects observed at current ambient concentrations and the lack of a demonstrated threshold, staff makes the following comments:

1. In any air basin in California that currently attains the ambient air quality standards for ozone, the air quality should not be degraded from present levels.
2. Fund additional research investigating the responses of human subjects to multi-hour exposures to O<sub>3</sub> concentrations between 0.04 and 0.08 ppm.
3. The standards be revisited within five years, in order to re-evaluate the evidence regarding the health effects associated with O<sub>3</sub> exposure.

## **1.3 Environmental and Economic Impacts:**

The proposed ambient air quality standards will in and of themselves have no environmental or economic impacts. Standards simply define clean air. Once adopted, local air pollution control or air quality management districts are responsible for the adoption of rules and regulations to control emissions from stationary sources to assure their achievement and maintenance. The Board is responsible for adoption of emission standards for mobile sources. A number of different implementation measures are possible, and each could have its own environmental or economic impact. These impacts must be evaluated when the control measure is proposed. Any environmental or economic impacts associated with the imposition of future measures will be considered if and when specific measures are proposed.

## **1.4 Environmental Justice Concerns:**

State law defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. Ambient air quality standards define clean air, therefore, all of California's communities will benefit from the proposed health-based standards.

## **1.5 Comment Period and Board Hearing:**

The staff recommendations in this Staff Report will be presented for review and comment at public workshops on July 14, in Sacramento, July 15, in El Monte, and July 16 in Fresno.

Staff findings and recommendations will be peer-reviewed by the Air Quality Advisory Committee (AQAC). AQAC will hold a public meeting to discuss their review this staff report. Details on the workshop and AQAC meeting may be obtained from the ARB website: [www.arb.ca.gov/research/aqs/ozone-rs/ozone-rs.htm](http://www.arb.ca.gov/research/aqs/ozone-rs/ozone-rs.htm) or by calling 916-445-0753.

Written comments on this Staff Report and the staff recommendations for revising the standard may be addressed to Dr. Deborah Drechsler, Ph.D. at the Air Resources Board, Research Division, P.O. Box 2815, Sacramento, CA 95612-2815 (ddrechsl@arb.ca.gov, 916-323-1526, 916-322-4357 FAX). Comments received by *August 2, 2004*, will be forwarded to the Air Quality Advisory Committee for consideration at their meeting.

Following the meeting of the Air Quality Advisory Committee (AQAC), staff will revise this Staff Report based on comments received from AQAC members and the public. The revised Staff Report will then be made available for a 45-day public comment period in advance of a public meeting of the Air Resources Board to consider the staff's final recommendations. The Board meeting is tentatively scheduled for December, 2004.

## **1.6 Reference**

Air Resources Board and Office of Environmental Health Hazard Assessment (2000). Adequacy of California Ambient Air Quality Standards: Children's Environmental Health Protection Act. Staff Report. Sacramento, CA. Available at <http://www.arb.ca.gov/ch/programs/sb25/airstandards.htm>.