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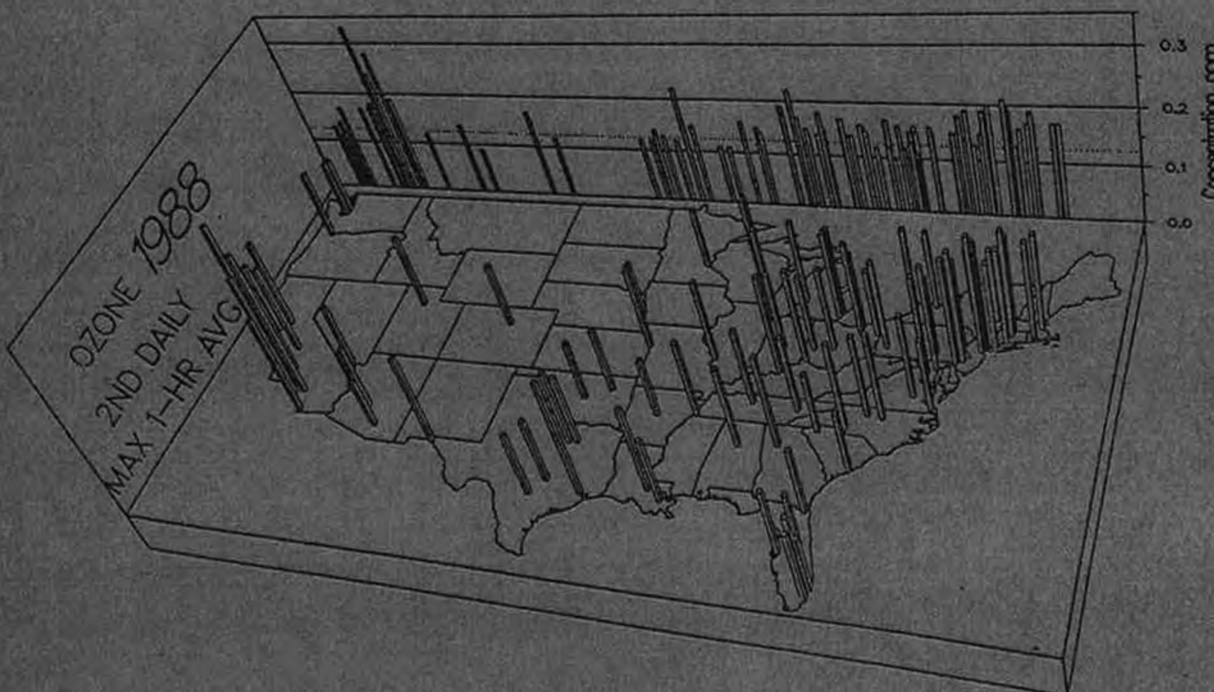
REVIEW OF THE NATIONAL AMBIENT AIR QUALITY STANDARDS FOR OZONE
ASSESSMENT OF SCIENTIFIC AND TECHNICAL INFORMATION

OAQPS STAFF PAPER



The cover illustration is an air quality map of the U.S. which displays the highest second daily maximum 1-hour average ozone concentration by metropolitan statistical area (MSA) for 1988. (National Air Quality and Emission Trends Report, 1988, EPA-450/4-001)

Preface

This document was finalized in June 1989 and reviews information from relevant studies of O_3 health and welfare effects and of exposure and risk analysis through early 1989. The assessment contained in this staff paper reflects information in the documents "Air Quality Criteria for Ozone and Other Photochemical Oxidants" (EPA-600/8-84-020F) and "Summary of Selected New Information on Effects of Ozone on Health and Vegetation: Supplement to Air Quality Criteria for Ozone and Other Photochemical Oxidants" (EPA-600/8-88/1-5a).

Acknowledgements

This staff paper is the product of the Office of Air Quality Planning and Standards (OAQPS). Tables and Figures not otherwise cited are original to this report. The principal authors include Dr. David J. McKee, Ms. Pamela M. Johnson, Mr. Thomas R. McCurdy, and Mr. Harvey M. Richmond. This report has been improved by comments from other staff within OAQPS, the Office of Research and Development, the Office of Policy and Program Evaluation, and the Office of General Counsel within EPA. Three drafts were formally reviewed by the Clean Air Scientific Advisory Committee and comments incorporated. Particularly important in the final review of this staff paper was the technical and editorial support provided by Ms. Victoria Atwell and the clerical and editorial support of Mrs. Patricia R. Crabtree and Mrs. Barbara Miles.

Helpful comments and suggestions were also submitted by a number of independent scientists, by officials from the State environmental agencies of Illinois, Minnesota, California and Texas, by the Department of the Navy, and the Department of Energy, and by environmental and industrial groups including the Natural Resources Defense Council, the American Lung Association, the Chemical Manufacturers Association, the American Petroleum Institute, and the Motor Vehicle Manufacturers Association.

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Executive Summary

This revised staff paper evaluates and interprets the available scientific and technical information that the EPA staff believe is most relevant to the review of primary (health) and secondary (welfare) national ambient air quality standards (NAAQS) for ozone (O_3) and presents staff recommendations on alternative approaches to revising the standards. Periodic review of the NAAQS is a process instituted to ensure the scientific adequacy of air quality standards and is required by section 109 of the 1977 Clean Air Act Amendments. The assessment in this staff paper is intended to help build a bridge between the scientific review contained in the EPA O_3 criteria document (hereafter referred to as CD) (U.S. EPA, 1986), and the CD Supplement (hereafter referred to as CDS) (U.S. EPA, 1988) prepared by the Environmental Criteria and Assessment Office (ECAO) and the judgments required of the Administrator in setting ambient standards for O_3. Therefore, the staff paper is an important element in the standards review process and provides an opportunity for review by the Clean Air Scientific Advisory Committee (CASAC) and the general public on proposed staff recommendations before they are presented to the Administrator. This staff paper has been revised based upon comments received from CASAC and the public and upon staff analyses which are available for public review.

Ozone is a trace constituent formed in the atmosphere as a result of a series of complex chemical reactions involving both anthropogenic and natural hydrocarbons and nitrogen oxides, oxygen and sunlight. At ambient concentrations often measured during warmer months, O_3 can adversely affect human health, agricultural crops, forests, ecosystems, and materials. Interactions of O_3 with nitrogen oxides and sulfur oxides may also contribute to the formation of acidic vapors and aerosols which might have direct effects on human health and welfare, as well as indirect effects following their deposition on surfaces. It should be noted that new evidence indicates that co-exposure to acidic aerosols can potentiate response to O_3.

Annual average background surface O_3 concentrations in the northern hemisphere generally range between 0.03 and 0.05 ppm but are as low as 0.015 to 0.020 ppm in the tropics (U.S. EPA, 1986, p. 3-80). Stratospheric intrusion is recognized as causing locally high O_3 levels for periods lasting from minutes to hours, but these intrusions are usually worse in spring, fall, and winter. In contrast, during the photochemically active summer months intrusion is less common and less severe. Summertime hourly O_3 levels have recently been reported to be as high as 0.35 ppm in one of the nation's most heavily populated metropolitan areas. Daily daylight seasonal averages of O_3 in some rural areas have been reported to be 0.06 ppm and higher.

Primary Standard

The staff reviewed scientific and technical information on the known and potential health effects of O_3 cited in the CD and the CDS. The information includes studies of respiratory tract absorption and deposition of O_3, studies of mechanisms of O_3 toxicity, and controlled human exposure, field, epidemiological and animal toxicology studies of effects of exposure to O_3 as well as air quality information. On the basis of this review, the staff derives the following conclusions.

1) Inhaled O_3 may pose health risks as a result of (a) penetration of O_3 into various regions of the respiratory tract and absorption of O_3 in this tract (b) provocation of pulmonary response resulting from chemical interactions of O_3 along the respiratory tract, and (c) extrapulmonary effects caused indirectly by reaction of O_3 in the lungs.

2) The risks of adverse effects associated with absorption of O_3 in the tracheobronchial and alveolar regions of the respiratory tract are much greater than for absorption in the extrathoracic region (head). Increased exercise levels are generally associated with higher ventilation rates and increased oronasal or oral (mouth) breathing. Greater O_3 penetration and exposure of sensitive lung tissue occurs when individuals are heavily exercising.

3) Factors which have been demonstrated to affect susceptibility to O_3 exposure are activity level and environmental stress (e.g., humidity, high temperature). Those factors which either have not been adequately tested or remain uncertain include age, sex, preexisting disease, nutrition, and smoking status.

4) Major subgroups of the population that may be at greater risk to the effects of O_3 include: (a) any individual exercising heavily during exposure to O_3, particularly those who are otherwise healthy individuals who may experience significantly greater than group mean lung function response to O_3 exposure, and (b) individuals with preexisting respiratory disease (e.g., asthmatics and persons with allergies). The data base identifying exercising individuals as being at greater risk to O_3 exposure is much stronger and more quantitative than that for individuals with preexisting respiratory disease. This is due to the large number of clinical studies investigating effects of O_3 on exercising persons.

5) The major effects categories of concern associated with exposures to O_3 include:
   (a) alterations in pulmonary function
   (b) symptomatic effects (e.g., cough, throat irritation)
   (c) effects on work or athletic performance

(d) aggravation of preexisting respiratory disease

(e) morphological effects (lung structure damage)

(f) altered host defense systems (e.g., increased susceptibility to respiratory infection)

(g) extrapulmonary effects (e.g., effects on blood enzymes, central nervous system, liver, endocrine system).

6) An important source of applicable exposure-response information for a short-term standard is controlled human exposure and field studies, which provide concentration-response relationships between alterations in pulmonary function and O_3 exposure concentrations. Other important sources of information for standard setting are epidemiological and toxicological studies. Epidemiology has provided associations between ambient O_3 exposures and lung function decrements and aggravation of existing respiratory disease, but with greater uncertainties about the exposures involved than with controlled human exposure and field studies. Animal toxicology data provide acute and chronic exposure effects information on increased susceptibility to respiratory infection, lung structure damage, and extrapulmonary effects. Although human exposure, epidemiology, and animal toxicology studies all have limitations in assessing adverse effects and risk, it is the weight of evidence

and integration of findings from all three disciplines which should be used in assessing health effects associated with exposure to O_3.

Based on scientific and technical reviews, CASAC comments, and policy considerations, the staff makes the following recommendations with respect to primary O_3 standards:

1) Ozone should remain as the surrogate for controlling ambient concentrations of photochemical oxidants.
2) The existing form of the standard should be retained (i.e., that the NAAQS is attained when the expected number of days per calendar year with maximum 1-hour average concentrations above the level of the standard is equal to or less than one).
3) The 1-hr averaging time of the standard should be retained.
4) The range of 1-hour average O_3 levels of concern for standard-setting purposes is 0.08 to 0.12 ppm in concordance with CASAC comments (CASAC, 1986, 1987, 1988) comments. This range is based solely on 1-2 hour exposure data.
5) Because there is a good health effects data base available on 1-2 hour exposures, the staff concurs with the CASAC conclusion (McClellan, 1989) that review of the scientific basis for the 1-hr O_3 primary standard be closed out. With this portion of the review complete, and after considering CASAC's views on all

issues, the Administrator will be in a position to make a regulatory decision on how and when to best act on the 1-hour standard.

6) In response to suggestions made by CASAC (1986, 1987, 1988), staff investigated the potential need and basis for a longer-term (6-8 hour) primary standard. Although an emerging data base reporting significant lung function decrements and symptoms in subjects exposed to O_3 for 6 to 8 hours has provided some evidence of effects below 0.12 ppm O_3, staff concurs with CASAC's conclusion that ". . . such information can better be considered in the next review of the ozone standards." (McClellan, 1989). It is recommended that EPA continue review of scientific information on health effects of prolonged exposure to O_3. Once these studies have been more completely evaluated during the next CD review, the Administrator will be able to assess the need for development of a longer-term O_3 primary standard.

7) Further review and analysis also will be necessary before fully assessing the need for a separate standard to protect against chronic effects of O_3. Data on nasopharyngeal removal, dosimetry modeling and health effects based on and chronic exposure of animals will be used for future animal extrapolation and risk assessment of chronic O_3 exposures.

Secondary Standard

The staff has reviewed the scientific and technical information on the known and potential welfare effects of O_3 cited in the CD and the CDS. This information includes impacts on vegetation, natural ecosystems, materials, and symptomatic effects on humans. Based on this review, the staff derives the following conclusions:

1) The mechanisms by which O_3 may injure plants and plant communities include (a) absorption of O_3 into leaf through stomata, followed by diffusion through the cell wall and membrane, (b) alteration of cell structure and function as well as critical plant processes, resulting from the chemical interaction of O_3 with cellular components, and (c) occurrence of secondary effects including reduced photosynthesis and growth and yield and altered carbon allocation.

2) The magnitude of the O_3-induced effects depends upon the physical and chemical environment of the plant, as well as on various biological factors (including genetic potential, developmental age of plant, and interaction with plant pests).

3) The weight of the recent evidence seems to suggest that long-term averages, such as the 7-hour seasonal mean, may not be adequate indicators for relating O_3 exposure and plant response.

4) Repeated peak concentrations are the most critical element in determining plant response. Exposure indicators which emphasize peak concentrations and accumulate concentrations over time probably provide the best biological basis for standard setting (See staff paper, p. X-50).

5) There is currently a lack of exposure-response information on forest tree effects. In addition, there is a broad range of uncertainty among scientists regarding O_3 effects on forest trees. Consequently there is no consensus on the most important averaging time for perennials or on the precise role of O_3 vs. other pollutants in causing forest decline. Therefore, the staff concludes that a separate secondary standard based on protection of forest trees is not warranted at this time.

6) There appears to be no threshold level below which materials damage will not occur; exposure of sensitive materials to any non-zero concentration of O_3 (including natural background levels) can produce effects if the exposure duration is sufficiently long. However, the slight acceleration of aging processes of

materials which occurs at the level of the NAAQS is not judged to be significant or adverse. Consequently, the staff concludes that materials data should not be used as a basis for adequately defining an averaging time or concentration level for the secondary standard and that the secondary standard should be based on protection of vegetation.

7) Effects on personal comfort and well-being, as defined by human symptomatic effects, have been observed in clinical studies at O_3 levels in the range of 0.12-0.16 for 1-2 hour exposures and at somewhat lower levels in extended exposure clinical and epidemiological studies. CASAC recommended that these effects be considered health effects in developing a basis for the primary standard for O_3.

Based on scientific and technical reviews, CASAC comments, and policy considerations, the staff makes the following recommendations with respect to secondary standards:

1) In consideration of the large base of welfare information attributing effects to O_3 exposure and the limited evidence which demonstrates welfare effects from exposure to ambient levels of non-O_3 photochemical oxidants, there appears to be little evidence to suggest a change in chemical designation from O_3 to photochemical oxidants.

2) Given the lack of effects data on forests and the preliminary nature of the Lee et al. (1988c) results regarding selection of the appropriate exposure statistic for crops, the EPA staff concludes that it may be premature at this point in time to change the form of the standard and the averaging time. It is our judgment that a 1-hr averaging time standard in the range of 0.06-0.12 ppm represents the best staff recommendation that could be made to the Administrator at this time to close out the review of the scientific data. This is consistent with CASAC comments (CASAC, 1987, 1988) urging EPA to consider a 1-hr averaging time and to act on the existing state of science rather than extend the review until a more exhaustive assessment is made of alternative averaging times. With this portion of the review complete, and after considering CASAC's views on all issues, the Administrator will be in a position to make a regulatory decision on how and when to best act on the 1-hr standard.

Alternatively, EPA could continue the standard review until the information on alternative exposure indicators has matured. Additional time for review and revision of Lee et al. (1988c) would allow the scientific community the opportunity to review the alternative indicators and move toward a consensus regarding selection of the most appropriate exposure indicator. The liability of this alternative is that it postpones action on the secondary standard and thus fails to utilize new and existing information to assess the most appropriate exposure statistic or the protection afforded by the current 1-hr standard.

X. Assessment of Welfare Effects and Related Welfare Issues Considered in Selecting Secondary Standard(s) for Ozone

Of the phytotoxic compounds commonly found in the ambient air, O_3 is the most prevalent, impairing crop production and injuring native vegetation and ecosystems more than any other air pollutant (Heck et al., 1980). Some of the effects of O_3 reported in the literature occur at O_3 levels at or below natural background concentrations in many areas of the country (see Section IV. for further discussion of background values). Ozone has also been shown to damage elastomers, textile fibers and dyes and certain types of paints. Other photochemical oxidants of importance to effects on vegetation, ecosystems and materials are nitrogen dioxide (NO_2) and peroxyacetyl nitrates. Air Quality Criteria for Oxides of Nitrogen (U.S. EPA, 1982) and Review of the NAAQS for NO_2: Assessment of Scientific and Technical Information (U.S. EPA, 1984) previously assessed the phytoxicity of NO_2, and thus NO_2 will not be discussed in this staff paper. In addition, while at a given dose the peroxyacetyl nitrates are more phytotoxic than O_3 (p. X-22), they generally occur at significantly lower ambient concentrations. Because phytotoxic concentrations of peroxyacetyl nitrates are less widely distributed than those of O_3 (CD, p. 6-1), the focus of this staff paper will be on the effects of O_3.

The objective of this section of the staff paper is to assess the current basis for the O_3 secondary NAAQS as contained in Chapters 6, 7 and 8 of the CD. In addition, the section will summarize new analyses that address key issues of concern for the secondary standard: relationships of various air quality indicators, crop loss estimates, averaging times and forest response to O_3. Key new studies that relate to the issue of averaging time(s) will also be discussed to determine whether new effects information suggests any change in existing secondary NAAQS for O_3.