Air Resources Board

State of California

Governor Arnold Schwarzenegger

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Review of the California Ambient Air Quality Standard For Nitrogen Dioxide

Staff Report

Initial Statement of Reasons for Proposed Rulemaking

January 5, 2007

California Environmental Protection Agency

Air Resources Board

California Environmental Protection Agency

Linda S. Adams, Secretary

Printed on Recycled Paper

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Air Resources Board

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California Ambient Air Quality Standard
For Nitrogen Dioxide

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Acknowledgements

In addition, staff also wish to thank and acknowledge the following individuals from the Air Resources Board: Sara Adams, Rebecca Boyer, Ken Bowers, Richard Corey, Robert Effa, Michael FitzGibbon, Peggy Jenkins, Karen Magliano, Steve Mara, Eileen McCauley, Mena Shah, Ken Stroud, William Vance, Tony VanCuren, and Bob Weller.

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Acronyms and Abbreviations

AAQS	Ambient Air Quality Standard
AM	Alveolar Macrophage
AQAC	Air Quality Advisory Committee
ARB	California Air Resources Board
Board	California Air Resources Board
CFR	Code of Federal Regulations
EPDC	Expected Peak Daily Concentration
FEV_1	Forced Expiratory Volume in One Second
HDL	High Density Lipoprotein
HNO_3	Nitric Acid
IgE	Immunoglobulin E
N	Nitrogen
NAAQS	National Ambient Air Quality Standard
Nitro-PAHs	Nitro-Polycyclic Aromatic Hydrocarbons
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_3^-	Nitrate
NO_X	Nitrogen Oxides (Nitric Oxide + Nitrogen Dioxide)
O_3	Ozone
OEHHA	Office of Environmental Health Hazard Assessment
PM	Particulate Matter
ppb	Parts per Billion
ppm	Parts per Million
U.S. EPA	United States Environmental Protection Agency
WHO	World Health Organization

1 Executive Summary

The California Health and Safety Code Section 39606 requires the Air Resources Board to adopt ambient air quality standards at levels that adequately protect the health of the public, including infants and children, with an adequate margin of safety. Ambient air quality standards are the legal definition of clean air. In December 2000, as a requirement of the Children's Environmental Health Protection Act (Senate Bill 25, Escutia, Statutes 1999, Health and Safety Code Section 39606 (d)(1)), the Air Resources Board (ARB or Board), approved a report, "Adequacy of California Ambient Air Quality Standards" (ARB and OEHHA, 2000) that contained a brief review of all of the existing health-based California ambient air quality standards.

Following this review, the standard for nitrogen dioxide (NO_2) was prioritized to undergo full review after review of the standards for particulate matter (including sulfates) and ozone. Staff from the ARB and the Office of Environmental Health Hazard Assessment (OEHHA) has reviewed the scientific literature on public exposure, atmospheric chemistry, health effects, and welfare effects of NO_2. This Staff Report: Initial Statement of Reasons (Staff Report) presents the findings of the review and the staff recommendations to revise the NO_2 standard in order to adequately protect public health. The proposed revisions to the ambient air quality standard for NO_2 are based on the ARB and OEHHA review contained in the Technical Support Document and the recommendation of OEHHA, as required by Health and Safety Code Section 39606(a)(2).

1.1 Summary of the Staff Findings/Initial Statement of Reasons

The complete findings of the review of the NO_2 standard are contained in the Technical Support Document. Based on the findings of that review, OEHHA submitted a recommendation to revise the NO_2 standard to adequately protect public health. This Staff Report summarizes the results of the staff review presented in the Technical Support Document. The Staff Report also describes the formal review process by both the public and a scientific peer-review panel, before submitting the final report and staff recommendations to the Board.

1.1.1 Summary of Non-Health Issues

The Staff Report contains information and discussions of non-health topics to provide a context for the health review and the staff recommendations for the State NO_2 standard.

1.1.1.1 Physics and Chemistry of Nitrogen Dioxide

NO_2 is a pungent gas that, along with fine airborne particulate matter, contributes to the reddish-brown haze characteristic of smoggy air in California. NO_2 is one of the nitrogen oxides (NO_X) that is emitted from high-temperature combustion processes, such as those from automobiles and power plants. NO_X is primarily composed of nitric oxide (NO) and NO_2. Home heaters and gas stoves used for cooking can also produce substantial amounts of NO_2 in indoor settings. The NO_2 in the atmosphere is derived both from direct combustion emissions and from emissions of NO followed by its subsequent chemical conversion to NO_2. Both NO and NO_2 are involved in a series of chemical reactions in the ambient air that produce additional pollutants such as ozone, nitrate aerosols, nitric acid, and other nitrogen-containing compounds that are known to be toxic.

1.1.1.2 Emissions

Since emissions of NO are generally higher than directly emitted levels of NO_2, and NO is converted to NO_2 by a series of photochemical reactions, most emissions are primarily measured as NO_X (primarily NO and NO_2). Emissions of NO_X vary regionally in California. For example, statewide mobile sources account for approximately 81% of total NO_X emissions. For most NO_X categories, higher emissions occur during the day than at night, and higher emissions occur on weekdays rather than on weekends. NO_X emissions from electric utility fuel combustion are higher in summer, while emissions from fuel combustion for space heating are higher in winter. As a whole, emissions of NO_X have been decreasing over the last two decades, and they are expected to have an overall decrease in the future.

Background NO_2 is defined as ambient NO_2 that results from uncontrollable processes. In general, background NO_2 levels result from natural emissions; long-range transport is small and unlikely to alter peak concentrations. It is believed that the most significant contributors to background NO_2 in California are from wildfires, lightning discharges, and soil emissions.

1.1.1.3 Indoor and Microenvironmental Exposures

Indoor NO_2 levels can exceed the current 1-hour NO_2 standard due to indoor sources such as gas stoves and unvented space heaters. There are also potential microenvironmental exposures to NO_2. For example, on the roadway where numerous diesel trucks and buses are driven, measurements of NO_2 emissions indicate that exposures can be near the current 1-hour NO_2 standard. Hence, proximity to these vehicular sources impacts exposure.

1.1.1.4 Concentrations Near Sources (Spatial Concentrations)

A number of investigators have reported on the concentrations of NO_2 in relation to its sources. For example, NO_2 concentrations and their relationship to the distance and location from freeways or roadways have been reported by a number of investigators (Singer et al. 2004, Roorda-Knape et al. 1998, Wu et al. 2005, Jerrett et al. 2005). In general, NO_2 typically decreased with downwind distance from freeways and the upwind concentrations were similar to regional levels. Ross et al. (2006) reported on the intra-urban distribution of NO_2 using a land use regression model. Traffic density within 300 m was the most important predictor of NO_2 concentrations, accounting for over 54% of the variation. Several investigators have reported that ambient concentrations of NO_2 vary greatly depending on location, with the greatest concentrations measured near freeways or roadways. Individuals spending significant time near major roadways or other large sources may be exposed to significantly higher concentrations of NO_2 and other pollutants, relative to concentrations measured at background monitors. For example, an analysis of roadside concentrations of NO_X and NO_2 was performed in London during 1997-2003 (Carslaw 2005). The author indicated that there has been a downward trend in NO_X, but a steady or increasing level of NO_2 resulting in an increase in the NO_2 to NO_X ratio. He noted that the increased use of diesel particulate filters fitted to diesel buses was likely an important contributing factor to this trend. As part of their design, diesel particulate filters may catalytically produce excess NO_2 when attempting to control PM. They therefore emit higher levels of NO_2 and have been used in London for a number of years. The author also noted that new light- and heavy-duty engine technologies and management approaches may also be contributing to this trend.

1.1.1.5 Ambient Air Quality and Attainment

NO_2 is monitored continuously at more than 100 sites in California. The data for each monitoring site are reported as 1-hour average concentrations. During the years 2002 through 2004, the State 1-hour standard was not exceeded in any of the air basins with the exception of one exceedance in the South Coast Air Basin in 2002. However, for designation attainment purposes, the value was considered and an extreme concentration event.

The monitoring method specified by Title 17, California Code of Regulations (CCR), Section 70200 is the chemiluminescence method based on the Federal Reference Method for the determination of NO_2 in the atmosphere (40 CFR, Part 50, Appendix F). California Approved Samplers for NO_2 are described in the “Air Monitoring Quality Assurance Manual, Volume IV, Part D: Monitoring Methods for NO_2.” As with monitoring for other criteria pollutants, the federal reference method (FRM) requires that monitors be located away from major sources such as power plants and highways so that more general population exposures be recorded.

1.1.1.6 Welfare Effects

With few exceptions, no visible injury to vegetation has been reported at concentrations below 0.20 ppm, and these occurred when the cumulative exposures extended to 100 hours or longer. The U.S. EPA concluded from studies with green beans as bio-indicators of NO_2 injury, that foliar injury symptoms were unlikely to occur on even the most susceptible plant species at concentrations of NO_2 prevalent even in the most polluted areas of the U.S.

With respect to critical loads of nitrogen deposition in California, relatively little is known of the effects of N deposition on terrestrial and aquatic ecosystems in the state due to its enormous diversity of vegetation and soil types, except for some intensively studied sites in southern California. In addition, these sites are exposed to multiple interacting abiotic and biotic stress factors, so isolating the adverse effects of specific rates of N deposition has not yet been possible. Thus, no specific recommendations for critical loads of total N can be made at this time. Based on results from southern California, it is suggested that at total N deposition rates of ca. 20 kg/ha/y or greater, some evidence in changes in soil chemistry and spring runoff may be detected.

For visibility effects, a decrease in the NO_2 concentrations could result in an increase in visibility in two ways. NO_2 contributes to reduction of visibility both directly, by selectively absorbing the shorter blue wavelengths of visible light, and indirectly by contributing to the formation of nitrate aerosols. Gaseous NO_2 turns air a reddish brown color, appearing as either a defined plume from an emission source or as a component of diffuse haze. The NO_2 and fine PM nitrate are two pollutants often found together, and are contributors to the hazy-brown sky conditions observed in the South Coast Air Basin, the San Joaquin Valley, and elsewhere. By lowering the NO_2 concentrations less than the current state standard of 0.25 ppm, would result in lowering fine airborne PM nitrate. A reduction in airborne fine PM nitrate would improve visibility.

1.1.2 Health Effects of NO_2

A number of investigators have reported relevant health effects from low-level exposure to NO_2 in sensitive human populations. Additional supportive evidence is derived from studies on animals.

1.1.2.1 Controlled Human Exposure Studies

Asthmatics appear to be especially sensitive to NO_2. Recent controlled human exposure studies with asthmatic volunteers have observed that NO_2 exposure increases allergen responsiveness, with effects observed with short-term (i.e., 15- or 30-minute duration) concentrations as low as 0.26 ppm. These studies found that exposures to NO_2 followed by inhaled allergen resulted in decrements in lung function, an increased inflammatory response, and/or evidence of activation of eosinophils compared with filtered air controls. In addition, there is evidence that for a subset of asthmatics, exposures to NO_2 at levels near the current ambient air quality standard (i.e., 0.2 to 0.3 ppm for 30 minutes to 2 hours) may cause increased airway reactivity. Finally, there are no clinical effects generally seen in non-asthmatic volunteers below 1 ppm NO_2.

1.1.2.2 Epidemiological Studies

The strongest epidemiological evidence of an effect of NO_2 is observed in the studies of respiratory disease, including studies measuring both short- (24 hours or less) and long-term (one or more years) exposures. The time-series studies of the association between NO_2 and both hospital admissions and emergency room visits for asthma are fairly consistent and robust. NO_2 concentrations (24-hour average) ranged from approximately 18 to 36 ppb). In addition, several panel studies of asthmatics showed an effect of NO_2 on symptoms, medication use, and lung function. Less robust evidence suggests associations with mortality, hospitalization for cardiovascular disease, and low birth weight. Some issues regarding these associations include: 1) determining the relevant exposure concentrations and averaging times, and 2) separating out confounding variables such as co-pollutants, seasonality, and weather. Despite these issues, a number of studies provide data supporting the need for a long-term average standard. The results of the epidemiological studies are consistent with the health effects when NO_2 alone is tested in the controlled chamber studies and in the toxicological studies.

1.1.2.3 Laboratory Toxicological Studies

The toxicological studies provide evidence that the developing lung is a target of NO_2 toxicity. Prolonged, repeated exposures of young animals to NO_2 during lung development have shown changes in bronchiolar/alveolar structure, including proliferation of certain types of epithelial cells and altered cellularity, and thickness in the gas exchange area of the lung (e.g., 6 week exposure, 7 hr/d, 5 d/wk at 0.25 ppm; 8-week exposure, 4 hr/d, 5 d/wk, at 0.5 ppm). Exposure of animal models to high concentrations of NO_2 (5 ppm NO_2 or greater) have been consistent in producing one or more indicators of allergic asthma including enhancement of delayed-type dyspneic symptoms, increased serum IgE levels, increased pulmonary eosinophilia and epithelial injury, and increased bronchial hyperresponsiveness. In summary, the toxicological results provide support for the health effects information reported in clinical and epidemiological studies.

1.2 Setting California Ambient Air Quality Standards

An ambient air quality standard (AAQS) is the legal definition of clean air. California ambient air quality standards are defined in Health and Safety Code Section 39014 and in Title 17, California Code of Regulations Section 70101. The AAQS establishes the maximum allowable levels of air pollutants that can be present in outdoor air for a given averaging time without causing harmful health effects to most people. Health and Safety Code Section 39606(b) authorizes the ARB to adopt standards for ambient air quality that are developed “in consideration of public health, safety, and welfare, including but not limited to health, illness, irritation to the senses, aesthetic value, interference with visibility, and the effects on the economy”. The California Health and Safety Code Section 39606, requires the Air Resources Board to adopt ambient air quality standards at levels that adequately protect the health of the public, including infants and children, with an adequate margin of safety. The objective of ambient air quality standards is to provide a basis for preventing or abating adverse health or ecological effects due to air pollution (Title 17, California Code of Regulations Section 70101).

During the review of the State AAQS, a number of important factors are considered and evaluated by the ARB and OEHHA. In consultation with ARB, OEHHA provides detailed analyses of the available health information for the criteria pollutant. Health-based air quality standards are based on the recommendation of OEHHA. The Air Quality Advisory Committee (AQAC), a scientific peer review committee appointed by the Office of the President of the University of California, convenes at a scheduled public meeting to independently evaluate the scientific basis of draft recommendations for revising California AAQS. In conducting its review, AQAC specifically considered whether the documentation adequately addressed:

- The extent of evidence of effects at or below the existing ambient air quality standard.
- The nature and severity of those effects.
- The magnitude of risk when ambient levels are at or near the level of the existing standard.

- The available evidence that children may be more susceptible than adults.
- The degree of outdoor exposure relative to the level of the standard.

The public is involved in the review process through public meetings and workshops and may comment on the staff review and findings and recommendations in person at workshops, at the AQAC and ARB Board meetings, and using the ARB web page.

California ambient air quality standards are comprised of four elements:
(1) a definition of the air pollutant,
(2) an averaging time (for example, hour or annual average),
(3) a pollutant concentration (for example, ppm or ug/m^3), and
(4) a monitoring method to determine attainment of the standard.

To protect the public health and welfare from the adverse effects of NO_2, the ARB previously established a short-term ambient air quality standard for NO_2 of 0.25 ppm averaged over one hour (1-hour standard). This standard was last formally reviewed in 1992. The U.S. Environmental Protection Agency (U.S. EPA) established a long-term ambient air quality standard for NO_2 of 0.053 parts per million (ppm) averaged over one year (an annual average). That standard was last reviewed in 1995 and was retained.

1.3 Staff Recommendations for the NO_2 Standard

Based on the ARB/OEHHA review of the scientific literature and recommendations by OEHHA, staff concludes that the current NO_2 standard does not adequately protect public health. Staff recommends that the following revisions be made to the California ambient air quality standard for NO_2:

1. NO_2 will continue to be the pollutant addressed by the standard.

2. NO_2 1-hour-average standard – reduce the current 1-hour-average standard for NO_2 of 0.25 ppm to **0.18 ppm (180 ppb), not to be exceeded**.

3. NO_2 annual-average standard – establish a new annual-average standard for NO_2 of **0.030 ppm (30 ppb)**, **not to be exceeded.**

4. Monitoring method—retain the current monitoring method for NO_2 which uses the chemiluminescence method for determining compliance with the State ambient air quality standard for NO_2.

5. Incorporate by reference (17 California Code of Regulations, Section 70101) all federally approved methods (i.e., samplers) for NO_2 as "California Approved Samplers". This will result in no change in air monitoring equipment practices, but will align state monitoring requirements with federal requirements.

These recommendations are based on the following findings:

1. Enhanced inflammatory response in asthmatics after exposures to 0.26 ppm NO_2 from 15 minute to 30 minutes, followed by an exposure to an airborne allergen.

2. Increased airway reactivity in asthmatic individuals following exposures to 0.2 to 0.3 ppm NO_2 for 30 minutes to 2 hours.

3. Since some of these effects were observed after only 30 minute exposures, an additional margin of safety is necessary when determining a 1-hour standard.

4. Evidence from time-series epidemiological studies based on 24-hour average NO_2 concentrations indicate increased asthma symptoms and medication use as well as emergency room visits and hospitalization for asthma, particularly in children. There is also evidence, though not as robust, for premature mortality and hospitalization for cardiovascular disease. The annual average NO_2 level in these studies is between 0.023 to 0.037 ppm.

5. Evidence from epidemiological studies showed that long-term exposures (i.e., one or more years) to NO_2 may lead to changes in lung function growth in children, symptoms in asthmatic children, and preterm birth. The annual average NO_2 level in these studies was 0.030 to 0.044 ppm.

6. With respect to infants and children:

    a. Infants and children have disproportionately higher exposure to NO_2 than adults due to their greater ventilation rate and greater exposure duration.

    b. Children may be more susceptible to the effects of NO_2 than the general population due to potential effects on the developing lung.

    c. Children with asthma have a higher degree of airway responsiveness compared with adult asthmatics.

1.4 Other Recommendations

Based on the adverse health effects, staff makes the following recommendations:

1. The spatial distribution of the air monitoring sites for NO_2 should be re-evaluated to determine if they adequately characterize exposures to NO_2, especially for infants, children, asthmatics, and individuals living near high volume roadways. Based on the results of this review, staff should evaluate and recommend the locations of monitoring sites to adequately determine Californian's exposures to NO_2.

2. Based on the review of the health evidence, additional areas of research have been identified which may be useful in reducing important uncertainties. These areas include: (1) clinical studies on the effects of NO_2 on sensitive subpopulations using other exposure concentrations and durations, biomarkers and outcomes, as less invasive techniques are developed. Also, other potentially susceptible subgroups can be examined including individuals with pre-existing cardiovascular or chronic

respiratory diseases and more severe asthmatics. Finally, an examination of the environment-gene interactions may be productive in identifying subgroups at risk; (2) toxicologic studies on the developing lung; (3) epidemiologic studies that attempt to separate out the effects of NO_2 from other pollutants, and studies that examine both personal and ambient exposure to NO_2. In addition, it would be useful to examine (in either epidemiologic, toxicologic, or clinical settings) the role of NO_2 in modifying the effects of ambient exposures to particulate matter and other pollutants. Finally, epidemiologic studies involving vulnerable pediatric populations (i.e., infants born prematurely or infants and children with chronic lung conditions) would be useful.

3. The standards should be revisited within five years, in order to re-evaluate the evidence regarding the health effects associated with NO_2 exposure.

4. In any air basin in California that currently attains the ambient air quality standard for NO_2, air quality should not be degraded from present levels.

1.5 Public and Peer Review of the Staff Recommendations

The draft version of this Staff Report was released to the public on April 14, 2006 and presented for review and comment at public workshops on May 8 and 11, 2006 in Sacramento and Los Angeles, respectively.

The draft Staff Report was reviewed by the Air Quality Advisory Committee (AQAC), a scientific peer review committee, appointed by the University of California, Office of the President. The AQAC independently evaluates the scientific basis of staff findings and recommendations in the draft Staff Report for revising the California ambient air quality standard for NO_2. The AQAC ensures that the scientific basis of the recommendations for the NO_2 standard is based on sound scientific knowledge, methods, and practices. The AQAC held a public meeting June 12-13, 2006 to discuss its review of the draft Staff Report, comments submitted by the public, and staff responses to those comments. The AQAC concluded that the report was well written and researched, and that the proposed revision to the State NO_2 standard was adequately supported. The AQAC findings, public comments, and staff responses can be found in Appendices C and D of the Technical Report Document. Staff revised the draft Staff Report based on comments received from the AQAC and the public.

1.6 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 ARB is responsible for adoption of emission standards for mobile sources and consumer products. 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.

1.7 Environmental Justice Considerations

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. The available literature suggests there appears to be no special vulnerability related to race, ethnicity, or income level, although there may be higher exposures. For example, the concentrations of NO_2 near roadways tend to be higher than those measured regionally, and some investigators have reported that higher percentages of minorities and people with lower income live near busy roadways (Green et al. 2004, Gunier et al. 2003).

1.8 Comment Period and Board Hearing

Release of this Staff Report opens the official 45-day public comment period required by the Administrative Procedures Act prior to the public meeting of the Air Resources Board to consider the staff's recommendations. Please direct all comments to either the following postal or electronic mail address:

Clerk of the Board
Air Resources Board
1001 "I" Street, 23rd Floor
Sacramento, California 95814

http://www.arb.ca.gov/lispub/comm/bclist.php

To be considered by the Board, written submissions not physically submitted at the hearing must be received at the ARB no later than 12:00 noon, February 21, 2007. Public workshops will be scheduled for January 2007 to present the final staff recommendations and receive public input on the Staff Report. Information on these workshops, as well as summaries of the presentations from past workshops and meetings are available by calling (916) 445-0753 or at the following ARB website:
http://www.arb.ca.gov/research/aaqs/no2-rs/no2-rs.htm

An oral report summarizing the staff recommendations for revising the NO_2 standard will be presented to the Board at a public hearing scheduled for February 22, 2007.

The staff recommends that the Board adopt the proposed amendments to the ambient air quality standard for NO_2 as stated above. The proposed amendments and their basis are described in detail in this Staff Report and Technical Support Document, which contains the findings of ARB and OEHHA staff's full review of the public health, scientific literature, and exposure pattern data for NO_2 in California. The full staff review contained in the Technical Support Document is divided into chapters on non-health topics, including chemistry of NO_2 formation and deposition, NO_2 precursor sources and emissions, NO_2 exposure, and background levels, measurement methods, and welfare effects of NO_2 exposure. The Technical Support Document also contains a summary of the health effects of NO_2 and an in-depth discussion of the basis for the staff recommendation.

2 Background and Overview

2.1 Setting Ambient Air Quality Standards

An ambient air quality standard (AAQS) is the legal definition of clean air. California ambient air quality standards are defined in Health and Safety Code Section 39014 and in Title 17, California Code of Regulations Section 70101. Four elements are listed for this definition:

1) A definition of the air pollutant, 2) an averaging time, 3) a pollutant concentration, and 4) a monitoring method to determine attainment of the standard.

The AAQS establishes the maximum allowable levels of air pollutants that can be present in outdoor air for a given averaging time without causing harmful health effects to most people. Health and Safety Code Section 39606(b) authorizes the ARB to adopt standards for ambient air quality that are developed “in consideration of public health, safety, and welfare, including but not limited to health, illness, irritation to the senses, aesthetic value, interference with visibility, and the effects on the economy”. The objective of ambient air quality standards is to provide a basis for preventing or abating adverse health or ecological effects due to air pollution (Title 17, California Code of Regulations Section 70101).

During the review of the State AAQS, a number of important factors are considered and evaluated by ARB, OEHHA, the Air Quality Advisory Committee (AQAC), and the public. In consultation with ARB, OEHHA provides detailed analyses of the available health information for each criteria pollutant. Health-based air quality standards are based on the recommendation of OEHHA. The AQAC, a scientific peer review committee appointed by the Office of the President of the University of California, convenes at a scheduled public meeting to independently evaluate the scientific basis of draft recommendations for revising the California AAQS. The public is involved in the review process through public meetings and workshops and may comment on the staff review and findings and recommendations in person at workshops, at the AQAC and ARB Board meetings, and using the ARB web page.

2.1.1 Children’s Environmental Health

California Health and Safety Code Section 39606 requires the Air Resources Board to adopt ambient air quality standards at levels that adequately protect the health of the public, including infants and children, with an adequate margin of safety. In December 2000, as a requirement of the Children’s Environmental Health Protection Act (Senate Bill 25, Escutia, Stats. 1999, Health and Safety Code Section 39606 (d)(1)), the ARB approved a report, “Adequacy of California Ambient Air Quality Standards” (ARB and OEHHA, 2000), that contained a brief review of all of the existing health-based California ambient air quality standards. The report identified NO_2 as one of the highest priorities for further detailed review, after PM10 and ozone, which were reviewed in 2002 and 2005, respectively. An important underlying premise of the AAQS evaluation process is that sensitive sub-populations, such as children, are to be protected from adverse health effects. As a part of developing an AAQS, a margin of safety is added to account for possible deficiencies in the health data and measuring methodology.

2.1.2 Current California One-Hour NO_2 Standard

The current California AAQS for NO_2 is 0.25 ppm averaged over one-hour, not to be exceeded and was set in 1992. The most relevant health and welfare effects from NO_2 exposure identified in the 1992 review are: "a potential to aggravate chronic respiratory disease and respiratory symptoms in sensitive groups." Further, there is risk to public health implied by pulmonary and extra-pulmonary biochemical and cellular changes and pulmonary structural changes, which are observed in short-term animal tests at or above the concentration of the standard. The welfare effect cited is contribution to atmospheric discoloration by NO_2, as initially adopted in 1966 and reviewed in 1992. (Title 17, California Code of Regulations Section 70200).

2.1.3 Current National Long-Term Annual Average NO_2 Standard

The current national ambient air quality standard for NO_2, initially adopted in 1971 and last reviewed in 1995, is an annual standard of 0.053 ppm (100 $\mu g/m^3$) calculated as the arithmetic mean of the 1-hour NO_2 concentrations. The value is based, in part, on epidemiological studies conducted by Shy et al. (1970 a,b), who reported decreases in lung function (FEV_1) for children (ages 7 to 8) living in areas with relatively high (greater than 0.06 ppm) annual average NO_2 levels. However, follow-up studies by the same investigators (Shy et al. 1973, 1978; Pearlman et al. 1971) did not confirm these findings. Emphasis was subsequently placed on animal exposure studies using relatively high concentrations of NO_2. Investigators reported damage to host defense mechanisms, as well as emphysematous-like lesions in the lungs. Investigators have also reported that NO_2 exposure caused an increase in the animal's susceptibility to infection resulting from immune system effects (U.S. EPA 1995). The U.S. EPA indicated that "based on the data available in 1985, retaining the annual NAAQS of 0.053 ppm was seen as a means of providing protection from long-term health effects and some measure of protection against possible short-term health effects (50 FR 25541, June 19, 1985). In 1995, the U.S. EPA again reviewed the NO_2 standard. The staff paper cited evidence for small changes in pulmonary function in asthmatics exposed to NO_2 between 0.2 and 0.5 ppm and increased airway responsiveness to asthmatics at rest within the range of 0.2-0.3 ppm. A meta-analysis of studies in children living in homes with gas stoves provided support for increased risk for developing respiratory disease, but it was difficult to use these studies to establish a quantitative relationship between estimated exposure and symptoms for use in determining a standard. Thus, an annual average standard of 0.053 ppm was retained during the last review.

2.1.4 World Health Organization (WHO) Guidelines

The World Health Organization (WHO) has published Air Quality Guidelines for Europe (WHO 2000a,b, 2003, 2006) which are not ambient air quality standards, but are "the basis for protecting public health from adverse effects of air pollutants, eliminating or reducing exposure to hazardous air pollutants, and to guide national and local authorities in their risk management decisions" (WHO 2000a,b). The WHO guidelines include both toxic air pollutants (such as benzene, for example) and criteria pollutants such as NO_2.

Based on the review of the literature, the WHO indicated that the lowest observable acute effect level for NO_2 was near 0.2 to 0.3 ppm based on clinical studies showing increased airway responsiveness in asthmatics. However, it was difficult to determine "…a clearly defined concentration–response relationship for NO_2 exposure..." (WHO 2000 a,b). The WHO also indicated that it would propose a 50% margin of safety because of additional evidence of possible effects below 0.2 ppm. These include a statistically significant increase in response to a bronchoconstrictor (increased airway responsiveness) with exposure to 190 $\mu g/m^3$ (0.1 ppm) in one study (Orehek et al. 1976) and a pooled analysis suggesting changes in airway responsiveness in asthmatics below 365 $\mu g/m^3$ (0.2 ppm). On the basis of these human clinical data, the WHO (2000a,b) proposed a 1-hour guideline of 200 $\mu g/m^3$ (0.106 ppm).

For long-term chronic exposure, the WHO reported that "although there is no particular study or set of studies that clearly support selection of a specific numerical value for an annual average guideline, the database nevertheless indicates a need to protect the public from chronic NO_2 exposure." Epidemiological studies of exposures to NO_2 from indoor sources suggested increased risk of lower respiratory illness in children, but the exposures could not be readily extrapolated to the outdoor situation. The WHO 2000 report stated, "Outdoor epidemiological studies have found qualitative evidence of ambient exposures being associated with increased respiratory symptoms and lung function decreases in children (annual average concentrations of 50–75 $\mu g/m^3$ (0.026–0.040 ppm or higher))." Further, the WHO indicated that these results were consistent with findings from indoor studies, although they do not provide clear exposure–response information for NO_2. In these epidemiological studies, NO_2 has appeared to be a good indicator of the pollutant mixture. Furthermore, animal toxicological studies show that prolonged exposures to NO_2 can cause decreases in lung host defenses and changes in lung structure. The WHO recommended an annual value of 40 $\mu g/m^3$ (21 ppb) (WHO 1997, 2000), but acknowledged that there were difficulties in ascribing the observed effects solely to NO_2 because of other pollutants in the ambient air that were correlated with NO_2. The WHO recently published an update of its guidelines (WHO 2006a) and reaffirmed the WHO 2000 guideline values of 40 $\mu g/m^3$ (21 ppb) for annual mean and 200 $\mu g/m^3$ (0.106 ppm) for 1-hour mean.

2.1.5 Monitoring Method for Current Standard

The California ambient air quality standard for NO_2 (Title 17, California Code of Regulations Section 70200) stipulates that gas phase chemiluminescence is the method to be used to measure NO_2. The standard also allows an equivalent method to be used to determine NO_2 ambient concentrations (Section 70200). See the Technical Support Document for more details. The ARB staff recommends that the current chemiluminescence method continue to be designated as the approved method in California for determining compliance with California's Ambient Air Quality Standard for NO_2. Staff also recommends that all federally approved chemiluminescence methods be designated as “California Approved Samplers” for NO_2. This will result in no change in air monitoring practices, but will align state monitoring requirements with federal requirements. To accomplish this, staff recommends modification of Title 17, California Code of Regulations Section 70100.1 to read in part: “NO_2 Monitoring Methods. The method for determining compliance with the NO_2 ambient air quality standard shall be the chemiluminescence Federal Reference Method for the determination of NO_2 in the atmosphere (40 CFR, Part 50, Appendix F). California Approved Samplers for NO_2 are set forth in the Air Monitoring Quality Assurance Manual, Volume IV, Part D: Monitoring Methods for NO_2.”

Accuracy and precision of the NO_2 concentrations are reflected in the field audit data. (ARB 2004, 2006). Accuracy is represented as an average percent difference of measurements of a NIST standard introduced through the probe used for NO_2 sampling. The average percent difference is the combined differences from the certified value of all the individual audit points. For 2002, 2003, 2004, and 2005, the percent differences were: 1.1, 0.9, -0.7, and -2.1, respectively. These are operating within the ARB’s control limits (+/-15%) (ARB 2004, 2006). The standard deviation (statistical variability) of these measurements reflect the precision of the method. For 2002, 2003, 2004, and 2005 the standard deviation of the method as evaluated by audit was 5, 5.3, 4.5, and 4.5 percent, respectively (ARB 2004, 2006).

As with monitoring for other criteria pollutants, the federal reference method requires that monitors be located away from major sources such as power plants and highways, in order to record general population exposures.

2.2 Physical and Chemical Properties of NO_2

Although NO_2 measured in the atmosphere can be directly emitted from combustion sources, much of the NO_2 is formed indirectly from emissions of NO that are subsequently converted photochemically to NO_2. In sunlight, NO_2 is a precursor in the formation of several other air pollutants, such as ozone (O_3), nitric acid (HNO_3), and nitrate (NO_3^-)-containing particles. NO_2 levels in air vary with direct emission levels, and with changing conditions (e.g., sunlight) that shift its relationship with other reactive airborne nitrogen oxides in a complex chemical linkage. Not only is NO_2 an important precursor of anthropogenic O_3, it is also the key agent in the formation of several airborne toxic substances. These include HNO_3, fine particles, peroxyacetyl nitrate, nitrosamines, and nitro-polycyclic aromatic hydrocarbons (nitro-PAHs).

2.3 Sources and Emissions of Nitrogen Oxides

2.3.1 Sources

NO_2 is both directly emitted and a by-product of atmospheric photochemical reactions of other NO_X species. Since emissions of NO are generally higher than directly emitted levels of NO_2, most emissions are primarily measured as NO_X. Mobile sources (including cars, trucks, and off-road mobile equipment) made up about 81% of the total statewide NO_X emissions in 2004. About 51% of the total NO_X emissions were from on-road motor vehicles (cars, trucks, and buses) and 30% were from other mobile sources (off-road equipment, trains, ships, and farm equipment) (ARB 2005a).

Stationary sources of NO_X include both internal and external combustion processes in industries such as manufacturing, food processing, electric utilities, and petroleum refining. These sources were about 16% of the total statewide NO_X emissions. Area-wide sources, which include residential fuel combustion, managed burning, and fires, contributed only a small portion of the total NO_X emissions, about 3%.

2.3.2 Emissions

Emissions of NO_X vary regionally in California. For example, statewide mobile sources account for approximately 81% of NO_X emissions even though this value ranges from 69% for San Joaquin Valley air basin to 90% for the South Coast air basin (values are expressed as percentages of the total NO_X emissions for each area.) NO_X emissions for individual source categories have daily, weekly, and seasonal variations. For most NO_X categories, higher emissions occur during the day rather than at night, and higher emissions occur on weekdays rather than on weekends. NO_X emissions from electric utility fuel combustion are higher in summer, while emissions from fuel combustion for space heating are higher in winter. As a whole, emissions of NO_X have been decreasing over the last two decades, and they are expected to have an overall decrease in the future. The NO_X emission trends (tons/day, annual average) and sources of emissions are summarized in Table 1.

Table 1. Emission Trends by NO_X by Source Category.

NOx Emission Trends (tons/day, annual average)										
Emission Source	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
All Sources	**4811**	**4982**	**4945**	**4871**	**4128**	**3629**	**3026**	**2499**	**2059**	**1811**
Stationary Sources	1228	1250	1009	909	696	602	506	519	538	556
Area-wide Sources	83	88	91	89	87	90	93	89	88	89
On-Road Mobile	2435	2459	2721	2675	2301	1915	1518	1127	757	532
Gasoline Vehicles	2149	1975	1936	1789	1535	1113	757	536	371	266
Diesel Vehicles	286	484	784	885	766	802	761	590	386	266
Other Mobile	1065	1185	1125	1199	1044	1022	908	764	675	634
Gasoline Fuel	43	48	52	61	60	67	74	68	62	60
Diesel Fuel	941	1052	988	1043	899	868	748	614	528	483
Other Fuel	82	85	85	95	85	87	86	83	85	90

2.4 Exposure to NO_2

2.4.1 Ambient Concentrations

NO_2 is monitored continuously at more than a hundred sites in California. The data for each monitoring site are reported as 1-hour average concentrations. Although the 1-hour data are reported, these values can, if needed, be summarized as daily, seasonal, or annual arithmetic mean concentrations. These data are especially used in determining the number of days during which measured concentrations exceed the State NO_2 standard. For the purpose of evaluating long-term NO_2 air quality trends and population exposures, the maximum concentration usually is not the best measure, because maximum concentrations can be highly influenced by year-to-year variations in meteorology.

In contrast to the maximum values, two calculated statistics that provide more stable measures of long-term trends are the *peak indicator value* and the *moving 3-year mean*. The peak indicator represents the maximum concentration expected to occur once per year, on average. The peak indicator is based on a statistical calculation using three years of ambient monitoring data and is calculated for each monitoring site in an area. The highest peak indicator value among all sites in an area is generally used when evaluating area-wide air quality. A moving 3-year mean of the annual maximum measured concentrations also tends to be a more stable trend indicator, when compared to the measured maximum concentration. Although the moving 3-year mean is not as robust as the peak indicator, the 3-year mean does tend to moderate some of the year-to-year variation caused by meteorology. This yields data that are more suitable for trend analysis, when compared with data for individual years.

The federal NO_2 annual arithmetic mean standard is 0.053 ppm. The entire state has been designated as unclassified/attainment for the past decade. For example, for the year 2004, the annual arithmetic means for the air basins in California varied from 0.0065 ppm to 0.0337 ppm (6.5 to 33.7 ppb), for the North Central Coast and South Coast Air Basins, respectively, which are well below the federal annual arithmetic mean standard.

To provide a snapshot of the levels of NO_2 in the state during the last few years, maximum measured 1-hour NO_2 concentrations are presented in Table 2 for the years 2002 through 2004. During this period, the State 1-hour standard was not exceeded in any of the air basins with the exception of one exceedance in the South Coast Air Basin in 2002. This measurement, a 1-hour concentration of 0.262 parts per million (rounds to 0.26 ppm), is an exceedance of the State NO_2 standard. Because State designations are based on three years of data, the 0.26 ppm measurement was evaluated for designation purposes during three separate years. In all cases, the 0.26 ppm measurement was higher than the rounded peak indicator, or Expected Peak Day Concentration (EPDC or peak indicator) value, and therefore, was excluded from the State designation process as an extreme concentration event. As a result, the South Coast Air Basin maintained its attainment designation. In 2003, the maximum 1-hour concentration in the South Coast Air Basin had dropped significantly to 0.163 ppm.

In general, the South Coast, Salton Sea, San Diego, Sacramento Valley, and Mojave Desert Air Basins have higher maximum 1-hour values than the other regions. Mountain Counties did not have a sufficient amount of data for 2004 to produce any meaningful summary statistics for comparison. The maximum 1-hour values in the Mountain Counties region for 2002 and 2003 are less than half the state 1-hour standard. Currently, there are no sites collecting NO_2 data in the Mountain Counties region. Almost all regions have experienced noticeable variability in maximum 1-hour values over the past three years. This is expected and can be partly attributed to year-to-year meteorological variability. With the exception of the one exceedance in the South Coast, maximum 1-hour concentrations were well below the state standard of 0.25 ppm, and varied from 0.037 ppm for the North Coast air basin to 0.146 ppm for the Sacramento Valley air basin for the year 2004.

Table 2. Maximum 1-hour NO_2 concentrations in each air basin for the years 2002 through 2004.

Basin	Year	Maximum 1-Hour Concentration ppm
Lake Tahoe	2002	0.088
	2003	0.059
	2004	0.068
Mojave	2002	0.101
	2003	0.095
	2004	0.103
Mountain Counties	2002	0.043
	2003	0.019
	2004	NA
North Central Coast	2002	0.049
	2003	0.053
	2004	0.139
North Coast	2002	0.08
	2003	0.053
	2004	0.037
Sacramento Valley	2002	0.09
	2003	0.102
	2004	0.146
Salton Sea	2002	0.138
	2003	0.189
	2004	0.108
San Diego	2002	0.126
	2003	0.148
	2004	0.125
San Francisco Bay	2002	0.08
	2003	0.081
	2004	0.073
San Joaquin Valley	2002	0.107
	2003	0.092
	2004	0.083
South Central Coast	2002	0.064
	2003	0.103
	2004	0.071
South Coast	2002	0.262
	2003	0.163
	2004	0.157

Notes: Days exceeding State 1-hour standard are distinct area wide days, meaning the exceedance day is counted only once, even if multiple sites experienced an exceedance on the same day. The State NO_2 standard is exceeded when the concentration is equal to or greater than 0.25 ppm. NA = No data available.

2.4.2 Indoor Concentrations

Although the ambient air quality standards are based on outdoor monitoring, indoor and microenvironmental concentrations of NO_2 indicate that personal exposures to NO_2 can be much higher than levels reflected by ambient station data.

2.4.2.1 Indoor Concentrations

Indoor/outdoor NO_2 ratios vary greatly. They range from less than 1 for homes without an indoor source to values greater than 3 for homes with indoor sources (Lee et al. 2002, Petreas et al. 1988). In the absence of continually-emitting indoor sources, indoor NO_2 levels can decline quickly due to infiltration of outdoor air and reactive processes. Indoor NO_2 reacts on indoor surfaces to produce nitrous acid (HONO), and has a lifetime of about one hour.

In California, indoor exposures to NO_2 are determined by the presence and use of indoor sources, particularly gas appliances, and outdoor NO_2 concentrations. The main factors influencing indoor NO_2 concentrations are gas stoves, indoor-outdoor air exchange rates, and the effects of season. Winter levels are typically higher than those in summer, and there is greater use of gas appliances in winter (Schwab et al. 1994, Spengler et al. 1994, Monn 2001).

Indoor mean NO_2 concentrations range from 0.008 to 0.056 ppm, measured with averaging times of days to a week, and indoor maximum levels range from about 0.1 to 0.4 ppm or greater, averaged over a similar time period. This is of concern because these indoor measurements have been made with passive monitors that utilize a long averaging time, and do not adequately reflect peak exposure levels that occur throughout the day. Continuous (or real-time) measurements indicate indoor levels can reach more than 0.4 ppm during routine cooking with a gas stove (Fortmann et al. 2001), and 0.6 ppm (mean) to 1.5 (maximum) ppm with use of unvented space heaters such as kerosene heaters (Girman et al. 1982), which are illegally used by a small percent of California homes. Therefore, Californians who spend time in a kitchen near an operating gas stove or range, or use unvented combustion space heaters, may experience very high exposures to NO_2.

2.4.2.2 Personal Exposure

Personal exposure to NO_2 is largely influenced by the type of fuel used for cooking in the home, and outdoor NO_2 concentrations. The median personal exposure level measured using a 48-hour passive badge sampler in one Los Angeles basin study was 0.035 ppm, with a 99^{th} percentile value of 0.090 ppm (Spengler et al. 1994).

In summary, Californians can be exposed to indoor and personal NO_2 levels that exceed the current ambient air quality standard. People's proximity to indoor sources such as gas stoves and unvented space heaters presents a public health concern, especially in light of recent epidemiology studies showing associations of health impacts with gas stove use.

2.4.3 Microenvironmental Concentrations

Westerdahl et al. (2005) reported in-vehicle NO_2 levels on specific road segments in the Los Angeles area. In the 3-4 day study, the concentrations ranged from 0.023 (±0.016) to 0.039 (± 0.012) ppm on the road. Fitz et al. (2003) measured a number of pollutants including NO_2 inside and outside of diesel school buses driven on typical commute routes in Los Angeles. The average NO_2 level within the conventional diesel-powered school bus was higher (about 0.076 ppm) than in the bus equipped with a particle trap (about 0.043 ppm). The concentrations of NO_2 measured in parallel outdoors were about 2-3 times less than NO_2 levels measured within the bus.

Roadside concentrations of NO_2 are another potential microenvironmental exposure area. A number of studies have found increased levels of NO_2 (and NO_X) in close proximity to busy roadways with rapid decline to near background concentrations within 150-300 meters of the road (Rodes et al. 1981, Singer et al. 2004). On days when ambient ozone concentrations are low, the rate of conversion of NO to NO_2 may be limited by ozone concentrations (Rodes et al. 1981). Analyses of roadside concentrations of NO_X and NO_2 have been reported by Carslaw (2005) in London during 1997-2003; the author reported a downward trend in NO_X, and a steady or increasing trend for NO_2 levels, resulting in an increase in the NO_2 to NO_X ratio, which the author ascribes, in part, to the increased use of diesel particulate filters fitted to buses.

2.4.4 Spatial Variability of NO_2

Spatial variability of NO_2 concentrations, or the concentration distributions from primary sources, has been studied by a number of investigators. One of the main focuses has been on the study of NO_2 concentrations in relation to the distance and location from freeways or roadways. For example, Singer et al. (2004) reported that typically, NO_2 concentrations are the highest next to the roadway, and decrease with the distance downwind of the roadway. The authors reported that schools upwind or far downwind of freeways were similar to regional pollution levels. For schools located within 350 m downwind of a freeway, concentrations of NO_2 and NO_X increased closer to the freeway, with the highest concentrations measured at a school located directly adjacent to a major freeway and shopping center (60% and 100% higher than regional concentrations, respectively).

In another study, Roorda-Knape et al. (1998) measured traffic related pollutants such as PM2.5, benzene, and NO_2 indoors and outdoors of schools located near roadways in the Netherlands. The authors reported that NO_2 concentrations in classrooms were significantly correlated with traffic intensity, percentage time downwind, and distance of the school from the road. Ross et al. (2005) reported on the intra-urban distribution of NO_2 using a new exposure classification technique. Their evaluation indicated that this model approach was very good in predicting NO_2 concentrations.

Jerrett et al. (2005) reviewed NO_2 air pollution concentration models. One relevant finding is that the inverse distance weighting (IDW) model used for the population exposure estimates may result in over-smoothing of actual concentrations and therefore may not provide a representative spatial patterns of exposure. Wu and colleagues (2005), as part of the Southern California Children's Health Study (CHS), developed an Individual Exposure Model to better evaluate children's long term exposure to air pollutants. The values were derived from the regional monitoring stations used for the CHS. The authors reported that overall within-community variability of personal exposures was highest for NO_2 (+/- 20-40%) and suggested that proper siting of air monitoring stations relative to emission sources is important to better estimate community mean exposures.

As noted above, there is considerable variability in ambient NO_2 concentrations, and federal monitoring siting requirements require regional (for example, urban scale) rather than microscale measurements. These regional monitors may not capture the highest concentrations in areas near major roads. These spatial differences in exposures may affect populations disproportionately. Investigators have reported that children living in census tracts with high traffic density and attending California public schools located near busy roads are disproportionately minority and economically disadvantaged (Gunier et al. 2003, Green et al. 2004).

An evaluation of NO_2 concentrations with respect to traffic sources will help us better understand the spatial patterns and how urban or neighborhood scale monitors represent more source impacted levels. However, monitoring stations must still meet federal siting requirements.

2.5 Summary of Relevant Health Effects

A number of investigators have reported relevant health effects from low-level exposure to NO_2 in sensitive human populations. Additional supportive evidence is derived from studies on animals. For more detailed information of the health effects of NO_2, refer to the Technical Support Document for NO_2. A summary of the scientific information regarding the relevant health effects follows.

2.5.1 Controlled Human Exposure Studies

Controlled human exposure studies (also referred to as clinical studies) are conducted under defined and controlled laboratory conditions to measure and evaluate potential health effects. These types of studies are important in helping to characterize exposure-response relationships to a specific air pollutant such as NO_2 alone or in combination with other pollutants. Human clinical studies, however, are limited to exposures of short duration (generally from minutes to a few hours) and are designed to study mild and, at times, transient responses. Human clinical studies are limited to a relatively small number of individuals tested who are generally relatively healthy. Additionally, the acute responses reported in clinical studies cannot necessarily be used to predict health effects of chronic or repeated exposure.

Clinical studies of healthy individuals showed no evidence of effects on lung function, airway responsiveness, or airway inflammation at levels of NO_2 below 1 ppm.

Individuals with asthma appear to be more sensitive to effects of NO_2 on airway responsiveness. For a number of studies of asthmatics, short-term exposures to NO_2 at 0.2-0.3 ppm resulted in an increase in airway responsiveness approximately one hour post-exposure (Kleinman et al. 1983 (0.2 ppm, 2 hour), Jörres et al. 1990 (0.25 ppm, 30 min.), Bylin et al. 1988 (0.27 ppm, 30 min.), Bauer et al. 1986 (0.3 ppm, 30 min.)). Strand et al. (1996) observed no effect 30 minutes after exposures to NO_2 (0.25 ppm), but observed an increase in airway responsiveness 5 hours after exposure. However, the findings have not been consistent across other studies with similar (but not identical) protocols (see Chapter 6, Technical Support Document). The reasons may be due, in part, to differences in the subjects recruited for the various studies. Even in clinical studies where, on average, there are no differences between responses with filtered air vs. NO_2 exposures, the data on individual responses suggest that there is substantial inter-individual variability in response. Thus, the clinical studies of asthmatics suggest that some individuals experience increased airway responsiveness after exposures to NO_2 in the range of 0.2-0.3 ppm. Several studies found transient decreases in lung function in asthmatics at 0.3 ppm during the initial part of the exposure, but the findings were not consistent. The effects of NO_2 on airway inflammation in asthmatics have not been adequately studied.

Recent clinical studies in subjects with asthma have also shown that NO_2 exposure increases allergen responsiveness, with effects observed at exposures as low as 0.26 ppm for 15-30 min. Studies found that exposures to NO_2 followed by inhaled allergen resulted in decrements in lung function (Strand et al. 1997, 1998). Subsequent studies using similar exposure protocols found evidence of an enhanced allergic response after NO_2 exposures compared with filtered air controls, including an increased inflammatory response in lung fluid (Barck et al. 2002), and evidence of activation of eosinophils in lung fluid and sputum (Barck et al. 2002, 2005). Decrements in lung function were not observed in these studies. Although not all endpoints were seen consistently across studies using very similar exposure protocols, there is a biologically plausible coherent body of evidence that brief exposures to NO_2 (0.26 ppm for 30 min) can enhance the allergic response in mild asthmatics.

A small number of studies evaluated effects in individuals with chronic obstructive pulmonary disease (COPD). Several found small decrements in lung function (FEV_1) at 0.3 ppm, but the findings were inconsistent. Older smokers may also be a subgroup at increased risk of lung function decrements at NO_2 levels slightly above the California 1-hour standard for NO_2 of 0.25 ppm.

A limited number of studies explored the cardiac, vascular, and systemic effects of NO_2 exposure, but these data were not conclusive. Finally, limited studies explored the effects of NO_2 on airway responsiveness to other pollutants challenges, with inconsistent results. However, several studies found that NO_2 at levels only slightly above the California standard may act synergistically with SO_2 in enhancing responses to allergen challenge.

Overall, the clinical studies suggest NO_2 exposures near the current ambient air quality standard for NO_2 (0.25 ppm, 1-hour average) may enhance the response to inhaled allergen in people with allergic asthma. For a subset of asthmatics, exposures to NO_2 at levels near the current ambient air quality standard may cause increased airway reactivity.

The limitations of controlled human exposure studies are discussed in detail in Chapter 6 of the Technical Report. Study subjects were primarily healthy adults, and mild asthmatics. Therefore, the more vulnerable populations such as the fetus, young children, the elderly, more severe asthmatics, and asthmatics with respiratory symptoms have not been studied in this setting. There is limited data on effects with repeated episodic peak exposures which might be the more relevant exposure scenario for populations.

2.5.2 Epidemiological Studies

Epidemiology is the study of the distribution of a disease in a population and the factors associated with the disease. The study duration can range from a relatively short period (hours to weeks) to a long period (years). Epidemiological studies have the advantage of acquiring data from a large human study population having real-world exposures. The studies can also focus on susceptible population groups, such as children, and can evaluate chronic health effects. However, real-world exposures consist of a complex mixture of air pollutants, some of which correlate closely with NO_2. Therefore, one difficulty is to separate out the NO_2 effects from all other air pollutant effects.

Support for the proposed long-term standard (annual average) is derived primarily from epidemiological studies. There are a number of health effects that have been associated with exposure to NO_2, including mortality, hospital visits, cardiovascular effects, low birth weight, and long-term lung function decreases in children. A number of epidemiological study designs are used in these studies, including time-series analyses and panel studies. The strongest epidemiological evidence of an effect of NO_2 on human health is derived from the studies of respiratory disease, including studies measuring both short- (24-hour) and long-term (one or more years) exposure. The time series studies evaluating the relationship between NO_2 and both hospital admissions and emergency department visits for asthma in children and adults are fairly consistent and robust (Peel et al. 2005, Simpson et al. 2005, Galan et al. 2003, Atkinson et al. 1999, Hajat et al. 1999, Anderson et al. 1998, Sunyer et al. 1997, Lee et al. 2006). The associations between NO_2 and these health outcomes often remained significant in models that included both NO_2 and particulate matter, even when the latter pollutant was also statistically significant. In addition to these daily time series studies, several asthma panel studies, including some from California, showed an effect of NO_2 on symptoms, medication use, and lung function (Schildcrout et al. 2006, Delfino et al. 2004, Delfino et al. 2003, Delfino et al. 2002, Mortimer et al. 2002, Ostro et al. 2001, Linaker et al. 2000, Boezen et al. 1999). The effects of long-term exposure to NO_2 (which may represent NO_2 *per se* or be a marker of traffic-related pollutants) have been clearly demonstrated in European studies (Kramer et al. 2000, Janssen et al. 2003), in a cross-sectional study of children in Alameda, California (Kim et al. 2004) and in the

Children's Health Study (CHS) in Southern California (Gauderman et al. 2004, Gauderman et al. 2005). The finding from the CHS of reduced lung function growth and attained lung function at age 18 years in children exposed to higher levels of NO_2 over an eight-year period is especially important, since it is a risk factor for chronic diseases and premature mortality later in life. These respiratory health effects have been observed in areas with average NO_2 levels of 18 to 57 ppb, with many in the range of 23 to 37 ppb.

Less robust findings have suggested associations between NO_2 and mortality, hospitalization for cardiovascular disease, and low birth weight. For these endpoints, the findings for NO_2 are often significantly attenuated when other pollutants are added to the regression model, making it difficult to assert that there is an independent effect of NO_2.

Health risks from NO_2 exposure may result from NO_2 itself or its reaction products, including O_3 and secondary particles. Alternatively, NO_2 may augment the effects of other pollutants. Also, since NO_2 concentrations are highly correlated with other traffic-related air pollutants, (e.g., fine particulate matter), NO_2 may be acting as a surrogate for the causal pollutant. For example, in some studies when an adjustment for particles was made, the NO_2 risk estimates were greatly reduced and often became non-significant. This result may indicate that the concentration response seen for NO_2 is largely the consequence of other pollutants. In some studies, however, especially in Europe, the strongest effect was found for NO_2 whereas particulate matter had a weaker effect. Specifically, stronger indications of an independent effect of NO_2 come from studies on hospital admissions for cardiovascular diseases and asthma, and from studies evaluating indoor effects especially among asthmatics and infants at risk of asthma. In addition, a multi-city study in Europe (Katsouyanni et al. 2001) found that the effect of PM10 was higher in cities with higher average NO_2 levels.

2.5.2.1 Summary

A number of epidemiological studies published over the last several years have demonstrated associations between NO_2 exposure and several health effects. These health effects include mortality, cardiopulmonary effects, decreased lung function, respiratory symptoms, and emergency room visits for asthma. The findings for respiratory disease have been particularly robust. Some issues regarding these associations include: 1) determining actual exposure concentrations including indoor sources, 2) separating out confounding variables such as co-pollutants, seasonality, and weather, and 3) determining precise averaging times from these studies ranging from 1-hr maximum levels to 24-hr averages to a few weeks. Despite many of these issues, a number of studies provide data supporting the need for a long-term average standard. The finding that there are very close correlations of NO_2 with other pollutants such as fine particulate matter in these studies makes interpretation challenging. However, the results of the epidemiological studies are consistent with the health effects when only NO_2 alone is tested in the controlled chamber studies, and in the toxicological studies. These results provide additional supportive information for potential health effects and for setting NO_2 standards that will be protective with an adequate margin of safety.

2.5.3 Toxicological Studies

Dosimetry modeling studies support the animal and human exposure studies in that the primary site of lung damage due to inhalation of NO_2 is the bronchiolar-alveolar duct region (Overton 1984). Dosimetry modeling has also estimated tissue dose of inhaled NO_2 in various species at different airway levels and in alveoli, and indicates that humans may receive 2-4 times greater maximal tissue dose of NO_2 at the centriacinar region relative to experimental animals (Miller et al. 1982). Thus, the higher experimental exposures typically employed in animal studies are relevant to ambient human exposures.

Toxicological studies with animals or cells in culture provide scientific information on the site and mechanism of action of NO_2. Studies using cell labeling techniques that measure cellular injury and repair processes have shown increased proliferative activity in bronchiolar epithelium of animals following acute exposure to 0.8 ppm NO_2 (Barth et al. 1994). Changes in pulmonary biochemistry observed in animal studies as a result of NO_2 exposure may result in altered activities of protective and repair mechanisms in the lung. For example, alteration of arachidonate metabolites following acute or short-term exposure to 0.5 ppm NO_2 may be related to damage of alveolar macrophage (AM) cell membranes, and may impede the ability of the lung to protect itself from microbial infection (Robison et al. 1993). Reduced superoxide release by AMs, which kills infectious organisms, may also impede lung defense.

Prolonged, repeated exposures of young ferrets and mice to 0.25 to 0.5 ppm NO_2 during lung development have shown changes in bronchiolar/alveolar structure, including proliferation of certain epithelial cells and altered cellularity, increased tissue thickness in the gas exchange area of the lung, and alterations of structural proteins (elastin) in lung tissue (Sherwin and Richters 1995a, Sherwin and Richters 1995b, Sherwin and Richters 1985, Rasmussen and McClure 1992). Thus, the developing lung is a target of NO_2 toxicity.

Rats from a strain that is prone to obesity were exposed to 0.16 ppm NO_2 for 24 weeks (Takano et al. 2004). This exposure resulted in changes in blood levels of triglycerides, HDL, and HDL/total cholesterol ratio, suggestive of atherogenic cardiovascular effects and indicative of the possibility that animals with compromised health may be a sensitive model for NO_2-induced toxicity.

Exposure of animal allergic asthma models to concentrations of about 5 ppm NO_2 or greater have produced consistent indicators of asthma including enhancement of delayed-type dyspneic symptoms, increased serum IgE levels, increased pulmonary eosinophilia and epithelial injury, and increased bronchial hyperresponsiveness (Kitabatake et al. 1995, Gilmour et al. 1996, Ohashi et al. 1998, Papi et al. 1999, Mi et al. 2002). Lower NO_2 concentrations have been less consistent in producing indicators of asthma in these animal models, although increased airway hyperresponsiveness has been demonstrated with prolonged NO_2 exposures at concentrations as low as 1 ppm (Fujimaki et al. 1998, Hubbard et al. 2002, Kobayashi and Miura 1995).

In vitro test systems using human bronchial epithelial cells (HBEC) and human lung fibroblasts have shown increased release of proinflammatory cytokines, and cell membrane damage in response to acute NO_2 exposures of 0.075 to 0.4 ppm (Bayram et al. 2001, Bayram et al. 2002, Ritter et al. 2001, Devalia et al. 1993, Bayram et al. 1999). Decreased viability was observed in lung fibroblasts and HBECs exposed to NO_2 (Ritter et al. 2001). A significant enhancement of release of molecules associated with allergy from HBECs of asthmatic (but not non-asthmatic) individuals has also been observed with NO_2 exposure (Bayram et al. 2001, Bayram et al. 2002). Nasal mucosal tissue in culture exposed to NO_2 exhibited increased histamine release, which is associated with response to allergens (Schierhorn et al. 1999). Alveolar macrophages exposed acutely to 0.1 to 0.5 ppm NO_2 released reactive oxygen species, and a number of inflammatory mediators (Kienast et al. 1994, Kienast et al. 1996). Although no conclusions regarding *in vivo* dose-response assessment can be drawn from the *in vitro* data, the *in vitro* results provide mechanistic support for the observed enhancement of response to allergens in asthmatics.

In summary, the toxicological results are consistent with and supportive of the health effects information reported in clinical and epidemiological studies.

2.6 Welfare Effects

2.6.1 Damage to Vegetation

With few exceptions, no visible injury to vegetation was reported at concentrations below 0.20 ppm, and these occurred when the cumulative duration of exposures extended to 100 hours or longer. Furthermore, the U.S. EPA concluded from studies with green beans as bioindicators of NO_2 injury, that foliar injury symptoms were unlikely to occur on even the most susceptible plant species at concentrations of NO_2 prevalent even in the most polluted areas of the U.S. No reports of plant exposures to NO_2 published since this analysis have altered this conclusion. At concentrations at or below the current 1-hour standard, vegetation effects are not expected.

The importance of atmospheric deposition of fixed nitrogen compounds in altering the structure and functioning of plant and aquatic communities has been the subject of numerous recent reviews, as described in Chapter 9 of the Technical Support Document. Some of the changes reported include induced nutrient deficiencies or imbalances, and interactive effects with air pollutants. With respect to critical loads of nitrogen deposition in California, relatively little is known of the effects of nitrogen deposition on terrestrial and aquatic ecosystems in the state, except for the intensively studied sites in southern California. California possesses an enormous diversity of vegetation and soil types and large-scale gradients in the types and amounts of nitrogen deposition. In addition, these ecosystems are exposed to multiple interacting abiotic and biotic stress factors, so isolating the adverse effects of specific rates of nitrogen deposition has not yet been possible. Thus, no specific recommendations for critical loads of total nitrogen can be made at this time. Based on results from southern California, it is suggested that at total nitrogen deposition rates of ca. 20 kg/ha/yr or greater, some evidence in changes in soil chemistry and spring runoff may be detected. Above 30 kg nitrogen/ha/yr, biological effects on soil microorganisms and sensitive native plants may be observed, and prolonged exposure to >40 kg nitrogen/ha/yr may significantly affect plant community structure and function.

2.6.2 Visibility

NO_2 contributes to reduction of visibility both directly, by selectively absorbing the shorter blue wavelengths of visible light, and indirectly by contributing to the formation of nitrate aerosols. Gaseous NO_2 turns air a reddish brown color, appearing as either a defined plume from a strong NO_X source or as a component of diffuse haze. Nitrate aerosols predominantly scatter light, creating a white haze. These two pollutants are often found together, and are contributors to the hazy-brown sky conditions observed in the South Coast Air Basin, the San Joaquin Valley, and elsewhere.

During the review of the 1992 State NO_2 ambient air quality standard, it was determined that meeting the 0.25 ppm one-hour standard would sufficiently protect against any visibility degradation, since it was calculated that the majority of the effect was due to fine particulate matter (ARB 1992). Fine airborne nitrate (primarily ammonium nitrate) levels would likely decrease as NO_2 levels decrease. This would have a positive effect on visibility by decreasing fine PM.

2.7 Staff Findings & Basis for Recommendations

The current California ambient air quality standard for NO_2 is 0.25 ppm averaged over one hour. The staff review found that health effects may occur at levels near the current standard, thus indicating that the current standard alone is not sufficiently protective of human health. The following is a summary of staff's findings.

2.7.1 Short-Term Exposure Effects

1. Enhanced airway inflammatory response was reported after allergen challenge in asthmatics exposed to NO_2 at 0.26 ppm for 15 minutes to 30 minutes (in single or repeated doses).
2. Increased airway reactivity was found among a subset of asthmatics after exposures to NO_2 in the range of 0.20 to 0.30 ppm for 30 minutes to 2 hours.
3. Evidence of health effects such as inflammatory responses and airway reactivity was reported for relatively healthy asthmatics exposed in the range of the current standard for 30 minutes, demonstrating the need for a margin of safety.

2.7.2 Longer-Term Exposure Effects

1. Evidence from time-series studies indicate effects of 24-hour average NO_2 on asthma symptoms and medication use as well as emergency room visits and hospitalization for asthma, particularly in children. There is also evidence, though not as robust, for premature mortality and hospitalization for cardiovascular

disease. The annual average NO_2 level in these studies is between 0.023 to 0.037 ppm.

2. Evidence from epidemiological studies showed that long-term exposures (i.e., one or more years) to NO_2 may lead to changes in lung function growth in children, symptoms in asthmatic children, and preterm birth. The annual average NO_2 level in these studies was 0.030 to 0.044 ppm.

2.7.3 Consideration of Infants and Children

Staff found that infants and children have disproportionately higher exposure to NO_2 than adults due to their greater ventilation rate and greater exposure duration. Children may be more susceptible to the effects of NO_2 than the general population due to potential effects on the developing lung. In addition, children with asthma have a higher degree of airway responsiveness compared with adult asthmatics.

2.7.4 Monitoring Method for NO_2

ARB staff recommends retaining the current monitoring method for NO_2 – gas-phase chemiluminescence – which is used for determining compliance with this State ambient air quality standard. ARB staff further recommends the incorporation by reference (Title 17, California Code of Regulations Section 70101) of all federally approved chemiluminescence methods as “California Approved Samplers” for $NO_{2.}$ This will not result in any change in air monitoring practices, but will align state monitoring requirements with federal requirements.

2.7.5 Environmental Justice Considerations

Ambient air quality standards define clean air; therefore, all of California’s communities will benefit from the proposed health-based standards. Moreover, the State standards are designed to protect the most sensitive members of the population, such as people with pre-existing lung or heart disease, and children. These air standards are also designed with a margin of safety to further protect sensitive populations. However, as noted above, there is considerable variability in ambient NO_2 concentrations, and exposure to NO_2 emitted from mobile and stationary sources may present itself as an environmental justice issue since the location of residences, schools, work and transportation corridors, may be near these sources.

Environmental justice is defined 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” (Senate Bill 115, Solis; Stats 1999, Ch. 690; Government Code 65040.12(c)). ARB’s environmental justice policies apply to all communities in California, but environmental justice issues have been raised more in the context of low-income and minority communities. These communities may experience higher exposures to some pollutants, such as to NO_2, as a result of the cumulative impacts of air pollution from roadways and stationary facilities located in their neighborhoods (Green et al. 2004, Gunier et al. 2003). An evaluation of monitor locations should help in the analyses of representative exposures to NO_2.

To mediate these possible exposures in the future, local air pollution districts and community members need to work together in land use evaluations to further reduce pollution exposure including exposure to NO_2. The ARB has developed a guideline document on land use with respect to air quality entitled, "Air Quality Land Use Handbook: A Community Health Perspective" (ARB 2005b). Land use considerations should involve the review of the many sources that emit NO_2. The ARB handbook recommends that planning agencies strongly consider proximity to these sources when considering new locations for "sensitive" land uses, such as homes, medical facilities, daycare centers, schools, and playgrounds. The handbook is available from the ARB website at http://www.arb.ca.gov/ch/handbook.pdf.

2.7.6 Public Outreach and Peer-Review

The draft Staff Report and the draft Technical Support Document on NO_2 were released to the public on April 14, 2006. After a public review and comment period, the documents were reviewed by the Air Quality Advisory Committee (AQAC), a scientific peer review committee appointed by the Office of the President of the University of California to independently evaluate the scientific basis of staff findings and recommendations in the draft Staff and Technical Documents. The AQAC held a public meeting on June 12-13, 2006 to discuss its review of the draft Staff Report and Technical Support Document, comments submitted by the public, and staff responses to those comments.

ARB and OEHHA staff will conduct public workshops on the NO_2 standard prior to the Board Hearing and invite the public to openly address questions and provide comments, including those related to environmental justice. The current documents – a Staff Report containing staff's findings, and a companion detailed Technical Support Document – are available for review and comment.

Community outreach for the standard review process involves a number of methods to disseminate information, including mailings, web "list serve" announcements, public meetings, and workshop presentations. The web "list serve" notifies the public of scheduled public meetings and workshops, and the availability of the Staff Report and the Technical Support Document. Public workshops on the proposed NO_2 standard are planned for Sacramento and El Monte. Individuals or parties interested in receiving notifications via the list serve on NO_2 or related ambient air quality standard issues, may enroll at the following internet location at no cost: www.arb.ca.gov/listserv/aaqs.htm.

Additional information on the standards review process is also available at the NO_2 review schedule website at: www.arb.ca.gov/research/aaqs/no2-rs/no2-rs.htm

2.7.7 Environmental and Economic Impacts

Ambient air quality standards 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 and consumer products. A number of different implementations 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 evaluated when specific measures are proposed.

2.7.8 Comment Period and Board Hearing

The recommendations in this Staff Report will be presented for review and comment at public workshops in Sacramento and El Monte, California. Staff findings and recommendations have been peer-reviewed by the AQAC in a public meeting to discuss their review of this Staff Report and Technical Support Document. Details on the workshop and AQAC meeting may be obtained from the ARB website: www.arb.ca.gov/research/aaqs/no2-rs/no2-rs.htm, or by calling 916-445-0753.

The revised Staff Report and Technical Support Document will 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 scheduled for February 22, 2007. Please direct all comments to either the following postal or electronic mail address:

Clerk of the Board
Air Resources Board
1001 "I" Street, 23rd Floor
Sacramento, California 95814

http://www.arb.ca.gov/lispub/comm/bclist.php

To be considered by the Board, written submissions not physically submitted at the hearing must be received at the ARB no later than 12:00 noon, February 21, 2007.

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Appendix A
Proposed Amendments to California Code of Regulations

and

Air Monitoring Quality Assurance Manual Volume IV, Part D (Document Incorporated by Reference)

Proposed Regulation Order

Proposed Amendments to Regulations for the State Ambient Air Quality Standard for Nitrogen Dioxide

Note: Language to be added is underlined and language to be removed is shown in ~~strikeout~~. Asterisks (****) indicate that a portion of the regulation not being amended is not shown here. In section 70200, Table of Standards, no changes are proposed to standards for any substances not listed.

Amend sections 70100.1 and 70200 (Table of Standards) of title 17, California Code of Regulation, to read as follows:

Division 3. Air Resources Board

Chapter 1. Air Resources Board

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Subchapter 1.5. Air Basins and Air Quality Standards

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Article 2. Ambient Air Quality Standards

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§ 70100.1. Methods, Samplers, and Instruments for Measuring Pollutants

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(d) *NO_2 Methods.* The method for determining compliance with the NO_2 ambient air quality standard shall be the chemiluminescence Federal Reference Method for the determination of NO_2 in the atmosphere (40 CFR, Part 50, Appendix F- Measurement). California Approved Samplers for NO_2 are set forth in the Air Monitoring Quality Assurance Manual, Volume IV, Part D: Monitoring Methods for NO_2 as adopted on [Insert date of adoption]. Samplers, methods, or instruments determined in writing by the Air Resources Board or the Executive Officer to produce equivalent results for NO_2 shall also be California Approved Samplers for NO_2.

Authority cited: Sections 39600, 39601 and 39606, Health and Safety Code. Reference: Sections 39014, 39606, 39701 and 39703(f), Health and Safety Code.

Section 70200. Table of Standards ***

Substance	Concentration and Methods*	Duration of Averaging Periods	Most Relevant Effects	Comments
Nitrogen Dioxide	0.~~25~~ 18 ppm	1 hour	a Short-term exposures may lead to adverse health effects in asthmatics: increased airway reactivity and enhanced allergic response after allergen challenge. ~~(1). Potential to aggravate chronic respiratory disease and respiratory symptoms in sensitive groups.~~ ~~a (2). Risk to public health implied by pulmonary and extra-pulmonary biochemical and cellular changes and pulmonary structural changes, which are observed in short-term animal tests at or above concentration of the standard.~~ b. Contribution to atmospheric discoloration.	a. ~~The~~ Both standards ~~is~~ are intended to prevent adverse health effects. b. The 1 hour standard imposes an upper limit on adverse effects on welfare, including atmospheric discoloration by NO_2.
	0.030 ppm Gas Phase Chemiluminescence**	Annual	Longer term exposures may lead to increased respiratory symptoms and medication use in asthmatics, emergency room visits for asthma in children, hospitalization for respiratory and cardiovascular disease, and premature mortality. Longer term exposures may also lead to changes in lung function growth in children, symptoms in asthmatic children, and pre-term birth. Children may be more susceptible to the potential effects of nitrogen dioxide on the developing lung.	

*Any equivalent procedure which can be shown to the satisfaction of the Air Resources Board to give equivalent results at or near the level of the air quality standard may be used.
**These standards are violated when concentrations exceed those set forth in the body of the regulation. All other standards are violated when concentrations equal or exceed those set forth in the body of the regulation.
***Applicable statewide unless otherwise noted.

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NOTE: Authority cited: Sections 39600, 39601(a) and 39606(b), Health and Safety Code.
Reference: Sections 39014, 39606(b), 39701 and 39703(f), Health and Safety Code.

Air Monitoring Quality Assurance Manual

Volume IV

Part D: Monitoring Methods for Nitrogen Dioxide

The method for determining compliance with the NO_2 ambient air quality standard shall be the chemiluminescence Federal Reference Method for the determination of NO_2 in the atmosphere (40 CFR, Part 50, Appendix F). California Approved Samplers for NO_2 are set forth in the Air Monitoring Quality Assurance Manual, Volume IV, Part D: Monitoring Methods for NO_2.

The current U.S. EPA "List of Designated Reference and Equivalent Methods" may be obtained through the U.S. EPA Technology Transfer Network Ambient Monitoring Technology Information Center web site at http://www.epa.gov/ttn/amtic/criteria.html. The following method constitutes "California Approved Samplers" for NO_2 for the purposes of determining compliance with California's ambient air quality standard: Gas phase chemiluminescence method for the determination of NO_2 in the atmosphere (40 CFR, Part 50, Appendix F). The specific instruments approved are:

Advanced Pollution Instrumentation, Inc. Model 200 NO_2 Analyzer - *Automated Reference Method*: RFNA-0691-082 "Advanced Pollution Instrumentation, Inc. Model 200 Nitrogen Oxides Analyzer". [Federal Register: Vol. 56, page 27014, 06/12/91]

Beckman Model 952-A NO/NO_2/NO_x Analyzer - *Automated Reference Method*: RFNA-0179-034 "Beckman Model 952-A NO/NO_2/NOx Analyzer". [Federal Register: Vol. 44, page 7806, 02/07/79]

Bendix Model 8101-B Oxides of Nitrogen Analyzer - *Automated Reference Method*: RFNA-0479-038 "Bendix Model 8101-B Oxides of Nitrogen Analyzer". [Federal Register: Vol. 44, page 26792, 05/07/79]

Bendix/Combustion Engineering Model 8101-C Oxides of Nitrogen Analyzer - *Automated Reference Method*: RFNA-0777-022 "Bendix or Combustion Engineering Model 8101-C Oxides of Nitrogen Analyzer". [Federal Register: Vol. 42, page 37435, 07/21/77]

Columbia Scientific Industries Models 1600 and 5600 Analyzers - *Automated Reference Method*: RFNA-0977-025 "CSI Model 1600 Oxides of Nitrogen Analyzer". [Federal Register: Vol. 42, page 46574, 09/16/77]

Dasibi Model 2108 Oxides of Nitrogen Analyzer - *Automated Reference Method*: RFNA-1192-089 "Dasibi Model 2108 Oxides of Nitrogen Analyzer". [Federal Register: Vol. 57, page 55530, 11/25/92]

DKK-TOA Corporation Model GLN-114E Nitrogen Oxides Analyzer – *Automated Reference Method*: RFNA-0798-121 "DKK-TOA Corporation Models GLN-114E and

GLN-114E-1 Nitrogen Oxides Analyzer". [Federal Register: Vol. 63, page 41253, 08/03/98]

Environnement S. A. Model AC31M NO_2 Analyzer - *Automated Reference Method*: RFNA-0795-104 "Environnement S. A. Model AC31M Chemiluminescent Nitrogen Oxide Analyzer". [Federal Register: Vol. 60, page 38326, 07/26/95]

Environnement S. A. Model AC32M NO_2 Analyzer - *Automated Reference Method*: RFNA-0202-146 "Environnement S. A. Model AC32M Chemiluminescent Nitrogen Oxides Analyzer". [Federal Register: Vol. 67, page 15567, 04/02/02]

Horiba Instruments Models APNA-360 or APNA-360-CE NO-NO_2-NO_x Monitor - *Automated Reference Method*: RFNA-0196-111 "Horiba Instruments, Inc. Models APNA-360 or APNA-360-CE Ambient NO-NO_2-NO_x Monitor". [*Federal Register*: Vol. 61, page 11404, 03/20/96]

Horiba Instruments Model APNA-370 NO2 Monitor *Automated Reference Method*: RFNA-0506-157 "Horiba Instruments Incorporated Model APNA-370 Ambient NOx Monitor," standard specification, operated with a full scale fixed measurement range of 0 - 0.50 ppm with the automatic range switching off, at any ambient temperature in the range of 20 ℃ to 30 ℃, and with a 0.3 micrometer sample particulate filter installed. [Federal Register: Vol. 71, page 25587, 05/01/06]

Meloy Model NA530R Nitrogen Oxides Analyzer - *Automated Reference Method*: RFNA-1078-031 "Meloy Model NA530R Nitrogen Oxides Analyzer". [Federal Register: Vol. 43, page 50733, 10/31/78 and Vol. 44, page 8327, 02/09/79]

Monitor Labs Model 8440E Nitrogen Oxides Analyzer - *Automated Reference Method*: RFNA-0677-021 "Monitor Labs Model 8440E Nitrogen Oxides Analyzer". [Federal Register: Vol. 42, page 37434, 07/21/77; Vol. 42, page 46575, 09/16/77; Vol. 46, page 29986, 06/04/81]

Monitor Labs/Lear Siegler Model 8840 Nitrogen Oxides Analyzer - *Automated Reference Method*: RFNA-0280-042 "Monitor Labs or Lear Siegler Model 8840 Nitrogen Oxides Analyzer". [Federal Register: Vol. 45, page 9100, 02/11/80 and Vol. 46, page 29986, 06/04/81]

Monitor Labs/Lear Siegler Model 8841 Nitrogen Oxides Analyzer - *Automated Reference Method*: RFNA-0991-083 "Monitor Labs or Lear Siegler Model 8841 Nitrogen Oxides Analyzer". [Federal Register: Vol. 56, page 47473, 9/19/91]

Philips Model PW9762/02 NO/NO_2/NO_x Analyzer - *Automated Reference Method*: RFNA-0879-040 "Philips Model PW9762/02 NO/NO_2/NO_x Analyzer". [Federal Register: Vol. 44, page 51683, 09/04/79]

Seres Model NOx 2000 G Nitrogen Dioxide Analyzer *Automated Reference Method:* RFNA-0706-163 “Seres Model NOx 2000 G Nitrogen Dioxide Ambient Air Analyzer,” operated with a full scale measurement range of 1 - 0.50 ppm, at any ambient temperature in the range of 20℃ to 30 ℃. [*Federal Register:* Vol. 71, page 42089, 07/25/06]

SIR S.A. Model S-5012 Nitrogen Oxides Analyzer - *Automated Reference Method*: RFNA-0804-152. [Federal Register: Vol. 69, page 47924, 08/06/04]

Teledyne - Advanced Pollution Instrumentation, Inc. Models 200A, 200AU, 200E; Teledyne Analytical Instruments Model 9110A; or Teledyne Monitor Labs sensor-e™ Model TML-41 NO_2 Analyzers - *Automated Reference Method*: RFNA-1194-099 “Teledyne - Advanced Pollution Instrumentation, Inc. Models 200A, 200AU, 9110A, or 200E; Teledyne Analytical Instruments Model 9110A; or Teledyne Monitor Labs, Inc. sensor-e™ Model TML-41 Chemiluminescence Nitrogen Oxides Analyzer”. [Federal Register: Vol. 59, page 61892,12/02/94]

Teledyne Monitor Labs/Casella/Ecotech Models ML9841, ML9841A/EC9841A, Teledyne Monitor Labs/Casella/Ecotech Model ML9841B/EC9841B, or Wedding & Associates Model 1030 NO_2 Analyzers - *Automated Reference Method*: RFNA-1292-090– “Teledyne Monitor Labs, Casella Monitor, or Ecotech Models ML9841, ML9841A/EC9841A, or ML9841B/EC9841B, or Wedding & Associates, Inc. Model 1030 Nitrogen Oxides Analyzers”. [Federal Register: Vol. 57, page 60198, 12/18/92]

Thermo Electron/Thermo Environmental Instruments Model 14 B/E – *Automated Reference Method*: RFNA-0179-035 “Thermo Electron or Thermo Environmental Instruments, Inc. Model 14 B/E Chemiluminescent $NO/NO_2/NO_x$ Analyzer”. [Federal Register: Vol. 44, page 7805, 02/07/79 and Vol. 44, page 54545, 09/20/79]

Thermo Electron/Thermo Environmental Instruments Model 14 D/E – *Automated Reference Method*: RFNA-0279-037 “Thermo Electron or Thermo Environmental Instruments, Inc. Model 14 D/E Chemiluminescent $NO/NO_2/NO_x$ Analyzer”. [Federal Register: Vol. 44, page 10429, 02/20/79]

Thermo Environmental Instruments Models 42, 42C, 42*i* $NO/NO_2/NO_x$ Analyzer - *Automated Reference Method*: RFNA-1289-074 “Thermo Environmental Instruments Inc. Model 42, Model 42C, or Model 42*i* $NO\text{-}NO_2\text{-}NO_x$ Analyzer”. [Federal Register: Vol. 54, page 50820, 12/11/89]