

**FINAL 2007 AQMP  
APPENDIX I**

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**HEALTH EFFECTS**

**JUNE 2007**

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**APPENDIX 1**

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**HEALTH EFFECTS**

**Health Effects of Air Pollution**  
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## **INTRODUCTION**

This document presents a summary of scientific findings on the health effects of ambient air pollutants. The California Health and Safety Code Section 40471(b) requires that the South Coast Air Quality Management District prepare a report on the health impacts of particulate matter in the South Coast Air Basin, in conjunction with the preparation of the Air Quality Management Plan revisions. This document, which was prepared to satisfy that requirement, also includes the effects of the other major pollutants.

## **HEALTH EFFECTS OF AIR POLLUTION**

Ambient air pollution is a major public health concern. Excess deaths and increases in illnesses associated with high air pollution levels have been documented in several episodes as early as 1930 in Meuse Valley, Belgium; 1948 in Donora, Pennsylvania; and 1952 in London. Although levels of pollutants that occurred during these acute episodes are now unlikely in the United States, ambient air pollution continues to be linked to increases in respiratory illness (morbidity) and increases in death rates (mortality).

The adverse health effects associated with air pollution are diverse and include:

- Increased mortality
- Increased health care utilization (hospitalization, physician and emergency room visits)
- Increased respiratory illness (symptoms, infections, and asthma exacerbation)
- Decreased lung function (breathing capacity)
- Lung inflammation
- Potential immunological changes
- Increased airway reactivity to a known chemical exposure - a method used in laboratories to evaluate the tendency of airways to have an increased possibility of developing an asthmatic response
- A decreased tolerance for exercise.

The evidence linking these effects to air pollutants is derived from population-based observational and field studies (epidemiological) as well as controlled laboratory studies involving human subjects and animals. There have been an increasing number of studies focusing on the mechanisms (that is, on learning how specific organs, cell types,

and biochemicals are involved in the human body's response to air pollution) and specific pollutants responsible for individual effects. Yet the underlying biological pathways for these effects are not always clearly understood.

Although individuals inhale pollutants as a mixture under ambient conditions, the regulatory framework and the control measures developed are mostly pollutant-specific. This is appropriate, in that different pollutants usually differ in their sources, their times and places of occurrence, the kinds of health effects they may cause, and their overall levels of health risk. Different pollutants, from the same or different sources, may sometimes act together to harm health more than they would acting separately. Nevertheless, as a practical matter, health scientists, as well as regulatory officials, usually must deal with one pollutant at a time in determining health effects and in adopting air quality standards. To meet the air quality standards, comprehensive plans are developed such as the Air Quality Management Plan (AQMP) and the Air Toxics Control Plan (ATCP). These plans examine multiple pollutants, cumulative impacts, and transport issues related to attaining healthful air quality. A brief overview of the effects observed and attributed to various air pollutants is presented in this document.

This summary is drawn substantially from reviews presented previously (SCAQMD, 1996 and 2003), and from reviews on the effects of air pollution by the American Thoracic Society (ATS, 1996), the U.S. EPA reviews for ozone (U.S. EPA, 2006), Carbon Monoxide (U.S. EPA, 2000), and Particulate Matter (U.S. EPA, 2004), from a published review of the health effects of air pollution (Brunekreef and Holgate, 2002), and from reviews prepared by the California EPA Office of the Environmental Health Hazard Assessment for Particulate Matter (Cal EPA, 2002) and for Ozone (Cal EPA, 2005). More detailed citations and discussions on air pollution health effects can be found in these references.<sup>1</sup>

## **OZONE**

Ozone is a highly reactive compound, and is a strong oxidizing agent. When ozone comes into contact with the respiratory tract, it can react with tissues and cause damage in the airways. Since it is a gas, it can penetrate into the gas exchange region of the deep lung.

The EPA primary standard for ozone is 0.08 ppm averaged over eight hours. The California Air Resources Board (CARB) has established standards of 0.09 ppm averaged over one hour and at 0.070 ppm averaged over eight hours.

The major subgroups of the population considered to be at increased risk from ozone exposure are outdoor exercising individuals including children and people with preexisting respiratory disease(s) such as asthma. The data base identifying the former

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<sup>1</sup> Most of the studies referred to in this appendix are cited in the above sources. Only more recent specific references will be cited in this summary.

group as being at increased risk to ozone exposure is much stronger and more quantitative than that for the latter group, probably because of a larger number of studies conducted with healthy individuals. The adverse effects reported with short-term ozone exposure are greater with increased activity because activity increases the breathing rate and the volume of air reaching the lungs, resulting in an increased amount of ozone reaching the lungs. Children may be a particularly vulnerable population to air pollution effects because they spend more time outdoors, are generally more active, and have a higher ventilation rate than adults.

A number of adverse health effects associated with ambient ozone levels have been identified from laboratory and epidemiological studies (EPA, 1996; ATS, 1996). These include increased respiratory symptoms, damage to cells of the respiratory tract, decreases in lung function, increased susceptibility to respiratory infection, and increased risk of hospitalization.

The Children's Health Study, conducted by researchers at the University of Southern California, followed a cohort of children that live in 12 communities in southern California with differing levels of air pollution for several years. A publication from this study found that school absences in fourth graders for respiratory illnesses were associated with ambient ozone levels. An increase of 20 ppb ozone was associated with an 83% increase in illness related absence rates (Gilliland, 2001).

The number of hospital admissions and emergency room visits for all respiratory causes (infections, respiratory failure, chronic bronchitis, etc.) including asthma show a consistent increase as ambient ozone levels increase in a community. These excess hospital admissions and emergency room visits are observed when hourly ozone concentrations are as low as 0.08 to 0.10 ppm.

Numerous recent studies have found positive associations between increases in ozone levels and excess risk of mortality. These associations persist even when other variables including season and levels of particulate matter are accounted for. This indicates that ozone mortality effects are independent of other pollutants (Bell, 2004).

Several population-based studies suggest that asthmatics are more adversely affected by ambient ozone levels, as evidenced by increased hospitalizations and emergency room visits. Laboratory studies have attempted to compare the degree of lung function change seen in age and gender-matched healthy individuals versus asthmatics and those with chronic obstructive pulmonary disease. While the degree of change evidenced did not differ significantly, that finding may not accurately reflect the true impact of exposure on these respiration-compromised individuals. Since the respiration-compromised group may have lower lung function to begin with, the same degree of change may represent a substantially greater adverse effect overall.



A recent publication from the Children's Health Study focused on children and outdoor exercise. In communities with high ozone concentrations, the relative risk of developing asthma in children playing three or more sports was found to be over three times higher than in children playing no sports (McConnell, 2002). These findings indicate that new cases of asthma in children are associated with heavy exercise in communities with high levels of ozone. While it has long been known that air pollution can exacerbate symptoms in individuals with respiratory disease, this is among the first studies that indicate ozone exposure may be causally linked to asthma.

In addition, human and animal studies involving both short-term (few hours) and long-term (months to years) exposures indicate a wide range of effects induced or associated with ambient ozone exposure. These are summarized in Table 1.

Some lung function responses (volume and airway resistance changes) observed after a single exposure to ozone exhibit attenuation or a reduction in magnitude with repeated exposures. Although it has been argued that the observed shift in response is evidence of a probable adaptation phenomenon, it appears that while functional changes may exhibit adaptation, biochemical and cellular changes which may be associated with episodic and chronic exposure effects may not exhibit similar adaptation. That is, internal damage to the respiratory system may continue with repeated ozone exposures, even if externally observable effects (chest symptoms and reduced lung function) disappear.

In a laboratory, exposure of human subjects to low levels of ozone causes reversible decrease in lung function as assessed by various measures such as respiratory volumes, airway resistance and reactivity, irritative cough and chest discomfort. Lung function changes have been observed with ozone exposure as low as 0.08 to 0.12 ppm for 6-8 hours under moderate exercising conditions. Similar lung volume changes have also been observed in adults and children under ambient exposure conditions (0.10 - 0.15 ppm). The responses reported are indicative of decreased breathing capacity and are reversible.

In laboratory studies, cellular and biochemical changes associated with respiratory tract inflammation have also been consistently reported in the airway lining after low level exposure to ozone. These changes include an increase in specific cell types and in the concentration of biochemical mediators of inflammation and injury such as cytokines and fibronectin. These inflammatory changes can be observed in healthy adults exposed to ozone in the range of 0.08 to 0.10 ppm.

The susceptibility to ozone observed under ambient conditions could be due to the combination of pollutants that coexist in the atmosphere or ozone may actually sensitize these subgroups to the effects of other pollutants.

Some animal studies show results that indicate possible chronic effects including functional and structural changes of the lung. These changes indicate that repeated inflammation associated with ozone exposure over a lifetime may result in sufficient damage to respiratory tissue such that individuals later in life may experience a reduced quality of life in terms of respiratory function and activity level achievable. An autopsy study involving Los Angeles County residents provided supportive evidence of lung tissue damage (structural changes) attributable to air pollution.

A recent study of birth outcomes in southern California found an increased risk for birth defects in the aortic and pulmonary arteries associated with ozone exposure in the second month of pregnancy (Ritz et al., 2002). This is the first study linking ambient air pollutants to birth defects in humans. Confirmation by further studies is needed.

**TABLE 1**  
**Adverse Health Effects of Ozone (O<sub>3</sub>)**  
**(Summary of Key Studies)**

O <sub>3</sub> Concentration and Exposure Hr, ppm	Health Effect
Ambient air containing 0.10 - 0.15 daily 1-h max over days to weeks	<p>Decreased breathing capacity, in children, adolescents, and adults exposed to O<sub>3</sub> outdoors</p> <p>Exacerbation of respiratory symptoms (e.g., cough, chest pain) in individuals with preexisting disease (e.g., asthma) with low ambient exposure, decreased temperature, and other environmental factors resulting in increased summertime hospital admissions and emergency department visits for respiratory causes</p>
<p>≥0.12 (1-3h)</p> <p>≥0.08 (6.6h)</p> <p>(chamber exposures)</p>	<p>Decrements in lung function (reduced ability to take a deep breath), increased respiratory symptoms (cough, shortness of breath, pain upon deep inspiration), increased airway responsiveness and increased airway inflammation in exercising adults</p> <p>Effects are similar in individuals with preexisting disease except for a greater increase in airway responsiveness for asthmatic and allergic subjects</p> <p>Older subjects (&gt;50 yrs old) have smaller and less reproducible changes in lung function</p> <p>Attenuation of response with repeated exposure</p>
≥0.12 with prolonged, repeated exposure (chamber exposures)	<p>Changes in lung structure, function, elasticity, and biochemistry in laboratory animals that are indicative of airway irritation and inflammation with possible development of chronic lung disease</p> <p>Increased susceptibility to bacterial respiratory infections in laboratory animals</p>

From: SCAQMD, 1996

In summary, acute adverse effects associated with ozone exposures have been well documented, although the specific causal mechanism is still somewhat unclear. Additional research efforts are required to evaluate the long-term effects of air pollution and to determine the role of ozone in influencing chronic effects.

## **PARTICULATE MATTER**

Airborne particulates are a complex group of pollutants that vary in source, size and composition, depending on location and time. The components include nitrates, sulfates, elemental carbon, organic carbon compounds, acid aerosols, trace metals, and material from the earth's crust. Substances of biological origin, such as pollen and spores, may also be present.

Until several years ago, the health effects of particulates were focused on those sized 10  $\mu\text{m}$  (micrometers) aerodynamic diameter and smaller. These can be inhaled through the upper airways and deposited in the lower airways and gas exchange tissues in the lung. These particles are referred to as PM<sub>10</sub>. EPA initially promulgated ambient air quality standards for PM<sub>10</sub> of 150  $\mu\text{g}/\text{m}^3$  averaged over a 24-hour period, and 50  $\mu\text{g}/\text{m}^3$  for an annual average. EPA has very recently rescinded the annual PM<sub>10</sub> standard, but kept the 24-hour standard.

In recent years additional focus has been placed on particles having an aerodynamic diameter of 2.5  $\mu\text{m}$  or less (PM<sub>2.5</sub>). A greater fraction of particles in this size range can penetrate and deposit deep in the lungs. The EPA recently lowered the air quality standards for PM<sub>2.5</sub> to 35  $\mu\text{g}/\text{m}^3$  for a 24-hour average and reaffirmed 15  $\mu\text{g}/\text{m}^3$  for an annual average standard. There was considerable controversy and debate surrounding the review of particulate matter health effects and the consideration of ambient air quality standards (Kaiser, 1997; Vedal, 1997) when the EPA promulgated the initial PM<sub>2.5</sub> standards in 1997.

Since that time, numerous studies have been published and some of the key studies were closely scrutinized and analyses repeated. The result is that there are now substantial data confirming the adverse health effects of PM<sub>2.5</sub> exposures.

There are also differences in the composition and sources of particles in the different size ranges that may have implications for health effects. The particles larger than 2.5  $\mu\text{m}$  (often referred to as the coarse fraction) are mostly produced by mechanical processes. These include automobile tire wear, industrial processes such as cutting and grinding, and resuspension of particles from the ground or road surfaces by wind and human activities.

In contrast, particles smaller than 2.5  $\mu\text{m}$  are mostly derived from combustion sources, such as automobiles, trucks, and other vehicle exhaust, as well as from stationary combustion sources. The particles are either directly emitted or are formed in the atmosphere from gases that are emitted. Components from material in the earth's crust, such as dust, are also present, with the amount varying in different locations.

Attention to another range of very small particles has been increasing over the last few years. These are generally referred to as "ultrafine" particles, with diameters of 0.1  $\mu\text{m}$

or less. These particles are mainly from fresh emissions of combustion sources, but are also formed in the atmosphere from photochemical reactions. Ultrafine particles have relatively short half lives (minutes to hours) and rapidly grow through condensation and coagulation process into larger particles within the PM<sub>2.5</sub> size range. These particles are garnering interest since laboratory studies indicate that their toxicity may be higher on a mass basis than larger particles, and there is evidence that these small particles can translocate from the lung to the blood and to other organs of the body.

The health effects of ambient particulate matter have been recently reviewed (ATS, 1996; U.S. EPA, 2004, Brunekreef, 2002). In addition, the California Air Resources Board (CARB) and the Office of Environmental Health and Hazard Assessment (OEHHA) have reviewed the adequacy of the California Air Quality Standards for Particulate Matter (Cal EPA, 2002).

The major types of effects associated with particulate matter include:

- Increased mortality
- Exacerbation of respiratory disease and of cardiovascular disease as evidenced by increases in:
  - Respiratory symptoms
  - Hospital admissions and emergency room visits
  - Physician office visits
  - School absences
  - Work loss days
- Effects on lung function
- Changes in lung morphology

The U.S. EPA has recently lowered the short-term ambient air quality standard for fine particles (PM<sub>2.5</sub>) and has rescinded the annual standard for PM<sub>10</sub>. The current federal and California standards are listed below:

<u>Standard</u>	<u>Federal</u>	<u>California</u>
PM10 24-Hour average	150 $\mu\text{g}/\text{m}^3$	50 $\mu\text{g}/\text{m}^3$
PM10 Annual Average	--	20 $\mu\text{g}/\text{m}^3$
PM 2.5 24-Hour Average	35 $\mu\text{g}/\text{m}^3$	--
PM 2.5 Annual Average	15 $\mu\text{g}/\text{m}^3$	12 $\mu\text{g}/\text{m}^3$

### **Short-Term Exposure Effects**

Epidemiological studies have provided continued and consistent evidence for most of the effects listed above. An association between increased daily or several-day-average concentrations of PM10 and excess mortality and morbidity is consistently reported from studies involving communities across the U.S. as well as in Europe, Asia, and South America. A review and analysis of epidemiological literature for acute adverse effects was undertaken by Dockery and Pope to estimate these effects as percent increase in mortality associated with each incremental increase of PM10 by 10  $\mu\text{g}/\text{m}^3$ . The estimates are presented in Table 2. It appears that individuals who are elderly or have preexistent lung or heart disease are more susceptible than others to the adverse effects of PM10.

**TABLE 2**  
 Combined Effect Estimates of Daily Mean  
 Particulate Pollution

	% Change in Health Indicator per each 10 µg/m <sup>3</sup> Increase in PM10
Increase in daily mortality	
Total deaths	1.0
Respiratory deaths	3.4
Cardiovascular deaths	1.4
Increase in hospital usage (all respiratory diagnoses)	
Admissions	1.4
Emergency department visits	0.9
Exacerbation of asthma	
Asthmatic attacks	3.0
Bronchodilator use	12.2
Emergency department visits*	3.4
Hospital admissions	1.9
Increase in respiratory symptom reports	
Lower respiratory	3.0
Upper respiratory	0.7
Cough	2.5
Decrease in lung function	
Forced expiratory volume	0.15
Peak expiratory flow	0.08

\* One study only

(Source: American Journal of Respiratory and Critical Care Medicine, Vol. 153, 113-50, 1996)

Many recent studies have confirmed that excess mortality and morbidity are associated with particulate matter levels. Estimates of mortality effects from these studies range from 0.3 to 1.7% increase for a 10 µg/m<sup>3</sup> increase in PM10 levels. The National Morbidity, Mortality, and Air Pollution Study (NMMAPS), a recent study of the largest U.S. cities, determined a combined risk estimate of about a 0.5% increase in total mortality for a 10 µg/m<sup>3</sup> increase in PM10 (Samet, 2000a). This study also analyzed the effects of gaseous co-pollutants. The results indicated that the association of PM10 and mortality were not confounded by the presence of the gaseous pollutants. When the gaseous pollutants were included in the analyses, the significance of the PM10 estimates remained. The PM10 effects were reduced somewhat when O<sub>3</sub> was also considered and

tended to be variably decreased when NO<sub>2</sub>, CO, and SO<sub>2</sub> were added to the analysis. These results argue that the effects are likely due to the particulate exposures; they cannot readily be explained by coexisting weather stresses or other pollutants.

The NMMAPS study (Samet 2000b) was one that used a flawed statistical software package. The investigators have reanalyzed their data using corrected settings for the software (Dominici, 2002a, Dominici 2002b). When the estimates for the 90 cities in the study were recalculated, the estimate changed from 0.41 percent increase in mortality for a 10 µg/m<sup>3</sup> increase in PM<sub>10</sub> to a 0.27 percent increase. There remained a strong positive association between acute exposure to PM<sub>10</sub> and mortality. Thus while the quantitative estimate is reduced, the major findings of the study did not change.

Studies of PM<sub>2.5</sub> also find associations with elevated mortality. The estimates for PM<sub>2.5</sub> generally are in the range of 2.0 to 8.5% increase in total deaths per 25 µg/m<sup>3</sup> increase in 24-hour PM<sub>2.5</sub> levels. The estimates for cardiovascular related mortality range from 3.0 to 7.0% per 25 µg/m<sup>3</sup> 24-hour PM<sub>2.5</sub>, and for respiratory mortality estimates range from 2.0 to 7.0% per 25 µg/m<sup>3</sup> 24-hour PM<sub>2.5</sub>.

Several studies have attempted to assess the relative importance of particles smaller than 2.5 µm and those between 2.5 µm and 10 µm (PM<sub>10-2.5</sub>). While some studies report that PM<sub>2.5</sub> levels are better predictors of mortality effects, others suggest that PM<sub>10-2.5</sub> is also important. Most of the studies found higher mortality associated with PM<sub>2.5</sub> levels than with PM<sub>10-2.5</sub>. For example, a study of six cities in the U.S. found that particulate matter less than 2.5 µm were associated with increased mortality, but that the larger particles were not. Other studies in Mexico City and Santiago, Chile reported that PM<sub>10-2.5</sub> was as important as PM<sub>2.5</sub>. Overall effects estimates for PM<sub>10-2.5</sub> fall in the range of 0.5 to 6.0 % excess mortality per 25 µg/m<sup>3</sup> 24-hour average.

The relative importance of both PM<sub>2.5</sub> and PM<sub>10-2.5</sub> may vary in different regions depending on the relative concentrations and components, which can also vary by season. More research is needed to better assess the relative effects of fine (PM<sub>2.5</sub>) and coarse (PM<sub>10-2.5</sub>) fractions of particulate matter on mortality.

A number of studies have evaluated the association between particulate matter exposure and indices of morbidity such as hospital admissions, emergency room visits or physician office visits for respiratory and cardiovascular diseases. The effects estimates are generally higher than the effects for mortality. The effects are associated with measures of PM<sub>10</sub> and PM<sub>2.5</sub>. Effects are also associated with PM<sub>10-2.5</sub>. Thus, it appears that when a relatively small number of people experience severe effects, larger



numbers experience milder effects, which may relate either to the coarse or to the fine fraction of airborne particulate matter.

In the NMMAPS study, hospital admissions for those 65 years or older were assessed in 14 cities. Hospital admissions for these individuals showed an increase of 6% for cardiovascular diseases and a 10% increase for respiratory disease admissions, per 50  $\mu\text{g}/\text{m}^3$  increase in PM10. The excess risk for cardiovascular disease ranges from 3-10% per 50  $\mu\text{g}/\text{m}^3$  PM10 and from 4-10% per 25  $\mu\text{g}/\text{m}^3$  PM2.5 or PM10-2.5.

Similarly, school absences, lost workdays and restricted activity days have also been used in some studies as indirect indicators of acute respiratory conditions. The results are suggestive of both immediate and delayed impact on these parameters following elevated particulate matter exposures. These observations are consistent with the hypothesis that increased susceptibility to infection follows particulate matter exposures.

Some studies have reported that short-term particulate matter exposure is associated with changes in lung function (lung capacity and breathing volume); upper respiratory symptoms (hoarseness and sore throat); and lower respiratory symptoms (increased sputum, chest pain and wheeze). The severity of these effects is widely varied and is dependent on the population studied, such as adults or children with and without asthma. Sensitive individuals, such as those with asthma or pre-existing respiratory disease, may have increased or aggravated symptoms associated with short-term particulate matter exposures. Several studies have followed the number of medical visits associated with pollutant exposures. A range of increases from 3% to 42% for medical visits for respiratory illnesses was found corresponding to a 50  $\mu\text{g}/\text{m}^3$  change in PM10. A limited number of studies also looked at levels of PM2.5 or PM10-2.5. The findings suggest that both the fine and coarse fractions may have associations with some respiratory symptoms.

The biological mechanisms by which particulate matter can produce health effects are being investigated in laboratory studies. Inflammatory responses in the respiratory system in humans and animals exposed to concentrated ambient particles have been measured. These include effects such as increases in neutrophils in the lungs. Other changes reported include increased release of cytokines and interleukins, chemicals released as part of the inflammatory process. The effects of particulate matter may be mediated in part through the production of reactive oxygen species during the inflammatory process. Recent reviews discuss mechanistic studies in more detail (Brunekreef, 2002; Brook, 2004).

## **Long-Term Exposure Effects**

While most studies have evaluated the acute effects, some studies specifically focused on evaluating the effects of chronic exposure to PM<sub>10</sub> and PM<sub>2.5</sub>. Studies have analyzed the mortality of adults living in different U.S. cities. After adjusting for important risk factors, these studies found a consistent positive association of deaths and exposure to particulate matter. A similar association was observable in both total number of deaths and deaths due to cardiorespiratory causes. A shortening of lifespan was also reported in these studies.

Significant associations for PM<sub>2.5</sub> for both total mortality and cardiorespiratory mortality were reported in a study using data from the American Cancer Society. A re-analysis of the data from this study confirmed the finding (Krewski, 2000). The Harvard Six Cities Study evaluated several size ranges of particulate matter and reported significant associations with PM<sub>15</sub>, PM<sub>2.5</sub>, sulfates, and non-sulfate particles, but not with coarse particles (PM<sub>15</sub> – PM<sub>2.5</sub>). An extension of the Harvard Six Cities Cohort confirmed the association of mortality with PM<sub>2.5</sub> levels (Laden, 2006). These studies provide evidence that the fine particles, as measured by PM<sub>2.5</sub>, may be more strongly associated with mortality effects from long-term particulate matter exposures than are coarse compounds.

A follow-up study of the American Cancer Society cohort confirmed and extended the findings in the initial study. The researchers estimated that, on average, a 10 $\mu$ g/m<sup>3</sup> increase in fine particulates was associated with approximately a 4% increase in total mortality, a 6% increase in cardiopulmonary mortality, and an 8% increase risk of lung cancer mortality (Pope, 2002). The magnitude of effects is larger in the long-term studies than in the short-term investigations. An analysis of the American Cancer Society Cohort from the Los Angeles area used a more detailed estimate of long-term PM<sub>2.5</sub> exposures and found that the risk of mortality was up to three times higher than estimated with the national cohort (Jerrett, 2005). These findings indicate that long-term exposures may be more important in terms of overall health effects.

Recent studies report evidence indicating that particulate matter exposure early in pregnancy may be associated with lowered birth weights (Bobak, 1999). Other studies from the U.S., the Czech Republic and Mexico City have reported that neonatal and early postnatal exposure to particulate matter may lead to increased infant mortality. A more recent study in Southern California found increased risks for infant deaths associated with exposures to particulates and other pollutants (Ritz, 2006). These results suggest that infants may be a subgroup affected by particulate matter exposures.

In addition, some long-term effect studies have reported an increased risk of mortality from lung cancer associated with particulate matter exposures. A study involving California Seventh Day Adventists (very few of whom smoke) has reported an association of lung cancer mortality with PM<sub>10</sub> levels. It is not clear from these studies

whether the association relates to causation of disease, or whether individuals with cancer are more susceptible to other effects of particles leading to the observed mortality association. A recent study that followed a large number of individuals living in the largest U.S. cities found elevated lung cancer risk associated with long term average PM<sub>2.5</sub> levels (Pope, 2002).

Several studies have assessed the effects of long-term particulate matter exposure on respiratory symptoms and lung function changes. Associations have been found with symptoms of chronic bronchitis and decreased lung function. A study of school children in 12 communities in Southern California showed significant association of particulate matter with bronchitis or phlegm in children with asthma. These effects were also associated with NO<sub>2</sub> and acid vapor levels.

A cohort of fourth graders from the Southern California communities was followed over a period of four years by the Children's Health Study. A lower rate of growth in lung function was found in children living in areas with higher levels of particulate pollution (Gauderman, 2000). Decreases in lung function growth were associated with PM<sub>10</sub>, PM<sub>2.5</sub>, PM<sub>10-2.5</sub>, acid vapor, and NO<sub>2</sub>. There was no association with ozone levels. The investigators were not able to identify independent effects of the pollutants, but noted that motor vehicle emissions are a major source of the pollutants.

A follow-up study on a second cohort of children confirmed the findings that decreased lung function growth was associated with particulates, nitric oxides, and elemental carbon levels (Gauderman, 2002). Elemental carbon is often used as a measure for diesel particulate. Additionally, children who moved to areas with less air pollution were found to regain some of the lung function growth rate (Avol, 2001). By the time the fourth graders graduated from high school, a significant number showed lower lung function. The risk of lower lung function was about five times higher in children with the highest PM<sub>2.5</sub> exposure when compared to the lowest exposure communities (Gauderman, 2004). These deficits are likely to persist since the children were at the end of their growth period.

Despite data gaps, the extensive body of epidemiological studies has both qualitative and quantitative consistency suggestive of causality. A considerable body of evidence from these studies suggests that ambient particulate matter, alone or in combination with other coexisting pollutants, is associated with significant increases in mortality and morbidity in a community.

In summary, the scientific literature indicates that an increased risk of mortality and morbidity is associated with particulate matter at ambient levels. The evidence for particulate matter effects is mostly derived from population studies with supportive evidence from clinical and animal studies. Although most of the effects are attributable to particulate matter, co-pollutant effects cannot be ruled out on the basis of existing studies. The difficulty of separating the effects may be due to the fact that particulate

levels co-vary with other combustion source pollutants. That is, the particle measurements serve as an index of overall exposure to combustion-related pollution, and some component(s) of combustion pollution other than particles might be at least partly responsible for the observed health effects.

## **ULTRAFINE PARTICLES**

As noted above, numerous studies have found association of particulate matter levels with adverse effects, including mortality, hospital admissions, and respiratory disease symptoms. The vast majority of these studies used particle mass of PM<sub>10</sub> or PM<sub>2.5</sub> as the measure of exposure. Some researchers have postulated, however, that ultrafine particles may be responsible for some of the observed associations of particulate matter and health outcomes (Oberdorster, et al, 1995; Seaton, et al, 1995). Ultrafine particles are generally classified of 0.1 μm and small diameter.

Several potential mechanisms have been brought forward to suggest that the ultrafine portion may be important in determining the toxicity of ambient particulates, some of which are discussed below.

For a given mass concentration, ultrafine particles have much higher numbers and surface area compared to larger particles. Particles can act as carriers for other adsorbed agents, such as trace metals and organic compounds; and the larger surface area may transport more of such toxic agents than larger particles.

Smaller particles can also be inhaled deep into the lungs. As much as 50% of 0.02 μm diameter particles are estimated to be deposited in the alveolar region of the lung.

## **CARBON MONOXIDE**

The high affinity of carbon monoxide (CO) to bond with oxygen-carrying proteins (hemoglobin and myoglobin) results in reduced oxygen supply in the bloodstream of exposed individuals. The reduced oxygen supply is responsible for the toxic effects of CO which are typically manifested in the oxygen-sensitive organ systems. The effects have been studied in controlled laboratory environments involving exposure of humans and animals to CO, as well as in population-based studies of ambient CO exposure effects. People with deficient blood supply to the heart (ischemic heart disease) are known to be susceptible to the effects of CO. Protection of this group is the basis of the existing National Ambient Air Quality Standards for CO at 35 ppm for one hour and 9 ppm averaged over eight hours. The health effects of ambient CO have been recently reviewed (U.S. EPA, 2000).

Inhaled CO has no known direct toxic effect on lungs but rather exerts its effects by interfering with oxygen transport through the formation of carboxyhemoglobin (COHb, a chemical complex of CO and hemoglobin). Exposure to CO is often evaluated in

terms of COHb levels in blood measured as percentage of total hemoglobin bound to CO. COHb levels in non-smokers range between 0.3 and 0.7% and 5 to 10% in smokers. COHb levels in excess of 1.5% in a significant proportion of urban nonsmoking populations can be considered as evidence of widespread exposure to environmental CO.

Under controlled laboratory conditions, healthy subjects exposed to CO sufficient to result in 5% COHb levels exhibited reduced duration of maximal exercise performance and consumption of oxygen. Studies involving subjects with coronary artery disease who engaged in exercise during CO exposures have shown that COHb levels as low as 2.4% can lead to earlier onset of electrocardiograph changes indicative of deficiency of oxygen supply to the heart. Other effects include an earlier onset of chest pain, an increase in the duration of chest pain, and a decrease in oxygen consumption.

Animal studies associated with long-term exposure to CO resulting in COHb levels that are equivalent to those observed in smokers have shown indication of reduction in birth weight and impaired neurobehavior in the offspring of exposed animals.

Recent epidemiological studies conducted in Southern California have indicated an association with CO exposure during pregnancy to increases in pre-term births. (Ritz, 2000). However, the results were not consistent in different areas studied. The increase in the pre-term births was also associated with PM10 levels. Another study found increased risks for cardiac related birth defects with carbon monoxide exposure in the second month of pregnancy (Ritz, 2002). Further study is needed to confirm these observations.

## **NITROGEN DIOXIDE**

The California EPA is currently reviewing the health effects of nitrogen dioxide (Cal EPA, 2006). Evidence for low-level nitrogen dioxide (NO<sub>2</sub>) exposure effects is derived from laboratory studies of asthmatics and from epidemiological studies. Additional supportive evidence is derived from animal studies.

Epidemiological studies using the presence of an unvented gas stove as a surrogate for indoor NO<sub>2</sub> exposures suggest an increased incidence of respiratory infections or symptoms in children.

Recent studies related to outdoor exposure have found health effects associated with ambient NO<sub>2</sub> levels, including respiratory symptoms, respiratory illness, decreased lung function, increased emergency room visits for asthma, and cardiopulmonary mortality. However, since NO<sub>2</sub> exposure generally occurs in the presence of other pollutants, such as particulate matter, these studies are often unable to determine the specific role of NO<sub>2</sub> in causing effects.

The Children's Health Study in Southern California found associations of air pollution, including NO<sub>2</sub>, PM10, and PM2.5, with respiratory symptoms in asthmatics (McConnell, 1999). Particles and NO<sub>2</sub> were correlated, and effects of individual

pollutants could not be discerned. A subsequent analysis indicated a stronger role for NO<sub>2</sub> (McConnell, 2002).

Ambient levels of NO<sub>2</sub> were also associated with a decrease in lung function growth in a group of children followed for eight years. In addition to NO<sub>2</sub>, the decreased growth was also associated with particulate matter and airborne acids. The study authors postulated that these may be a measure of a package of pollutants from traffic sources. (Gauderman, 2004).

Results from controlled exposure studies of asthmatics demonstrate an increase in the tendency of airways to contract in response to a chemical stimulus (bronchial reactivity). Effects were observed with an exposure to 0.3 ppm NO<sub>2</sub> for a period ranging from 30 minutes to 3 hours. A similar response is reported in some studies with healthy subjects at higher levels of exposure (1.5 - 2.0 ppm). Mixed results have been reported when people with chronic obstructive lung disease are exposed to low levels of NO<sub>2</sub>.

Short-term controlled studies of animals exposed to NO<sub>2</sub> over a period of several hours indicate cellular changes associated with allergic and inflammatory response and interference with detoxification processes in the liver. In some animal studies the severity of the lung structural damage observed after relatively high levels of short-term ozone exposure is observed to increase when animals are exposed to a combination of ozone and NO<sub>2</sub>.

In animals, longer-term (3-6 months) repeated exposures at 0.25 ppm appear to decrease one of the essential cell-types (T-cells) of the immune system. Non-specific changes in cells involved in maintaining immune functions (cytotoxic T cells and natural killer cells) have been observed in humans after repeated exposure (4-6 days) to >0.6 ppm of NO<sub>2</sub> (20 min. - 2 hours). All these changes collectively support the observation reported both in population and animal studies of increased susceptibility to infections, as a result of NO<sub>2</sub> exposure.

## **SULFUR DIOXIDE**

Controlled laboratory studies involving human volunteers have clearly identified asthmatics as the most sensitive group to the effects of ambient sulfur dioxide (SO<sub>2</sub>) exposures. Healthy subjects have failed to demonstrate any short-term respiratory functional changes at exposure levels up to 1.0 ppm over 1-3 hours.

In asthmatics, brief exposure (10 minutes) to SO<sub>2</sub> at levels as low as 0.25 ppm can result in significant alteration of lung function, such as increases in airway resistance and decreases in breathing capacity. In some, the exposure can result in severe symptoms necessitating the use of medication for relief. The response to SO<sub>2</sub> inhalation is observable within 2 minutes of exposure, increases further with continuing exposure up to 5 minutes then remains relatively steady as exposure continues. SO<sub>2</sub> exposure is generally not associated with any delayed reactions or repetitive asthmatic attacks.

No significant changes have been reported from studies, which have evaluated the effects of exposure to co-pollutants (ozone or nitrogen dioxide), prior to or in conjunction with SO<sub>2</sub> exposure.

Animal studies have shown that despite SO<sub>2</sub> being a respiratory irritant, it does not cause substantial acute or chronic toxicity in animals exposed at ambient concentrations. However, relatively high exposures (10 ppm of SO<sub>2</sub> for 72 hours) in mice can lead to tissue damage, fluid accumulation and sloughing of respiratory lining. Sensitization to allergies is observable in guinea pigs repeatedly exposed to high levels (72 ppm) of SO<sub>2</sub>. This effect needs further evaluation in clinical and population studies to identify any chronic exposure impact on both asthmatic incidence and attacks in a population.

Some epidemiological studies indicate that the mortality and morbidity effects associated with the fine fraction of particles show a similar association with ambient SO<sub>2</sub> levels. In these studies, efforts to separate the effects of SO<sub>2</sub> from fine particles have not been successful. Thus, it is not clear whether the two pollutants act synergistically, or whether being generated from similar combustion sources they represent the same pollution index for the observed effects.

## **SULFATES**

Based on a level determined necessary to protect the most sensitive individuals, the California Air Resources Board in 1976 adopted a standard of 25 µg/m<sup>3</sup> (24-hour average) for sulfates.

In recent years, a vast majority of effects (mortality and morbidity) associated with fine particles (PM<sub>2.5</sub>) and sulfur dioxide have shown a similar association with ambient sulfate levels in some population studies. The efforts to fully separate the effects of sulfates from other coexisting pollutants have not been successful. This may be due to the fact that these pollutants covary under ambient conditions, having been emitted from common sources; and the effects observed may be due to the combination of pollutants, rather than a single pollutant.

A clinical study involving exposure of human subjects to sulfuric acid aerosol indicated that adolescent asthmatics may be a susceptible population subgroup with some changes in lung function observed with exposures below 100 µg/m<sup>3</sup>. In general, however, laboratory exposures of human volunteers to sulfates at or near ambient levels have not found significant changes in lung function.

Results from animal studies involving exposures to sulfuric acid aerosol, ammonium bisulfate and ammonium sulfate indicate that acidic particles (former two) are more toxic than non-acidic particles (latter). In addition, the severity or magnitude of both mortality and morbidity effects is relatively higher in population studies of the eastern United States and Canada where sulfate concentrations are higher than for those

observed in the western United States. Mixed results have been reported from studies which attempted to ascertain the role of acidity in determining the observed toxicity.

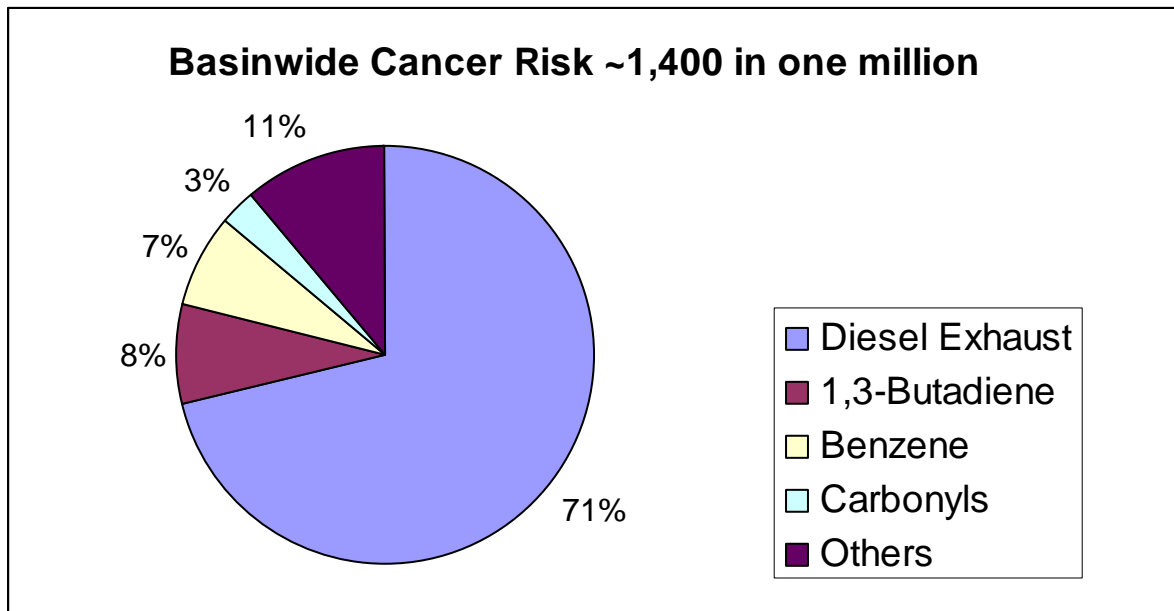
## **TOXIC AIR CONTAMINANTS**

Toxic air contaminants are pollutants for which there generally are no ambient air quality standards. Under California's Air Toxics Program, CARB staff and OEHHA assess the health effects of substances that may pose a risk of adverse health effects. These effects are usually an increased risk for cancer or adverse birth outcome. After review by the state Scientific Review Panel, the CARB holds a public hearing on whether to formally list substances that may pose a significant risk to public health as a Toxic Air Contaminant.

CARB and OEHHA also establish potency factors for air toxics that are carcinogenic. The potency factors can be used to estimate the additional cancer risk from ambient levels of toxics. This estimate represents the chance of contracting cancer in an individual over a lifetime exposure to a given level of an air toxic and is usually expressed in terms of additional cancer cases per million people exposed.

The SCAQMD conducted a study on the ambient concentrations and estimated the potential health risks from air toxics (SCAQMD, 2000). A one year monitoring program was undertaken at 12 sites throughout the SCAB. Over 30 substances were measured, and annual average levels were calculated. The results showed that the overall risk for excess cancer from a lifetime exposure to ambient levels of air toxics was about 1,400 in a million. The largest contributor to this risk was diesel exhaust, accounting for 71% of the air toxics risk. A breakdown of the major contributors to the air toxics risk is shown in the following graph.





**FIGURE 1**

Major pollutants contributing to Air Toxics Cancer Risk in the South Coast Air Basin

For non-cancer health effects, OEHHA has developed acute and chronic Reference Exposure Levels (RELs). RELs are concentrations in the air below which adverse health effects are not likely to occur. Acute RELs refer to short-term exposures, generally of one-hour duration. Chronic RELs refer to long-term exposures of several years. The ratio of ambient concentration to the appropriate REL can be used to calculate a Hazard Index. A Hazard Index of less than one would not be expected to result in adverse effects.

The key air toxics contributing to risk from mobile and stationary sources are listed below.

**TABLE 3**

Key Air Toxic Air Contaminants in the SCAB

Mobile Sources	Stationary Sources
Acetaldehyde	Hexavalent Chromium
Benzene	Methylene Chloride
1,3 Butadiene	Nickel
Diesel Exhaust	Perchloroethylene
Formaldehyde	Trichloroethylene

## **CONCLUSION**

The vast body of scientific evidence shows that the adverse impacts of air pollution in human and animal health are clear. A considerable number of population-based and laboratory studies have established a link between increased morbidity and in some instances, earlier mortality and air pollution.

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**ATTACHMENT 1**

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**COMMENTS RECEIVED ON DRAFT APPENDIX I FROM SCAQMD ADVISORY COUNCIL**

The letter requesting comments and a copy of comments received follow.

Staff responses to comments are in Attachment 2.





*Jean*

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STEPHEN R. MAGUIN  
Chief Engineer and General Manager

March 27, 2007

South Coast Air Quality Management District  
21865 E. Copley Drive  
Diamond bar, CA 91765-4182

Attention: Elaine Chang, DrPH



Comments on Appendix I  
Draft 2007 Air Quality Management Plan

Dear Elaine:

Thank you for the opportunity to represent LACSD and the Home Rule Advisory Group (HRAG) in submitting comments on Appendix I of the 2007 Draft Air Quality Management Plan. Speaking on behalf of the HRAG, while the AQMP has varying degrees of significant impacts on all the participants around the table, we all recognize the very considerable effort that is involved in developing an AQMP and applaud your efforts. We have the following comments on Appendix I and the health aspects of the draft 2007 AQMP:

1. While we believe Dr. Ospital has done a very good job assembling the documentation in support of the health effects associated with criteria air pollution, there was little or no explanation within the appendix or the plan as to how the plan was going to better things. There is, of course, a tacit understanding that lower levels of pollution should reduce health effects. Perhaps a few paragraphs could be added to the document to this effect. Perhaps enhanced health effects might be used as an additional consideration in the ranking of control measures so that the most beneficial measures health-wise are implemented first.
2. We continue to be confused about the focus on health effects of toxic air contaminants. On Page I-20 of the Appendix, the basin-wide cancer risk is reported to be 1400 in a million, largely the impact of Diesel particulate matter and other mobile source emissions. Page 3.1-54 of the Draft AQMP Program EIR also says that exposure to environmental pollution only accounts for two percent of cancer cases. But then we also looked at Dr. Thomas Mack's 2004 work Cancers in the Urban Development<sup>1</sup>, a detailed analysis of which was presented to the Mobile Source Committee by Dr. Ospital in 2004. In the last paragraph on Page 7 of the 645 page tome, in a section entitled *Environmental and Other Causes of Cancer* the author states, "...no local increase in

<sup>1</sup> Cancers in the Urban Environment: Patterns of Malignant Disease in Los Angeles County and Its Neighborhoods; Thomas Mack, Dept. of Preventive Medicine, Keck School of Medicine, Norris Comprehensive Cancer Center, University of Southern California; Elsevier Academic Press, 2004.

Etaine Chang

- 2 -

March 27, 2007

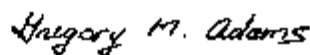
cancer due to pollution has yet been clearly identified in the United States. Even such highly publicized sites of pollution as the Love Canal, Three Mile Island and those popularized in the movies *Erin Brockovich* and *A Civil Action* did not produce clear evidence of a cancer excess, although each of these examples of irresponsible industrial contamination represented a clear potential danger to local residents and may have produced other medical problems."

In the very last sentence of that same book on Page 645, Dr. Mack also states, "As of this writing, no evidence of a malignancy caused by a strictly environmental carcinogen has yet been confirmed." We believe some clarification should be considered in the AQMP that acute and chronic effects of toxic air pollution should take priority, as far as regulations are concerned, over carcinogenic health effects.

3. It is also unclear how readings at air quality monitoring stations correlate with AQMP strategy. We are aware of SCAQMD efforts at the Rubidoux station, for instance, to improve the local road surfaces to reduce PM emissions, that hopefully will result in reduced monitor readings. We believe that a check should be done of all the District monitoring stations to confirm that they are not impacted by unusual site conditions and that they are reading truly representative air.
4. We believe that some analysis of indoor air quality and PM2.5 is appropriate at this time. A significant portion of human exposures to PM2.5 occurs indoors, where people spend ~85-90% of their time.<sup>2</sup>

We thank you for this opportunity to comment.

Yours very truly,  
S. R. Maguin



Gregory M. Adams  
Assistant Departmental Engineer  
Air Quality Engineering  
Technical Services Department

GMA:ch

cc: Jane Cemej  
Barry Wallerstein  
Jean Ospital

<sup>2</sup> *Journal of the Air and Waste Management Association*, March 2007, *Indoor/Outdoor Relationships, Trends, and Carbonaceous Content of Fine Particulate Matter in Retirement Homes of the Los Angeles Basin*, p.366.

March 25, 2007

Dr. Elaine Chang  
Deputy Executive Officers of Planning,  
Rule Development and Area Service

Dear Dr. Chang,

It was nice talking with you and thank you for allowing me an extension on my comments for the AQMP - Health Effects of Air Pollutions- Appendix I document.

The overall documentation is excellent, and the following recommendations are not corrections but simply suggestions.

**OZONE- I-2:** Since ozone is such a strong oxidizing agent, perhaps a short explanation of how oxidizing agents affect biological tissues could be added.

**PARTICULATE MATTER-I-11:** The percentage change in health indicator for PM-10 is well documented in Table 2, page I-7-12. However, there is no percentage change for PM-2.5 health indicators. Does that imply that biological mechanisms, mortality and morbidity data for both particulate matter are the same, despite their variations in size and sources? If they are the same, that should be stated. If not, a second table for percentage change for PM 2.5 health indicators should be added.

**ULTRAFINE PARTICLES-I-15:** There are some reports indicating that the ultrafine particles might be embedded in cellular mitochondria. If that is correct, it would mean ultrafine particles are ubiquitous in every cell, therefore affecting cellular ATP production. That could explain why particulate matter might exacerbate diabetic conditions.

**SULFUR DIOXIDE and SULFATES I-18-19:** Perhaps a short definition of the differences between sulfur dioxide and sulfates could be included.

Respectfully Submitted,

Sam Huang, Ph.D  
Member -SCAQMD Advisory Council  
7458 Whitegate Ave.  
Riverside, CA 92506



**South Coast  
Air Quality Management District**

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*Office of the Executive Officer*  
*Barry R. Wallerstein, D.Env.*  
909 396 2100, fax 909 396 3340

February 28, 2007

Mr. Greg Adams  
Los Angeles County Sanitation District  
1955 Workman Mill Road  
Whittier, CA 90607

Re: SCAQMD Advisory Council

Dear Mr. Adams:

I would like to congratulate and welcome you as a member of the South Coast Air Quality Management District Advisory Council. I have attached a copy of the council's policies as well as a copy of the current roster.

Attached also for your review is Appendix I of Draft 2007 Air Quality Management Plan (AQMP)—Health Effects of Air Pollutants. This document presents a summary of scientific findings on the health effects of ambient air pollutants. The California Health and Safety Code Section 40471(b) requires that the South Coast Air Quality Management District Board prepare a report on the health impacts of particulate matter in the South Coast Air Basin in conjunction with the preparation of the AQMP. This document was prepared to fulfill that requirement. The Health and Safety Code also directs that the report be submitted to the Advisory Council for review and comment.

Please review the attached document and provide your comments by March 21, 2007.

2

Thank you again for agreeing to serve as a member of the Advisory Council. Should you have any questions on this matter, please do not hesitate to contact Elaine Chang, Deputy Executive Officer of Planning, Rule Development & Area Sources, at (909) 396-3186.

Sincerely,



Barry R. Wallerstein, D.Env.  
Executive Officer

BRW/drw  
Enclosures

cc: Home Rule Advisory Group  
(w/o enclosures)

From: Office of the Executive Officer	Date: 3/28/07
To: Elaine Cheung	
Cc: 0	BRW
Prepared by:	For your info: <input checked="" type="checkbox"/> heading <input checked="" type="checkbox"/>
Approved for:	signature, cc:

Emily D.P. Nelson, D.Env.  
Health and Environmental Risk Consultant  
P.O. Box 3703  
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760-333-1776

March 26, 2007

Dr. Barry Wallerstein  
Executive Officer  
South Coast Air Quality Management District  
21865 Copley Drive  
Diamond Bar, CA 91765-4178

Re: Appendix I Review  
Draft 2007 Air Quality Management Plan

Dear Barry,

Thank you for the opportunity to serve as a member of the South Coast Air Quality Management District Advisory Council. I look forward to making a positive contribution.

I have reviewed Appendix I of the Draft 2007 AQMP Health Effects of Air Pollutants. Since the document's summary is substantially taken from prior reviews, it was an easy review for me. The relevant studies have been discussed or referred to in a concise yet complete way for these purposes. I did note that two studies referred to in the Ultrafine Particles discussion on page I-15 (Oberdorster, et al, 1995 and Seaton, et al, 1995) are not included in the references section at the end of the appendix. I have spoken with Dr. Jean Ospital about this today.

I am sorry for the delay in my response. I was in Washington, DC last week and did not realize this review had not been completed.

Sincerely,



Emily Nelson, D.Env.

cc: Supervisor S. Roy Wilson

**ATTACHMENT 2**

**STAFF RESPONSES TO COMMENTS RECEIVED**

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Comment:

Citations missing in References section.

Response:

The missing citations are below.

Oberdorster G, et al. 1995. "Association of Particulate Air Pollution and Acute Mortality: Involvement of Ultra-Fine Particles." *Inhalation Toxicol* 7:111-124.

Seaton A, et al. 1995. "Particulate Air Pollution and Acute Health Effects." *Lancet* 345:176-178.

Comment:

Include an explanation of how oxidizing agents affect biological tissue.

Response:

Oxidants such as ozone can readily react with biochemicals in tissues to alter their chemical structure and affect their biochemical functioning.

Comment:

Are percent changes in health indicators for PM<sub>2.5</sub> the same as for PM<sub>10</sub>? Include a table for percentage change for PM<sub>2.5</sub> indicators as was done for PM<sub>2.5</sub>.

Response:

The table for PM<sub>10</sub> was used to provide a brief summary of information related to daily changes in PM levels with various health indicators, and was taken from a previous review paper. The discussion for PM<sub>2.5</sub> associated outcomes includes a brief description of some of the more recent studies of health effects, which does include percentage changes associated with changes in ambient exposures. The discussion shows that the relative changes associated with PM<sub>2.5</sub> levels are not the same as those with PM<sub>10</sub>. The discussion also points out that some studies indicate the effects from PM<sub>10</sub> exposures may be attributed to the PM<sub>2.5</sub> component, whereas other studies indicate that the fraction of PM<sub>10</sub> larger than 2.5 μm diameter also contribute. The relative contribution of the different fractions of PM<sub>10</sub> to health outcomes is an ongoing area of research.



Comment:

Ultrafine particles may affect cellular ATP production, and this could explain why particulate matter might exacerbate diabetic conditions.

Response:

Studies have indeed shown that ultrafine particles can penetrate into cell mitochondria and result in cell death. The mechanism is thought to include oxidative injury to cellular components. While there are studies that indicate individuals with diabetes may be more sensitive to the effects of air pollutants, staff opinion is that there are not sufficient data available to determine whether particulate exposures exacerbate diabetic conditions.

Comment:

Include a definition of the differences between sulfur dioxide and sulfates.

Response:

Sulfur dioxide (SO<sub>2</sub>) occurs as a gas in the atmosphere, whereas sulfates (referring to the ion SO<sub>4</sub><sup>-2</sup>) are generally found as a component of particulate matter.

Comment:

Add a discussion on how the AQMP would reduce health effects.

Response:

Staff assessment of the benefits of implementing the AQMP and attaining the ambient air quality standards is included in the Socioeconomic Report.

Comment:

Some clarification should be considered in the AQMP that acute and chronic effects of toxic air pollutants should take priority, as far as regulations are concerned, over carcinogenic effects.

Response:

Staff position is that all adverse effects are important.

Comment:

A check should be done of all the District monitoring stations to confirm that they are not impacted by unusual site conditions.

Response:

This is beyond the scope of Appendix I. The air quality monitoring network stations are sited in conformance with federal and state guidelines to be at locations representative of regional air quality.

Comment:

An analysis of indoor air quality and PM<sub>2.5</sub> should be included.

Response:

There are few studies on the health effects on indoor PM<sub>2.5</sub> exposures. The study cited by the commenter did not provide information on health effects.

