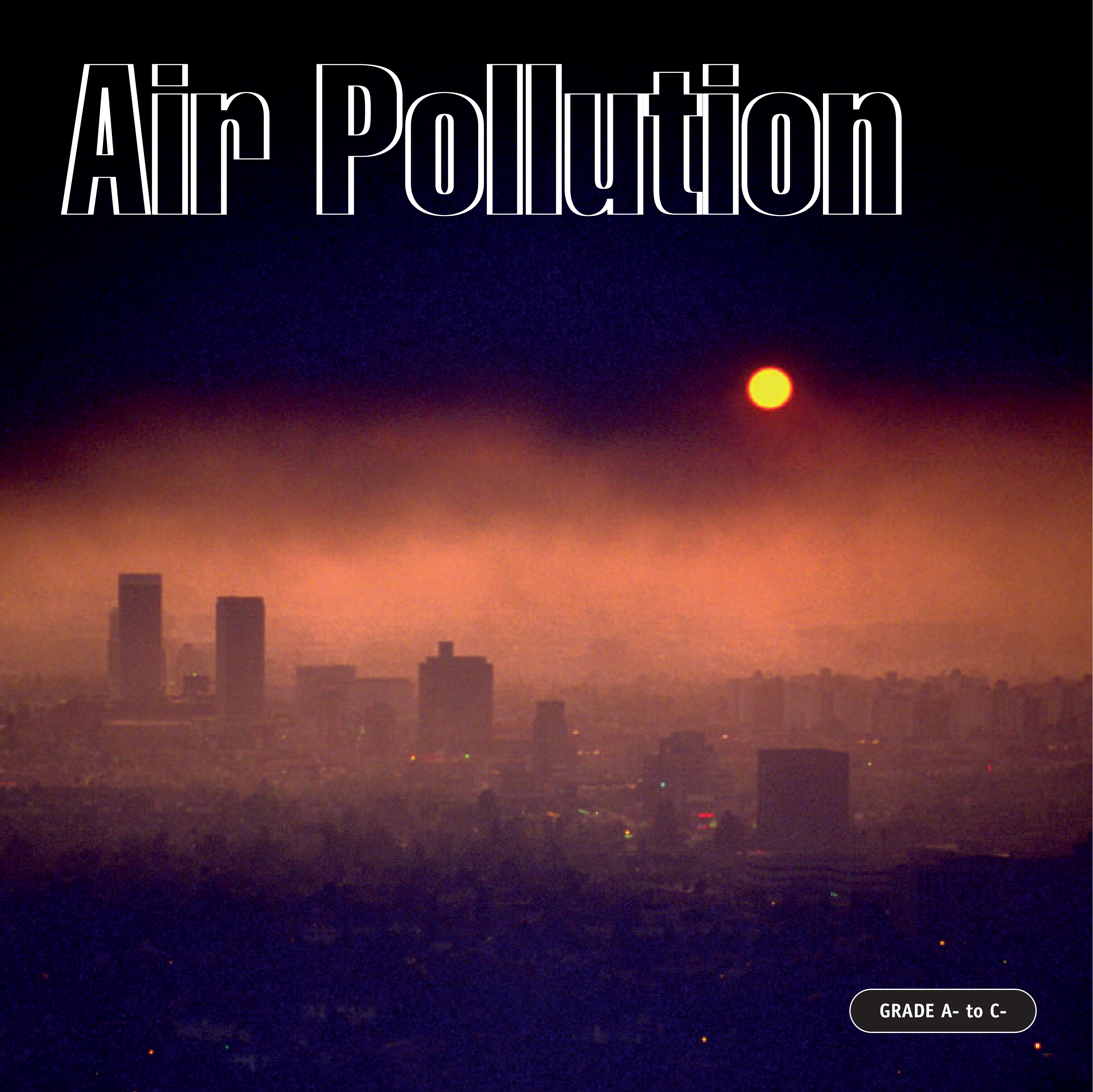
Air Pollution



GRADE A- to C-

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INTRODUCTION

The 1998 Report Card reviewed the past effectiveness and future prospects of air pollution policy in the region. Policies up to that time, which resulted in spectacular improvements in air quality, were awarded a grade of A. Looking forward, a grade of C reflected the lack of effective control strategies in the pipeline, and was accompanied by the prediction that air quality would cease to improve, and indeed might start to deteriorate again. In RC 2000 we reviewed the status of air toxics in Southern California, and in RC 2001 the role of particulate matter in the region was described. Here, we revisit what remains one of the most serious environmental quality issues facing Southern California. We review how the quality of the air we breathe has changed since 1998, including the current status of air pollution, the effectiveness of long term emissions control programs, and prospects for future air quality in the region.

OZONE, PARTICULATE MATTER, CARBON MONOXIDE AND AIR TOXICS

Southern California has long been famous for smog. By the end of World War II, the clean air and views of the mountains that drew millions to Southern California were replaced by a noxious haze that we now refer to as photochemical "smog." This aspect of Southern California living has been the target of the nation's jabs for decades, but in recent years the tremendous progress in cleaning up the air seemed to be turning the region's image around. Houston registered more days above the ozone standard than Los Angeles for two years running in 1999 and 2000, and the Central Valley of California appeared on the verge of joining Southern California by becoming the second region in the nation with an air quality problem designated by the US EPA as "extreme." In 2001, however, the Los Angeles area regained the ozone title, and in 2003 the ozone levels became strikingly worse than in the preceding four years. Instead of creeping down toward the federal standards for ozone, levels appear to have bottomed out and threaten to increase.

The seriousness of the air pollution problem in the South Coast Air Basin (SoCAB, consisting of Los Angeles, Orange and parts of Riverside and San Bernardino counties) was the primary force behind the granting in the early 1970's of special regulatory status to the state of California to control sources of air pollution. California has used this special status with great success to demand tighter emissions standards from automobile manufacturers than those required by the federal government, as well as numerous other special formulations, from lower volatility paints to less toxic gasoline. The results of the regulations made at the state, local, and national levels have been nothing short of spectacular. For example, the peak ozone concentration in the SoCAB decreased from a high of 680 parts-per-billion (ppb) in 1955 to a low of 169 ppb in 2002 (but then increased to 216 ppb in 2003).

Air pollution has many components. The best known is ozone, a colorless gas that restricts breathing, exacerbates asthma, and limits plant growth. The other prominent components are particulate matter and air toxics, which may promote respiratory disease, cancer, birth or developmental defects or mortality. Particulates are tiny liquid or solid particles 10 microns or smaller—about a thousand 10-micron particles would fit in a grain of fine sand. Air toxics are airborne chemicals, such as dioxins, mercury and perchloroetheylene, which are individually likely to induce specific diseases. In earlier years, several additional air pollutants also posed a significant threat to public health, but these have been successfully controlled in the region. In the last few years, carbon

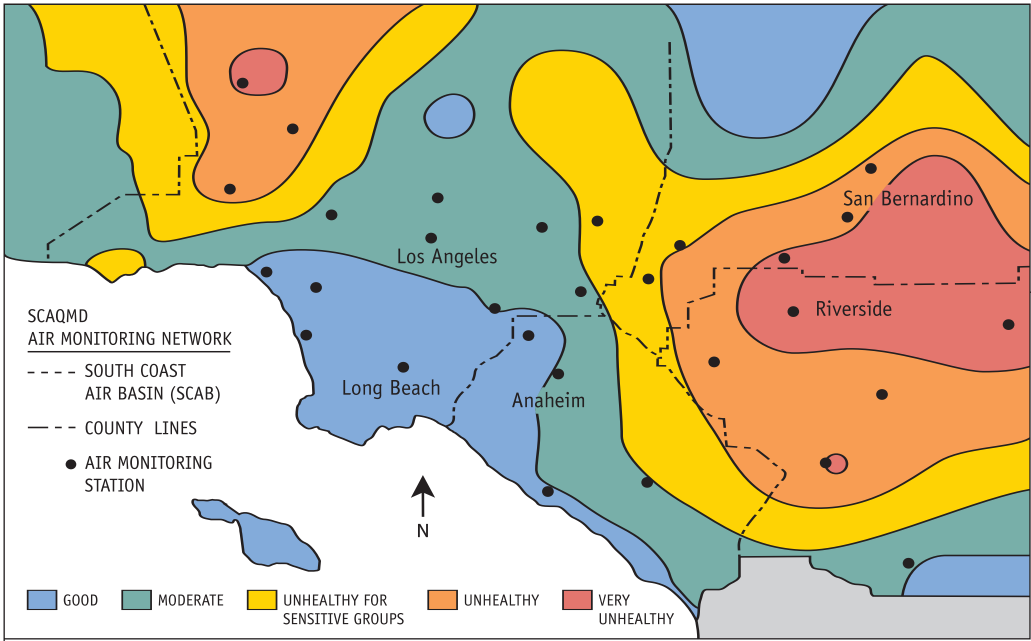

Figure 1: The geographical distribution of ozone levels on July 10, 2003, a typical high ozone day in Southern California. These levels were recorded at 4:40 in the afternoon, about when ozone reached its maximum levels that day.

monoxide has been reduced sufficiently to meet the federal standard, joining the ranks of sulfur dioxide, nitrogen dioxide, and lead: air pollution problems that have been solved in Southern California.

Most air toxics and carbon monoxide are released directly from sources, while much of the particulate matter and essentially all ozone form in the atmosphere from the reactions of volatile organic compounds (VOCs) and oxides of nitrogen (NO_x), in the presence of bright sunlight. Air pollution is almost inevitable in the Los Angeles area because the local topography, persistent sea breezes, and the high-pressure system that resides in the area so much of the year work together to trap pollutants that react photochemically with sunlight to make smog.

Ozone Concern about air pollution by many long-term residents of Southern California has dropped over recent decades. Over the long term, peak concentrations of ozone and related gaseous pollutants have subsided, along with the most noticeable short-term health effects of air pollution. Gone are the days of coughing, shortness of breath, and stinging eyes that once accompanied smog alerts. The federal 1-hour standard for ozone is now exceeded 35-60 days each year, down from over 200 days in the 1970s. However, in the summer of 2003, O_3 made headlines again as the air quality noticeably declined and the SoCAB experienced its first stage 1 smog alert since 1998.

Very high ozone levels form mostly in the central and eastern parts of SoCAB, and in the Santa Clarita and San Fernando valleys (Figure 1). Ozone requires NO_x, VOCs, and the right weather to form. Since overall emissions of NO_x and VOCs trend over periods of a few years to decades, much of the short term variability in ozone is due to weather: some years are hotter and sunnier, with more stagnant air conditions that tend to trap air near the surface. Of recent years, the weather has been particularly conducive to forming ozone in 1998 and 2003, while 1999, 2000 and 2001 provided cleaner than average conditions. 2002 was closer to average, but it also fell on the clean side. This trend is borne out in Figure 2, which shows the maximum 1-hour averaged ozone concentration for each year. Ozone was basically flat for 1999-2001, up slightly in 2002, and much higher in 2003. If we correct for the meteorology in those years, the overall trend in the ozone is approximately flat for the last 5 years.

As the air quality improved through the 1990s, so did our understanding of what makes people ill. Health effects research in the 1980's and early 1990's led to a new ozone standard averaged over a longer time period (8 hours), but at a lower concentration. The eight-hour standard was put in place in 1997, but was challenged in court and not made into a regulation until 2002.

Particulate matter standards are exceeded throughout the year, and throughout the basin, from the coastal cities to the mountain slopes, and the current annually averaged PM2.5 loading in the region is about 40% higher than the federal standard.

Healthy individuals typically do not notice being exposed to lower concentrations of ozone over longer time periods, but such exposure is a better indicator of adverse health impacts.

Nearly every day in summer, or about 110 days per year, a portion of the South Coast Air Basin exceeds the new 8-hour standard (Figure 3). The Los Angeles area is not required to meet the 8-hour standard until it has met the 1-hour standard, for which the current regulatory target is 2010. In general it is much easier to reduce peak concentrations than it is to reduce concentrations over longer time periods, evidence for which can be seen by comparing Figures 2 and 3. While we may one day meet the federal 1-hour standard (although not by 2010) meeting the 8-hour standard will be far more difficult.

Particles During the summer smog season, and even during winter, most residents can still see air pollution, as they look across distances of a few miles or more. The tiny particles that affect health also scatter light, obscuring vistas and giving the air a whitish or grayish hazy appearance. Particles are believed to adversely affect health in several ways. Some particles deposit largely in the upper respiratory tract and promote inflammation that exacerbates asthma and other acute respiratory illnesses. Other particles deposit deep in the lung, where the chemicals they carry can initiate cancers or enter the blood stream and promote inflammation of the circulatory system, increasing incidences of stroke and heart attack. Thus, particles not only affect respiratory health but can also induce mortality.

Like ozone, the federal standard for particulate matter has been changed recently, shifting the focus from particles 10 microns and smaller to particles 2.5 microns and smaller (PM2.5). PM2.5 requires different strategies to control because while much of PM10 is generated by mechanical grinding (e.g., as cars move over roadways), PM2.5 comes primarily from combustion sources (including gasoline and diesel engines) and from reactions in the atmosphere that convert NO_x and VOCs to particulate matter. As in the case of the ozone standard, the SoCAB is required to meet the older PM10 standard first, by 2006, and the new PM2.5 standard after that date. PM10 has been essentially flat over the last decade. Widespread routine PM2.5 data collection only began in 1999. Like ozone and PM10, during 1999-2002 there is no discernable trend in PM2.5, either up or down, when we correct for meteorology. The PM2.5 standard is exceeded throughout the year, and throughout the basin, from the coastal cities to the mountain slopes, and the current annually averaged PM2.5 loading in SoCAB is about 40% higher than the federal standard (Figure 4).

Air Toxics The air toxic of greatest concern is diesel exhaust, which is a mixture of toxic gases and particles. Reductions in exposure to diesel exhaust have been slow, decreasing by at most 30% from 1990 to 2000. Benzene and butadiene, released by cars and trucks, follow diesel exhaust in toxicity ranking. These were decreased substantially in the early to mid-1990s primarily with the introduction of Phase II reformulated gasoline, but lost their downward momentum in the latter half of the decade. Other airborne toxics such as hexavalent chromium are serious problems local to their specialized sources, but present little threat to the health of the SoCAB population overall.

AIR POLLUTION AND HEALTH

While healthy individuals are now able to more or less ignore air pollution, sensitive residents of Southern California still suffer from the worst air in the nation. Children who

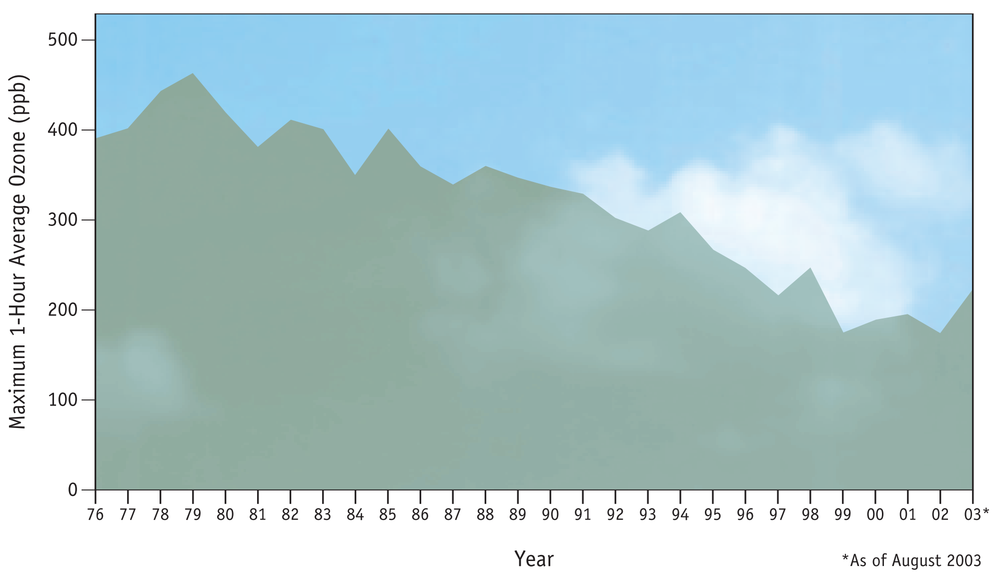

Figure 2: Maximum 1-hr average ozone concentrations in the southern California air basin from 1976-2003, in parts per billion (ppb). The 2003 data includes measurements up to August 31, only about two-thirds of the way through the smog season.

Dramatic reductions of VOC and NO_X emissions through 1998 rank as one of our great environmental achievements...

grow up in the more polluted parts of Southern California have lower lung function and more severe asthma. Estimates of premature deaths from air pollution in the SoCAB range from 1500 to 9000 per year, and air toxics are expected to generate several thousand additional excess cancers. While ozone impacts much of the air basin, it is worst in the eastern portions and inland valleys. Particle levels are elevated throughout SoCAB, and toxic diesel exhaust is particularly high near air and shipping ports, and along freeways and heavily traveled surface streets. Air pollution affects everyone, but lower income residents often have higher exposures by virtue of where they live, work, study or play.

CONTROLLING THE SOURCES OF AIR POLLUTION

Air quality is improved by controlling the sources of pollution. Most human activities result in emissions of some magnitude and type, whether VOCs, NO_x, particles, or toxics. Here we will address several of the major sources of air pollution, including gasoline and diesel powered vehicles and consumer products. The regulatory authority for the various sources of pollutants is divided as follows: The USEPA covers interstate transportation sources such as airplanes, trains and ships; the state of California has jurisdiction over autos, light trucks, buses and consumer products; and the South Coast Air Quality Management District (SCAQMD) regulates stationary sources such as local industries and power plants and other sources such as construction activities. Finally, city and county governments have primary influence on air pollution through the transportation, land-use and development policies they establish. Policies regarding sprawl, traffic congestion, and alternative transportation such as light rail largely predetermine the quantity of vehicle use, the largest source of pollutants.

In order to control air pollution, it is necessary to know how much of which pollutants are emitted from which sources, and to a lesser degree, when. This information is compiled into an emissions inventory, which is a crucial, but by its nature flawed, tool for planners. Compiling emissions inventories is very difficult and labor intensive due to the sheer number of sources and tremendous variability within classes of, or even single, emission sources. For example, emissions from paint cans and household solvents can vary by more than a factor of 10 depending on how tightly they are capped and the temperature at which they are stored. The emissions inventory in use by the SCAQMD has other types of errors as well; for example the driving cycle typically used to predict automobile emissions, which are notoriously difficult to quantify, assumes cars never exceed the speed limit.

...but from 1999 combined NO_x and VOC emissions may have dropped by only half or less of that reported.

Measured concentrations of pollutants in the atmosphere provide an alternative method to track progress in reducing pollutant emissions, and several types of pollutants are monitored routinely at sites around SoCAB. Measured concentrations, when collected from many sites, chosen to be representative and not unduly influenced by polluters in the immediate neighborhood, show what is really happening to collective emissions of smog precursors and air toxics. Unfortunately atmospheric measurements have a limited ability to reveal progress in mitigating *individual* pollutant sources.

The SCAQMD's emissions inventory estimated combined emissions of VOCs and NO_x in the Los Angeles basin were at 3600 tons/day in 1987. By 1998, these had reportedly been reduced to about 2350 tons/day. Up until 1998 or so, these dramatic reductions (although not necessarily the absolute amounts) were corroborated by atmospheric measurements of ozone, NO_x and VOCs, all of which dropped substantially. This, together with earlier reductions, ranks as one of the great environmental achievements of the last 50 years, given the enormous growth in population and vehicles in the SoCAB during that period.

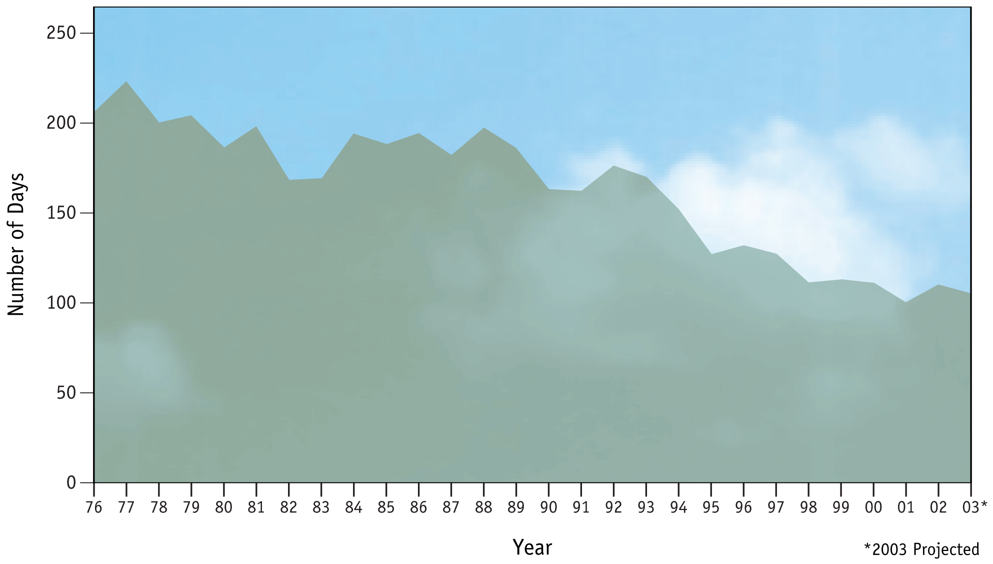

Figure 3: The number of days exceeding the 8-hour ozone standard in the SoCAB. Improvements in this health-based metric are less pronounced than they are for the exceedences of the older federal standard for maximum 1-hour ozone concentrations.

Between 1999 and 2003, the SCAQMD's inventory indicates that combined VOC and NO_x emissions declined to around 1800 tons/day, about 23%. During this time the ambient ozone levels, when corrected for meteorology, have stayed very roughly flat (as discussed earlier). The NO_2 measurement data indicates a decline in NO_x emissions, but somewhat less than that reported in the inventory. Because atmospheric measurements of VOCs are much more expensive than NO_x measurements, VOCs are measured at fewer stations and with lower frequency. Within this more limited data set, VOCs do not appear to have declined much during the four years from 1999 through 2002, indicating that combined NO_x and VOC emissions have dropped perhaps by only one-third to half of that planned in the emissions inventory. Unfortunately it is not possible to tell from these data which pollutant sources have not been diminished as anticipated.

To meet the 1-hour ozone standard, and make substantial progress on the PM2.5 and 8-hour ozone standards, combined VOC and NO_x emissions need to decrease at least to 800 tons/day, around a third of what they were in 1998. These reductions must be made in the face of continued growth in the economy, population, and vehicle miles traveled, and at a time when most of the easy and inexpensive controls have already been made.

Passenger Vehicles In Southern California, the emissions inventory suggests approximately 30% of NO_x and VOCs come from

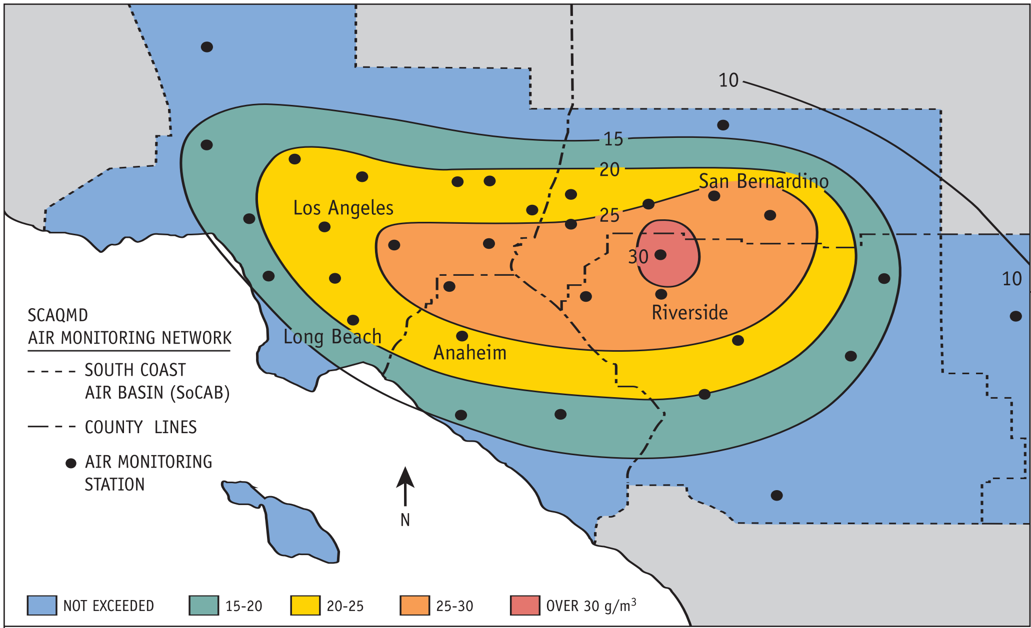

Figure 4: The geographical distribution of particulate matter with diameter less than 2.5 microns, annually averaged. The numbers on the contours indicate the particulate matter mass, in micrograms per cubic meter. The health-based federal and state ambient air quality standards, in micrograms per cubic meter, are 15 and 12, respectively.

passenger vehicles, including SUVs (down from about 40% in 1995). Today, new passenger cars roll off the assembly line with quite low emissions, but as they age their emissions can increase substantially. Cars emit both NO_x and VOCs while they are running, and in addition a substantial amount of VOCs are emitted as gasoline evaporates and escapes from leaky gas caps and fuel lines, and during re-fueling. Some cars eventually become so-called "super emitters" as a result of emissions system failure. These 10% of vehicles release about 60% of all vehicle emissions. The California Smog Check Program is intended to detect and repair (or remove) the super-emitters, but to date the program has had limited success (see below).

Emissions control devices are increasingly durable, so that cars that are 10 or 15 years old now are cleaner than cars of the same age 10 years ago. Similarly, we can expect that passenger car emissions will continue to decrease as the vehicle fleet turns over. There are some caveats, however. On the down side, SUVs and light trucks represent 50% of all new vehicles sold in California, and have much higher emissions allowances (and lower fuel economy standards) than passenger cars. Requirements to bring emissions of new SUVs down to the levels of other passenger cars are just being phased in, but as the current SUV fleet ages it will diminish improvements in air quality. On the positive side, the widespread adoption of hybrid vehicles like the Toyota Prius, Honda Civic, and others could improve matters significantly. Design improvements aside, since emissions for aging cars are roughly related to the quantity of fuel consumed, future emissions of hybrids will be smaller. While the recently scrapped zero emission vehicle program had its limitations, zero emission vehicles have value because they don't burn gasoline and thus never become super emitters.

During the 19-year period between 1965 and 1984, a series of engine design changes and addition of catalysts and on-board computers reduced emissions from new cars by more than 10 fold. Emissions from in-use cars and trucks have been reduced by nearly another factor of 10 since the early 1980's using a three-pronged approach: reformulating gasoline, redesigning refueling equipment, and implementing inspection and maintenance programs.

Reformulated gasoline was introduced in the South Coast Air Basin in two phases, in 1992 and 1996. Reformulation changes the makeup of gasoline to reduce its rate of evaporation, reactivity (or smog-forming potential), levels of air toxics such as benzene and butadiene, while increasing oxygenates. A higher oxygenate content in fuel reduces carbon monoxide emissions. Tighter vehicle

Progress controlling toxic emissions from diesels has been slow. Exposures to diesel emissions is elevated near air and shipping ports, and along heavily travelled freeways and surface streets.

emissions standards contributed to the tremendous improvements in air quality during the 1990s, but much of it was due to gasoline reformulation. Unfortunately, at this point most of the improvements from gasoline reformulation have now been realized. A phase III gasoline is currently being introduced, but this mostly replaces the oxygenate MTBE, which causes water pollution, with ethanol. Little or no benefit to air quality is anticipated from this substitution.

Transfer, storage and vehicle refueling all result in significant VOC emissions. The introduction of devices to capture the gasoline vapor in a gas tank as it is replaced by liquid fuel during fill-up was a highly effective control measure when it was implemented 20 years ago. Today, fixing faulty vapor recovery devices and selling better portable gas containers may deliver more improvements. Consumer behaviors such as topping off during refueling, and accidental gasoline spillage at gas stations, at home and in marinas, all add up to a significant VOC source as well. Unfortunately, changing these behaviors has proved difficult.

Inspection and maintenance (I/M) programs (called ‘Smog Check’ in California) attempt to keep emissions low throughout the life of a car by catching and repairing high emitting vehicles. While I/M programs have certainly helped, both the older gas station test and the new central test facility I/M program have reduced emissions less than planners hoped. There are several reasons for this, including tampering by drivers, fraud by repair shops, and, in the case of the gas station test, a limited ability to simulate real-world driving. I/M programs are most easily improved by extending the warranties of emissions systems, thereby improving the repair rate for high emitters.

Alternatives to the I/M program include buyout programs whereby high emitting vehicles are purchased for several hundred dollars and crushed for scrap. These programs work, but are expensive. Remote sensing systems exist that can catch high polluting vehicles on the road. While there is resistance to these programs due to the “big brother” aura associated with them, they have been successfully implemented in other states.

Diesel Emissions Diesels are large emitters of NO_x and toxic particles and gases. They emit only low levels of VOCs in part because diesel fuel does not evaporate easily. While progress in controlling gasoline vehicle

Black smoke from a heavy-duty diesel truck.

emissions has been tremendous, progress in controlling diesel emissions has been hindered by several factors unique to this source. Diesel engines are built to last for 500,000 miles or more, and have a useful life of up to 30 years. Fleet turnover is slow. While limited regulations to clean up diesels have been in place since the early 1990s, most diesels sold before 1998 had engine controllers that performed well during emissions testing, but not in actual use, resulting in minimal improvements for diesels during this time.

Cleaner post-1998 vehicles make up a small fraction of the current vehicle fleet. This presents the difficult problem of cleaning up the pre-1998 diesels. Some emissions reductions can be achieved by reprogramming on-board computers, and by other changes such as turning off engines at longer stops and providing electricity at ports and truck stops to eliminate the need to run the engine to generate electricity (e.g., for refrigeration or cabin use). Technology to retrofit older diesels is mostly still in the development stage. Controlling diesel emissions from mobile sources remains a high priority, and more regulations are slated to phase in later in this decade.

Consumer Products Emissions controls over the past several decades have focused on vehicles, historically the major sources of pollutants, and on industrial and commercial sources. Over time, however, as motor vehicle and industrial emissions are ratcheted down, other sources become more important. Currently residential sources comprise the second largest source category for VOC emissions. Consumer products include paints and strippers, personal care products like hair spray and rubbing alcohol, cleaning products, pesticides, lighter fluid and the like. It is perhaps remarkable that a single bottle of turpentine, a poorly sealed gallon of paint in the garage, or even nail polish remover can make a difference in air pollution. However, in the households of 16 million residents in South Coast Air Basin, they add up. So far, progress has been minimal at controlling most of these sources. State laws prohibiting banning any product category contribute to the problem; for example, even though pump hair spray can replace aerosol cans, the aerosol version is protected. Efforts are underway to reformulate many products to make them less volatile or reactive, as was done for gasoline. Nevertheless, improvements are expected only to keep pace with the growth of sources.

Without significant shifts in development practices, innovative control strategies and aggressive technology forcing, guided by a higher quality emissions inventory, air quality may not improve much. It may even get worse.

Suzanne Paulson has been a professor in the Department of Atmospheric Sciences at the University of California at Los Angeles (UCLA) since 1994. Dr. Paulson's research focuses on fundamental and applied aspects of chemistry in urban and rural air, including investigations of oxidizing species in aerosol particles, production of oxidizing free radicals during urban and rural photochemical smog formation, development of new instrumentation, and analysis of organics in ambient air and in human breath. She is the author of over forty publications in this field, and has received the National Science Foundation Career Award. Dr. Paulson holds a bachelor's degree in Chemistry from the University of Colorado and an M.S. and Ph.D in Environmental Engineering Science from Caltech. She has served as an advisor to several organizations, including the California Air Resources Board and the World Health Organization.

GRADES

Current air quality is the result of policies put in place over the last several decades. While the improvements over the past three decades, and especially during the early and mid-1990s, were stunning, progress has slowed. More great leaps forward such as those afforded by automobile catalysts and reformulated gasoline are not on the horizon, and the ozone and particle problems in Southern California remain a major challenge. While the current approach of making improvements to existing regulatory approaches may be able to roughly balance substantial growth in population, vehicle miles traveled, and economic activity over the next several years, the past five years of data from the atmosphere have shown that this type of approach will not lead SoCAB to the clean air we need.

Improvements in air quality from hybrid vehicles if they are widely accepted soon will not arrive for nearly a decade, and meaningful fuel cell benefits will follow many years after that. Without significant shifts in development practices, innovative control strategies and aggressive technology forcing, guided by a higher quality emissions inventory, air quality may not improve much. It may even get worse.

Our last assessment gave an A for policies up to that time, and C looking into the future. Based on the present analysis, our overall assessment of progress over the past decades is therefore lowered to an **A-**. Looking into the future, there are many new policies being phased in or in the planning stages, but recent experience indicates they are not aggressive enough. Moreover, the new standards will be harder to meet, and all indications are that we will not meet them anytime soon. Additional policies to phase out or replace highly polluting diesel busses and trucks are overdue. For the future, we give a **Grade of C-**.

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